Informal Science Learning: an investigation of how novelty and motivation affect interest development at a mobile laboratory

CORS, Rebecca

Abstract

MobiLLab is a mobile science education program designed to awaken young people's interest in science and technology (S&T). Perceived novelty, or unfamiliarity, has been shown to affect pupils' educational outcomes at similar out-of-school learning places (OSLePs) such as museums and science centers. A study involved 215 mobiLLab pupils who responded to three surveys: a pre-preparation, at-visit, and post-visit survey. Results provide evidence for four dimensions of pupils' at-visit novelty: curiosity, exploratory behavior, oriented feeling, and cognitive load. Findings also show that classroom preparation time, pupils' perceived capability with technology, and dispositional curiosity related most strongly to their S&T attitudes. The study offers specific insights into how educators can develop materials, activities, and learning settings that appeal to both genders and that support development of desired educational outcomes, such as interest and knowledge. As settings that foster learner autonomy, OSLePs are uniquely positioned to engage learners in S&T topics and careers.

URN : urn:nbn:ch:unige-915158
DOI : 10.13097/archive-ouverte/unige:91515

UNIVERSITÉ DE GENÈVE
Section Physique

FACULTÉ DES SCIENCES
Professeur A. Mueller

Informal Science Learning

An investigation of how novelty and motivation affect interest development at a mobile laboratory

THÈSE
Présentée à la Faculté des sciences de l'Université de Genève
pour obtenir le grade de Docteur ès sciences,
mention didactique des sciences

par
Rebecca Cors
de
Liechtenstein

Thèse No 5019
Liechtenstein, novembre 2016

UNIVERSITÉ DE GENÈVE

FACULTÉ DES SCIENCES

Doctorat ès Sciences
Mention didactique des sciences

Thèse de *Madame Rebecca CORS*

intitulée :

"Informal Science Learning
An Investigation of
Novelty, Motivation and Interest Development
at a Mobile Laboratory"

La Faculté des sciences, sur le préavis de Monsieur A. MUELLER, professeur ordinaire et directeur de thèse (Section de physique), Monsieur N. ROBIN, professeur (Institut de didactique des sciences naturelles, Haute Ecole Pédagogique de St Gall, Suisse) et Monsieur K. KAMPOURAKIS, docteur (Section de biologie), autorise l'impression de la présente thèse, sans exprimer d'opinion sur les propositions qui y sont énoncées.

Genève, le 11 novembre 2016

Thèse - 5019 -

Le Décanat

N.B. - La thèse doit porter la déclaration précédente et remplir les conditions énumérées dans les "Informations relatives aux thèses de doctorat à l'Université de Genève".

FRONT MATTER

Acknowledgements

I am grateful to many individuals for helping through the dissertation process. Advisors Andreas Müller and Nicolas Robin together supported me in developing a deeper understanding of informal learning programs and how to evaluate and investigate them. The mobiLLab team, whose members tolerated, and more often showed curiosity about and insights into the study, were a joy to work with. Members of the Institute for Teaching Science (IFN), particularly Luzia Förster, provided excellent support for deploying research instruments and maintaining my morale. A number of other co-workers and researchers at the University of Teacher Education in St. Gallen (PHSG) offered all types of tools, tips, comradery, and encouragement, even though I worked directly with few of them. Thanks also goes to the Mobile Laboratory Coalition and leaders of other mobile lab and science center programs, who generously shared their insights during the background investigation and results interpretation. The science education research network (SERN), who even once met at CERN (European Organization for Nuclear Research), served as some of my best constructive critics. Special mention goes to Rosa Hettmansperger, who provided important coaching for statistical analysis and unmatched praise for my efforts to maintain the connection between data and the field.

Dedication

I dedicate this dissertation to the people who reminded me to keep my sense of humor through the ups and downs of doctoral research and to keep cultivating my convictions as well as my creativity. Among these are Gerhard Amann, Mary Büchel, Dylan Cors, Leonard Cors, Andrea Eugster, Luzia Förster, Eddie Goldstein, Ruth Ospelt, Nicolas Robin, Larry Salsbury, Mirjana Schädler, Philip Schädler, Bill Sell, Natalie Stankovic, Monika Vogt, and Beth Walsch.

Flying is learning how to throw yourself at the ground and miss.

--Douglas Adams, The Hitchhiker's Guide to the Galaxy

THIS PAGE LEFT INTENTIONALLY BLANK

Summary

The central focus of the mobiLLab study was on how novelty affected motivation and learning at out-of-school learning places (OSLePs).

Overview and research need

OSLePs such as science centers and mobile laboratories have been developed over the last 30 years to pique the interest of youth in science and technology (S&T) topics and careers. Results from existing studies are mixed about whether these OSLePs promote pupils' educational outcomes, and show almost no effect over the long term. Findings from a handful of studies suggest that novelty, or unfamiliarity, can affect how learners profit from OSLeP experiences. These studies have identified several factors that influence learners' at-visit novelty perceptions, such as previous content knowledge and familiarity with the OSLeP setting. Some of these studies show links between these novelty influence factors, pre-visit classroom preparation, and at-visit exploratory behavior and also educational outcomes. With an average of six hours of classroom preparation, the mobiLLab program at the University for Teacher Education in St. Gallen, Switzerland (PHSG) presented an opportunity to better understand the role of novelty at OSLePs.

Process

A three-step inquiry strategy consisted of an exploratory background investigation to define a research focus, a mixed-methods pilot study to test variables and design, and a main study to examine relations between novelty factors and pupils' educational outcomes. An early product of this process was identification of three novelty influence factors (NIFs) thought to most strongly affect how novel pupils found the mobiLLab visit to be: previous content knowledge, how often they visit other OSLePs, and their technological capability. Technological capability indicates whether pupils 'tinker' or seek direction and support when they interact with technology. Analysis of pilot study data, which was collected through pupil and teacher pre- and post-visit surveys and teacher interviews, confirmed the importance of these NIFs. It also pointed to the importance of understanding pupils' at-visit novelty experience. The main study examined links among three constructs: pupils' NIFs, at-visit novelty experience factors (NEFs), such as exploratory behavior, and their affective 'core S&T outcomes,' which were defined as pupil S&T interest, attitude and self-concept of ability. The main study involved 215 pupils, who completed pre-visit, at-visit, and post-visit surveys in spring 2015. About one-half of the pupils watched pre-visit novelty-reducing videos, which were embedded into E-Learning tutorials for six of the mobiLLab experimental posts. The videos were designed to encourage tinkering with mobiLLab equipment.

Selected Results

For the full main study sample, changes in core S&T outcomes were mixed, something found by other studies of informal science learning for the same age group. Findings show a small-to-medium-sized increase in attitude towards science ($p=.042$, $d=.39$) and technology ($p=.013$, $d=.35$), a medium-sized decrease in interest in technology ($p<.001$, $d=.52$) (interest in science did not change significantly), and a moderate decrease in self-concept with respect to science ($p<.001$, $d=.53$) and technology ($p<.001$, $d=.79$). Boys ranked all core S&T outcomes, both before and after the mobiLLab visit significantly higher than girls did. *Based on these findings, it appears that pupils gained a new* *appreciation for S&T through their mobiLLab experience (better attitude), they developed no interest in S&T, and decided that S&T is just not for them (decreased self-concept).*

Through a factor analysis, four factors that describe pupils' at-visit novelty experience were identified. Exploratory behavior accounted for 12% of the variation in pupils' responses about their novelty experience. Curiosity feeling, also called curiosity state, and cognitive load, explained 29% and 8% of variation in pupils' responses, respectively. Oriented feeling, based on how well-organized pupils thought the visit was, was also identified as a novelty experience factor (NEF). The number of novelty-reducing videos pupils watched did not relate significantly to pupils' NEFs. Designed to reduce pupils' unfamiliarity with the setting, these short (90-120 seconds) videos were likely eclipsed by the 6-hour classroom preparation and 12-minute E-learning that pupils experienced during preparation. To explore relations between NIFs, NEFs, and pupils' core S&T outcomes, advanced multivariate techniques (multivariate analysis of variance and multivariate multiple regression) were used. Results reported about predictive strength of NIFs and NEF are in percentages, which come from the R^2 output from regression analysis.

All three NIFs were shown to relate significantly to NEFs. The combination of predictor NIF technological capability and the covariate dispositional curiosity (trait) explained 8% of the variation in pupils' at-visit exploratory behavior, 26% of the varation in their oriented feeling, 13% of the variation in their cognitive load, and 5% of the variation in their curiosity state. Another NIF, how often pupils visited technology-related OSLePs, explained 15% of the variation in pupils' at-visit exploratory behavior, 3% of the variation in their cognitive load, and 9% of the variation in thier curiosity state. A third NIF, pupils' pre-visit knowledge, explained 3% of the variation in thier curiosity state. *These findings show links between pupil novelty factors and how they perceived novelty at the mobiLLab visit.*

The only NIF that significantly predicted variations in how both science and technology educational outcomes changed was technological capability. Tinkerers had a significantly more positive attitude towards technology before the mobiLLab visit than direction seekers did, and their attitude did not change from pre- to post-visit. Meanwhile direction seekers developed a moderate improvement in their attitude towards technology from before to after the mobiLLab visit, $F(1,169)=1.26$, $p=.003$. Similarly, tinkerers' interest in natural science was greater and remained steady, while direction seekers showed a significant decrease in interest in natural science $F(1,168) =5.24$, $p=.023$. Another NIF, how often pupils frequented natural science-related OSLePs, only predicted variations in how pupils' *natural science* outcomes changed. Effect sizes for NIF predictions of how core S&T outcomes changed were small. *These findings show links between pupil novelty factors and several affective educational outcomes.*

Results also showed that all NEFs were linked one or all of pupils' core S&T outcomes. For example, pupils who exhibited more exploratory behavior started (pre-visit survey) with greater core S&T outcomes and these outcomes remained virtually unchanged. However, pupils who explored less showed slightly greater decreases in interest $F(1,171)=8.0$, $p=.005$, and self-concept of ability, $F(1,171)=4.60$, $p=.033$, related to natural science. Likewise, pupils who reported more exploratory behavior had more positive self-concept to technology, which remained unchanged from before-to-after the mobiLLab visit, $F(1,173)=4.66$, $p=.032$. Similarly, those pupils who reported feeling more oriented maintained their self-concept slightly better than their less oriented peers, $F(1,174)=5.24$, $p=.023$. The strength of these predictions was small. Also, the NEFs curiosity and cognitive load were shown to relate significantly to more positive post-visit core S&T outcomes. *These findings provide evidence for links between how pupils perceived novelty at the mobiLLab visit and their affective educational outcomes.*

Some secondary results emerged. The study identified dispositional curiosity and gender as important covariates for studies about OSLePs. Additionally, a four-item pre-visit knowledge test provides evidence that pupils gained knowledge about electromagnetic radiation concepts from classroom preparation and also from the mobiLLab visit.

Discussion and Implications
The mobiLLab study is grounded in the real-world challenges of mobiLLab, which supports the relevancy of results to other informal learning programs. The study produced data from a moderately large sample and bridges research written in German and in English.

This work provides evidence of the importance of a new novelty influence factor (NIF), technological capability, for understanding pupils' experiences at OSLePs such as science centers and mobile laboratories. Another strong predictor of pupils' at-visit novelty was dispositional curiosity, which was incorporated in the research design as a covariate. Another noteworthy finding is that pupils who describe themselves as tinkerers and/or as explorers had more positive affective educational outcomes and that these ratings remained virtually unchanged by the mobiLLab experience. Findings also show that tinkerers were more intrinsically motivated at the mobiLLab experience than their direction-seeking peers and were twice as likely to be boys.

Results point researchers and OSLeP program managers to specific areas for further work. By examining both pupil novelty factors, such as technological capability, and also at-visit novelty factors, studies can assess how classroom preparation affects pupils' OSLeP experiences. Such studies can go also further in identifying factors that optimize learners' at-visit curiosity, exploratory behavior, oriented feeling and cognitive load, factors linked to more positive S&T interest, attitude and self-concept of ability. Also, given evidence that some variables act as mediators and moderators, researchers should consider a path analysis approach.

Findings provide specific insights into how informal science learning program managers can develop materials, activities and learning settings that appeal to both genders and that support learners' understandings about how they interact with technology. As settings that foster learner autonomy, OSLePs are uniquely positioned to engage learners in nature, science and technology topics and careers. These programs are also important for promoting scientific literacy in our societies. As such, another important are for research is examining how informal learning experiences promote people's thoughtful engagement in societal issues around S&T and their responsibility towards resources and environments.

“Education is not about filling buckets. It's about lighting fires.“

- attributed to William Butler Yeats (poet, 1865-1939)

Résumé

La présente étude examine le rôle de la nouveauté dans les espaces d'apprentissage extra-scolaires, tels que les centres de diffusion de la culture scientifique, les laboratoires mobiles comme le « mobiLLab » choisi pour cette étude.

Aperçu et axes de recherche

Les espaces d'apprentissage extra-scolaires tels que les cités des sciences et les laboratoires mobiles se sont développés au cours des trente dernières années pour susciter l'intérêt des élèves pour la science et la technologie et les carrières dans ces domaines. Les résultats d'études existantes restent mitigés quant à l'influence positive de la visite de ces espaces sur l'aboutissement des élèves en science et en technologie. De plus, ces études ne montrent quasiment aucun effet sur le long terme. Les résultats de quelques études concernant la réduction de la nouveauté ou le manque d'affinité des élèves ont mis en évidence une différence dans la manière dont les élèves vivent ce moment dans ces espaces de science, ainsi que dans leur aptitude à en profiter pleinement. Ces études identifient plusieurs facteurs liés à la nouveauté pour les élèves, comme la connaissance des contenus proposés ou une certaine familiarisation avec ces espaces de diffusion scientifique. Au-delà, elles montrent les liens entre ces facteurs et le comportement des élèves au cours de leur visite, aussi bien en termes d'exploration, que d'aboutissements éducatifs sur le plan cognitif et affectif. Jusqu'ici, aucune étude ne semble s'être intéressée aux espaces consacrés aux technologies, où la nouveauté liée à la technologie peut susciter un certain inconfort chez les élèves. Avec une durée moyenne de préparation en classe de 6 heures, le programme mobiLLab proposé par la Haute École Pédagogique de St.Gall (Suisse) offre une opportunité pour mieux comprendre les facteurs liés à la nouveauté dans les espaces d'apprentissage extra-scolaires.

Approche

Une démarche en trois phases a été mise en place, comprenant tout d'abord une recherche de fond afin de délimiter le focus de la recherche, puis une étude pilote mixte visant à tester les variables et le design de recherche et enfin une étude principale pour mesurer et relier les facteurs liés à la nouveauté et l'intérêt des eleves pour les sciences et les techniques. Un premier produit de ce processus est l'identification de trois facteurs influents de la nouveauté (NIF) susceptibles d'impacter fortement la manière dont les élèves vont trouver l'expérience mobiLLab : le savoir existant sur les contenus proposés, le nombre de fois qu'ils ont visité d'autres espaces scientifiques du même type et leur aptitude technologique. Ce dernier facteur indiquant si les jeunes sont plutôt du type 'bricoleur' ou à la recherche de soutien et d'encadrement dans leur relation à la technologie. Les résultats de l'étude pilote, comprenant une analyse de la littérature dans le domaine, des évaluations des élèves et des enseignants avant et après la visite de mobiLLab et des interviews des enseignants ont confirmé l'importance des NIFs et de comprendre l'expérience de la nouveauté par les élèves au cours d'une visite. Dans ce sens, l'étude principale s'est concentrée sur les liens existants parmi ces trois constructions : les NIFs des élèves, les facteurs d'expérience de la nouveauté (NEF) pendant la visite, comme par exemple une attitude exploratrice et les aboutissements (outcomes) affectifs comme l'attitude, l'intérêt et le concept de soi. L'étude principale s'est adressée à 215 élèves, qui ont rempli, au printemps 2015, des évaluations avant, pendant et après une visite mobiLLab. Près de la moitié des élèves ont en plus participé à une expérience dans laquelle ils avaient la possibilité de regarder quatre vidéos visant à réduire la nouveauté et à encourager le caractère 'bricoleur'.

Sélection de résultats
L'étude principale a montré des changements mitigés concernant les aboutissements (outcomes) dans le domaine de la science et de la technologie, éléments déjà présents dans d'autres études. Les résultats révèlent une croissance réduite à moyenne de l'attitude des jeunes envers la science ($p=.042$, $d=.39$) et la technologie ($p=.013$, $d=.35$), une décroissance de l'intérêt pour la science (non significatif) et la technologie ($p<.001$, $d=.52$) et une baisse modérée du concept de soi en lien avec la science ($p<.001$, $d=.53$) et la technologie ($p<.001$, $d=.79$). Les résultats obtenus sont significativement différents entre les filles et les garçons pour tous les aboutissements étudiés. Ces résultats pourraient suggérer que les élèves se forment une nouvelle appréciation de la science et de la technologie par le biais de leur expérience avec mobiLLab (une attitude plus positive) ou alors ne se découvre pas d'intérêt particulier pour les sciences et décident tout simplement que la science et la technologie ne sont pas faites pour eux (concept de soi).

Grâce à une analyse factorielle, quatre facteurs décrivant l'expérience des jeunes durant une visite mobiLLab ont pu être identifiés. Le comportement explorateur, une variable considérée dans d'autres études au sujet de la nouveauté dans les espaces d'apprentissage extra-scolaires, décrit 12 pour cent de la variation dans la réponse des élèves au sujet de la nouveauté. Le sentiment de curiosité et la charge cognitive, renvoient respectivement à 29 et 8 pour cent de la variation dans les réponses des élèves. Le sentiment d'orientation, fondé sur le regard porté par les élèves sur la bonne organisation de la visite mobiLLab, a été identifié comme un facteur d'expérience de la nouveauté (NEF). Le nombre de vidéos visant à une réduction de la nouveauté ayant été regardé n'a pas de lien significatif avec l'expérience de la nouveauté par les jeunes. Ceci explique probablement pourquoi les jeunes ont été moins influencés par les 90 à 120 secondes de vidéos que par la moyenne de 6 heures de préparation et l'usage de plusieurs segments d'E-learning de 12 minutes. Dans le but d'explorer les relations entre NIFs, NEFs et les aboutissements (outcomes) dans le domaine de la science et de la technologie, une analyse multivariée (analyse multivariée de la variance et de type régression multiple) a été réalisée.

Les trois facteurs d'influence de la nouveauté (NIFs) ont une relation significative avec le niveau de curiosité des jeunes durant la visite mobiLLab. L'aptitude technologique NIF associée à la co-variable tendance à la curiosité explique 8 pour cent de la variation du comportement explorateur durant la visite, 26 pour cent de le la variation du sentiment d'orientation, 13 pour cent de la variation de la variable charge cognitive et 5 pour cent de la variation de leur état de curiosité. Une comparaison des coefficients standardisés montre que la tendance à la curiosité est un plus grand prédicteur de l'état de curiosité ($\beta=.27$) que la capacité technologique ($\beta=.13$). Un test de médiation montre également que la tendance à la curiosité est un prédicteur plus direct de l'état de curiosité. Un autre NIF, le nombre de fois où les élèves visitent un espace d'apprentissage extra-scolaire explique 15 pour cent de la variation dans le comportement explorateur des élèves durant la visite, 3 pour cent de la variation de leur charge cognitive et 9 pour cent de la variation de leur état de curiosité. Le troisième NIF, le savoir des élèves avant la visite, explique 3 pour cent de la variation de leur état de curiosité. *Ces résultats montrent les liens entre les différents facteurs chez les jeunes et la manière dont ils perçoivent la visite mobiLLab.*

Le seul NIF prédisant de manière significative les variations dans les aboutissements (outcomes) liés à la technologie chez les jeunes est láptitude technologique. Les 'bricoleurs' ont de manière significative, une attitude plus positive envers la science et la technologie avant une visite mobiLLab, qui ne changera pas suite à la visite, alors que les élèves qui cherchent un encadrement développent au cours du temps une attitude plus positive envers la technologie, $F(1,169)=1.26$, $p=.003$. De manière similaire l'intérêt élevé des 'bricoleurs' pour les sciences de la nature dès le début est resté important. Chez les jeunes cherchant un encadrement, on observe par contre une baisse de l'intérêt pour les sciences de la nature $F(1,168)=5.24$, $p=.023$. Le seul autre NIF prédisant significativement les variations dans les aboutissements (outcomes) des élèves dans les sciences de la nature est le nombre de fois où ils visitent des espaces d'apprentissage extra-scolaires en lien avec les sciences de la nature.
Les résultats montrent également que tous les NEFs sont liés aux aboutissements des élèves en science et technologie. Par exemple, des jeunes montrant un comportement explorateur plus affirmé débute (analyse avant la visite) avec de meilleurs aboutissements fondamentaux en science et technologie et que ces aboutissements restent virtuellement inchangés ; alors que des élèves moins explorateurs montrent une baisse de leur intérêt $F(1,171)=8.0$, $p=.005$, et de leur concept de soi $F(1,171)=4.60$, $p=.033$, en lien avec les sciences de la nature. Le comportement explorateur est ainsi en lien avec le concept de soi par rapport à la technologie $F(1,173)=4.66$, $p=.023$. Similairement, des élèves plus orientés maintiennent des aboutissements fondamentaux élevés dans le domaine de la science et de la technologie, alors que des élèves qui se sentent moins attirés développent un concept de soi moins positif envers la technologie $(1,174)=5.24$, $p=.023$. Les élèves étant les plus curieux pendant la visite présentent des aboutissements fondamentaux dans le domaine scientifique et technologique plus positifs après la visite ; la charge cognitive étant un prédicteur de force équivalente de la variation du concept de soi pour les aboutissements après la visite. *Ces résultats montres les liens entre la manière dont les élèves perçoivent la nouveauté durant une visite mobiLLab et leurs aboutissements sur le plan affectif.*

Des résultats secondaires peuvent être également mentionnés. Premièrement, la présente analyse identifie la tendance à la curiosité et le genre comme des co-variables importantes pour l'étude de l'apprentissage dans de tels espaces extra-scolaires. Un test de connaissances avec quatre items a montré que les élèves apprennent quelque chose sur le thème des radiations électromagnétiques suite à la préparation en classe de la visite mobiLLab.

Conclusions
La présente étude mobiLLab a mis en avant un ensemble de facteurs liés à la nouveauté pour l'analyse de la nouveauté dans les espaces d'apprentissage extra-scolaires et a permis de tester plusieurs des indicateurs de la nouveauté au cours d'une visite. L'étude est ancrée dans la réalité et les défis d'un programme de laboratoire mobile, a produit des données sur la base d'un échantillon de taille moyenne et a permis de mettre en lien des études en allemand et en anglais. L'étude mobiLLab a montré tout particulièrement l'importance d'un nouveau facteur d'influence de la nouveauté (NIF), la capacité technologique, pour la compréhension des expériences des élèves dans le cadre de ces espaces d'apprentissage extra-scolaires.

Un autre apport de l'étude est la définition d'une série de facteurs d'expérience de la nouveauté pendant une visite (NEFs) : le comportement explorateur, le sentiment d'orientation, le sentiment de curiosité et la charge cognitive. Les résultats montrent également que la tendance à la curiosité est un prédicteur important en lien avec la mesure de la nouveauté pendant une visite. Un autre résultat, tout aussi important est que les élèves qui se décrivent eux-mêmes comme des 'bricoleurs' et des explorateurs ont un intérêt, une attitude et un concept de soi plus positif envers la science et la technologie, qui restent plus ou moins inchangés au cours de l'expérience avec mobiLLab. Dans le même temps, ceux qui cherchent plus d'encadrement et de soutien montrent des variations à la hausse et à la baisse de leurs aboutissements (outcomes) sur le plan affectif, ce qui indique que ce sont les élèves qui ont le plus de chance d'être influencés par des expériences dans des espaces d'apprentissage extra-scolaires.
De plus, afin d'obtenir des aboutissements affectifs plus positifs et résistants, les résultats montrent que les 'bricoleurs' sont intrinsèquement plus motivés par l'expérience mobiLLab, sont le plus souvent des garçons, sont considérés comme plus « technologically literate », une compétence d'une importance croissante à l'ère numérique. Les résultats mettent également en évidence que l'état de curiosité est fortement lié aux autres NEFs et aux aboutissements affectifs positifs, suggérant qu'il est un facteur de motivation mettant en lien les facteurs plus positifs de nouveauté et l'apprentissage. Finalement, les résultats contribuent à accumuler des preuves pour des idées connues de longue date concernant les liens entre nouveauté, curiosité et exploration.

Les résultats désignent aux chercheurs, enseignants et managers d'espaces d'apprentissage extra-scolaires, des points précis pour les développements à venir. Comment pouvons-nous susciter la curiosité des élèves cherchant du soutien ou ceux ayant moins dáptitudes sur le plan de la technologie ? Comment pouvons-nous mieux comprendre la relation entre l'expérience de la nouveauté pendant la visite d'espaces d'apprentissage extra-scolaires et le développement de l'intérêt des apprenants ?

Contents in Brief

Contents in Detail

List of Figures

Publications

Book Chapters, Papers

Cors, R., & Nicolas, R. (October 2016). Evaluating informal science education: Identifying and measuring meaningful indicators of program effectiveness for a mobile laboratory program. Journal of Finnish Universities of Applied Sciences. (Special Issue: EAPRIL 2016), Available online: https://uasjournal.fi/in-english/strategies-for-evaluating-informal-science-education-identifying-and-measuring-meaningful-indicators-of-program-effectiveness-for-a-mobile-laboratory-program/.

Cors, R., Müller, A., Robin, N. (2015). Advancing Informal MINT Learning: Preparation and Novelty at a Mobile Laboratory. New Perspectives in Science Education, 53-58.

Cors, R., Matsubae, K., & Street, A. (2013). P is for process and parity: How MFAs, transdisciplinarity, complex adaptive systems thinking and education reform are keys to better managing phosphorus. In K. A. Wyant, J. R. Corman, and J. Elser (Eds.), Phosphorus, Food, and Our Future. Oxford Press.

Ulrich, A.E. & Cors, R. (2011). Global TraPs: An international effort to promote sustainable use of phosphorus. In: Ecoregion Perspectives. Sustainable Agriculture in the Baltic Sea Region in times of peak phosphorus and global change. Baltic 21 Series No. 4/2011.26-28.

Cors, Rebecca. 2004. “Improving U.S. State Agency Environmental Management through Organizational Learning, Action Research, and International Exchange,” Gaylord Nelson Institute for Environmental Studies, Land Resources. Program Thesis, University of Wisconsin – Madison.

Cors, Rebecca, Sandy Courter, et al. 2003. “An International Case for Sharpening the Focus on Facilitation Skills in Undergraduate Engineering Curricula.” American Society for Engineering Education Annual Conference Proceedings.

Cors, Rebecca, Sandy Courter, et al. 2003. “Promoting Environmental Protection Through Collaborative, Learning-Based Approaches.” American Society for Engineering Education Annual Conference Proceedings.

Eagan, Patrick and Rebecca Cors. 2003. “An Organizational Change Strategy to Improve Environmental Protection.” International Symposium on Electronics and the Environment in conjunction with the IEEE Electronics and Recycling. Summit Proceedings, Boston, MA.

“Industry and Ecology, a Partnership that Works,” Wisconsin Academy Review, Madison, Wisconsin. Authored by Rebecca Cors and Pat Eagan. Winter 2003.

Cors, Rebecca and Craig Rendahl. 1994. “Detectability of Vehicle Emission Hydrocarbons: The Wisconsin Inspection/Maintenance (I/M) Analyzer and the Remote Vehicle Emissions Sensing (RVES) System.” Optical Sensing for Environmental and Process Monitoring Conference Proceedings. McLean, VA.

Reports

- Cors, R. (2013). MobiLLab Program Background Investigation: Directions for Program Improvement and Evaluation Research (Verschaffen eines Überblicks des mobiLLabs) (pp. 32). St. Gallen, Switzerland, University of Teacher Education (Pädagogische Hochschule St. Gallen).
- Global TraPs event feedback and evaluation survey, ETH Zurich. Zurich, March 2011, September 2011.
- Parent Satisfaction Survey, Common Threads Farm, Lummi Island, Washington. May 2009.
- Observation Instrument (used to evaluate 2008 summer institute training), Building Bridges Between Science and Math, Educational Services District 189, Washington. July 2008.
- Observation Findings, 2008 summer institute training, Building Bridges Between Science and Math, Educational Services District 189, Washington. July 2008.
- Results of a Web-Based Teacher Survey, Building Bridges Between Science and Math, Educational Services District 189, Washington. October 2008.
- Summary of Peace Corps China Experience. August 2007.
- "We're testing a new method to measure emissions," Wisconsin Department of Natural Resources. I produced this fact sheet to inform the public about research my team was conducting to test and evaluate Remote Vehicle Emissions Sensing equipment (infrared remote sensing technology for on-road measurement of vehicle emissions). 1996.

Lectures and Workshops Delivered

- Mobile Lab Think Tank – improving how we interest pupils in STEM. *Mobile Laboratory Coalition Conference, Columbus Ohio, July 12-15, 2016.*
- Promoting pupil interest in science & technology: A study about novelty at a mobile laboratory. 9. Schweizer Forum Fachdidaktiken Naturwissenschaften, *Freiburg, Switzerland. January 29th, 2016*
- Novelty at a mobile laboratory: Overview of results. Meeting of the Science Education Research Network at the CERN (European Organization for Nuclear Research), Geneva*, October 12-15, 2015*
- Advancing informal MINT learning: preparation & novelty at a mobile laboratory. *New Perspectives in Science Education Conference, Florence, March 21,2015*
- Novelty at a mobile laboratory: Pilot Study Results. *PHSG Research Colloquium. St. Gallen, Switzerland. 25. September, 2014*
- Preparation and learning at a mobile laboratory - Pilot study results. Paper presented at the GDCP-Jahrestagung, Bremen, Germany. September 2014.
- "Engaging under-represented groups in Global TraPs," a transdisciplinary research effort led by ETH Zurich and the International Fertilizer Development Center. Zurich, Switzerland. August 2011.
- "Academic writing in English for non-native speakers," An Appreciative Inquiry workshop for the Natural Social Science Interface group, ETH Zurich, Switzerland. March 2011.
- „Warum schützen meine Nachbarn die Umwelt nicht?" (Why don't my neighbors live sustainably?), facilitated discussion about behavior change campaigns, Liechtenstein Verein Welt und Heimat, March 2010.
- "Focus Group Research Methods," Sociology Department, Western Washington University Sociology Department, Bellingham, Washington. Fall 2008, Winter 2009.

- “Encouraging Pro-Environmental Behaviors and Lifestyles,” Society for Human Ecology International Conference: Community Based Social Marketing (Session Coordinator), Western Washington University, Bellingham, Washington, USA. Fall 2008.
- “China and Global Population Issues,” Sociology Department, Western Washington University Sociology Department, Bellingham, Washington. Spring 2008.
- “Peace Corps Service in China,” Fairhaven College, Bellingham, Washington, USA. Fall 2007.
- “The Great Turning,” Facilitated a public meeting discussion of this book by David Korten for the Bellingham Unitarian Fellowship, Green Sanctuary Program, Washington. Fall 2007.
- “Effective Technical Presentations,” University of Wisconsin-Madison, School of Engineering, Design and Analysis of Manufacturing Systems course. Spring 2003, Spring 2004.
- “A Conversation about Organizational Learning,” University of Wisconsin-Madison, Madison, Wisconsin, USA. Fall 2003.
- “Appreciative Inquiry: Building on Success Stories.” Facilitated an Appreciative Inquiry Session with Mary Buchel, for the American Society for Training and Development Exposition, Milwaukee, Wisconsin, 2003.

Key Words

informal learning, interest, curiosity, motivation, science and technology, STEM

Glossary and Acronyms

The following terms and acronyms are used throughout the thesis and are defined as follows. Some have a particular meaning for this study, which is provided on the page listed.

CV	Covariate
DV	Dependent variable
ISCED	The International Standard Classification of Education (**ISCED**) is a statistical framework for organizing information on education maintained by the United Nations Educational, Scientific and Cultural Organization (UNESCO).
IV	Independent variable
MINT	Mathematik, Informatik, Naturwissenschaft und Technik (the German version of STEM).
NEF	Novelty experience factors. See Figure 14 on page 75.
NIF	Novelty influence factors. See page See Figure 14 on page 75.
Novelty	Feelings of unfamiliarity at OSLePs that relate to learning. See Figure 14 on page 75.
OECD	Organization for Economic Co-operation and Development
OSLePs	Out-of-school-learning-places. See page 14.
PISA	Program for International Student Assessment.
S&T	Science and technology.
School track	For the mobiLLab study, participating pupils were enrolled in one of two different levels, or tracks, of vocational high school. See page 106.
STEM	Science, Technology, Engineering and Math.

I. INTRODUCTION

1 Background and Relevance of the Investigation

MobiLLab is an award-winning program developed and operated by the University of Teacher Education in St. Gallen (PHSG), Switzerland to awaken the interest of youth in science and technology. Why was the program developed and what value do such programs provide around the world? What priorities of the mobiLLab program drove the research? And how will the work inform educators and researchers who want to better understand out-of-school learning places (OSLePs)? This introduction describes how this study is relevant to society, for research and for educators, and for OSLeP managers in the field.

1.1 Social relevance: a dearth of science and technology workers

In spite of good science and math scores in secondary school (Eichenberger, 2010), young people in Switzerland, as in many other developed countries, show low interest in these subjects (Sjøberg & Schreiner, 2010). Moreover, too few young Swiss who show talent in science and math are completing university degrees in these disciplines and are choosing non-tech professions or professions outside of industry (MINT-Meter, 2012; Vogel-Misicka, 2012) The result is a shortage of high technology and industry workers and rising concerns about their science literacy. These concerns about a technology-related workforce shortage and science literacy reflect worldwide trends, according to the Relevance of Science Education (ROSE) report. The report explains, “These negative attitudes may be long-lasting and in effect rather harmful to how people later in life relate to S&T as citizens” (Sjøberg & Schreiner, 2010, p. 4). This trend comes at a time when demand for science and technology graduates is growing and importing high-tech and industry workers has become necessary in Switzerland as well as in many parts of Europe (PresenceSwitzerland, 2012). To address the lack of ‘home-grown’ industry and technology workers, mobile laboratory and science center programs started operating in countries including Germany and Switzerland in the 1980s and 1990s, respectively. A study that contributes to improving such OSLePs has societal relevance.

Encouraging the country´s young people to select jobs in science and industry is a high priority for Switzerland and neighboring areas (P. Haas, Deputy General Manager of the Liechtenstein Chamber of Commerce, personal communication, October 5th, 2012). In 2012, the Swiss Academy of Engineering Sciences (SATW) conducted a study called the Swiss Barometer of Young Talent in STEM (Science, Technology, Engineering, and Math) subjects (*MINT-Nachwuchsbarometer Schweiz*) (Huber, 2014). Findings, listed in Table 1, shed some light on reasons that Swiss youth do not choose careers in science and technology.

The SATW recommended that studies and careers in science and technology (S&T) be made more attractive, especially for girls. Examples include developing interdisciplinary studies that combine, for example, health and technology, because health-related lessons have been shown to appeal to girls. Also, companies need to adapt their culture and structures so that they appeal to young people. Likewise, young people need to see professions like engineering as versatile, creative, and relevant to their lives. To encourage youth’s talents in S&T, the SATW recommends strengthening out-of-classroom learning and raising parents' awareness.

Table 1: Selected findings from the Swiss Barometer of Young Talent in STEM subjects (Huber, 2014):

- School and family do not promote interest in technology very strongly; the family encourages interest in technology more strongly than school.
- Girls feel much less encouraged in technology than boys. For the sciences, there is no difference between how girls and boys feel encouraged.
- Male relatives such as fathers and grandfathers are important role models and agents that support interest in technology.
- Technology-related gender stereotypes persist.
- Boys and girls, who have been supported to work with technology, have a higher self-concept on in relation to technology than those that have been little promoted.
- Girl needs to be supported so that they same high self-concept in terms of technology as boys.
- Mathematics is the least popular STEM school subject for both genders; in young women physics is the least popular school subject.
- The popularity of STEM subjects for Swiss pupils has hardly changed last thirty years
- Girls value most highly careers that offer a varied work environment or allow them to work independently; for boys, career, income and status are more important.
- Science and engineering professions are thought by high school students as advanced and useful, but also as a complex.

1.2 Field relevance: mobiLLab science education program

The mobiLLab science education program was developed to spark the interest of youth in science and technology. Since its inception in 2008, the University of Teacher Education in St. Gallen (PHSG) has operated the mobiLLab program as a vehicle for providing hands-on training in science experimentation with high-technology equipment to pre-service teachers, secondary school pupils and in-service teachers. The program was developed to support the PHSG strategy to promote interest in STEM careers, referred to in German as MINT (Math, Informatics, Natural science, Technology) careers, among Switzerland's youth. School visits are designed for pupils aged 14 to 16 years old who attend secondary school level 1, as described on page 106). These pupils generally either pursue further vocational training or transfer into the university preparatory secondary school level II (German: *Gymnasium*). Each September, visits are scheduled to schools whose teachers have applied. In accordance with its funder contract, mobiLLab schedules a minimum of 20 school visits per year in the Swiss canton St Gallen and some nearby cantons.

1.2.1 A typical visit

For teachers to be eligible to apply for a mobiLLab visit, they are expected to participate in a day-long orientation training, held each August at the PHSG. After this orientation training, teachers may apply for mobiLLab to bring 12 laboratory experiments, listed in Table 2, into their classroom for a morning or afternoon. During a typical half-day at participating schools, there are four, forty-five minute periods. Teachers are asked to work with pupils in advanced of the mobiLLab visit to choose their four experimental posts. At orientation training, mobiLLab trainers recommend that teachers have pupils prepare for their four experimental posts by reviewing E-Learning tutorials. The E-Learning tutorials last 10- to 13-minutes and are illustrated audio sequences that introduce the theory, equipment and sometimes applications for each experimental post. The last part of each E-Learning tutorial is a quiz consisting of about 10 questions.

Table 2: List of mobiLLab experimental posts.

Infrared camera and Pyrometer *Is our classroom well insulated? Is the „cold metal“ in our classroom really colder than the „warm wood“?*	Food analysis How much sugar is my soft drink? In food products?
X-ray Fluorescence *Does my tongue ring contain any poisonous metals?*	Visible Light Analysis with Spectrometer *Why do colors from a fluorescent light look differently than sunlight?*
Exhaust Gas Analyses *Does my moped produce the same exhaust when idling as when accelerating?*	Spiro-ergometer: Respiratory Gases *At what level of physical exertion does my body burn only carbohydrates?*
Ultraviolet Radiation *Do my sunglasses protect my eyes from the sun’s ultraviolet radiation?*	Highspeed camera *Do air- and water-filled balloons burst in the same way?*
Industrial Microwave Synthesis *Can I produce a perfume in a few minutes?*	Household Microwave Applications *Is it possible to produce popcorn in a microwave?*
Ion Chromatography *Is our tap water as “pure” as mineral water?*	IR Spectroscope *What is the chemical composition of my perfume? Of a plastic bag?*

Trainers also ask teachers to have pupils prepare their own questions for each experimental post. There are worksheets (*Journalblätter)*, which include questions for pupils to consider, blank spaces for pupils to write down their own questions and blank spaces for pupils to record the results of their experimentation. The E-Learning tutorials and a glossary of terms are available through the password-protected mobiLLab webpage http://www.mobillab.ch/. At another password-protected webpage teachers can gain access to the *Journalblätter worksheets* and experimental post information including theory, experimenting instructions and electronic versions of the posters displayed during the mobiLLab visit.

A typical school visit begins at the PHSG building, where the deployment team loads the experiment equipment into a van, Figure 1, and drives to the school. The mobiLLab van arrives at the school before classes start and sets up experiment stations in a classroom. Pupils work in pairs, independent of frontal instruction, as depicted in Figure 2, ideally following through the instructions at each station and also exploring their own questions through experimentation.

Figure 1: The mobiLLab van.

Figure 2: Pupils at mobiLLab experimental posts: Exhaust Gas Measurement (top left), Microwave Synthesis (top right), and Spiro-ergometer (bottom).

1.2.2 A day for tinkering with technology

The mobiLLab offers pupils an opportunity to work independently and in an evaluation-free environment, something thought to promote engagement in activities and interest development. In contrast to most classroom experiences, where pupils regularly encounter goals, deadlines, tests and other directives, teachers and the mobiLLab team present the mobiLLab visit as a day for trying things out and working in a self-directed manner. Pupils work in pairs, as shown in Figure 2 and, in addition to following step-by-step directions at each post, are encouraged to play around and 'tinker' with the equipment. Pupils are asked to try to deal with unexpected results on their own before turning to a mobiLLab coach. This independent problem-solving is supported by inquiry-based responses from mobiLLab coaches, who offer comments and questions (and no direct answers) to support pupils in exploring their own explanations for their observations. Pupils are also encouraged to bring items from home to test. At the Food Analysis Post, for example, pupils test the sugar content of soft drinks and home-made jam. Sometimes pupils bring tap or pond water to analyze via ion chromatography or metal objects to analyze with x-ray fluorescence.

> "If you improve or tinker with something long enough, eventually it will break or malfunction."
>
> - Arthur Bloch, American writer and satirist, author of the Murphy's Law books

1.2.3 Research planning: identifying mobiLLab program priorities

The impetus for a research investigation about mobiLLab emerged in 2011, when the mobiLLab program completed its third year of operation. A new program supervisor wanted evaluate the program before further developing it and encountered complementary opportunities: 1) funding to conduct a research investigation of mobiLLab and 2) interest by the faculty group to develop research experience related to program evaluation and mixed-methods research.

MobiLLab program priorities

Before designing the research investigation, the author led a background investigation to identify aspects of the mobiLLab program the team most wanted to learn about. During the background investigation, the mobiLLab team processed feedback from stakeholders to develop a theory of change for the program – a 'logic model' map of program resources, outputs and outcomes. The strategy to develop the mobiLLab theory of change was based on a program evaluation process from Taylor-Powell (2003). The details of the background investigation are described starting on page 60. By reviewing literature relevant to the program priorities identified by the theory of change, a focus for the mobiLLab pilot investigation was identified. A central goal of this study was to enable the mobiLLab team and researchers to better understand what it means to awaken pupils' interest in mobiLLab-related science and technology. The study examined how interest development was affected by classroom preparation, by pupil feelings of unfamiliarity, or novelty, and by teacher attitudes. Results of the pilot study are described on page 66.

Exchanges with mobile laboratory education programs worldwide

During the background investigation, mobiLLab became a member of the Mobile Laboratory Coalition http://www.mobilelabcoalition.com/wp/ and began regularly attending the research-practice conferences of EAPRIL (Association for Practitioner Research on Improving Learning). These opportunities for exchange are an important part of ensuring that research about mobiLLab supports improvements in program operation, and also that results are relavent to other, similar programs.

1.3 Research relevance

1.3.1 A revolution in science learning

Since the 1960s, science educators began writing about how a revolution in science learning was taking place and there was a new recognition of the important role of informal learning in people's lives (Rennie, 2007). On the eve of the opening of the first 'exploratoriums,' Frank Oppenheimer

(1968), American particle physicist and founder of the Exploratorium in San Francisco, described the unique contribution that hands-on experimental aspect of out-of-school learning places offer:

> "Explaining science and technology without props can resemble an attempt to tell what it is like to swim without ever letting a person near the water" (p. 206).

Educators describe how this revolution in science learning has evolved and that now people worldwide, have "unprecedented access to science education opportunities from cradle to grave, 24/7, through an ever-growing network of educational opportunities beyond schooling which include visits to museums, zoos, aquariums, science centers, natural area parks and reserves, television, radio, films, books and magazines, and increasingly through personal games, podcasts, the Internet, and other social networking media" (Falk & Dierking, 2012, p. 1063). This continuously growing infrastructure of organizations and tools that offer scientific learning opportunities "serves as a web of influences that shapes people's understandings, attitudes, aesthetic beliefs, and values" (p. 1072).

1.3.2 Agendas for research about informal science learning

As the number and types of out-of-school programs and tools has proliferated, research about it has evolved in a fragmented manner due to several factors (Bell, 2009): 1) there is a disconnect between research about OSLePs and research about classrooms, 2) OSLePs have diverse goals, 3) researchers from different disciplines focus on different aspects of OSLePs and employ different methods, 4) investigations often need to support program evaluations, which are critical for demonstrating the effectiveness of OSLePs, so they can maintain the funding that keeps them going, and 5) media and technology provide greater access to scientific information and are employed by OSLePs to offer even more diverse environments, yet they also introduce platforms for unverified, incorrect information. While recognizing the value of diversity, experts call for development of common language and constructs for research about OSLePs, and for investigators to build on previous work (2009).

In an effort to foster more cohesiveness among OSLeP research efforts, the Ad Hoc Policy Committee on Informal Science Education of the National Association for Research in Science Teaching (Dierking et al., 2003). Their policy statement named six avenues for research in the domain of out-of-school learning.

1) Examining the Precursors to the Actual Engagement in Learning
Out-of-school learning is self-motivated, voluntary, and guided by learners' needs and interests, so certain aspects of learning are critical to investigate, e.g., the role of motivation, choice and control, interest, and expectations in the learning process.

2) Taking into Account the Physical Settings Where Learning Takes Place
The physical setting in which learning takes place is extremely important, so learning needs to be investigated in authentic contexts.

3) Exploring the Social and Cultural Mediating Factors in the Learning Experience
Out-of-school learning is strongly socio-culturally mediated, so research designs need to offer opportunities to explore social and cultural mediating factors including the role of conversations, social learning networks, cultural dimensions, and the use of groups as well as individuals as the unit of analysis.

4) Promoting Longitudinal Research Designs That Recognize Learning Is Cumulative
Learning is a cumulative process involving connections and reinforcement between the variety of learning experiences a person encounters in his life: at home, during schooling, and out in the community and workplace. Designs need to offer opportunities to investigate all dimensions of learning and their connections in a variety of settings across a span of time which will allow us to understand how these experiences are used and connected to subsequent experiences longitudinally.

5) Investigating the Process of Learning
Learning is both a process and a product, so we need to investigate the processes of learning as well as the products.

6) Expanding the Variety of Methods Used to Carry Out Our Research
The very nature of informal learning requires multiple creative methods for assessing it in a variety of ways under a variety of circumstances. Thus, innovative research designs, methods, and analyses are critical (e.g., conversation/discourse analysis, constructivist tools such as concept mapping and personal meaning mapping, social learning network analysis, hierarchical linear modeling).

Some researchers have also identified a need for more studies that involve interdisciplinary teams, an approach which promises to inform development of more comprehensive theories that can guide research about the many different, and evolving, types of out-of-school learning programs:

> "… abstraction from multiple perspectives including methodological and analytical approaches and broader conceptions of learning hold the promise of emergent knowledge that will be transformative of practice to the betterment of visitor learning. No single definition of learning unites informal learning research, and moreover, changes in paradigm have shifted and continue to shift both the focus and locus of research direction and resulting corpus of knowledge in the field" (Anderson & Ellenbogen, 2012, p. 1179).

1.3.3 Research to complement evaluation

While the goal of the mobiLLab study was to test theory and factors in new ways, and contribute to research about how young people learn about science and technology, another important purpose was to support program evaluation and improvement. Because mobiLLab program faculty helped with developing research priorities, with developing survey and interview scripts, and with interpreting results, findings have supported program improvements. This iterative involvement in the mobiLLab study by program faculty supported development of a research design that measures constructs that are relevant to program goals and priorities, such as novelty of technology and pupil interest, and measures aspects of these constructs that are meaningful for program stakeholders. A detailed description of how the mobiLLab background investigation was conducted to identify indicators of program effectiveness and a relevant research investigation is described by Cors and Robin (Cors & Robin, 2016). Naturally, it was important to recognize how evaluation and research activities are different, something described by Patton (2002):

> "Research, especially basic research, differs from evaluation in that its primary purpose is to generate or test theory and contribute to knowledge for the sake of knowledge. Such

knowledge, and the related theories, may in turn inform action and evaluation, but action is not the primary purpose of fundamental research" (p. 10).

Results of the mobiLLab research investigation are described in this dissertation. Findings from the evaluation work are described in a separate research paper (Cors & Robin, 2016).

1.4 Summary

The low popularity of STEM (science, technology, engineering, and math) subjects and careers among Swiss youth has hardly changed over the last thirty years. As a result, Switzerland now has to import some of its science and technology workers from other countries for its growing workforce, a trend that contributes to the country's economic fragility. For this reason, Switzerland is developing and studying strategies to train and recruit local youth for careers in science and technology. One example of such an effort is the mobiLLab program, which offers a half-day opportunity for pupils in Eastern Switzerland to 'tinker' with high technology experimental equipment. MobiLLab, similar to many mobile laboratories worldwide, describes its core purpose as 'awakening pupils' S&T interest.' Through a background investigation, the mobiLLab team identified main factors believed to affect pupil S&T interest: pre-visit activities, novelty (feelings of unfamiliarity), and teacher attitude. Investigation of these factors through a pilot study, and then a main study focused more sharply on novelty factors that affect pupils' educational outcomes, are described in the following chapters. An investigation of the mobiLLab program responds to societal, educator, and researcher concerns. That is, it promises to support improvements in informal learning programs, like mobiLLab, which are designed to prepare and motivate more youth for jobs in S&T that support our societies. By investigating the specific example of mobiLLab in Eastern Switzerland, this thesis sought to identify factors that educators can leverage for optimizing learner experiences at science and technology out-of-school experiences. Moreover, an investigation can consider how existing theoretical frameworks can remain relevant to the ever-evolving nature of informal learning programs and research investigations about them.

2 Goals of the document

The goal of this document is threefold:

1. Paint of vivid picture of the role of novelty at out-of-school learning places by telling the story of the mobiLLab study.

2. Explain how a three-step inquiry strategy was important for designing a research study that produced findings relevant to the mobiLLab program. These three steps were a background investigation to identify a research focus; a mixed-methods pilot study to test study variables and design; and a main study to examine links among novelty factors and pupils' interest development.

3. Clearly and cohesively present results, so that researchers and educators from a variety of disciplines can understand them and see how they are relevant to their own research and their efforts to develop and manage their own informal learning programs.

II. THEORY AND STATE OF RESEARCH

3 Views of Interest and Novelty through an Informal Learning Lens

3.1 Definitions and dimensions for informal learning

This review of theory, frameworks, and ideas about novelty at informal learning places begins with a review of how researchers define informal learning. Following is a brief account of the history of, and current types of, informal learning venues, which for this study are called out-of-school learning places (OSLePs). Finally, a description of the Contextual Model of Learning, a broad, well-known framework for research about informal learning that was put forth by John Falk and Lynn Dierking (2000), is provided.

3.1.1 What is informal learning?

Learning that happens outside of school has been given a number of different names, such informal learning, non-formal learning, free-choice learning, real-world learning, and hands-on learning. According to the US National Research Council, Board on Science Education, informal science learning can occur just about anywhere:

> "Beyond the schoolhouse door, opportunities for science learning abound. Each year, tens of millions of Americans, young and old, explore and learn about science by visiting informal learning institutions, participating in programs, and using media to pursue their interests. Thousands of organizations dedicate themselves to developing, documenting, and improving science learning in informal environments for learners of *all* ages and backgrounds. They include informal learning and community-based organizations, libraries, schools, think tanks, institutions of higher education, government agencies, private companies, and philanthropic foundations. Informal environments include a broad array of settings, such as family discussions at home, visits to museums, nature centers, or other designed settings, and everyday activities like gardening, as well as recreational activities like hiking and fishing, and participation in clubs. Virtually all people of all ages and backgrounds engage in activities that can support science learning in the course of daily life." (Bell et al., 2009, p. 1).

The CAISE (center for advancement of informal science education) defines informal learning in holistic terms of Lifelong, Life Wide (occurring across multiple venues) and Life Deep (occurring at different levels of complexity) dimensions and recognizes that these experiences occur in people's private, academic and professional lives http://www.informalscience.org/nsf-aisl. Existence of this prominent, worldwide community of informal learning practitioners and researchers underscores how informal learning has come to be recognized as an integral part of promoting science and technology learning.

Generally defined by (type of) setting. Rennie (2007) described informal science learning as something that occurs outside of classrooms. She named characteristics of informal learning, such as learners' greater freedom of choice and how activities are often non-evaluative and non-competitive, yet emphasized how this learning is continuous and avoids developing a precise definition: "If learning is an ongoing, cumulative process that occurs from experience in a range of settings, it does not make sense to try to distinguish it as formal or informal" (p 126).

Some attempts have been made to describe just what type of setting, or place, makes a learning experience informal. For example, Eshach (2007) proposed definitions for two types of out-of-school learning: non-formal learning, which is planned and structured; and informal learning, which occurs spontaneously. The Organization for Economic Co-operation and Development (OECD) recognizes these definitions for non-formal and informal learning, and describes how outcomes for each vary per country (Werquin, 2010). Eshach explained that even though exploring these categories offers a better understanding of what informal learning is, some experiences and programs do not seem to fit into these categories. He concluded that such sharp distinctions between formal and informal learning are inappropriate, as the physical setting is only one of a list of factors that define informal learning.

Other researchers refer to learning outside the classroom as 'out-of-school learning.' In their book a about informal learning from the perspective of teaching geography, Sauerborn and Brühne (2009) also observe that there are many definitions of out-of-school learning. They suggest a multiple-place definition is more appropriate for out-of-school learning, something that emphasizes the importance of context for understanding of geography. Their definition classifies out-of-school learning places with four categories: Nature, Cultural World, Places where people meet, and the Work and production world (p 81).

Anderson and Ellenbogen (2012) also considered definitions for informal learning based on setting. They review how the term 'informal learning' has generally been used to refer to either designed settings outside of school, such as science museums and afterschool clubs, or as non-designed environments, such as forests. They describe designed settings as structured, episodic (not repeated), and those that are navigated freely. However, depending upon one's values and beliefs about humans' ways of knowing, they explain, one could consider some day-to-day activities as formal learning. Moreover, efforts to distinguish informal from formal learning through lists of characteristics oversimplifies important aspects of learning. They conclude that "the classification of learning contexts and experiences as formal or informal are somewhat arbitrary and can be argued and debated by researchers and educators depending on their epistemology of learning and the values to which they subscribe."

The proposed categories for informal learning settings from Dorie et al. (2012) are probably the most relevant to the mobiLLab study. Their rough, systematic review of eight common learning settings involved categorizing each setting according to four different scales of learning: self-directed/collaborative, active/passive, learner/goal oriented, and mandatory/voluntary. The results of the analysis are the FILE (Formal and Informal Learning Environments) taxonomy shown in Table 3. According to the taxonomy, 'Curricular Learning,' or any learning that takes place during normal school hours, tends to be more teacher-directed, passive, goal-oriented, and mandatory. They note that since the mid-1980s, the classroom culture has been shifting to more active student participation. On the other hand, 'Learning in Designed Settings,' or learning that takes place according to a less explicit learning agenda in places like science centers, museums, zoos, and aquariums, tends to be more collaborative, active, learner-directed, and voluntary. The mobiLLab program fits to this category. The authors recognize that the boundaries between informal and formal learning are often blurred and offer the taxonomy as a guide for educators, who may wish to incorporate some elements of informal learning into their classroom lessons. The results can also be useful to researchers, who can employ the taxonomy as a lens through which to explore learning strategies across different learning environments.

Table 3: The FILE (Formal and Informal Learning Environment) taxonomy of learning environments (taken from Dorie et al, 2012)

Learning Environment	Description
Curricular Learning	anything during normal school hours
Learning in Designed Settings	science centers, museums, zoos, aquariums
Extracurricular Learning	tutoring, afterschool programs, design competitions, etc.
Outreach Learning	developed through an outside source
Learning from Media	books, television, games, social network, internet
Service Learning	e.g. Engineers Without Borders, Engineering for a Sustainable World
Everyday Learning	play, family conversations
Professional Learning	workplace learning, professional societies, internships, co-ops

Out-of-school learning events are transient. Organized most often as one-day events, informal learning experiences are recognized as programs designed to introduce new and different windows through which to view our world, providing fodder for reconstructing and applying knowledge (Rennie, 2007). Even though the short-term nature of these events makes it difficult to measure their effectiveness, they are popular with teachers and evidence is mounting that, when properly linked with classroom lessons, they boost science learning (Tran, 2011).

Focus on affective outcomes. Informal science learning programs are generally developed to promote affective outcomes, such as positive attitudes and confidence in doing science (Franzblau et al., 2011; McGinnis et al., 2012). Indeed, mobile laboratory leaders worldwide describe their primary goal as supporting development of pupils' interest in science, so they will become more scientifically literate citizens and they will be more likely to consider careers in science and industry (R. Cors, 2013). Researchers and educators describe the importance of affective outcomes by emphasizing how attitude and curiosity relate to various ways of knowing, in all types of OSLeP settings, and contribute to learning over time:

> "an important role of affect in the visit experience is to prime the learner for subsequent instruction. In other words, an enjoyable and successful visit experience is an important outcome because it can predispose the learner to engage in further cognitive learning. Motivation and willingness to engage in further instruction are most likely to be the important affective outcomes of a visit. In terms of other affective outcomes relating to science, a short visit is more likely to raise students' awareness about science, scientists and future careers than to result in a fundamental change of attitude with respect to these things, although this may also occur." (Rennie, 1994, p. 263).

Participant autonomy presents challenges and opportunities. Compared to classroom learning informal learning offers a more self-directed and autonomous experience, which introduces both challenges and opportunities. A main characteristic of formal learning is that individuals make few choices about who you learn with, who you learn from, what you will learn, where you will learn, how long you will be given to learn it, and so on. Museum consultant McManus describes how, "as a result of these restrictions, on the individual, formal education institutions are very efficient, admirable means of communicating knowledge… In contrast, informal education is entirely free choice" (McManus, 1992, p. 165). Falk and Dierking (2012) established the term free-choice learning, which is meant to recognize how such experiences are learner-centered, rather than institution-centered:

> "Free-choice learning describes the nonlinear, self-directed learning that occurs when individuals have primary responsibility for determining the what, when, where, how, why, and with whom of learning. Although the term free-choice learning does not define the where of learning entirely, currently most free-choice learning occurs outside of the formal education system" (p 106).

While learners value the autonomy of informal learning and often draw motivation from, for example, being able to make more decisions about how their experience proceeds, a free-for-all format is not successful without structure (Aubusson et al., 2012). Critics say that informal learning often employs too little guidance in instruction, overwhelming learners' working memory because they are processing too much novel information, which leads to possible misunderstandings and prevents teachers from gauging whether learners are having problems (Castranova, 2002; Kirschner et al., 2006). This co-existence of these opportunities and pitfalls has been described by some (Aubusson et al., 2012) as the 'inherent paradox' presented by the autonomy encountered by learners at OSLePs:

> "It seems inherently paradoxical but autonomy and independent learning require high support if learners are to flourish in intellectually challenging science learning environments… That is, for students to become autonomous learners in informal environments they require extensive mentoring and support from their teachers in school environments. Hence, what is required is not anarchy but a rebalancing and shift of emphasis that entwines school science with out-of-school science learning experiences and processes" (p. 1131).

With appropriate structure and preparation, informal science learning experiences have the potential to engage learners, prepare and inspire them to work with S&T, and offer practice with important workplace skills such as project management and teamwork skills (Aubusson et al., 2012; Franzblau et al., 2011). MobiLLab, with its step-by-step instructions and coaching from the mobiLLab team, offers the structure that teachers in Eastern Switzerland want. This structure, they say, means that mobiLLab is easy to work with, offering diverse benefits: the program covers topics found in the cantonal curriculum; mobiLLab reinforces other experiences pupils have, such as tours of industry facilities and hands-on science projects; the visit is an opportunity for pupils to work with experimental experiments the schools cannot afford; and pupils can build their confidence in working with complicated instruments (R. Cors, 2013).

Conclusion: Informal science learning is generally defined as learning that occurs outside of the classroom, but is not defined by what types of learning occurs there. The places where informal learning takes place, called out-of-school learning places (OSLePs) for this study, have come to be recognized as an integral part of promoting science and technology learning. Examples of learning environments that related most closely to the mobiLLab are 'designed settings' such as science centers and other mobile laboratories. In comparison with formal learning, OSLePs offer more opportunities for autonomy and self-directed learning, which means participants often require support in the form of orientation, structured activities, and coaching. Experienced generally as transient, one-time events, they have been developed primarily to contribute to affective outcomes and inspire youth about related studies and careers. When successful, informal learning experiences enable people to participate in science, build interest in and motivation about science, and develop confidence with teamwork and hands-on skills.

3.1.2 Out-of-school learning places (OSLePs): a brief history

The first out-of-school learning places (OSLePs) in the west took the form of public education forums in Europe and North American, starting during the Renaissance. This section briefly describes these early forms of museums and how, starting in the 1960s, the educational role of OSLePs became ahigher societal priority.

Early forms. Traditional museums have a dual role of displaying collections and educating visitors. One of the first places in Western society designed to support learning about science and culture outside of school were the ‘cabinets of curiosity’ of Europe of the 16th, 17th and 18th century (Impey & MacGregor, 2001). Also called ‘closets of rarities’ or ‘Wunderkammer,’ these private collections were designed to feed the hunger for learning that was a trademark of the Renaissance. Sometimes viewed as quaint and whimsical, these collections are actually more often recognized as alluring because of their unexpected and unique objects. Object included dazzling and exotic items from precious stones to lizard skin to animal bones and were sometimes arranged to support storytelling. These collections were popular because of people’s rising interest during this period in antiquity and discoveries of the new world.

In American in the 19th century, two forums offered access to public education outside of school education: Lyceums and Chautauquas (Bell et al., 2009). The Lyceums, modeled after the early Greek halls of learning, brought the public together with experts in science and philosophy for lectures, debates, and scientific experiments. The Chautauqua movement, a successor to the Lyceum movement, expanded these forums to address the social and geographic isolation of America’s farming and ranching communities. The Chautauqua, a type of educational family summer camp, brought well-known lecturers and entertainers of to rural communities, where there was a strong hunger for both entertainment and education. These movements were driven by the notion that in a democratic nation, an educated populace is needed to inform public policy.

Today’s landscape. Starting in the 1960s, the educational role of OSLePs in the West started becoming increasingly focused and defined. This reinforced in the 1990s by governments in countries including America, Great Britain, and Canada, who started requiring programs to develop educational policy to receive funding (Rennie, 2007).

McManus (1992) described how, during this period, science-focused OSLePs developed. He relates how a ‘first-generation’ of museums, which had been focused on collections and authoritative information, began first in the 1960s and 1970s to design exhibits to appeal to the needs and interests of visitors. Next a ‘second-generation’ of OSLePs, primarily science and industry museums, focused even more on visitors, seeking to inspire and inform with hands-on exhibits and real-world examples. ‘Third-generation’ science OSLePs reflect a broader shift in museums to focus on ideas, rather than exhibits. These more recent OSLePs took on primarily two forms: theme-related exhibits and science centers. The theme-related exhibitions featured visitor-relevant topics such as evolution or health and sometimes were offered in the form of whole museums, such as the Smithsonian's Air and Space Museum in Washington, D.C. In the 1980s, science centers were established and proliferated rapidly. McManus provides a vivid description of how science centers evolved around the world:

> "Around a dozen {were} established in Britain since 1987. Launch Pad, at the Science Museum, London, Techniquest in Cardiff, and the Exploratory in Bristol were among the pioneers. Science centers are often stared by educationists, museum staff, scientists or engineers having in common a strong personal commitment to the communication of their enthusiasm for science… American professionals established the American Association of Science and Technology Centres (ASTC) in 1973 as a museum grouping which did not require conservation and collections research for full membership" (McManus, 1992, p. 164).

Today science-focused OSLePs come in myriad forms, from science centers to zoos and museums to community-based science programs. One portrayal of the landscape of informal science education venues is offered by Falk and colleagues (2012b), Figure 3, adapted by Müller (2008) to include science centers, mobile laboratories and science shows. This 'landscape' of informal learning community types is based on 25 interviews with OSLePs program managers and educators. The goal of each 45-minute, exploratory interview was to better understand informal learning practitioners from a variety of communities described their work in relation to informal learning and how they viewed their respective professional communities. The landscape of informal science education shows learning venues in relation to one another based on how closely interviewees identified with informal educators (x-axis) and how closely they identified with the goal of promoting public understanding of STEM (y- axis).

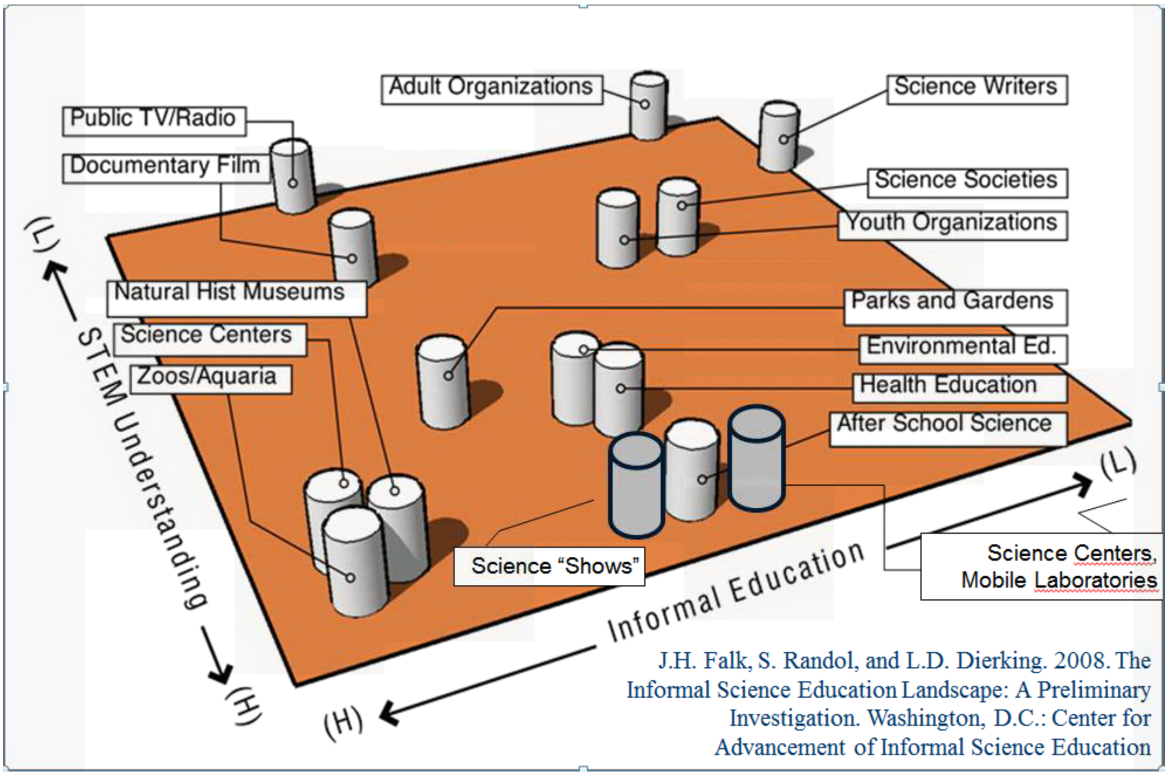


Figure 3: The landscape of informal science education based on identification with informal education and public understanding of STEM (adapted by A. Mueller from Falk et al. 2008).

3.1.3 Dimensions of informal learning

Research about informal learning places focuses primarily on the interaction of two dimensions of the learner experience: their individual factors and the setting factors. Depending upon the descriptions, social factors are thought of as independent or control variables. Probably the most well-known framework developed for informal learning studies is Falk and Dierking's Contextual Model of Learning (2000). Offered as a holistic view of learning at museums, it illustrates how four dimensions of informal learning experiences continuously interact. These dimensions, show in Figure 4, are the personal context, the physical context, the sociocultural context, and time.

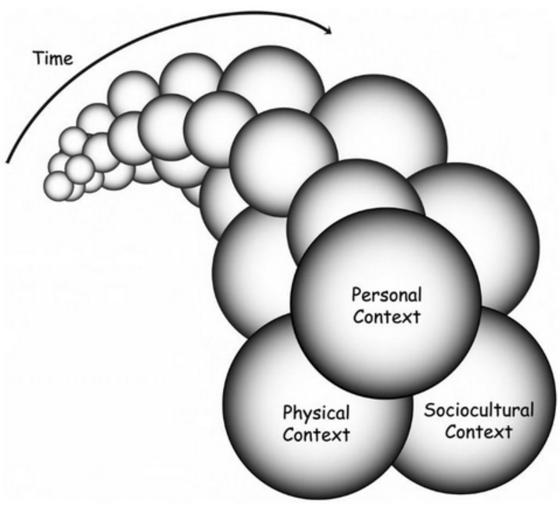


Figure 4: The Contextual Model of Learning illustrates how personal, physical, sociocultural, dimensions continuously interact over time to affect learning at out-of-school learning places.

The Contextual Model of Learning includes twelve critical factors that are categorized into one of the three contexts (Table 4), but emphasizes that these contexts overlap and are not separable. Personal Context factors are about what individuals bring to the learning experience: visitor motivation and expectations, prior knowledge, prior experiences, prior interests, and choice and control. Sociocultural Context factors have to do with group and other social elements affect learning. Physical Context factors describe the attributes of the setting that can affect learning: advanced organizers (preparation), orientation to the physical space, architecture and large-scale environment, design and exposure to exhibits and programs, and subsequent reinforcing events and experiences.

Table 4: The Contextual Model of Learning consists of three contexts and twelve factors that affect learning in informal environments (Falk and Dierking, 2000)

Personal Context	Sociocultural Context	Physical Context
1. Visit motivation and expectations 2. Prior knowledge 3. Prior experiences 4. Prior interests 5. Choice and control	6. Within group social mediation 7. Mediation by others outside the immediate social group	8. Advance organizers 9. Orientation to the physical space 10. Architecture and large-scale environment 11. Design and exposure to exhibits and programs 12. Subsequent reinforcing events and experiences outside the museum

The broad nature of the Contextual Model of Learning means that it is often employed as a framework that can be valuable, for example, for relating studies that look at different aspects of the OSLeP experience. However, individual studies of OSLePs generally explore just several of the twelve factors from the Contextual Model of Learning at one time. This is primarily because their aim is to produce strong evidence of the effects (or lack thereof) of a few factors through, for example, triangulated data. Nonetheless, the Contextual Model of Learning reminds investigators about how important it is to consider control variables that indicate what factors outside of their experimental design, such as gender or home language, could be affecting learners' experiences besides the main independent variables, such as classroom preparation. In a paper about learning at a science center, Falk and Storksdieck (2005) articulate how the Contextual Model of Learning was designed to offer a framework, rather than a model, for studying the on-going interactions of myriad variables over time:

> "The Contextual Model of Learning is not a model in its truest sense; it does not purport to make predictions other than that learning is always a complex phenomenon situated within a series of contexts. More appropriately, the "model" can be thought of as a framework. The view of learning embodied in this framework is that learning can be conceptualized as a contextually driven effort to make meaning in order to survive and prosper within the world; an effort that is best viewed as a continuous, never-ending dialogue between the individual and his or her physical and sociocultural environment" (p. 745).

Other informal learning researchers describe similar frameworks for investigating OSLePs. For example, in framing their research agenda for OSLeP studies, the NARST Ad Hoc Committee (Dierking et al., 2003) described how informal learning is 1) a personal process, 2) that is contextualized, and 3) that takes time. These categories capture the factors that are most relevant to informal learning, which shapes overall learning, adding new perspectives and conceptions one uses to construct new knowledge:

> "In the past decade, research in the social and natural sciences has demonstrated that learning is strongly influenced by prior knowledge and experience, interest, and motivations, all shaping the expectations that people have for a learning experience. Learning is also a cumulative process—it can take days, weeks, or even months for new experiences to be sufficiently integrated with prior knowledge before learning is measurable let alone noticeable even to the learner. New data also suggest that most learning has more to do with consolidation and

> reinforcement of previously understood ideas than with the creation of totally new knowledge structures" (p. 110).

3.2 Interest as an OSLeP educational outcome

Driven by a societal need to interest youth in science and technology careers, this section describes how development of interest from an OSLeP experience is an outcome important to educators, program managers and employers of scientists and technology experts. Definitions of and theories describe how interest development depends upon a person's current dispositional interests and the interestingness of the object of potential interest. Developed to attract people and then engage learners in an activity, OSLePs are thought to be designed support this 'catch-hold' process. Interest development as a dependent variable is often studied alongside self-concept of ability and attitude, and studies have shown that interest in and knowledge about science differs from interest in and ability about experimenting and technology.

3.2.1 Individual interest

This section describes how individual interest has been seen and important for effective education since the beginning of the 20th century. According to interest development theories put forth by Krapp (1999) and by Hidi and Renninger (2006), the enduring dispositional interest develops when situational interest is triggered and lasts for long enough to become internalized.

Defining interest and its development

American philosopher and educator John Dewey is recognized at a pioneer in the field of experiential education. He described interest in an education context as a harmonization, or 'unification,' of a person with the object or topic of interest (Dewey, 1913). According to his views, interest develops when a person realizes the relevance of the object of interest, that is, they can relate the object to an already-existing area of interest. In his view, internal motivations and autonomy in learning are critical for interest development. Moreover, interest is critical for effective education.

In a review of literature about interest, Hidi and Renninger (2006) also found that interest, in the form of attention and goals, can have strong influences on learning. They go on to explain how interest is thought differ from other motivation variables in that it is the results of interaction between a person and 'a particular content.' They explain: "The potential for interest is in the person but the content and the environment define the direction of interest and contribute to its development" (p.112). In a more recent publication (Renninger & Hidi, 2015) they summarize how evidence from neuroscience supports Dewey's ideas about how interest is key to learning:

> "Although not all of Dewey's ideas were supported by subsequent research, many of them were. Neuroscience information was unavailable to Dewey. Now, this research suggests that there are biological correlates of interest indicating that interest is inherently rewarding. Recent findings suggest that interest is its own reward and that the development is even more powerful {for driving learning} than Dewey suggested" (p. 6).

Person-object theory of interest development

Educational psychologists also have defined interest development as a result of interactions between an individual and the object of potential interest. However, in his person-object theory of interest development (POI), Krapp (1999) gives more detail to the processes that results from these interactions. The theory is based the idea that the development of interest takes place when individuals interact with their environment. Another underlying idea is that interest is made up of cognitive and affective elements, so that it involves not only enjoyment, but a personal relevance and openness to engage. POI emerged out of three views on interest outlined by Krapp et al. (1992). The first perspective is of interest as a dispositional characteristic of the person. The second view is of the interestingness of the learning context. The third view of interest is as a psychological state that is closely linked to both the dispositional characteristics of the person and the interestingness of the context. The development of enduring, dispositional interest occurs when situational interest is triggered, or aroused, and lasts for long enough to become internalized. Krapp (2002) describes internalization as a process that involves a learner progressing through two levels of situational interest before a final transition to a more enduring dispositional interest, as shown in Figure 5. First, the learner experiences a situational interest, which is aroused, or 'caught,' by attraction to an/or curiosity about an object. Then, if the learners' attention is 'held' and they continue to interact with the object, their interest shifts to what Krapp calls a more stable situational motivational state of working interest. Then, if the learner's stabilized situational interest lasts through enough subsequent situations, it can develop into an individual interest in something.

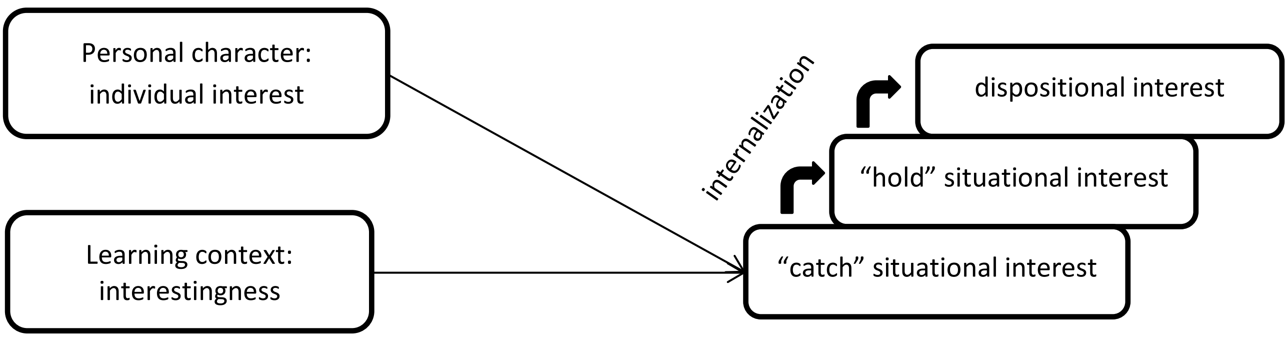


Figure 5: Interest development theory (a synthesis of descriptions and illustrations from Krapp (1999, 2002)).

Krapp (2002) elaborates on how interest in a new topic or object develops: "The content of the learning material presented is not part of the subject area of the learer's already exisiting individual interests, rather the interesting factors in this specific situation 'awaken' the interest for a shorter or longer period of time. Under certain conditions, a longer-lasting {person-object}-relationship which meets the criteria of a personal interest can grow out of such a situational interest." p. 398.

The Four-Phase Model of Interest Development

Similar to Krapp's Person-Object Theory of interest development, Hidi and Renninger's (2006) Four-Phase Model of Interest Development also describes two phases of situational interest. The theory describes how interest develops through four phases. The first phase, called Triggered Situational Interest,' is sparked by surprising or personally relevant text or environmental features, and is often heavily externally supported. Learning situations involving group work and puzzles, for example, trigger this initial situational interest phase. The second phase, Maintained Situational Interest, occurs when the situational interest persists and reoccurs. This more stable situational interest is generally sustained when a person finds meaningfulness in a task, through for example project-based learning or one-on-one tutoring, and it is often externally supported. A third phase, called Emerging Individual Interest, refers to when a person seeks repeatedly to reengage with the content over time, which is accompanied by positive feelings about the content and storage of relevant knowledge. The final phase of the model is called Well-Developed Individual Interest and involves an enduring predisposition to engage with the content repeatedly over time. In this phase, a person tends to become more resourceful and feels effortlessness when working with the content. Learning situations that fosters this enduring interest are those that provide interaction and challenges that lead to building of knowledge.

According to this model, novelty of environment acts as a spark for interest development. That is, for each phase, interest development occurs through triggering process, described as “interactions or circumstances that can result in the reorganization of learner thinking by promoting uncertainty, surprise, novelty, complexity, or incongruity about the content in question” (Renninger, 2009, p. 107). OSLePs are to ‘spark’ the interest of visitors in displays and activities. Indeed, during research planning for the mobiLLab study, mobiLLab faculty talked about a goal of awakening pupils’ interest in S&T (R. Cors, 2013). Researches have recognized that these triggers for interest at OSLePs are form of novelty designed to attract and intrigue. For example, Falk and Dierking (2011) advise that pre-visit orientation should create a good balance of telling visitor what they will see and do and about unusual sights, sounds smells, but leaving some novelty left to the visitor to discover.

It is worth noting that differing ability to self-regulate behavior have been found to characterize each phase of interest in the Four-Phase Model of Interest Development, and that changes in these self-regulation occur when interest develops or recedes.

3.2.2 OSLePs are designed to “catch” and “hold” learner interest

In a review of literature about science labs in Germany, Priemer and Pawek (2014) assert that, designed well, OSLePs will “catch” and “hold” pupil interest in STEM subjects. They list several aspects of OSLePs thought to be important for sparking interest and then for cultivating and prolonging situational interest. Qualities of OSLePs that catch interest are how enjoyable and successful the learner felt the experience was; how stimulating learning setting is; and how authentic and novel (in an attractive, exiting sense) the setting is. Holding situational interest depends on how well OSLeP topics are linked to classroom learning, through “pre- and post-instruction, by multiple visits, and by integrating the visit to the school curriculum” (p.5). In the case of mobiLLab, team members articulated, that the half-day visit with pupils is designed to spark pupils’ sense of possibility about science and technology topics and careers (Cors, 2013).

Researchers and OSLeP program managers recognize the importance of personal relevance at OSLePs, where people visit only the exhibits they are attracted to or, in the case of mobiLLab, choose in advanced the experimental posts that sound interesting to them. For example, researchers have found that personal relevance, such as links to classroom lessons, affects how learners engage in informal learning experiences, and what they take away from them (Anderson, 1999; Tran, 2011).

3.2.3 Desired outcomes that relate to interest: self-concept of ability and attitude

When assessing interest development, particularly for science learning, researchers often also pay attention to attitude and self-concept. This is because, as described in this section, links have been identified among these variables and has been described in a review of studies about S&T interest (Potvin & Abdelkrim, 2014). Also, any investigation ´worth its salt´ recognizes that subjects are affected by experiences in more than one way, and sometimes differently from one another, and therefore it is wise to measure the dependent factor using more than one criterion measure (Stevens, 2002).

Self-concept of ability (SCA) is a person's idea about level of skill in an area. In a longitudinal study with children aged 6-17 from the Midwestern part of the United States, Denissen et al. (2007) explored the links among achievement, interest, and self-concept across academic domains of English, science, math, sports and music. Their work was based on the Expectancy-Value (E-V) theory of achievement, which focuses on the relations among achievement, domain-specific interests, and self-concept. They found evidence that interest and self-concept were most strongly associated with one another and that they varied with gender. The link between interest and self-concept was slightly higher if it included all domains and slightly lower if it included science education. They summarize:

> "Across all calculated indexes, the average level of coupling was positive. Individuals generally felt competent and interested in domains where they achieve well, and were interested in domains where they perceive their personal strengths. The degree of coupling was the highest between interest and SCA and the lowest between interest and achievement. For all indexes, evidence for an increase in coupling across time was found. Female gender was related to a lower level of coupling" (p. 430).

In their model of learning and performance, Dresel and Lämmle (2011) view self-concept, along with interest, as individual factors critical for motivation to learn. They describe self-concept as generally depending upon expectations related to the learning situation. Several studies at science centers and mobile laboratories have examined both interest and self-concept (sometimes called 'confidence in science ability' or 'perceived ability in learning science') as dependent variables, sometimes finding an improvement in self-concept from before to after the visit (Barmby et al., 2005; Brandt et al., 2008; Dowell, 2010; Engel, 2004; Meier, 2015; Pawek, 2009).

Considering the importance of **attitude towards science** is relatively newer for educators, who have had two conflicting perspectives about how to define scientific literacy. That is, science educators have been divided about whether the curriculum should emphasize subject matter or life situations in which science plays a key role (Roberts, 2007). The former view was based on the idea that if someone has knowledge of science they can apply that scientific knowledge in their lives, an assumption that ignores the role of attitude. The creators of PISA (Program for International Student Assessment) 2006 responded to this idea that attitude plays a major role in whether and how people act on their science knowledge, as articulated by Bybee and McCrae (2011):

> "There is an assumption that scientific knowledge directly influences personal decisions and behaviours. This assumption gives little or no recognition of a domain that includes interests, attitudes, beliefs, and values which influence personal decisions… PISA 2006 science took a

step in this direction by including attitudinal dimension in the definition of scientific literacy and the assessment" (p. 8).

In a synopsis of the thinking behind the PISA 2006 attitudinal items, Bybee and McCrae describe how a person's early, repeated experiences with science, both in and out of school, shape their beliefs, emotions, and dispositions to science (Bybee & McCrae, 2011). They emphasize how attitudes represent a system of cognitions and emotions that relate to action, which is strongly liked to students' interest in science. Indeed, many studies about attitude to S&T employ this "classical construct of attitude, which usually consists of three components (cognitive, affective and behavioural), and the idea of positive or negative (like or dislike) inclinations towards an object," as described in a literature review by Potvin and Hasni (2014, p. 95). The PISA 2006 questionnaire was ultimately designed to characterize youth's attitudes in three areas (Figure 6): interest in science, support for scientific enquiry, and responsibility towards resources and environments.

PISA 2006 science attitudinal dimension

Interest in science
- Indicate curiosity in science and science-related issues and endeavours.
- Demonstrate willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods.
- Demonstrate willingness to seek information and have an ongoing interest in science, including consideration of science-related careers.

Support for scientific enquiry
- Acknowledge the importance of considering difference scientific perspectives and arguments.
- Support the use of factual information and rational explanations.
- Express the need for logical and careful processing in drawing conclusions.

Responsibility towards resources and environments
- Show a sense of personal responsibility for maintaining a sustainable environment.
- Demonstrate awareness of the environmental consequences of individual actions.
- Demonstrate willingness to take action to maintain natural resources.

Figure 6: PISA 2006 science attitudinal dimensions (recreated from Bybee and McCrae (2011)).

With a sharp focus on preparing and inspiring youth for careers in science and industry, and for participation as scientifically literate citizens, mobile laboratories in the United States are particularly focused on attitude towards science (Franzblau et al., 2011). Program evaluations commonly assess attitude to interest, usually along with interest in science, and study results are mixed about whether OSLeP experiences support improvements in attitude (Barmby et al., 2005; Dowell, 2011; Franzblau et al., 2011).

3.2.4 Interest varies depending upon science discipline and upon technology

During the mobiLLab background investigation (Cors, 2013), mobiLLab faculty discussed how many of the mobiLLab experiments have to do with technology-related science topics, such as physics at the infrared camera post. Moreover, pupils need to use the computer and other equipment even at the few experimental posts that have to do with biology, such as the Spiro-ergometer post for examining respiratory gases. They talked about wanting to promote ´technophilia,' or an attraction to working with science through technology, among pupils. However, most previous studies of similar programs ask pupils about their interest in science and not about their interest in technology.

A review of literature suggests that it would be appropriate to measure pupil interest in natural science separately from their interest in technology. This is based on findings from existing studies, which show that ´science interest´ for pupils worldwide depends upon the specific science discipline they are asked about, and also upon whether they are experimenting or not. That is, while some pupils are interested in physical sciences, such as physics and chemistry, others are more interested in earth and life sciences, such as biology and geology, and these topical interest differences sometimes correlate with gender (Buccheri et al., 2011; Bybee & McCrae, 2011; Potvin & Abdelkrim, 2014). For example, school lab studies by Pawek (2009) found science interest differed among pupils depending upon the discipline (Biology, Chemistry, Math or Physics). Moreover, studies at OSLePs show a difference between interest in science versus interest in experimentation (Itzek-Greulich et al., 2015; Pawek, 2009).

3.3 Individual novelty factors thought to affect interest development at OSLePs

Two theories inform us about the individual novelty-related factors thought to affect interest development at OSLePs. Self-Determination Theory (SDT) defines three 'basic needs' that must be met for person to engage and thrive in a learning environment (Deci et al., 1991). Orion and Hofstein's 'novelty space' theory defines three pupil factors thought to influence how unfamiliar learners perceive an OSLeP to be, a perception which studies suggest affects educational outcomes. These theories address the 'personal context' factors from The Contextual Model of Learning, a framework for informal learning research described on page 17.

3.3.1 Motivation, behavior, and interest at OSLePs

This section describes how the quality with which humans are motivated to engage in an activity are, according to SDT, driven primarily by conditions supporting a learner's experience of autonomy, competence, and social relatedness, known as the 'basic needs' for well-being and optimal functioning. This section outlines how the Person-Object Theory of Interest development (POI) is a cognitive-emotional system, where the basic needs of SDT play a crucial role in the emotional mechanism. Developed to provide a more social, autonomous learning experience, where competence is rarely tested, OSLePs are considered optimal for interest development because learners operate in a more self-directed manner. A final discussion point is about how, even though OSLePs generally offer more opportunities for such self-regulation, only learning that attracts learners through intrinsic appeal, such as novelty or challenge, will be driven by intrinsic motivation.

Self-Determination Theory

Deci and Ryan's Self-Determination Theory (SDT) (Deci & Ryan, 2000a; 1991) provides a lens for relating human personality and experiences to motivation and behaviors in life and in learning environments, including OSLePs. SDT is based on the idea that both self-determined and controlled behaviors are motivated or intentional but the processes in humans that regulate them are very different. According to SDT, we are inherently driven (out of the three basic needs) to internalize and engage in uninteresting activities that are useful.

SDT defines intrinsic and extrinsic sources of motivation and how they drive behavior. These different types of motivation are listen in table Table 5 (top row), which provides examples of behaviors we choose, depending upon the source of our motivation (extrinsic or intrinsic). For example, a learner who is motivated intrinsically engages because the task is interesting and would, for example, join a science club because she likes experimenting. An additional key aspect of SDT is how social and cultural context can support or 'thwart' people's potential. The quality with which humans are motivated to engage in an activity are, according to SDT, driven primarily by conditions supporting a learner's experience of autonomy, competence, and social relatedness, known as the 'basic needs' for well-being and optimal functioning. The quality of engagement, in turn, affects the quality of learner performance, persistence, and creativity.

Table 5: Intrinsic and extrinsic drivers of behavior, according to Self-Determination Theory (from Deci et al., 1991).

Extrinsically motivated				Intrinsic motivation
External regulation	Introjected regulation	Identified regulation	Integrated regulation	
Driver: Gain praise, avoid punishment	Coercion or seduction	Value the behavior as supporting a goal	Activity is in line with individual's coherent self	Activity is interesting.
Example: Doing homework to avoid punishment from teachers, parents	Go to class on time to avoid feeling like a bad person	Do extra math work to promote continued good performance	Creativity, conceptual or intuitive understanding are markers.	Join the science club because you like experimenting.
Degree to which contingent is internalized: Contingency is external.	Internalized rules or demands.	Identification with and acceptance of regulatory process.	Behavior fully assimilated with persons other values, needs, identities.	Completely internally driven. Individual seeks activity.

Autonomy and sense of choice
→→

According to SDT, the extent to which we integrate and internalize new ideas is a function of social context and its support for autonomy. Supports for competence and social relatedness will enhance motivation and internalization of regulations only when they are offered along with opportunities for autonomy. Examples of autonomy-supporting influences are when pupils choose task or decide how it will be carried out or, for example, when a teacher acknowledges feelings of pupils not liking the task. Indeed, informal learning experiences usually involve learners working more autonomously than in the classroom (page 10). Researchers have found that autonomous activity is valued by learners, at least in part, because there are usually opportunities for sharing learning with peers, or a feeling of social connection:

> "A consistent finding from school visits to zoos, natural history museums, and science centres has been that students' views of their own learning are entwined with their social environment and that visiting in small groups can provide optimal contexts for sharing information. They associate new knowledge with social value. When someone has seen something new they become special and can tell others about it…" (Aubusson et al., 2012, p. 1122).

The 'basic needs' of SDT drive interest development, according to POI

In a functional description of the Person-Object Theory of Interest development (POI), Krapp (2005) describes how the 'basic needs' defined by SDT are key influencers of interest development. POI is based on the idea that human are motivated by a dual-regulation system that consists of cognitive rational and also (partly subconscious) emotional control mechanisms. In this cognitive-emotional system, the basic needs of SDT play a crucial role in the emotional mechanism. The hypothesis here is that interest development will only occur if both cognitive-rational and emotional feedbacks are experienced in a positive way. Similarly, in her investigations of classroom learning using a Dual Processing Self-Regulation Model, Boekaerts et al. (2007; Boekaerts & Corno, 2005a; 2006) captures how pupils' efforts to meet cognitive-based and emotional-based goals drives their behavior in the classroom. She describes the classroom as a place of competing goals: "… the messy world of classroom learning creates a situation in which different goals compete for students' attention. Boekaerts' dual processing self-regulation model describes how learning goals interact with well-being goals" (2005, p. 199). She suggests that pupils choose well-being goals, such as drawing attention to themselves or withdrawing, over cognitive (on-task) goals when they are stressed and have no coping mechanisms.

Indeed, studies of OSLePs confirm a link between SDT's basic needs and participant interest. For example, research demonstrates that whether learners' basic needs were fulfilled at a student laboratory for molecular biology differed depended upon their dispositional interest in science. Through their study, Glowinski and Bayrhuber (2011, p. 385) found that, for pupils with low interest in science, meeting their basic needs for well-being was dependent upon pre-visit instruction, while their peers who were more interested in science did not need pre-visit instruction to fulfil their basic needs. These results also underscore the key role of classroom preparation for science learning at OSLePs.

OSLePs are optimal for self-directed learning

Based on the idea that OSLePs involve more learner choices and fewer teacher-initiated goals and assessments than classroom experiences, Boekaerts & Minnaert (1999) proposed that OSLePs optimize learning experiences in a way that fosters intrinsic motivation. She elaborates on how, at OSLePs, people more often develop their own goals in alignment with their needs and, they work in a self-directed manner, there is a better chance of developing desired educational outcomes:

> "What sets informal learning contexts apart from formal learning contexts is the perception of choice. Self-regulation, in the true sense of the word, will only emerge when students are allowed to learn in a context where they can weigh the feasibility and desirability of alternative actions and goals … using their own criteria. The perception of freedom of action (an appraisal which informs students that they can act according to their own wishes, expectations and needs) in a supportive context (where they can borrow resources when needed) will help them to translate their own needs, expectations and wishes into clear intentions (goal setting; see Boekaerts, 1999). The main point to be made is that students have a better chance of developing their own goals in accordance with their need structure when they are allowed to learn in a realistic context … in formal learning contexts students are expected to pursue teacher-defined and teacher-initiated goals and this calls for goal-maintenance, prompted by external regulation, rather than self-maintenance based on internal regulation. … However, most informal learning contexts are more powerful for developing criteria for success, progress, and satisfaction, which are in accordance with the students' own need structure. It should be evident that a dominant focus on developing and using one's own criteria will help students to develop and maintain specific learning outcomes" (p. 542).

Intrinsic motivation requires the draw of appeal. While informal learning may elicit more opportunities for self-regulation, only learning draws people in through intrinsic appeal will be regulated by intrinsic motivation. This is outlined by cognitive evaluation theory (CET) (Deci & Ryan, 2000b), a sub-theory of SDT that outlines the social and environmental factors that account for the variability in people's intrinsic motivation. This model suggests that the degree to which people's basic needs are met in a learning environment determines how intrinsically motivated they are to engage in an activity. The model holds true, however, only for those activities that spark people's interest:

> "It is critical to remember, however, that people will be intrinsically motivated only for activities that hold intrinsic interest for them, activities that have the appeal of novelty, challenge, or aesthetic value. For activities that do not hold such appeal, the principles of CET do not apply, because the activities will not be experienced as intrinsically motivated to begin with" (Ryan & Deci, 2000, p. 71).

3.3.2 Individual factors that impact 'novelty space'

This section describes how novelty in the form of unfamiliarity has been seen as a barrier to effective learning at OSLePs. Based on this ideas, Orion (1989) proposed that learners' experiences during a geology field trip depend upon how familiar they feel, something linked to three 'novelty space' factors: previous relevant knowledge (*cognitive* aspect), their familiarity with the field trip area (*geographic* aspect), and their previous outdoor event experiences (*affective* aspect).

NOTE: Orion (1991) and later studies about novelty space use the term 'psychologic' or 'psychological' to describe learner characteristics such as attitudes towards a field trip or apprehension and tiredness, which have to do with emotion. We instead use the term `affective´ to describe these learner characteristics, because it is more in line with established terminology.

Also described is a later work, through which Orion and Hofstein developed a list of seven dimensions about how individuals relate to OSLeP settings that are thought to influence learning (1997). One of these dimensions is relevant to their novelty theory, and to the mobiLLab study is called 'preparation and organization.'

Reducing 'novelty space' factors improves OSLeP experience

To investigate how to optimize pupil attitude and learning from field trips for geology courses, Orion (1989) built on the idea from Falk et al (1978) that the novelty of the field environment hinders learning on a field trip. The main hypothesis of the 'novelty space' framework (Orion, 1989), Figure 7, was that pupils' field trip experience will be more productive based on three 'pre-field' factors: their previous relevant knowledge (*cognitive* aspect), their familiarity with the field trip area (*geographic* aspect), and their previous outdoor event experiences (*affective* aspect[1]). The educational quality of a field trip depends upon learners' novelty space (or Familiarity Index) (Orion & Hofstein, 1994) and when these three pre-field variables are reduced before the field trip, learning is improved.

[1] Orion (1991) and later studies about novelty space use the term 'psychologic' or 'psychological' to describe learner characteristics such as attitudes towards a field trip or apprehension and tiredness, which have to do with emotion. We instead use the term `affective´ to describe these learner characteristics, because it is more in line with established terminology.

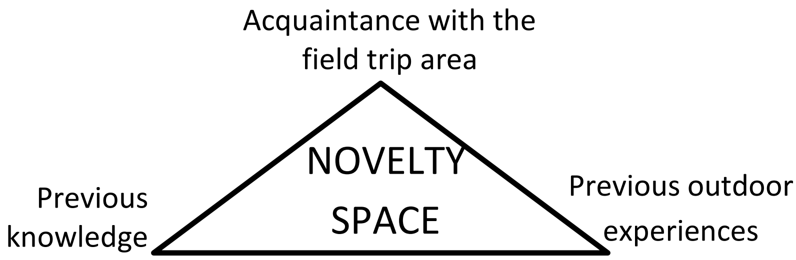


Figure 7: The three components of novelty space: pupils' previous knowledge, acquaintance of the field trip area, and previous outdoor experiences (Orion, 1989).

Novelty space can be reduced through appropriate preparation that reduces unfamiliarity (Orion, 1989). That is, 'previous knowledge' can be increased through classroom lessons and 'acquaintance with the field trip area' can be accomplished through showing films, maps and photos of the area. The third factor, more explicitly defined in a subsequent paper (Hofstein & Rosenfeld, 1996), is a measure of whether pupils view the field trip as a time for socializing and adventure or as a learning activity. This 'previous outdoor experiences' factor refers to an attitude, which had sometimes developed through participating in other field trips, that the time is solely for fun. A teacher can optimize this factor by explaining that the purpose of and activities for the field trip are designed to support their learning experience. This third factor actually gets at the impetus behind Orion's (Orion, 1989) effort, which was aimed at integrating the courses into the curriculum, and building teachers' and pupils' sense of purposefulness about the field trips:

> "Field trips are used, in general, for enrichment of classroom learning. Thus they usually occur at the end of the course, often as a sort of summary or "prize" for the students. The purpose of this article is to present a method of inserting field trips into geology courses… The approach suggested here views the field trip as a learning event which is an integral and indispensable component of the learning process" (p. 13).

Know-how to navigate an OSLeP setting

Later work by Orion and Hofstein and other several others researchers (1997), defined seven dimensions that describe how learners related to OSLePs that affect their learning. The dimensions of the SOLEI (Science Outdoor Learning Environment Inventory) are environmental interaction, integration, student cohesiveness, teacher supportiveness, open ended-ness, preparation and organization, and material environment. The dimension most relevant to their experience was 'preparation and organization,' a dimension that indicates the extent to which students were prepared for the field trip in terms of expectations and organization of the event. Similarly, Falk and Dierking (2011) describe how two kinds of pre-visit knowledge determine how much is learned: 1) content knowledge, which they say supports chunking of information into a subject area and 2) knowledge about how to use a museum, which they call 'museum savvy.' According to the Webster's and Cambridge Dictionaries, 'savvy' is used to describe someone who has a lot of practical knowledge and ability.

3.4 Novelty of place

This section describes the setting-related novelty factors thought to affect learning at OSLePs. Some frameworks view novelty as something overwhelming. To reduce the resulting overloads to working memory, educators have often developed materials based on cognitive load theory, yet cognitive load has not yet been studied as a variable related to novelty at OSLePs. Other models propose that a situation that introduces moderate levels of novelty lead to moderate levels of curiosity and on-task exploration, which in turn lead to optimal outcomes. Related research about curiosity shows that it has been related to novelty in general, but not yet in an OSLeP setting. Still other theories expand on this inverted-U relation between novelty, exploration and behavior, and there are several examples from OSLePs.

These frameworks for studying novelty of place and how it affects learning at OSLePs related most to the Contextual Model of Learning factor from the 'physical context' category that is called 'Orientation to the physical space.' Two other 'physical context' factors proposed by the Context Model of Learning also have to do with the setting, but are more specific to museums: 'Architecture and large-scale environment' and 'Design and exposure to exhibits and programs.' Two additional 'physical context' factors proposed by the Context Model of Learning have to do with preparation and post-visit activities, something explored by several studies described starting on page 45, namely 'Advanced organizers' and 'Subsequent reinforcing events and experiences outside the museum.'

3.4.1 Humans need to adjust to novelty of place

Novelty of OSLeP settings has been described as something overwhelming or disconcerting, something that learners need to overcome. For example, in discussing informal learning programs, Falk et al (2011) has observed how 'novelty of place' seems to cause anxiety and nervous behavior in children (p. 50). In an earlier paper, Falk and colleagues (Falk et al., 1978) described the 'novelty field-trip phenomenon' as an adjustment and adaptation process that learners use in response to initial feelings of disorientation when they arrive at an OSLeP, whose setting is typically designed to be stimulating. They unpack this idea by introducing how any time a learner encounters a new situation, he must first identify the new objects and then relate the objects to categories that are already familiar to him.

> "If the novel situation is a forest, the learner would first need to have the experience of "itemizing," or more likely locating, the trees, shrubs, vines, etc. before a useful concept of forest could be arrived at. Piaget …proposed the concepts of assimilation, accommodation, and equilibrium. If a learner enters a forest, but already possesses some structures for forests, the new setting is readily assimilated into the previously existing structures. However, if the setting is completely novel, a greater disequilibrium may occur, necessitating greater accommodation to the new information and the formation of entirely new structures before the learner reaches a state of relative equilibrium." (p. 128).

In learning settings Falk et al. (1978) explain, this process of adjustment occupies cognitive processes of the learner, distracting them from learning tasks. This adaptation process interferes with learning, so a person's ability to engage in a structured learning activity improves with time, as adjustment progresses. Similarly, educational psychologists suggest that the free exploration of novel, complex, unfamiliar environments, particularly without proper preparation or structure, may generate a heavy working memory load that hinders learning (Kirschner, 2006). The mobiLLab classroom preparation materials and recommendations (posted on the website), for example, were developed to familiarize pupils with the equipment, procedures, and concepts used at the visit, in order to prevent them from being overwhelmed during the visit. The hope is that, if pupils, for example, see photos of the mobiLLab equipment, understand the plan for the day, and learn about the procedures for operating them, they will need minimal time at the visit for orientation and can spend more time engaged at experimental posts. Educational psychologists recognize this type of instruction, which is designed to "ensure that learners' working memory is not overloaded," as cognitive load theory (CLT)-based instruction (Paas et al., 2010, p. 117). De Jong (2009) explains what cognitive load is and how it has become important to educational researchers:

> "Cognitive load is a theoretical notion with an increasingly central role in the educational research literature. The basic idea of cognitive load theory is that cognitive capacity in working memory is limited, so that if a learning task requires too much capacity, learning will be hampered. The recommended remedy is to design instructional systems that optimize the use of working memory capacity and avoid cognitive overload" (p. 105).

Through his review of studies about cognitive load and instruction, de Jong (2009) concludes that measuring cognitive load is difficult to do validly and reliably. For example, he explains that study participants' responses to questionnaire items are highly sensitive to small differences in item wording. He sees a number of limitations to cognitive load measurement: measures are always presented as relative; most frequently used measures are not sensitive to variations over time; studies that measure only one overall concept of cognitive load do not do justice to its multidimensional character; and such overall ratings are not meaningful when interpreting results in terms of cognitive theory.

While recognizing that there are practical problems with measuring a personal experience about workload, Hart and Staveland (1988) assert that "subjective ratings may come closest to tapping the essence of mental workload and provide the most generally valid and sensitive indicator. They provide the only source of information about the subjective impact of a task on operators and integrate the effects of many workload contributors" (p. 241). They also explain that people rarely quantify, remember or verbalize their impressions of workload and believe it is more effective to ask subjects to offer a less precise 'linguistic' rating for workload. They describe how such responses are more natural for people, who typically describe their experiences in verbal terms and with modifiers, such as 'high' or 'easy.' In addition, Hart and Staveland described the experience of workload as representing a "combination of immediate experiences and preconceptions of the rater and is, therefore, the result of constructive cognitive processes" (p.241.).

Based on these insights, Hart and Staveland, researchers at the NASA-Ames Research Center in California, involved 247 adults from a wide range of occupations in a study to develop a multi-dimensional workload rating scale. Subjects engaged in a series of tasks including simple cognitive and manual tasks, complex laboratory tasks and aircraft simulation, develop. The goal of the study was to develop a rating scale for workload that provided "a sensitive summary of workload variations within and between tasks that is diagnostic with respect to the sources of workload and relatively insensitive to individual differences among subjects" (p. 242).

The product of the work is the NASA-TLX (task load index) list of six dimensions of cognitive load, and their definitions, shown in Table 6. The process also produced some further insights from investigators about how people make subjective ratings of workload experiences. First, they explain that a phenomenon exists that people generally call workload, but its specific causes may differ from one task to the next. Second, ratings for a specific task are more representative of workload than a general, global rating of workload for an activity. Third, subjects' definitions of workload were different, which contributes to between-subject differences; (thereby contributing to between-subject variability); however, the specific sources of loading imposed by a task are more potent determinants of workload experiences than such *a priori* biases. Fourth, a score made up of combined dimensions of workload provides a measure that is more stable between raters than measures of a single dimension.

Table 6: Definitions of the dimensions of the NASA TLX workload rating scale (Hart & Staveland, 1988).

Dimension of workload	Endpoints	Descriptions
Mental demand	Low/ High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical demand	Low/ High	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal demand	Low/ High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Good/ Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/ High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration level	Low/ High	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

For an OSLeP like the mobiLLab program, some dimensional measures of the NASA-TLX scale are more appropriate than others. Specifically, the mental demand, temporal, effort and frustration dimensions would provide an indication of the degree to which pupils perceived workload during the mobiLLab visit. In contrast, there is rarely physical demand during a visit with a technology-related OSLeP, such as a science center or mobile laboratory; however, a field trip may involve some physical activity that demands some of learners' cognitive capacity. And while there are surely some OSLePs that tie performance to classroom learning, most do not.

3.4.2 Novelty and curiosity

Novelty has also been recognition as an aspect of something, an object or a place, that can inspire engagement in learning activities. For example, informal science researchers (Dierking et al., 2003) recognize the potential curiosity has for fostering learning at OSLePs: "Neuroscience research … demonstrates the importance of motivation, interest, and emotion in the learning process itself, suggesting that when people are interested and curious about something, there is a high possibility that they will follow up on that feeling with action, resulting in meaningful learning." (p. 110).

Based on ideas from Falk (1982) and Berlyne (1960), Anderson and Lucas (1997) hypothesized that too little or too much novelty would not produce the appropriate amount of curiosity behavior and exploratory behavior needed for learning. They illustrated their theory about the relations between novelty, curiosity, and learning in a diagram, shown in Figure 8. They define curiosity in the OSLeP context as “a stimulus to explore, manipulate and interact with the environment, which is generated by the individual’s feelings of perceived novelty.” They explain that “Low levels of perceived novelty result in low levels of curiosity behaviour and low levels of on-task behaviour, which are likely to result in potentially low levels of learning. Very high levels of perceived novelty result in high levels of exploration and setting information gathering, which take precedence over on-task, institutionally intended learning, and this is likely to result in low levels of learning” (p. 486).

This hypothesis from Anderson and Lukas (1997) introduced novelty as something that, at the appropriate level, can be attractive and appealing to learners, something central to some models about interest development in learning environments. These models, Krapp’s person-object theory of interest development (POI) (Krapp, 1999), and Hidi and Renninger’s Four-Phase Model of Interest Development (Hidi & Renniger, 2006), describe how interest development process is triggered by a some appealingly novel aspect of the object. Developed to pique people’s curiosity and then engage them in an activity, OSLePs are designed support this ‘catch-hold’ process (Priemer & Pawek, 2014).

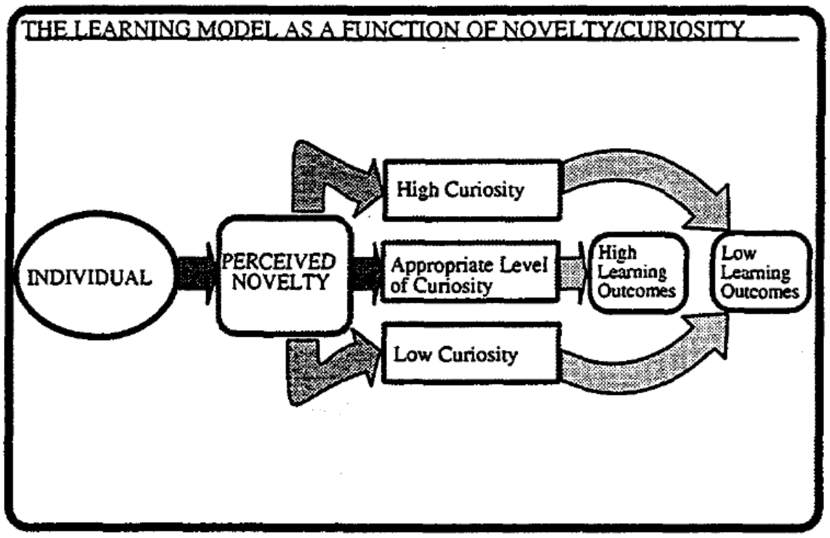


Figure 8: Hypothesized relations between perceived novelty, curiosity and learning outcomes from Anderson and Lucas (1997).

What exactly is curiosity and how does it relate to novelty, or unfamiliarity, at an OSLeP? Curiosity is described as a desire for new knowledge or experience, a desire that motivates exploratory behavior (Berlyne, 1951, 1960). Schmitt and Lahroodi (2008) asserted that curiosity has value unique for education and inquiry. It facilitates inquiry and discovery, but unlike other motivational drivers, sustains attention and action until something is known:

> "We suggest that the requirement that the attention sustains the desire to know makes curiosity generally (other things being equal) more valuable epistemically than other motivationally original desires to know such as the desire caused by a startlingly loud noise. For the fact that the desire to know in curiosity sustains one's attention to the topic makes it more likely that the desire will be satisfied than would be the case without this sustaining relation. The mutual support involved in curiosity is thus a feature of curiosity that makes it generally more valuable epistemically than other motivationally original desires to know" (p. 129).

Berlyne (Berlyne, 1954) made an early distinction between two types of curiosity, perceptual and epistemic curiosity. He described curiosity that drives exploration to experience more about a stimulus as perceptual curiosity (PC) and a drive to fill gaps in conceptual knowledge as epistemic curiosity (EC). In an effort to produce evidence that people exhibit these two types of curiosity, Litman and Spielberger (2003) conducted a survey study and factor analysis. Study results provided clear evidence of distinctions between PC and EC survey answers, and also determined that there were diversive (general) and specific (stimulus-driven) aspects of the EC construct. A presentation of different types of curiosity based on these findings is shown in Table 7. Both EC scales correlated strongly with scales from the Novelty Experiencing Scale (P. Pearson, 1970), which represents a tendency to approach or avoid novel stimuli.

Table 7: Typologies for curiosity based on Berlyne (1954) and Litman & Spielberger (2003)

Motivation type (Berlyne)	Definition	Exploratory behavior to decrease novelty (L&S)	Examples
Perceptual curiosity (PC)	desire to experience	'diversive': seek new experiences.	'like to discover new places'
		'specific': seek specific sensation.	'like to touch new fabric'
Epistemic curiosity (EC)	drive to know	'diversive': seek new information.	'enjoy exploring new ideas'
		'specific': seek knowledge about a topic.	'want to know how that machine works'

People come to OSLePs with differences in their general tendency to be curious. However, OSLePs are designed to be appealingly novel, so that they pique people's curiosity for that situation. Naylor (Naylor, 2007) identified a difference between people's dispositional curiosity and their feeling of curiosity in a certain situation. That is, he found significantly distinct responses to two types of curiosity: dispositional curiosity, which he called C-Trait, and situational curiosity, which he called C-State. His Melbourne Curiosity Inventory was developed through three separate studies. Correlations suggested that C-Trait was less sensitive to changes in situations than C-State. Although Naylor does not explore the relation between C-Trait and C-State, he speculates that they are linked.

3.4.3 Novelty and exploratory behavior

For their study of novelty at an OSLeP, Kubota and Olstad (1991) refer to a guiding framework that relates novelty to exploration. They refer to the definitions from Berlyne (1960) for two types of exploratory behavior:

> "The purpose of specific exploration is to reduce uncertainty produced by a particular, novel stimulus. In a scientific museum this might be a particular object or exhibit. On the other hand, the purpose of diversive exploration has been seen as an effort to reduce the uncertainty of a novel environment. For example, in a science museum, diversive exploration reduced the uncertainty of the entire exhibit hall by providing orientation to the elements within that environment" (p. 226).

In a review of literature about exploratory behavior to inform their informal learning research, Falk et al. (1978) learned that, for a number of organisms, exploration increases linearly with how novel the stimuli is. However, a number of findings suggest that novelty of place elicits one of three types of responses, or has 'three faces.' This holds true for experiences in general and for learning contexts in particular, and very specifically for novelty as an aspect of the OSLeP experience. Both Förster et al. (2010) and Falk et al. (1978, 1982) describe how novelty of events can elicit interest and increase curiosity, be threatening because it carries some risks, or be boring, causing an off-task search for stimulation.

One the one hand, some studies at OSLePs support assertions that perceived 'appealing' novelty can promote interest and curiosity. For example, Dohn (2010) describes how employing surprise, variety and novelty as instructional strategies were triggers for pupil interest during a field trip to an aquarium. An earlier study by Sandifer (2003) explored how the characteristics of interactive exhibits at a science museum are effective in attracting and holding the attention of visitors. One the other hand, there is also strong evidence that too much novelty can lead to response such as cognitive overload, confusion and anxiety. Falk et al. (1978), for example, assert that "extreme novelty leads to less exploration and even fear" (p. 128). In a third case, novelty has been shown to relate to boredom (Falk & Balling, 1982).

These three faces of novelty can be characterized in terms of a general law of psychology, the Yerkes-Dodson Law (YDL) (Baldi & Bucherelli, 2005; Roeckelein, 2006), which describes an inverted-U relationship between arousal (such as motivation or anxiety) and performance (such as attention, memory, problem solving). It states that there is an optimal level of arousal for performance, illustrated most commonly using the Hebbian graph Figure 9. More specifically, it describes how, increasing arousal will increase attention and performance (ascending leg of ∩), but only up to a certain point (highest point of ∩), beyond which there is a decrease of performance (descending leg of ∩). In mathematical terms, Yerkes-Dodson or inverted-U relationships are simply a function with a single maximum.

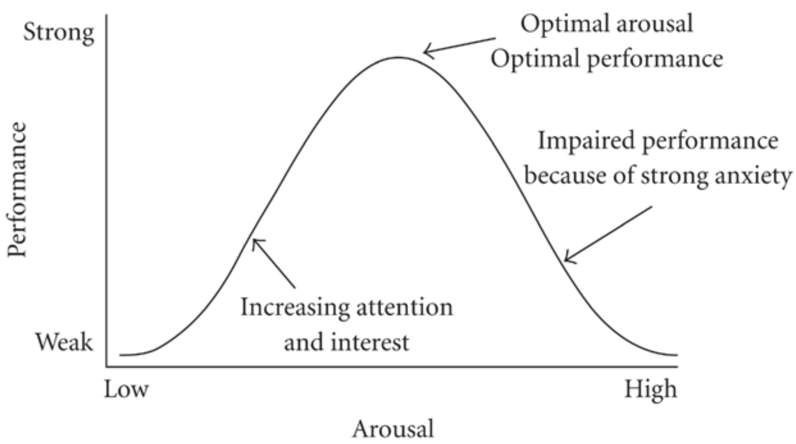


Figure 9: Hebbian version of the Yerkes–Dodson law (Wikipedia).

In conventional terms, the YDL suggests that without some motivating tension we have no reason to act. In this way, stress or tension can be thought of as a good thing. Humans are built to be motivated by stress. The problem is that too much stress can cause performance to decline again. The behavior in the downturn of the inverted-U has been called 'satisficing' and is quite differently motivated from the earlier stages of arousal/ stress. Rather than gain satisfaction or reward from actions, a person who is satisficing seeks any way of reducing their stress, sometimes choosing sub-optimal solutions and exhibiting performance decline. For example, researchers found that for complex way-finding tasks, people tend to learn only what is necessary and sufficient (Iyengar et al., 2012).

Similarly, psychologist and philosopher Berlyne writes that "we are indifferent to things that are either too remote from our experience or too familiar" (1960, p. 21). Lee and Crompton (Lee & Crompton, 1992) describe Berlyne´s findings about the relation between the novelty of objects and the exploratory behavior of laboratory rats as having an inverted-U shape:

> "Berlyne reported … {that} novel stimuli increase the extent of the exploratory behavior. However, extremely novel stimuli may discourage exploration. The relationship between exploratory behavior and novelty was found to be an inverted-U shaped function, with the maximum level of exploratory behavior being exhibited in the presence of moderately novel stimuli." (p. 743)

The YDL has also been employed to investigate non-cognitive psychological functions, such as aesthetic appraisal (Berlyne, 1963), suggesting it may be relevant to studies of affective educational outcomes. However, the author has only found two examples of investigations about science learning that have employed an inverted-U function to interpret investigation findings. The first study was by Falk and Balling (Falk & Balling, 1982), who found that an inverted-U best described the relation between novelty and findings about both behavior and learning at an OSLeP, described on page 50. In another study about classroom science learning, Sliva (2013), used the YDL model to describe results about the relation between classroom physics test performance and workload. It seems that the YDL and its empirical underpinnings have not yet been fully explored as a tool for investigating the relation between learning, novelty, motivation, and behavior at OSLePs.

3.5 Summary: Links between novelty and interest development at OSLePs

While definitions of informal learning vary, researchers generally agree that informal learning is something that occurs outside of school and some have proposed categories for different out-of-school settings (Anderson & Ellenbogen, 2012; Dorie et al., 2012; Eschach, 2007; Rennie, 2007). For the purposes of this research, informal learning refers to learning that occurs outside of school in designed settings, or settings that are developed with consideration for an educational agenda, such as museums and science centers. The places where this learning occurs will be referred to as out-of-school learning places (OSLePs). The landscape of informal science education consists of manifold types of venues, from natural history museums to science societies to mobile laboratories. Broad frameworks for investigating informal science education experiences describe the learning process as an interaction of individual, physical, sociocultural, and temporal factors. Researchers also find it important to recognize informal learning experiences as part of an on-going, lifelong, cumulative learning process.

Investigating interest development as a learning outcome at OSLePs is the focus of this study and the concept is central to several models from educational psychology. Krapp's Person-Object Theory of Interest Development (POI) (2002) and Hidi and Renninger's Four-Phase Model of Interest Development (2006) describe interest development as something that occurs through interactions between a person and the object of potential interest. The development of enduring dispositional interest occurs when situation interest is triggered and lasts for long enough to become internalized. Developed to attract people and then engage them in an activity, OSLePs are thought to be designed support this 'catch-hold' process. OSLeP studies that explore interest development as a dependent variable often also explore self-concept of ability and attitude, which have been shown to be closely coupled for many learners (Denissen et al., 2007; Dresel & Lämmle, 2011; Potvin & Abdelkrim, 2014). It is also worth noting that studies have found that interest in science differs for learners depending upon whether one refers to earth sciences like biology or to physical sciences like physics, and that these preferences are often differ depending upon gender (Bybee & McCrae, 2011). Moreover, interest in science can differ from interest in experimenting (Itzek-Greulich et al., 2015; Pawek, 2009).

Individual factors linked to interest development as OSLePs have to do with how engaged learners are, which depends upon how able they feel to direct their own learning (Krapp, 2005). Because they offer learners more choices and involve fewer externally set goals, OSLePs are thought to be optimal places for supporting self-directed learning. That is, they are places where learners tend to feel more competent, autonomous and socially connected, the 'basic needs' humans need to fulfill in order to thrive in life, according to self-determination theory (SDT) (Deci et al., 1991). These three 'basic needs' are thought to support engaged, on-task behavior that can foster interest development. However, while informal learning experiences may elicit more opportunities for self-determined behavior, only situations that are intrinsically interesting, via novelty or challenge or aestheics, will be self-regulated. Another set of individual factors that are thought to affect outcomes such as interest development have to do with how unfamiliar, or novel and overwhelming, a person finds an OSLeP situation. Three of these factors are described by Orion and Hofstein's (1991, 1994) novelty space theory: 1) previous content knowledge, 2) familiarity with the setting, and 3) attitude about the purpose of the OSLeP event.

Setting factors, or the degree to which learners find OSLeP settings to be novel, have also been related to interest development. Early work investigating OSLePs by Falk et al. (1978) was guided by the idea that too much perceived novelty causes learners to encounter disequilibrium. They describe how, to regain equilibrium, learners explore and process the new items in the environment in a way that requires cognitive capacity, something recognized by educational researchers as cognitive load (de Jong, 2009; Paas et al., 2010). Discussions about exploring have described two types of exploration: diversive exploration, which reduces uncertainty of a novel environment, and specific exploration, which is focused on an object or stimulus (Berlyne, 1960). The highest levels of specific, or task-related, exploration have been shown to relate to moderate levels of perceived novelty (Berlyne, 1960; Falk & Balling, 1982), something that can be described by an inverted-U function. In this vein, some OSLeP researchers hypothesize that, if novelty is experienced in moderation, then learners will feel curious and explore, which leads to learning (Anderson & Lucas, 1997). Studies of curiosity have shown links to novelty seeking measurements (Litman & Spielberger, 2003) and researchers have developed distinct measures for dispositional and situational curiosity (Naylor, 2007).

4 State of Research

This section describes studies about novelty at OSLePs that informed the mobiLLab study. A first part briefly reviews the history of research about science learning at OSLePs and then discusses studies about science learning at OSLePs similar to mobiLLab. In a second part, studies of novelty at OSLePs are reviewed. The last part offers descriptions of the mobiLLab background investigation and pilot study.

4.1 Research about learning science at OSLePs

For the last two decades, program evaluations and investigations have accompanied the proliferation of science museums and science centers, providing clues about what factors affect development of science interest. This section describes how the focus of studies about science learning at OSLePs have shifted over the last half-century from the effectiveness of exhibits to the visitor, how they construct knowledge, and how their attitudes are affected. A review of studies about science learning is presented in two groups. First discussed are evaluations of mobile laboratory programs in Europe and the United States that have been conducted over the past decade. These programs offer pupils a similar experience to mobiLLab and evaluation reports offered viewpoints about what factors influence science interest development at OSLePs like mobiLLab. Also reviewed are studies conducted over the last 12 years of pupil visits to school laboratories built by the German Centers for Air and Space (DLR) and similar programs. Even though these OSLeP venues differed somewhat in form and format from the mobiLLab offer, investigations of these educational laboratories provided valuable insights into studying interest development at OSLePs by a German-speaking population.

4.1.1 Brief overview of early studies of science learning at OSLePs

Studies of learning about science OSLePs first became somewhat common in the 1960s and took the form of visitor studies at museums that mostly evaluate the effectiveness of exhibits, as described by Rennie (2007). She explains how, in the 1970s and 1980s researchers shifted their focus to the visitor experience. A number of studies were influenced by education research and employed methodology used for studying learning in schools, such as pretest-post, control group designs that measured cognitive visitor outcomes. Other studies of this time were driven by a shift to thinking that exhibits should meet the needs of visitors, and qualitative approaches were used to gain insight into the affective aspects of visitors' experiences. With the 1990s came a focus on constructivist interpretations made by the visitor. By the 2000s, research about informal science learning became quite active, as both science museums and science centers had proliferated.

4.1.2 Studies at mobile laboratories worldwide

Studies of six mobile laboratories in England, Switzerland, and the United States, shown in Table 7, were mostly conducted as program evaluations, that is, comparing the results of the program with its goals (R. Cors, 2013). Two of the studies explore pupils' science knowledge or understanding as a dependent variable. All but one study look at the impact of the program on pupils' affective outcomes of interest in and/or their attitude to science, and some also explore science literacy, perceived ability, and future intentions/ careers. Three studies explored teacher and volunteer coach viewpoints in conjunction with pupil outcomes.

Results of the studies paint a mixed picture about the effectiveness of mobile laboratories to support improvements in interest in and attitude towards science. For example, the MdBioLab evaluation reported a "slight but statistically significant increase in interest (2.1 {of 25} points) between the pre-test and post-test (t=-14.28, p=.000)" (Dowell, 2010, p. 15), however effect sizes were not available. The report states that changes in interest varied with gender and race but not with school graduation rate, with scores on a standardized biology test, or with family or community income. The study also found that "students with medium and low levels of confidence prior to the lab showed gains in confidence after participating in the lab compared to students with high levels of confidence prior to the lab (who actually demonstrated a slight decrease in confidence)" (Dowell, 2010, p. 21), however no data were provided about this particular analysis.

In contrast, analysis of survey responses from participants in the Lab in a Lorry program, who ranged in age from 11 to 14 years, showed that attitudinal measures such as interest in and self-concept to science declined significantly from before to after the visit (Barmby et al., 2005). Results of a two-way analysis of variance (ANOVA) with repeated measures (no statistics provided) suggest that the decline related to pupils' age. That is, they report that there was no statistically significant difference in the decline in attitude to science between pupils who visited Lab in a Lorry and those who did not. Examination of these same measures for all pupils, whether or not they participated in the Lab in a Lorry, shows a decline for each measure for pupils from year 7 to year 8, and again from year 8 to year 9. Investigators conclude that, "although positively perceived, Lab in a Lorry was not enough to reverse this decline in attitudes towards science {that occurs as pupils get older}" (p. 10). The report emphasized a need for hands-on activities in order to allow teachers and pupils to communicate about their enthusiasm and knowledge about science, which was linked to positive feedback about the experience.

In some cases, the program leader shared a hypothesis about what works for their program during an interview. At the Paul Sherrer Institute, familiarity, and content understanding are thought to support interest development (Gassmann, personal communication, November 21, 2012). At the MdBioLab the greatest effect is thought to be on pupils who are unsure about their interest in and ability to do science (Colvin, personal communication, February 8, 2013). Several program leaders emphasized the limited ability of their studies, with just pre-and post- survey sampling to untangle influences from the mobile laboratory from other factors in pupils' lives.

Table 8: Descriptive Matrix of Evaluations of Mobile Laboratory Program (from Cors, 2013).

Program	Sample Distribution (TG/ CG)	Timing/ Duration	Goals/ Questions	Results/ Hypothesis (H)
iLab, PSI, Switzerland Pupil survey (Gassmann, 2012)	11,000/ -	Last part of PSI visit. Each year since 2008.	Seven questions about interest in and understanding of experiments.	80% Ps find experiments understandable and interesting. Found a significant correlation between pupils who understand experiments and those who find them more interesting. H: Familiarity and understanding support interest development.
MdBioLab, Maryland Pupil survey, teacher survey and interviews (Dowell, 2011)	970/ --	Sampling before and after lab visit. (1997-2011)	1-Test science knowledge and literacy, 2-Ask about attitudes towards science and careers, 3-Ask teachers about experience.	Ps showed knowledge increase, girls more, blacks less. Slight impact on interest and confidence in science or perceived usefulness of science. H: Greatest effect is on pupils who are unsure about their interest and ability; they become more confident with their competence to conduct experiment.
Lab in a Lorry, Great Britain, Pupil survey (Barmby et al., 2005)	268/ 81	2 weeks before, 2 weeks after ML visit. 2005.	Ps science interest, perceived ability, attitude, future intentions. Also teacher and volunteer interviews.	Both TG und CG Ps' attitudes toward science declined, consistent with decline with Ps age. Ps and volunteers' found experience enjoyable and motivating. H: Incorporating more hands-on work in the classroom may have more lasting effect on Ss' attitudes, Ts' professional development.
Morehead Science Center, North Carolina, Pupil survey (Harden, personal communication, November 20, 2012).	~6000/ ~3000-6000	Before, after the mobile lab visit during school year. Since 2002.	Questions about biology for honors biology pupils.	In some classes P survey scores were about two times greater after mobile lab visit than before. CG pupils who experience the same lesson but not the lab showed a smaller performance improvement. It is difficult to discern between effects from our mobile laboratory program and other factors in pupils' lives.
CityLab survey of teachers who use mobile laboratories in the US & Hong Kong (Franzblau et al., 2011)	Teachers of age 5-10: 48 11-13: 51 14-19: 75 / --	Online survey distributed in spring 2010.	What benefits do Ts attribute to their participation in MLs? What impact do Ts perceive that ML experience has on P learning, attitudes, behaviors?	Ts perceive that mobile labs successfully meet key goals of exposing Ps to advanced equipment and techniques, increasing Ps interest in science. Ts reported that P engagement, learning and retention were high, and rated mobile labs experience as better than other options such as museums, etc.
CityLab ML student survey Boston, Massachusetts*	540/ 123	2003	What is the impact of the CityLab and/or its mobile lab experience on pupils' attitudes about biotechnology?	Attitude gain for both TG and CG was small; however, Ps who visited CityLab or had a visit from its mobile lab developed a significantly more positive attitude than CG Ps.

TG=treatment group. CG=control group. H: hypothesis drawn from results. T=teacher. P=pupil.

4.1.3 Studies of school laboratories in Germany

Science laboratories designed for youth education have been around since at least 1984 and in 2015 more than 300 were in operation in Germany alone, according to a report from the network association LernortLabor (2015). These school laboratories, *Schülerlaboren,* have been an integral part of supporting STEM education (German: MINT (*Mathematik, Informatik, Naturwissenschaften, Technik*)). While they were generally developed to promote interest and knowledge about natural science and engineering among Germany's youth, there are some differences in the goals they emphasize. According to LernortLabor (2015), a typical school laboratory experience involves entire school classes in hands-on experimentation with equipment that may not be available at school. The labs are designed with 45-minute experiments relating to MINT topics that are meant to appeal to both genders. The mobiLLab program falls into the category of a 'teaching-learning lab,' *Lehr-Lern-Labor*, where pre-service science teachers coach pupils as they conduct lab experimentation as part of their training to be teachers. Other types of school labs in this network are the 'pupil research centers,' the 'school labs for science communication,' 'school labs for business,' and 'career-oriented school labs.' According to the LernortLabor report (2015), a core framework that guided development of Germany's science educational labs is Krapp's Person-Object Theory of Interest (POI) (2001) and they recognize the lab experience as a way to stimulate, or 'catch,' pupils' situational interest.

Table 8 describes eight investigations of science educational laboratories in Germany that have taken place over the past decade. The table lists the authors, variables, participants, and design for these studies. It is worth noting that, even though these studies are similar to the mobiLLab program because they involved a German-speaking population, other aspects are somewhat different. For example, the studies conducted by Engeln (2004) and Pawek (2009) were about pupil visits to school laboratories built by the German Centers for Air and Space (DLR). DLR laboratories are similar to mobiLLab in that pupils work independently on experiments that relate to physics and can consult faculty-coaches. However, pupils spent up to 120 minutes at DLR experimental stations and a school group may participate in lab activities for up to a week, whereas they spend 45 minutes as each mobiLLab station and spend a half-day with mobiLLab. Also, school groups go to DLR locations, whereas mobiLLab delivers the laboratory experience to schools. Another difference is seen in the types of experiments the laboratory offers. For example, Glowinski studied pupils who spent 1 to 3 hours conducting a polymerase chain reaction experiment, while the mobiLLab pupils conduct 45-minute experiments with equipment commonly found in Swiss industries.

Table 9: Summary of studies about school science labs in Germany (from Pawek 2014).

Author(s), Subject(s)	Variables	Participants	Design	Additional Information
Engeln (2004), physics	Characteristics of the science labs: authenticity, openness of the experiments, cooperation of students. Personal attributes: situational interest, dispositional interest, self-concept, gender	Age: 15-16 years n=334 (1st. survey) n=265 (2nd. survey)	Intervention with post-test and follow-up-test 12 weeks later	Five different science labs
Brandt (2005), chemistry	Self-concept, gender stereotypes, dispositional interest, intrinsic and extrinsic motivation	Age: 13-14 years n=494	Pre- and post-test, follow-up test four months	Design with control groups

Author(s), Subject(s)	Variables	Participants	Design	Additional Information
			later	
Scharfenberg (2005), biology	Acceptance of the science labs, knowledge acquisition, interest	Age: 18 years n=314	Pre- and post-test, follow-up test six weeks later	Design with control groups
Guderian (2007), physics	Situational interest, dispositional interest, curricular integration	Age: 11 and 16 years n=93	Pre- and post-test	Multiple visits to one science lab, curricular integration
Priemer et al. (2007), different subjects	Epistemic component of the situational interest	Age: 12-18 years n=709	Intervention with post-test	Different science projects in one science lab
Glowinski (2007), biology	Dispositional interest, situational interest	Age: 16-18 years n=458 (1st. survey) n=378 (2nd. survey)	Intervention with post-test and follow-up-test 10-12 weeks later	Five different science labs
Pawek (2009, 2012), physics	See Engeln (2004)	Age: 15-19 years n=734 (1st. study, 2009) Age: 17 n=83 (2nd. study, 2012)	1st. study: pre-, post-, and follow-up test design 2nd. study: second followup-test after one year	Four different science labs
Zehren (2009), chemistry	Inquiry experiment, curricular integration, motivation, interest, knowledge acquisition	Age: 14 years n=287 (1st. study) Age: 15 years n=131 (2nd. study) Age: 16 years n=100 (3rd. study) Age: 19 years n=92 (4th. study)	1st. study: post-test after five visits 2nd. study: second posttest after 1-5 additional visits 3rd. study: third post-test after 1 additional visit 4th. study: fourth post-test after up to 25 visits in total	Four different projects in one science lab, design with control groups

In a review of these studies, Priemer and Pawek (2014) explain that the laboratories were designed to foster development of pupils' interest in science. The interest construct is defined slightly differently, but mostly in accordance with what has been put forth by Krapp et al. (Krapp, 1999), described on page 19. Even though the investigations differ somewhat in the labs they studied and the way they measured interest, some patterns from the results are evident, as summarized in a review of these studies (Priemer & Pawek, 2014). Findings from most of the studies provide evidence that visits spark a situational interest in the science, measured as an interest in the experiments or other aspects of the experience. For example, Brandt found pupils showed short-term (situational) gains in self-concept of ability for chemistry, intrinsic motivation, and related career interest (Brandt et al., 2008, p. 172). It is worth noting that Brandt found that dispositional interest sank from pre- to post-survey and again from post- to follow-up survey. However, results from these studies are mixed regarding whether situational interest lasts long enough after the laboratory visit to support a shift in dispositional interest. For example, Pawek found that pupils sustained short-term gains in the emotional (fun) and value-oriented (importance) components of situational interest six to eight weeks after the visit, and even one year after the visit (data not provided) (Priemer & Pawek, 2014). In contrast, Guderian's study showed a gain in the epistemic component of situational interest from pre- to post-survey, but then a decline from post-to follow-up survey (Guderian, 2007, p. 119).

These studies identified several pupil factors that influenced situational interest. Several studies demonstrated that a dispositional interest in science (or in the specific discipline of the laboratory, such as chemistry), predicted situational interest (Engel, 2004; Glowinski, 2007; Guderian, 2007; Pawek, 2009). For example, 5^{th} graders in Guderian's study who came to the laboratory with more interest in physics reported a greater increase in the epistemic component of their situational interest than those with less initial interest in physics, ($F (1, 42) = 5.03$, $p = .030$, $f = 0.34$). Some results indicate that a proper preparation also made a difference in the development of aspects of situational interest (Engel, 2004; Glowinski 2007; Sharfenberger, 2005). Several studies have shown significant links between the 'basic needs' for humans to thrive, from Social Determination Theory (SDT), and situational interest. For example, pupils' feelings of competence and social relatedness have been shown, through structural equation modelling, to be significant predictors of situational interest in conducting science experiments (Glowinski & Bayrhuber, 2011). In another example, Pawek (2009, p. 101) found significant correlations between SDT's basic needs and emotional, value-related and epistemic aspects of situational interest. Specifically, the study found links between autonomy ('*Offenheit*') and aspects of situational interest (r=.21-.33); between competence/ understandability ('Verständlichkeit') and aspects of situational interest (r=.32-.49); and between social relatedness ('*Zusammenarbeit*') and aspects of situational interest (r=.20-.40). Age was another factor that related to situational learning. That is, similar to findings from the Lab in a Lorry evaluation (page 40), Guderian found that younger pupils' (5^{th} class) situational interest was moderately greater than older pupils' situational interest (8^{th} class), $t(77) = -2.35$, $p = .022$, $d = 0.53$. Findings from these studies showed no clear evidence of gender differences in development for situational interest, even though, for example, Brandt found girls had a less (dispositional) 'fascination' for chemistry, $F=(1,483)=8.92$, $p=.001$. Pawek also found no significant difference between boy and girls for development of situational interest and self-concept of ability. However, he notes that 'self-concept grew more and the epistemic component of {situational} interest decreased more for girls' (Pawek, 2009, p 116).

Characteristics of the laboratory setting were also found to influence situational interest. For example, Engel found that when pupils perceived a lab environment as more challenging, authentic, and understandable to be more closely linked to greater interest. Glowinski found that factors that made a difference with situational interest were understandability, a feeling that they gained some insight into how science research actually works, and the quality of the instruction at the visit. Guderian, whose study involved pupils who visited a laboratory three times, observed that the meaningfulness and enjoyment of the experience faded for pupils from the first to the third visit. The author attributes this decrease in laboratory appeal to their increasing familiarity (*'Gewohnungseffect'*) with the laboratory (Guderian, 2007, p. 117).

4.2 State of Research about novelty at OSLePs

Since the 1970s, a handful of studies have explored how novelty at OSLePs relates to learners' at-visit behavior and to cognitive and affective educational outcomes. Table 10 provides a summary of studies included in the literature review, listing the authors, the study sample size and subject ages, the novelty factors identified, and results for educational outcomes. A description of each study and a comparative discussion follows.

This in-depth literature review examines studies of novelty at OSLePs. The main focus was on comparing what novelty factors were investigated, how they were measured, how these factors were related to educational outcomes, and how the results were reported. The types and measures for educational outcomes were also reviewed and attention was given to the nature of the OSLeP. Using the research databases EBSCO, ERIC, FIS (German language database), Google Scholar and Science Direct, searches were made for studies of novelty at OSLePs using combinations of a short list of keywords: novelty, informal learning, science learning, technology, science center, mobile laboratory, science interest. The studies in included in the literature review are presented in chronological order, to reflect how the research has evolved over time. In the interest of comparing results, I calculated absent effect sizes when possible (Wilson, 2015). Effect sizes can be interpreted using the key at the bottom of Table 9.

Table 10: Summary of studies about novelty at out-of-school learning places (OSLePs).

Authors	N	Novelty Factors	Learners' cognitive, affective and behavioral outcomes
Falk et al. 1978	31 (20 girls) pupils who visited nature center in Maryland, ages 10-13	✓ Familiarity with wooded settings. *Note: Data confirmed knowledge of wooded setting was greater (p<.05) for Familiar group (TG) than Unfamiliar group.*	COGNITIVE: Test score improvements about foliage greater for Familiar than Unfamiliar group (p<.05). AFFECTIVE/ BEHAVIORAL: Unfamiliar group was rowdier, expressing more fears; less attentive to learning task than Familiar group.
Falk & Balling 1982	196 3rd (46 girls) and 5th (44 girls) graders in mid-Atlantic US	✓ Difference in learning environment *TG: studied biology of trees at a nature center (@NC)* *CG: studied same lesson at woods next to school (@SCH)*	COGNITIVE: Knowledge gain means showed grade x location interaction: Gr5@NC > Gr@SCH > Gr3@NC > Gr5@SCH. BEHAVIORAL: Gr3@SCH and Gr5NC more on-task. AFFECTIVE: no significant differences between TG, CG.
Kubota & Olstad 1991	64 Seattle pupils (32 girls) visited Pacific Science Centers' Science Playground, sixth grade (11-13)	✓ Familiarity with interactive exhibits. *Compared pupils who watched orienting video about exhibits (VE=vicarious exposure (TG)) with not (P=placebo).*	COGNITIVE: VE boys post-visit test scores better than VE girls, P pupils (p<.02). More exploratory behavior linked to better test scores (r=0.56). BEHAVIORAL: VE group exhibited more on-task exploratory behavior than the P group (p<.001), particularly VE boys (p<.001).
Orion & Hofstein 1991	296 geography pupils in Israel, classes 9-11	3 factors explain 22% of pupil attitude to learning: ✓ Content familiarity (cognitive) 10% ✓ Field trip seen as adventure versus learning (psychologic) 9% ✓ Geographic x-section (geographic) 3% *Intervention: different classroom preparations*	COGNITIVE: Pupils with a more complete preparation scored slightly better on rock identification post-test (d=0.36, p=.002) and on field trip science phenomena post-test (d=0.29, p=.01). AFFECTIVE: Slightly more pupils with a more complete preparation saw the field trip as a 'learning tool' (d=0.29, p=.01) that is for their 'individualized learning' (d=0.36, p=.002).
Anderson & Lukas 1997	75 (29 girls) pupils visiting Queensland Science Center, grade 8	✓ Pre-visit orientation (*treatment*) ✓ Previous visits to Center *TG: experienced pre-visit orientation.*	COGNITIVE: Pupils with pre-visit orientation (p<.05) and/or previously visited the Center (p<.01) scored moderately (both d=0.5) better on a science concepts knowledge post-visit test.
Jarvis & Pell 2005	300 pupils, ages 10-11, visiting the UK National Space Center	✓ Teacher attitude ✓ Classroom preparation for skills, schedule, roles, 'learning day,' content ✓ Interest of a parent, sibling	AFFECTIVE: More thorough prep & follow-up, positive teacher attitude related to 1) higher science enthusiasm scores that do not fade and 2) decreased anxiety that does not climb after the visit.
Cotton & Cotton 2009	37 undergraduate students, marine biology, South Africa	✓ Cognitive, psychological, geographical, social aspects; not always tied to outcomes *TG: Watched new CD for preparation.*	AFFECTIVE: Students who used novelty-reducing CD preparation found support materials more useful & had fewer difficulties adjusting to field trip environment.
Cors et al., 2014	208 (97 girls) pupils at a mobile laboratory, Switzerland, ages 12-16	✓ Technological capability ✓ Setting orientation ✓ Content knowledge *TG: Treatment teachers received additional preparation materials.*	AFFECTIVE: Technological capability predicted positive changes in interest, attitude, self-concept to technology (η_p^2 =.05). Also, longer classroom preparation predicted positive changes in affective outcomes for natural science (η_p^2 =.03). Teacher interviews: familiarity with equipment supports learning.

TG: treatment group. Gr: grade. Note: The size of significant differences can be interpreted by Cohen´s (1988) guidelines for effect size. For t-test results: small (d=0.2), medium (d=0.5), large: (d=0.8.): for multivariate results: small (η_p^2=.01), medium: (η_p^2=.06), large: (η_p^2=.14.).

4.2.1 Early studies focused on novelty and exploratory behavior

Novelty of OSLeP settings has been described in relation to the type of exploratory behavior subjects exhibit. For example, Falk et al. (1978) conducted an experiment to test their hypothesis that "a person's ability to attend to a structured learning task in a novel setting improves with time because behaviors interfering with such learning decrease with time spent in the setting" (p. 128). The study involved 31 pupils who visited Maryland's Chesapeake Bay Center for Environmental Studies to participate in a half-day experience measuring foliage height diversity, an activity designed to increase understanding of ecosystem succession. Based on where they lived, researchers assumed that two of the four groups of pupils were more familiar with wooded settings than the other two groups. Data confirmed that the 'familiar' group was significantly more familiar with the characteristics of a wooded setting than the 'unfamiliar' group. The familiar pupils' scores increased significantly more between a pre- and post-test than the unfamiliar pupils' on three test questions about foliage height. Based on observations, investigators suggest that this was due to greater attention to the learning task by the familiar group. In contrast, the unfamiliar group "tended to spend more time in behaviors not related to the actual activity. The time difference, however, failed significance…" (p. 132). Specifically, observers reported that unfamiliar pupil groups were more rowdy and teasing, spent less time on the field trip task and made more negative comments, mostly complaints about having to move off of the main trail and fears about snakes and poison ivy. Observations also show that the unfamiliar pupils gave warnings about poison ivy when it was not present, whereas the familiar pupils issued warnings when they saw the plant. Researchers remark that "perhaps significantly, the interfering behaviors seem to be more emotional in tone than cognitive" (p. 133). Falk and his team concluded that if pupils find a setting very novel, they first need to explore to become more familiar before they can concentrate on their assignments. They suggest that further research focus on better understanding pupils' experience with the OSLeP environments to leverage novelty in a way that augments learning:

> "Novelty, and the very powerful needs for exploration it generates, is an extremely important educational variable. The challenge for educators is to harness this variable to enhance rather than hinder our educational objectives. It is important to understand what is producing uncertainty and exploratory drives on the part of the child so that we can both stimulate it when useful and assuage it when necessary. The novel field-trip phenomenon should not be considered as a negative behavior to be overcome before "real" learning can occur, but rather as a dialogue between the child and his environment-something to understand and capitalize upon" (p. 133)

Similar results were found through a study of sixth-grade public school pupils, who participated in science museum field trips to the Pacific Science Center Playground, Seattle, where exhibits are designed for hands-on activity (Kubota & Olstad, 1991). They also framed their ideas about novelty in relation to exploratory behavior, explicitly referring to definitions from Berlyne (1960) for two types of exploratory behavior:

> "The purpose of specific exploration is to reduce uncertainty produced by a particular, novel stimulus. In a scientific museum this might be a particular object or exhibit. On the other hand, the purpose of diversive exploration has been seen as an effort to reduce the uncertainty of a novel environment. For example, in a science museum, diversive exploration reduced the uncertainty of the entire exhibit hall by providing orientation to the elements within that environment" (p. 226).

Kubota and Olstad's study involved 64 pupils who visited Seattle's Pacific Science Center. Vicarious Exposure group pupils (VE) experienced a novelty-reducing preparation in an audiovisual format. This slide presentation showed children voicing questions and remarks commonly heard during previous visits, including orienting comments about the location of objects, and 'how-to' remarks such as, "You have to be careful when..." Placebo group pupils (P) watched a slide/tape presentation about exhibits at another venue at the Pacific Science Center. Exploratory behavior was measured as the number of seconds in meaningful interaction with an exhibit and knowledge was measured through a post-test about the physical sciences. Results for exploratory behavior and for the knowledge test showed the same pattern: VE boys outscored all other pupils in the study, and P boys scored the lowest, whereas girls' scores from the two groups were not significantly different from each other. Based on a correlation analysis, investigators conclude that VE pupils have more positive outcomes because they spend more time with on-task behaviors. They explain that, while correlation between exploratory behavior and test scores for all subjects was quite low (r=0.32), the VE group correlation coefficient (r=0.56) was higher that of the P group (r=0.07). Investigators summarize these findings:

> "Reducing the novelty of the site apparently had the desired orienting effect upon the students in the VE group. Diversive exploration which normally occurs during the orientation period was minimized and the on-task exploration rose, resulting in high exploratory behavior scores. With greater time spent gathering information cognitive scores also increased. On the other hand, the placebo group's low correlation coefficient indicates little correlation between exploratory behavior and cognitive learning." (p. 231)

Regarding the group by gender interaction, the authors speculate sex-role socialization and/or gender-specific explorative tendencies were at play.

4.2.2 Novelty of place

Through comparing the same lesson conducted by pupils at a nature center and by pupils in a wooded area near school, Falk and Balling (1982) found evidence that setting affected learning. The study involved 196 pupils from two suburban schools in the mid-Atlantic area of the U.S. Participants were in 3rd (46 girls, 52 boys) and 5th (44 girls; 54 boys) grades and were studying the biology of trees. One class from each grade level went on a field trip to a nature center to collect and discuss tree data and the other class conducted the same activity at a wooded area next to their school. Each participant completed a pre-visit survey four weeks before the activity, and post-visit surveys, once the day after the field trip and again one month later. Observers recorded the behavior of each pair of pupils during their data collection, noting where their attention was directed.

Results indicated a significant knowledge gain for all pupils from before to after the field trip, t(195)=23.00, p<.001. The order of knowledge gain, based on mean change in scores, from greatest to least, showed an interesting order. The greatest knowledge gain was for 5th graders at the nature center, followed by 3rd graders at school, followed by 3rd graders at the nature center, followed by 5th graders at school. An analysis of covariance (ANCOVA) of the second post-test, using both the pretest and first post-test as covariates, shows just one significant effect: fifth grade girls who visited the nature center retained more knowledge content than any other group of pupils, shown through an interaction of sex by grade by location, $F(1,176) = 6.24$, $p < .025$. Comparison of (percentage of) time spent on assigned tasks showed two groups worked more of the time on-task: third graders next to their school and fifth graders at the nature center. They offer Pearson chi-squared test results, $x^2(1)=13.47$, $p<.001$, as evidence of the significant difference between on-task time of the groups, but they do not provide data about each group. The authors explain that the behavior category called 'attending to setting' was more frequently exhibited by the pupil groups who worked in a less on-task manner. "Fifth graders outside their schools and third graders at the nature center, the groups scoring lower on the cognitive measures for their ages showed more 'attending to setting' than the other two groups. This result tends to confirm the hypothesis that the environment itself was influencing behavior or the ability with which children could allocate their attention to the learning task. The fact that the locations in which 'attending to setting' was high were different for the two age groups, suggested that the older and younger children were responding differently to the environment" (p. 26). Finally, data from attitude items on the survey showed some differences between grade levels with regard to knowledge recall and enjoyment, but there were no significant differences between the groups that depended upon setting.

To interpret the how the differences in exploratory behavior related to pupil learning, Falk & Balling (1982) described an inverted-U, shown in Figure 9. They noticed that there were two different types of off-task behavior, and that "simply dividing behavior into 'on-task' and 'off-task' components is insufficient for a clear understanding of children's behavior or their underlying motivations" (p. 27). The fifth grade group working outside of school, Group A on the graph, exhibited off-task behavior that investigators described as looking around for something more stimulating, behavior of people who are bored. This group also showed a relatively low improvement in content learning. The other fifth grade group, who was at the nature center, Group C, showed the greatest improved score on a content test and exhibited the lowest level of off-task behavior. Also with relatively high content gains and low off-task behavior was Group B, third graders at the school. The other group of third graders had smaller test score improvements and more off-task behavior. Investigators likened the behavior Group D, that of affiliating more closely with one another and/or expressing a need to know where one another are, as typical of groups in an uncomfortably novel situation. "Perhaps the best way to integrate these data is to suggest a curvilinear model… that hypothesizes task learning and off-task behaviors as inverse functions, both of which are influenced by their setting novelty." (p. 27).

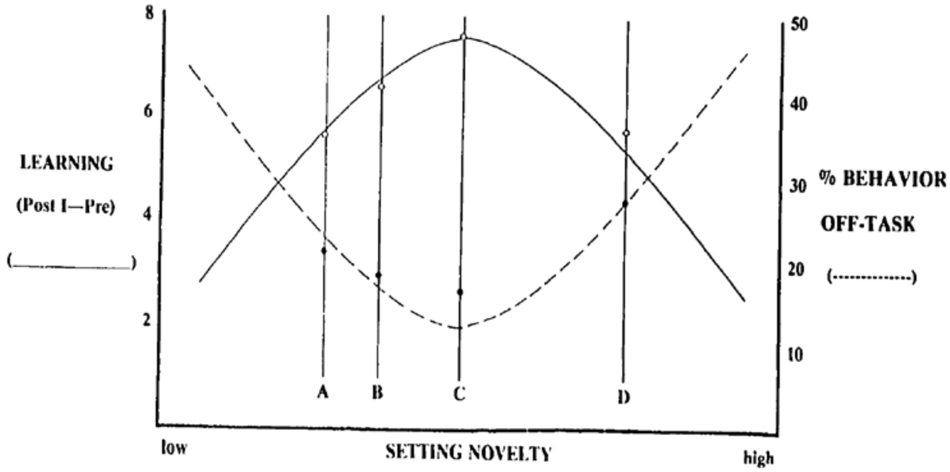


Figure 10: Early work by Falk and Balling (1982) suggests an 'inverted-U' relation between learning, behavior at out-of-school learning places, and setting novelty.

4.2.3 'Novelty space' and learning

Orion and Hofstein (1991a, 1994) tested how pupils' geology knowledge and their attitude towards a geology field trip were affected by three factors through to most influence their perceptions of novelty during the field trip. These factors were previous knowledge (cognitive), familiarity with the field trip area (geographic), and their attitude about the purpose of the field trip (affective[1]). A more detailed discussion about how these novelty influence factors were defined is on page 29. For the investigation, 296 geology pupils in grades 9 to 11, experienced either an Optimal Concrete Preparation (OCP) of 10 hours of cognitive, geographic and psychological (affective[1]) preparation; a Minimal Concrete Preparation (MCP) of 4 hours of only (cognitive) rock and soil Identification activity; or no novelty-reducing preparation (0 hours), called Traditional Frontal Preparation (TFP). Data from teacher interviews suggested that preparation and place of the field trip in the curriculum were important factors for success on assignments during the field trip and on post-trip knowledge tests and assignments. Data from questionnaires and tests, supported by observational data, showed significantly better post-trip knowledge test performance and also more positive attitudes based on type of preparation. That is, significantly more OCP pupils than TFP pupils saw the field trip as a 'learning tool' that is 'for their individualized learning.' However, when one calculates the strength of these relations, they are small (d=0.29 and d=0.36, respectively; N=296). Also, OCP pupils scored significantly better than TFP pupil on *rock identification* and *questions related to field trip phenomena*, again with small effect sizes (d=0.36 and d=0.29 respectively; N=296). It is worth noting that while OCP pupils showed better test performance and more positive attitudes toward the field trip, they did not differ significantly from the TFP group in their attitude towards the discipline of geology, measured through survey items about its difficulty, their interest and its importance.

Through a stepwise multiple regression analysis, Orion and Hofstein (1994) showed that the three novelty space factors explained just over one-fifth of the variation in pupils' attitude towards learning during the field trip. A closer look at each the individual novelty influence factors, described as 'pre field trip variables' (p. 1115), clarifies their relation to the dependent variable. The cognitive impact factor, "which is mainly related to the type of knowledge the student acquire before the field trip {that is} related to students' cognitive readiness for the event" (p. 1116). This cognitive factor explained ten percent of differences in pupils' enjoyment of and interest in the field trip. The geographic impact factor, differences in OCP and TFP pupil scores on drawing a geographic cross section of the field trip area, explained three percent of variations in pupil's attitudes. The affective ('psychologic') impact factor was defined as whether pupils viewed the field trip as a 'social-adventurous event' or a 'learning activity.' Differences in pupils' view of the purpose of the field trip explained nine percent of the variation in their attitudes towards learning. Investigators concluded that "Preparation that deals with the three novelty factors can reduce the novelty space to a minimum, thus facilitating meaningful learning during the field trip." (p. 1117).

In related research, Orion et al. (1997a), defined seven dimensions of out-of-school learning settings in the SOLEI (Science Outdoor Learning Environment Inventory), described on page 28. They describe how pupils responded differently to the SOLEI survey items, depending upon whether they experienced a more complete preparation (OCP) or a minimal preparation (TFP) before a field trip. Results "revealed clear advantages of optimal preparation," for most SOLEI dimensions (p. 169), including a moderately significant difference between complete and minimal preparation groups for 'preparation and organization' (p=.001, effect size=0.5). Researchers conclude that classroom preparation is important for preparing learners with relevant content information and orientation to the place and activities, but perhaps not for the social aspects of the field trip. They write, "Field trips can be successful as an instructional strategy and can create a positive learning environment, provided that students are prepared adequately and have a clear knowledge and understanding regarding the objectives and activities of the field trip" (p. 169).

4.2.4 Novelty, memory, previous visits and curiosity at OSLePs

Anderson and Lucas (1997) explored how pre-visit orientation and previous visits by pupils related to learning about science concepts for grade 8 pupils visiting the Queensland Science Center, Brisbane, Australia. The study was based on the premise that museums introduce high levels of perceived novelty, which "result in high levels of exploration and setting information gathering, which take precedence over on-task, institutionally intended learning" (p. 486). About half of the pupils experienced a 'pre-orientation' program of slides and descriptions of the science center, exhibits, and visit schedule, whereas the remaining 'no-orientation' pupils viewed a video about another science center. An analysis of variance (ANOVA) test showed significantly better performance on post-visit test questions about science concepts by pre-orientation pupils and by pupils who had previously visited the science center. The strength of these relations is reported as medium, with effect sizes a "little in excess of 0.5" (p. 489). Investigators speculate that better test scores from pupils who found exhibits memorable reflect an effect of novelty as an appealing factor. Investigators hypothesized that too little or too much novelty would not produce the appropriate amount of curiosity behavior by the pupils needed for improvements in learning, based on their theory described on page 32. However, their research design did not include a construct to measure curiosity.

4.2.5 Teachers' attitude and quality of preparation

Harnessing novelty to promote people's need for exploration, as described by Falk et al. (1978), depends upon well-designed preparation, and it is here where teachers play a most important role. In a study at a space center, Jarvis et al. (2005) examined the impact of pre and post-visit activities and on pupils' attitudes about science. The study involved a pupil pre-visit survey and post-surveys at three different times; observations of teachers, pupils, and assisting adults; and teacher and pupil interviews. Investigators found that "teachers' personal interest, preparation, action during the visit, and follow-up were important factors in influencing children's short- and long-term attitudes {towards science}" (p. 77).

Jarvis et al. (2005, p. 74) developed a teacher typology in order to compare pupil groups. An example of a Type 1 teacher's "very good" preparation involved watching a video about the sun and moon, practicing skills including using a compass for navigation, choosing the role they would play in the space ship simulation, direction that the visit 'wasn't a fun day, it was a learning day,' and discussion of what they could expect during the visit. Pupils also received structured at-visit and after-visit assignments. Type 2 teachers varied in the amount of time they devoted to preparation and/or follow-up, either because of poor planning or due to time constraints. Classes with Type 3 teachers had less personal enthusiasm for the space center and sometimes a focus on national standard assessment tasks. Through a cluster analysis, investigators identified evidence of a "teacher effect:"

Teacher Type 1. These classes started with high means for science enthusiasm (before the space center visit) and had consistently high means for science enthusiasm. Variation in science enthusiasm after the visit was insignificant, and scores remained high after 5 months.

Teacher Type 2. These classes started with fairly low enthusiasm for science, but this increased significantly after the visit (effect size=0.44 with $p<0.01$, paired t-test). Mean scores were still significantly elevated after 2 months.

Teacher Type 3. Classes with low mean pre-visit enthusiasm scores, which remained at a low level or declined over the 5 months without any apparent effect due to the visit.

Figure 3: Descriptions of three teacher types that Jarvis and Pell identified and related to pupils' science enthusiasm during a visit to space center (adapted from Jarvis and Pell, 2005, p. 73).

Jarvis and Pell (2005) report that at least one Type I teacher's pupils showed a "noticeable decline in anxiety levels" during the 5-month study, while exemplar Type 2 and Type 3 classes reported some increases in anxiety. Anxiety was defined as the degree to which pupils worry about schoolwork being difficult, being wrong, or being alone in school (p. 73). Jarvis and Pell note that the Type 1 preparation addressed all three novelty space factors:

"The children had been acquainted with the trip area and introduced to initial skills and knowledge beforehand. They were also 'psychologically' prepared by being given an expectation that the visit would be a learning experience. Consequently, these three 'novelty space' factors that can inhibit learning, identified by Orion and Hofstein (1994), were addressed" (p. 79).

NOTE: Orion and Hofstein (1994) and later studies about novelty space use the term 'psychologic' or 'psychologically' to describe learner characteristics such as attitudes towards a field trip, anxiety, and tiredness, which have to do with emotion. We instead use the term `affective´ to describe these learner characteristics, because it is more in line with established terminology.

Pupil interviews revealed that pupils' attitudes towards science were also shaped by reading science books at home and watching science television programs, especially with parents or grandparents.

4.2.6 The social aspect of novelty

Cotton and Cotton (2009) explored the social aspect of novelty, along with Orion's three novelty space factors (Orion, 1993), for British university students on a field trip in South Africa, using videos, audio-diaries, field logs and a post-course questionnaire. Students identified cognitive aspects of novelty, which they reported distracted them from learning: unfamiliar scientific names, new math and statistics concepts, and conflicting views from tutors. Affective aspects[1], such as apprehension and tiredness mostly having to do with uncomfortable accommodation, were also described as negative. The social aspect of novelty was defined as "the impact of personal relationships on the field trip experience." The social aspects of the field trip "encompassed the widest range of positive and negative responses." For example, the opportunity of getting to know other students was seen as positive, while homesickness and working with others could be frustrating. Investigators report that "there is also clear evidence, in the accounts of group work and of their relationship with lecturers, of the impact of social relationships on learning in this context" (p 172). Similarly, Falk and Dierking (2011) bring together results from a number of studies that show that novelty of place seems to cause anxious and nervous behavior in children, and suggest that social interaction can attenuate these feelings.

Cotton and Cotton (2009) also surveyed students about the effectiveness of a novelty-reducing preparation in the form of a CD. By comparing extreme groups who responded with 'strongly agree' or 'strongly disagree,' they concluded that those students who used the CD found materials more useful and adjusted more easily to field trip conditions. However, lack of data about the less extreme groups, and apparent arbitrary cut-off choices for groupings, does not allow the reader to generalize these extreme results to all students, limiting the meaningfulness of the comparison.

4.2.7 Novelty and technological capability

As described on page 66, in spring 2014, Cors et al. (2015a) conducted the pilot study. The investigation examined about how classroom preparation, pupils' novelty influence factors, and teacher attitudes related to pupils' learning, measured as their interest in, attitude to and self-concept to science and technology (S&T).

Based on a background study of the mobiLLab program (R. Cors, 2013), investigators identified three novelty influence factors: 1) previous knowledge, a cognitive impact factor, measured as pupils' grades, 2) a setting orientation factor measured as pupils' previous experiences at OSLePs; and 3) a technological capability factor that indicated whether pupils tended to explore and tinker, or to seek direction and support, when interacting with technology. The capabilities impact factor became part of the research design in response to interviews with mobiLLab program faculty and staff. They explained that a core goal of the program is to promote pupils' positive attitude towards doing science with technology. The technological capability construct used in the mobiLLab study is based on the capabilities dimension of technological literacy measured by Luckay and Collier-Reed's *Technological Profile Inventory* (TPI) (Luckay & Collier-Reed, 2011a).

The mobiLLab study involved 9 teachers and their pupils (N=208), who completed pre- and post-visit surveys. Investigators also observed mobiLLab school visits and conducted teacher interviews. Differences in changes in pupils' technology outcomes from pre- to post- visit survey could be explained by how technologically capable they perceived themselves to be (medium effect: η_p^2 =.05). The length of classroom preparation was the only other variable that significantly explained differences in changes in pupils' outcomes, this time with natural science outcomes. A detailed description of pilot study results is on page 66.

The Technological Profile Inventory. In the mid-2000s, better understanding the ´technological literacy´ of college applicants in South Africa, when secondary education was experiencing post-Apartheid development, led to development of the Technological Profile Inventory (TPI) (Luckay & Collier-Reed, 2011a). The TPI was developed to assess whether an applicant to an engineering university program at a South African university will have a successful academic career. The researchers describe a technologically literate person as someone who can "understand the nature of technology, have a hands-on capability and capacity to interact with technological artefacts, and … be able to think critically about issues relating to technology" (Collier-Reed, 2006, p. 15.).

The research began with exploratory interviews by Collier-Reed (2006) about the technological literacy of students applying to the University of Cape Town, from which categories were identified that describe aspects of their technological literacy. The ´capabilities´ category, which was of interest for the mobiLLab study, described how students sought to interact with technological artefacts: 1) receiving direction or instruction, 2) tinkering, and 3) engaging. Luckay et al. (2011a) then employed factor analysis and multivariate analysis of variance (MANOVA) tests to develop and validate the survey items that make up the TPI. Results indicated that students from different disciplines differed significantly in their responses about two technological capabilities scales: direction/ instruction ($p>.001$) and tinkering ($p>.001$) (see Table 10):

> "The result of the analysis was a modified version of the TPI where the data were found to be reliable and valid. The significant factors that defined … 'interaction with technological artefacts' were *Direction/Instruction* and *Tinkering*. A cohort analysis suggests Engineering students are statistically more likely to view technology as a process and interact with technological artefacts

with less fear and more self-initiation (Tinkering) – a more advanced technologically literate position. On the other hand the Arts students are more likely to expect direction or instruction from an authority figure (Direction/Instruction) when interacting with a technological artifact - a less technologically literate position" (Luckay & Collier-Reed, 2011b, p. 764).

Table 11: Responses from four student groups about different dimensions of their technological literacy (from (Luckay & Collier-Reed, 2011b)).

Dimension	Commerce			Engineering			Arts			School			Difference	
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*F*	*p*
Artefact	2.9	1.1	65	2.8	1.3	167	2.7	1.15	218	2.5	1.2	179	2.3	0.078
Process	4.6	0.7	65	4.9	0.8	167	4.5	0.82	218	4.8	0.8	179	12.9	0.000*
Direction/ Instruction	3.1	0.9	65	2.9	1.0	167	3.3	1.13	218	3.2	1.1	179	5.9	0.001*
Tinkering	4.9	1.2	65	5.5	1.2	167	4.9	1.36	218	5.3	1.2	179	7.6	0.000*
Engaging	5.1	1.2	65	5.1	1.1	167	5.0	0.96	218	5.1	0.9	179	0.9	0.453

* $p<0.05$ The sample consisted of 629 respondents.

Swiss youth's affinity to technology. A recent study of technology affinity by Güdel (2014) revealed differences between girls in boys in Switzerland. The study took place between 2010 and 2013 in North Western Switzerland and involved 480 7th and 8th grade pupils who experienced a new classroom teaching model, 'EXRETU' (Explicit, Reflective, Technology Education). EXRETU involved approximately 12 lessons which were designed to improve their affinity to technology. Factors specifically explored were pupils' conceptions of, interest in, and attitude about technology through pre-, post- and follow-up questionnaires.

Study findings showed that conceptions pupils have about technology are often rather vague, and are often related to their values. And if the pupils have a more specific conception, they focus on actions, skills, or strategies, rather than real-world uses of technology in science or engineering. A research paper about the study describes how their results revealed that boys and girls had different conceptions of technology:

> "Boys are rather 'function and product oriented.' They consider technology in a more specific way and associate it often with technical actions. Girls, on the other hand, have rather general conceptions, they show an orientation toward processes and useful applications and associate with technology competencies, skills and strategies" (Heitzmann & Güdel, 2014, p. 19).

Their results indicate that the pupils participating in the study were more interested in general aspects of technology than in than specific aspects. This is shown by results showing that pupils had a more positive attitude towards general aspects of technology, such as 'inventing, developing and building' (mean = 3.2 in a scale of one to four) than they had towards dealing with specific topics and activities (mean = 2.6-2.7). Even smaller (mean = 2.1) was their interest in working in specific fields of application of technology, such as 'design processes within the context of sustainability.' Findings showed moderate to large interest differences based on gender for 'understanding and evaluating' (d= 0.7), 'inventing, developing and building' (d= 0.7), and 'using and repairing' (d= 1.2). Moreover, girls self-efficacy for some technical activities, such as 'using and repairing', was substantially lower than boys self-efficacy (d=1.3). However, interest in "planning and designing" did not differ for girls and boys. They found that technology attitude often depended on pupils' attitude about gender roles. That is, "girls with open gender role orientations have a higher self-efficacy in technical tasks, show more interest in technology regarding future jobs and show more specific and general interest in technology, while the opposite could be found for boys" (Heitzmann & Güdel, 2014, p. 22).

Even though more than three quarters of the pupils reported that they liked the EXRETU technology lessons, their attitudes about technology decreased. For example, between the pre- and post-test, their attitude to technology sank by 11.7%. However, the effect of the lessons differed depending upon gender (Güdel, 2014, p. 201). Compared to the control group, girls improved slightly in their attitude to technology (German: *Einstellung zu Technik*) (d = 0.3) and their general interest in technology in school (*Allgemeines Interesse an Technik, insbesondere in der Schule*) (d = 0.3), and technology-related self-efficacy related to understanding and explaining ('*Technikspezifische Selbstwirksamkeitserwartung' in Bezug auf 'Technik verstehen & erklären'*) (d = 0.4). In contrast, boys had negative changes in affinity to technology. They showed a small decrease in their interest in technology in school (*Interesse an Technik in der Schule*) (d = -0.3) and interest in the work of producers related to technology understanding and evaluation ('*Interesse an Tätigkeiten der Produktherstellung' insbesondere in Bezug auf 'Technik verstehen & beurteilen'*) (d = -0.3).

4.2.8 Conclusions from the literature review

Findings from these eight studies, which include four studies with samples sizes greater than 190, demonstrate that reduced novelty relates to positive educational outcomes at OSLePs. Referring back to the summary matrix of study parameters (Table 9), allows for further comparisons.

Cognitive and affective outcomes. These studies provided evidence of improved educational outcomes in the form of greater enthusiasm, reduced anxiety, better test scores, more positive science and technology attitudes, more time-on-task and exploratory behavior, and improvements in learning and attitudes about science and technology. The more recent studies included in the literature review investigated primarily affective outcomes. This reflects how researchers and educators recognize OSLeP visits as one-off, transient events that are primarily meant to spark interest in science and contribute to learning content over time in combination with other programs, rather than as tool for focused content instruction (R. Cors, 2013; Rennie, 2007; Tran, 2011). This was demonstrated by a recent study of involving 1773 pupils at a Science Center Outreach Lab (SCOL), which showed that the science center offered no significant advantage over classroom instruction for gains in content knowledge (Itzek-Greulich et al., 2015). The authors of the study speculate that, at out-of-school learning events, "student's attention is often drawn to specific features of the learning environment rather than the learning material itself" and that this novelty could have produced a greater learner cognitive load that hindered learning (2015, p. 49).

Hands-on skills. The same study showed that, in an OSLeP environment, pupils had better 'Experimental Specific Knowledge' test scores than those who experience only classroom instruction (Itzek-Greulich et al., 2015), indicating the former acquired experimentation skills. This echoes findings from the two studies in this literature review that *linked learners' hands-on skills to more positive affective outcomes*. That is, Jarvis and Pell described how pupils who experienced an optimal preparation, which involved "practicing skills using compasses and coordinates as a basis for the navigation activities," reported steadily decreasing anxiety scores (2005, 74). Similarly, Cors et al. (2015b) found that a dispositional tendency to tinker, rather than seek support, to interact with technology related to more positive changes in interest in, attitude to, and self-concept to technology: "Most striking is the strong link (large MANCOVA effect) identified between pupils' tendency to explore technology and their S&T outcomes" (p. 56). This was supported by interviews with teachers, who explained how, for pupils to profit from the mobiLLab experience, it was important for them to become comfortable with experimental equipment.

Another observation is that *the strength of the effect* from novelty factors on educational outcomes in these studies is usually not reported. In fact, while six of eight the studies showed statistically significant results, effect sizes (or data to calculate them) were often unavailable.

The literature review shows that studies of novelty at OSLePs have focused on *five types of novelty influence factors (NIF)*. Table 11 shows in the left-hand column my proposed categories for these factors that influence learners' novelty experience, listing in the right-hand column descriptions of how various studies have measured each. For a Cognitive influence factor, studies assessed pupils' relevant content knowledge through grades and tests. For an Affective[1] influence factor, studies measured pupils' attitudes, particularly whether they expected a learning experience or fun and adventure, and their emotions, such as anxiety about doing things right. Some studies used a Setting Orientation factor to describe how much practical knowledge learners had for navigating the OSLeP. Many of these studies examined how well a novelty-reducing preparation helped pupils feel oriented to the schedule and spatial elements during the OSLeP experience.

Through interviews and student diaries, Cotton and Cotton identified aspects of a Social impact factor, which they define as the impact of personal relationships on learners' field trip experience (Cotton & Cotton, 2009). For a Capabilities impact factor, Cors et al (2015) identified links between pupils' dispositional and situational comfort with technology and their learning, while and Jarvis and Pell (2005) described skills training as part of optimal preparation.

NOTE: Several measures for novelty influence factors could be assigned to more than one category. For example, the geographic cross-section test score from Orion and Hofstein's study (1991) could be a categorized as a Cognitive impact factor, indicating how well pupils knew the content relevant to the field trip, or a Setting Orientation factor, indicating how prepared they were to navigate the landscape. Similarly, on could categorize Falk and Dierking's (1978) test score about a wooded setting as previous content knowledge or as a gage of familiarity with the setting.

Table 12: Studies have measured five types of novelty influence factors (NIFs) that affect learners' novelty experience at OSLePs.

Novelty influence factor (NIF) types	How studies defined and measured novelty influence factors
Cognitive	*Previous content knowledge* – knowledge test about core content of a given OSLeP, such as o Wooded setting characteristics test score (Falk et al., 1978) o Geology-related science phenomena test score (Orion & Hofstein, 1991a) o Geographic cross-section test score (Orion & Hofstein, 1991a) – Math and science grades (Cors et al., 2015a)
Affective	*Attitudes about and impressions of OSLeP experience* – Purpose of field trip: learning versus social-adventure (Orion & Hofstein, 1991a) – Apprehension and tiredness mostly having to do with uncomfortable accommodation (Cotton & Cotton, 2009) – Anxiety/ worries about finding schoolwork hard, being wrong (Jarvis & Pell, 2005)
Setting Orientation	*Practical knowledge for navigating OSLeP* – Whether learner lived closer to a wooded setting – confirmed by test of wooded setting characteristics (Falk et al., 1978) – Whether learner experienced pre-visit orientation (Anderson & Lucas, 1997; Jarvis & Pell, 2005; Kubota & Olstad, 1991; Orion & Hofstein, 1991a) – Whether learner previously visited that or similar OSLePs (Anderson & Lucas, 1997; Cors et al., 2015a; Falk et al., 1978) – Geographic cross-section test score (Orion & Hofstein, 1991a)
Social	*Impact of personal relationships on learner experience (all from Cotton and Cotton, 2009)* – Homesickness, adjusting to close company – Building closer relationships with lecturers
Capabilities	*Ability to work with OSLeP objects/ activities* – Skills using compasses, coordinates for navigation activities (Jarvis, 2005) – Technological capability: tendency to explore technology, rather than seek direction when working with technology (Cors et al., 2015a)

Measuring at-visit novelty experience. The literature review also shows that three of the eight studies about novelty at OSLePs characterized at-visit novelty in the form of exploratory behavior (Falk & Balling, 1982; Falk et al., 1978; Kubota & Olstad, 1991). As detailed in Table 12, these studies showed links between the NIF setting orientation and exploratory behavior and, in the case of Falk and Balling (1982), how this relates to learner age. Two studies showed that learners who were supposed to have more familiarity with the setting, either because they lived near a similar setting (Falk et al., 1978) or because they saw a pre-visit orienting video (Kubota & Olstad, 1991), exhibited more exploratory behavior. Falk and Balling (1982) also found significant links between learning setting and exploratory behavior, but through an inductive approach. Their results indicated that younger learners in a more novel setting work less on-task and display group affiliation behaviors indicating discomfort. Interestingly, they also found that older learners in a less novel setting also exhibit less exploratory behavior and show signed of boredom, or seeking stimulation. Also, based on results of teacher interviews, Cors et al. (2015) suggest that learners' comfort level with exploring experimental equipment would improve learners at-visit engagement (Cors et al., 2015a). These studies have demonstrated that how familiar learners are with a setting makes a difference in their exploratory behavior.

Table 13: Studies have related learners' novelty influence factors (NIFs) their exploratory behavior at OSLePs.

Novelty influence factor (NIF): Setting orientation	How setting orientation related to exploratory behavior
Familiarity with a wooded setting, based on whether lived to a wooded setting (Falk et al., 1978)	Familiar learners: More orderly, attentive, interested in the task. Gave warnings only when danger (poison ivy) was seen. Significantly more knowledge gain ($p<.05$). Unfamiliar learners: More rowdy and less attentive to the task. Made more negative comments about having to walk in the woods and expressed more fears about poison ivy, snakes, (even when not seen), etc.
Where learners conducted an exercise: at a nature center or at a wooded area near their school (Falk & Balling, 1982)	Two groups exhibited significantly more on-task behavior: comfortable in familiar situation (3rd graders at school) and stimulated by new situation (5th graders at nature center); same groups had more (albeit insignificant) knowledge gain. Uncomfortable with novel situation (3rd graders at nature center) and bored (5th graders at school) exhibited more 'attention to the setting' behaviors, such as keeping track of where their peers are.
Familiarity with interactive exhibits, depending upon whether learners saw an orienting video (familiar) or not (unfamiliar) (Kubota & Olstad, 1991)	Familiar: Spent significantly more time ($p<.02$) in meaningful interaction with exhibits (on-task), which was linked to better test scores ($r=.056$). Unfamiliar: Spent less time in meaningful interaction with exhibits.

However, these eight studies about novelty at OSLePs name other indicators of at-visit novelty that have not been explored through research. For example, several researchers describe pre-visit 'orienting' activities that should have reduced novelty, yet none measure how oriented learners feel at the visit (Kubota and Olstad, 1991; Orion and Hofstein, 1991; Anderson and Lukas, 1997; Jarvis and Pell, 2005; Cors, 2015). Another unexplored indicator of at-visit novelty named by previous studies is at-visit curiosity (Anderson and Lukas, 1997), which has been linked to novelty (Litman and Spielberger, 2003; Priemer and Pawek, 2014). A third unexplored indicator of at-visit novelty is how overwhelmed learners are by unfamiliarity, something described by several studies (Falk and Dierking, 1978; Kubota and Olstad, 1991). This feeling of being overwhelmed by new information or objects could be measured though cognitive load scales that have been developed for educational settings (Hart and Staveland, 1988).

Broader exploration of a suite of novelty experience factors (NEFs) would help us better understand the degree to which learners perceive their OSLeP experience as new or unfamiliar. Such information could help us learn whether, and by how much, novelty was reduced, and could also help us untangle the effects caused by NIFs from the many other variables that affect learner experiences at OSLePs.

4.3 The mobiLLab background investigation and pilot study

4.3.1 MobiLLab background investigation

In order to ensure that the mobiLLab investigation focused on field-relevant program issues and produced actionable results, the author conducted a background investigation between October 2012 and April 2013. The exploratory background investigation focused on these questions: What are the goals & priorities for the mobiLLab program? What can be learned from studies of similar programs? What are measurable measures of program effectiveness? What factors affect the effectiveness of the program? What strategies do informal learning researchers use to examine these factors?

Investigation activities, shown in Figure 10, included observations of and informal interviews with teachers and pupils during mobiLLab school visits, interviews with mobiLLab team members, interviews with representatives from similar programs worldwide and a review of relevant materials. These activities were conducted at the cantonal and national level, through the University of Teacher Training, St. Gallen (PHSG); by looking at issues from a Europe-wide perspective, such as PISA (Program for International Student Assessment); and at world issues, including OECD (Organization for Economic Cooperation and Development) reports about workforce and educational trends.

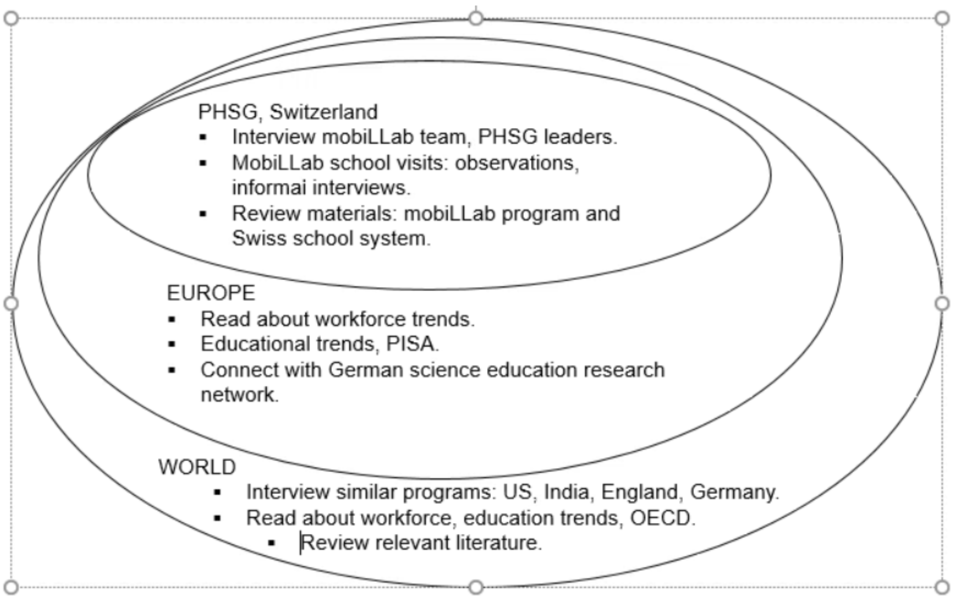


Figure 11: Scope of background investigation activities.

Feedback from Teachers and Pupils

Comments from teachers and pupils during the fall of 2012 give a first glimpse into their experiences with the mobiLLab program. Fourteen teachers commented on preparation with their pupils for a visit with mobiLLab. About half of the teachers said they asked pupils to choose their own experiments, however sometimes pupils complained that they did not receive their first choice. Almost every teacher said that they asked their pupils to look at the E-Learning tutorial for the four experimental posts they planned to work with. About one-fourth clearly stated that pupils looked at the E-Learning during class time. One teacher explained how she saw some pupils quickly "clicking through" the E-Learning sequence and quiz and imagined that they therefore did not retain very much from the tutorial. Teachers said pupils spent two to eight hours for classroom preparation, with most spending three to four hours. Teachers estimated that one-third to one-half of pupils prepared their own questions for working with the experiments and about one-third brought their own objects to test. About one-third of teachers assigned follow-up assignments, where pupils complete a short report or give a short presentation for one or more experiments they worked with. Some teachers took unexpected, sometimes innovative approaches. For example, as part of the experiment selection process, one teacher asked pupils to justify their 'top picks' and gave pupils with well-described justifications at least one of their favorite posts.

Teachers described a number of reasons for bringing mobiLLab to their schools that mostly had to do with benefits for pupils' science learning. Some said that mobiLLab complemented their work as teachers because it covers topics found in Stellwerk, a test used to assess pupils' knowledge skills for apprenticeships, and in the cantonal curriculum. Some described how the step-by-step instructions, coaching and support from the mobiLLab team and the fact that mobiLLab comes to the school make it nice to work with. Teachers found it beneficial that pupils can experience some independent learning time that is not teacher-led. They also described how mobiLLab compliments the other projects the pupils are involved with, such as tours of industry facilities and hands-on science projects. Some teachers commented on how mobiLLab provides an opportunity for pupils to work with complicated instruments and build their confidence. Some pupils and teachers describe the mobiLLab E-Learning material as helpful while others describe it as being too difficult or boring. Several teachers offered a suggestion to change the E-Learning videos, so that they would start with descriptions of real-world applications, explaining that it is easier to motivate pupils about experiments if they see it related to something they already know. Some teachers said the posters next to each experiment effectively illustrate science principals at a good level for pupils. Written comments from pupils were almost all positive, describing opportunities to experiment on their own and good coaching support when activities needed help. A few comments indicated that some pupils found some aspects of the experimental posts too difficult or that they took too long.

Similar Programs Worldwide

Results show that, even though programs around the world, captured in Table 13, vary in the volume of pupils they serve and in program depth and breadth, some themes and commonalities exist. Like mobiLLab, many interviewed mobile laboratory program representatives emphasize a primary goal of sparking pupils' interest in science and, secondarily, supporting development of competence in math and science and interest in related careers. Also like mobiLLab, many programs have an equity-related goal of bringing a laboratory experience to pupils, sometimes to schools who have far less equipment than others. Additional goals described by program leaders include promoting awareness of science in everyday life, appreciation for the usefulness of science to improve the human condition, improving public perception of science, demystifying sciences such as physics and molecular biology that are not depicted on popular television crime shows, promoting a sense of citizen responsibility in young people and supporting teacher professional development.

The mobiLLab Theory of Change

The author worked with the mobiLLab team to synthesize background investigation data to formulate a 'logic model,' shown in Figure 11, which captures how program resources and activities are intended to produce outputs and outcomes. As a depiction of how the mobiLLab program is supposed to work, the logic model is the mobiLLab team's 'theory of change.' The theory of change was developed through a logic modelling process adapted from Taylor-Powell (2003) at the University of Wisconsin-Madison, who defined a theory of change:

> "A theory of change is a description of how and why a set of activities--be they part of a highly focused program or a comprehensive initiative--are expected to lead to early, intermediate and longer term outcomes over a specified period" (p. 93).

According to the mobiLLab theory of change, promoting a 'technophilic' attitude in pupils is the core outcome for the program. A technophilic attitude is an attitude of awareness of, affinity for, and curiosity about science work conducted with technology. The mobiLLab team identified program activities and outcomes that are important for promoting technophilia in pupils, shown in **bold** in Figure 11. These 'hot spots,' or areas of greatest concern and possible impact, were pre-visit activities and materials; design of experiment stations; teacher attitudes and teaching approaches; and training of pre-service teachers who serve as mobiLLab coaches.

A literature review conducted with the mobiLLab logic model 'hot spots' in mind produced a list of relevant frameworks and approaches. These views came primarily from self-determination theory, novelty theory, and interest development theory, which are described as they relate to informal learning in chapter 3. Based on these ideas, and on a review of the limits on resources for research, a refined focus for the pilot study was developed. The goal was to better understand what it means to awaken pupils' interest in mobiLLab-related science and technology, and how that interest development is affected by pupil feelings of unfamiliarity, or novelty, and teacher attitudes. These topic areas and questions guided the pilot study.

Awakening pupils' interest. Promoting pupils' positive attitude about technology-related science experimentation is a core goal of the mobiLLab team, who describe their mission as promoting "technophilia," (in both pupils and teachers). MobiLLab team faculty described how the program is developed to offer pupils doing science using technological instrumentation. They wanted to better understand how the program promotes development of interest in technology-supported science. They wondered, *How effective is mobiLLab in promoting development of pupil interest in both science and technology?*

Pre-visit activities and novelty. Classroom preparation for a mobiLLab visit was a top concern for the mobiLLab team. They were particularly interested understanding to what extent pupils were involved with pre-visit activities (pupils reviewing E-learning and preparing their own questions). Their hypothesis was that a more complete preparation would reduce their experiences of unfamiliarity, or novelty, at the mobiLLab visit, which in turn determined the degree to which they engaged in activities at the experimental posts. *What mobiLLab website preparation materials do teachers use and how can we motivate teachers to use the pre-visit activities that mobiLLab recommends? What pre-visit activities best support pupils' engagement in mobiLLab experimentation and pupils' knowledge and interest gains?*

Teacher Attitude. Thought by mobiLLab team members, participating teachers and, also leaders from other programs worldwide to greatly influence the learning outcomes of pupils is teacher attitude and teaching approach. Teacher attitude and teaching approach as a key to improving educational outcomes is not a new idea and as early as the 1960s, the OECD (1966) asserted that "the teacher is the curriculum." To investigate this area, we need to answer the question, *What about teachers' attitude and teaching approach should we seek to better understand?*

Table 14: Programs similar to mobiLLab around the world.

Program Name	Setting; visit duration	Ps ages/ max Ps per visit/ Ps per year	PRE and POST Materials and Training	Roles
mobiLLab, PHSG, St. Gallen, Switzerland Since 2009	Bring up to 12 experiments into classroom. Half day per class group. Each P does 3-4 experiments.	13-16/ 24/ 900*	PRE: One-day teacher training required; E-learning and question-development recommended. POST: -	Ps pairs conduct experiments independently with coaching from mobiLLab Cs. Ts sometimes participate during visit.
iLab, Paul Scherrer Institut, Switzerland Since 2008	Ps visit sound or vacuum laboratory in the morning; take a facility tour in the afternoon.	14-15**/ 24/ 4000	PRE: - POST: -	PSI scientists lead full group discussions about Ps independent lab work. Ts can assist with program but have no official role.
Morehead Science Center North Carolina, USA Since 1999	Inside bus at school Ps spend about 1.5 hours with experiments. ***	14-18/ 24/ school year 6000; summer 800	PRE: One-day Ts training required for module that comes to classroom. POST: -	Morehead instructor leads discussions about Ps independent lab work. Ts required by signed agreement to stay on bus.
CityLab, Massachusetts, US. Science center since 1991; mobile since 1998.	Bus typically visits school for a week. Ps work in bus for up to 8 hours, sometimes during several sessions.	12-19/ 24/ 4000 - 5000	Ts asked to use CityLab PRE and POST lessons.	Instructors work with Ts to customize experi-ments for Ps. Then Ps work in bus inde-pendently, sometimes sharing equipment. Ts may coach or observe.
ForschungsExpress Kiel, Germany 2005-2009	Experiments brought into 2 classrooms. Ps have 2 hours of air, fire or plastic, and then switch.	9-11/ class size/ 2000	PRE: - POST: 5th hour talk with teachers about how to continue the learning. Leave behind material that teacher can use.	Each P conducts experiments independently (no pairs). Scientist leaders guide the experiment. Two Ss come to assist Ps. Ts observe or participate in experimentation.
Humboldt Bayer Mobile Berlin, Germany Since 2010	Intro and pre and post work in class-room. Ps work in truck as a research experiment base.	11-15/ 15/ 1,800	PRE: - POST: Ps publish the results on the Internet on BM website.	Instructors introduce tools, program format. Then, Ps design and conduct experiments about their surroundings. Ss are coaches. Ts oversee.
MdBioLab Maryland, USA Since 2003	Bus stays at school for a week. Inside bus Ps spend 50-90 minutes with experiments. ***	13-18/ 32/ 10,000	PRE: Ts introduce the concepts and science before visit. POST: Recommend extension activities.	Instructors lead discussions about Ps inde-pendent lab work. Ts sometimes participate or lead discussions.
Lab in a Lorry United Kingdom Since 2005	Inside bus at school Ps spend about 1 hour with 2 of 3 available experiments.	11-14/ 18/ up to 24,000	PRE: T informed about visit content. POST: Provide leave-behind materials.	For each experiment, a volunteer scientist/ engineer coaches Ps. Ts observe and manage.
Science on Wheels Several states in India Since 1999	Several visits to each participating rural school per year. Inside classroom or on school grounds.	11-17/ class size / 1.6 million (66 mobile laboratory vans)	PRE: Instructors work with Ts to find out what Ps need. POST: Leave 'Lab-in-a-box' with teachers for use when extending learning.	Driver and two instructors bring van to a school cluster base and deploy senior P instructors to give demos in classrooms. Ps observe and interact with experiments.

P=pupil; T=teacher; S=university students; C= coaches)*expected for school year 2012-2013. **can adjust program for ages 12-20. ***experiments can also be brought into the classroom. Note. PSI is not a mobile laboratory program, but a science center in Switzerland, interviewed in order to include an in-country comparison program.

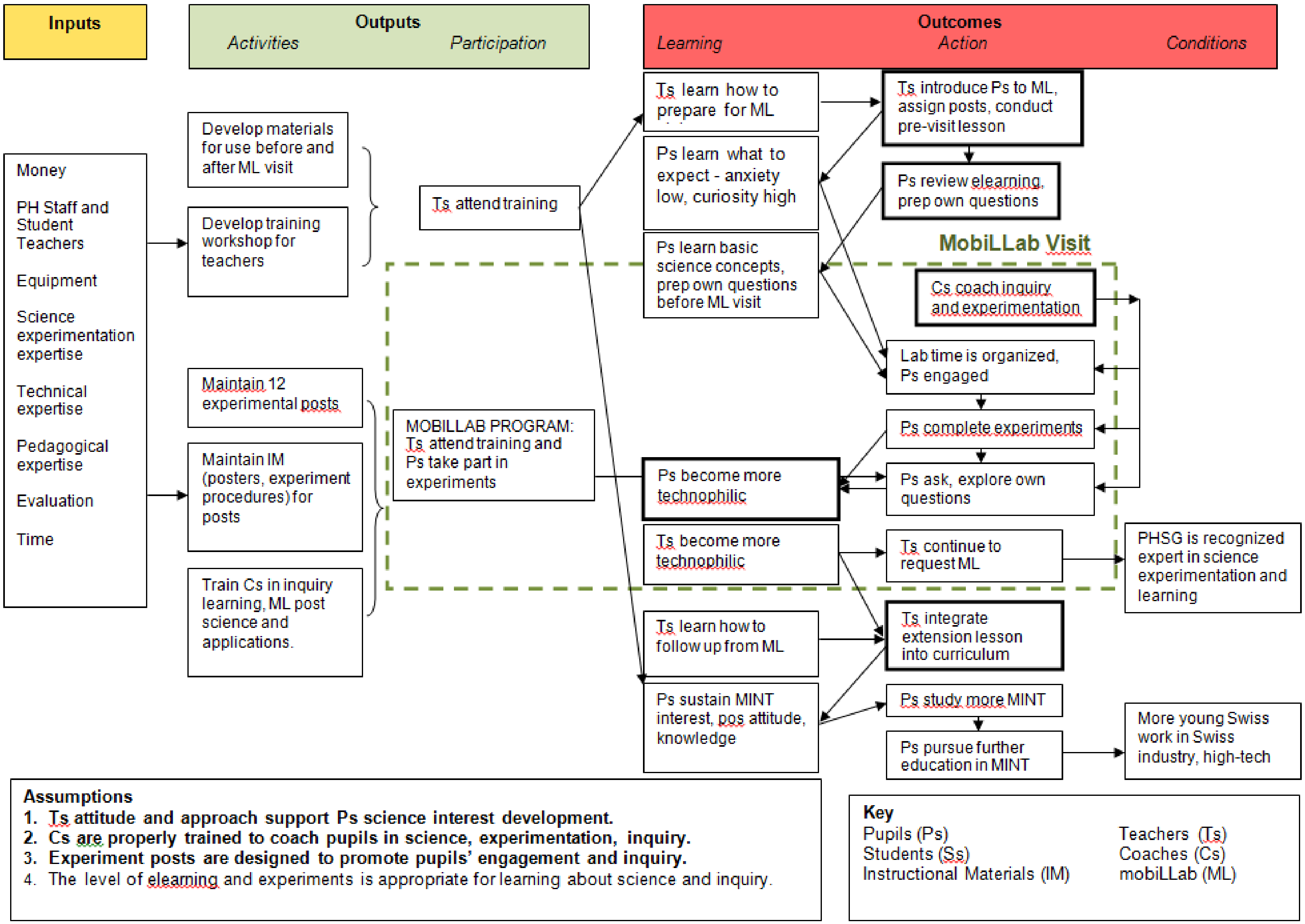


Figure 12: This logic model illustrates the mobiLLab program Theory of Action (Cors, 2013).

4.3.2 MobiLLab pilot study

The mobiLLab pilot investigation focused on how pupil novelty factors, classroom preparation, and teacher attitude related to pupils' affective educational outcomes. Affective educational outcomes, called 'core S&T outcomes' were measured as interest in, attitude to and self-concept to science, and (separate measures) to technology. A mixed-methods investigation was designed to explore the questions, 'How do differences in pre-visit activities and pupils' novelty factors explain variations in pupils' S&T outcomes at a mobile laboratory?' and 'What moderating role do teachers' attitudes play?'

A review of theoretical frameworks about novelty and OSLePs showed that these models were developed for investigating outdoor field trip experiences and did not address the particular case of a technology-related learning laboratory. Therefore, a modified novelty model was developed based on three factors thought to be most influential on pupils' mobiLLab experience: whether they explore or seek direction when working with technology (capability dimension), previous experiences with OSLePs (setting dimension), and previous S&T knowledge (cognitive dimension). A detailed description of how other how these novelty factors were selected is on page 53.

The mobiLLab pilot study took place in Spring 2014. Data collection involved 9 teachers and 15 of their class groups who experienced a mobiLLab visit. All nine teachers and 208 pupils completed pre- and post-visit surveys and investigators conducted mobiLLab school visit observations and interviews with all 9 teachers. Pupils responded to survey items about attitudes towards S&T in general and the mobiLLab program using 4-point Likert scale: "1"=completely untrue ("*stimmt gar nicht")*, "2" = somewhat true *("stimmt wenig*"), "3" = very/quite true ("*stimmt sehr"*), "4" completely true *("stimmt völlig"*). Paired t-tests revealed whether pupils' interest, attitude and self-concept regarding both science and technology changed significantly between pre- and post-surveys (when $p<0.05$). For significant changes, Cohen's d was calculated to indicate the magnitude of the change (Cohen's d can be interpreted from Cohen's (1988) effect sizes for t-tests: small d=0.2; medium d=0.5; large d=0.8.).

Methods

Through interviews and surveys, teachers described their classroom preparation and their experiences with the mobiLLab program. Teacher interviews took place at schools where teachers work and lasted 30 to 40 minutes. Interviews were conducted in a semi-structured manner, which involved following a scripted list of questions, with the flexibility to sometimes diverge from the script when opportunities arose to talk with teachers about study-relevant details. It was clear beforehand that there would not be enough time for teachers to comment on each of the preparation resources available on the mobiLLab website. In anticipation of the limited time, the interviewer (the author) asked teachers about some main resources, namely the introduction to mobiLLab PowerPoint presentation (*Einführung ins mobiLLab*), E-Learning, the worksheet (*Journalblätter*), and the step-by-step instructions for each post (*Kurzanleitung*). If other resources were discussed, these conversations were generally initiated by the teacher. A detailed description of the teacher interview instrument is provided on page 206.

It was expected that classroom preparation reports would differ between treatment teachers, who received additional preparation materials, and control teachers, who received no additional preparation materials. The procedure that was used to select balanced treatment and control groups is described on page 200. However, teachers' accounts of their preparation varied so little for most factors, that time was the only aspect from which a preparation typology could be created. Four preparation types, shown in Figure 12, were defined based on duration, or days before the school visit that preparation started, and on classroom lesson-hours (45 minutes each) devoted to preparation.

	Lesson time high (> 8 lesson-hours)	**Lesson time low (< 8 lesson hours)**
Duration long (started >15 days before mobiLLab)	2 teachers	3 teachers
Duration low (started <15 days before mobiLLab)	2 teachers	2 teachers

Figure 13: For the pilot study, a classroom preparation typology was based on duration (days before visit) and lesson-hours.

The effects that preparation and pupil novelty factors (independent variables (IVs)) had on pupil S&T outcomes (dependent variables (DVs)) were explored through multivariate analysis of variance (MANOVA) statistical tests. When any interactions between IVs occurred, each IV was tested separately. Teacher attitude variables were included in the tests as covariates (CVs). The magnitude with which each factor explains the variation between two groups, such as between boys and girls, can be roughly interpreted using Cohen's (1988) benchmarks for partial eta squared: small (η_p^2=.01), medium (η_p^2=.06) and large (η_p^2=.14).

Sample
Figure 14 shows averages and standard deviations of responses from pupils who completed both pre- and post-visit surveys (108 male; 97 female; 3 no response). Pupils indicated on average a relatively strong (*M=3.02*) tendency to explore technology and a positive perception of teachers' interest in S&T (*M=3.43*). Regarding technology-related themes, pupils' interest in technology was moderate and decreased slightly from pre- to post-visit survey (*M=2.55->2.43; d=0.18*), their attitude was pretty positive and showed no significant change (*M=3.04->3.07; p=0.284*), and their somewhat positive self-concept decreased slightly (*M=2.86->2.80; d=0.10*). Responses about natural science themes were similar: pupils indicated a moderate interest in natural science that decreased slightly (*M=2.52->2.44; d=0.13*), a somewhat positive attitude that showed no significant change (M=2.94->2.97; p=0.348), and a positive self-concept that decreased slightly *(M=2.87->2.82;d=0.09).* These slight decreases in affective outcomes, in this case interest and self-concept, are consistent with some findings from similar programs, as described on pages 40 and 42.

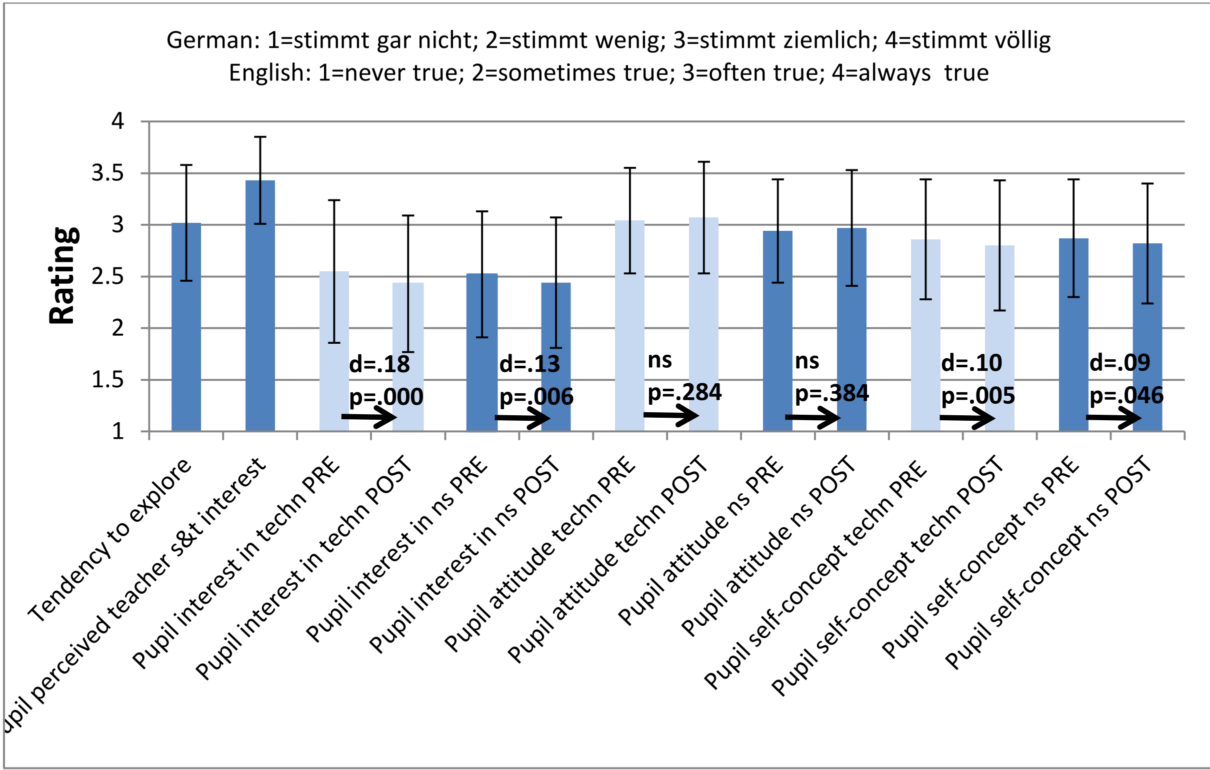


Figure 14: MobiLLab pilot study sample: pupils' tendency to explore technology, perceived teacher interest and S&T outcomes.

Results from pupil surveys

Factors identified through MANCOVA analysis that significantly related to pupils' S&T outcomes are shown in Table 14 below. Of greatest interest were factors that affect changes in pupils learning (within-subject affects), shown in the bottom rows. Differences in changes in pupils' technology outcomes from pre- to post-visit survey could be explained by how technologically capable they perceived themselves to be (medium effect: η_p^2 =.05).

The other variable that significantly explained differences in changes in pupils' outcomes, this time with natural science outcomes, could be explained by 'preparation type' (small-medium effect: η_p^2 =.03). A closer look at the effects of classroom preparation through post-hoc tests suggest that pupils who experienced a preparation that started closer to the mobiLLab visit and involved more classroom time ('duration short, lesson time high), showed significantly greater interest in both science ($p<0.049$) and technology ($p<0.012$) and a more positive attitude (science, $p<0.011$; technology, $p<0.010$). These results could suggest that when preparation starts too early, pupils have difficulty recalling these early preparation lessons and feel unprepared at the visit. Also, more classroom time may give pupils simply more opportunity to become familiar with relevant content and with the plan for the visit. Similar results were shown through a study by Glowinski and Bayrhuber (2011, p. 285), who examined how fulfillment of learners' basic needs at a student laboratory for molecular biology differed depending upon their dispositional interest in science.

Their results show that, for pupils who had a low interest in science, meeting their basic needs for well-being was dependent upon pre-visit instruction, while their peers who were more interested in science did not link their basic needs to pre-visit instruction. These results underscore the key role of classroom preparation for science learning at OSLePs.

Table 15: MobiLLab pilot study results showed that technological capability and preparation time significantly affect changes in pupil S&T outcomes.

Factor (Independent Variable)	Pupils' technology outcomes				Pupils' natural science outcomes			
	df	df error	F	η_p^2	Df	df error	F	η_p^2
Between-group comparisons: multivariate effects (p<0.05)								
Technological capability	3	197	32.3	.34	3	195	13.0	.17
Experience: techn OSLePs	3	195	25.1	.28	3	193	11.4	.11
Experience: nat.sci. OSLePs	not significant				3	193	8.3	.15
Math grades	3	195	4.0	.06	3	193	5.2	.07
Science grades	3	194	4.2	.06	3	192	11.0	.15
Preparation type	3	192	4.2	.06	3	190	2.2	.03
Gender	3	191	25.4	.29	3	189	5.7	.08
Perceived peer interest	3	191	4.4	.06	not significant			
Within-subject changes from pre-to post-survey: multivariate effects (p<0.05)								
Technological capability	3	197	3.4	.05	not significant			
Preparation type (time)	not significant				3	190	2.4	.03

Factors that most strongly distinguished between groups of pupils (between-group effects) are shown in the top part of Table 14. Factors that most strongly explained differences in pupils' overall technology outcomes were technological capability (η_p^2 =.34), how often they frequented technology-related OSLePs' (η_p^2 =.28), and 'gender' (η_p^2 =.29). Factors that most strongly explained differences in pupils' overall natural science outcomes were pupils' technological capability (η_p^2 =.17), how often they frequented natural science-related OSLePs (η_p^2 =.15), and science grades (η_p^2 =.15). The remaining factors showed a medium or small effect.

Factors with insignificant effects on core S&T outcomes (not shown in the table) were how oriented pupils felt to the visit, how engaged pupils were at the visit, perceived learning goal, type of post-visit task pupils completed, the experimental posts at which pupils worked, teacher attitude about situated and constructivist learning, perceived teacher interest in S&T and perceived peer interest in S&T. These results contrast with theories and findings from other researchers and in some cases may stem from the way variables were measured. Oriented feeling at OSLePs, for example, has been related to learning at a museum visit by Falk and Dierking (2011) and to learning during a field trip by Orion and Hofstein (1997). In fact the scale for oriented feeling used in the mobiLLab pilot study was adapted from the study by Orion and Hofstein (1997). However, mobiLLab pilot study results show no significant relations between how oriented pupils report they were, and their S&T interest, attitude, and self-concept. Also, other studies have shown a link between perceived peer interest (Prenzel & Duit, 2000), or teacher attitude about constructivist and situated learning (J Kuhn, 2010), or perceived teacher interest (Long, 2006) and pupil interest in school topics, yet the mobiLLab pilot study findings did not reveal such relations. Results from several studies have shown how the degree to which pupils were engaged in OSLeP activities, measured as observations of individual or pairs of pupils, related to knowledge gain (Falk & Balling, 1982; Kubota & Olstad, 1991). That the mobiLLab pilot study did not find similar findings may stem from how the measure for pupils' engagement at the visit was based on a rough observed estimate of how much each class group worked with experiments in an on-task manner. Similarly, even though other studies identify links between perceived learning goal(s) and educational outcomes (Boekaerts & Corno, 2005b; Högström et al., 2010), results of the mobiLLab pilot results reveal no such links. Again, this may be due to the non-specific nature of the measure, which was a class group estimate that was analyzed in relation to individual pupil educational outcomes.

Results from teacher interviews
Teacher interviews indicated that teachers were generally very satisfied with the program. They gave specific feedback about the advantages and challenges of preparation and also offered suggestions for a good preparation. There were also themes having to do with gender, tinkering, and pre-service student coaches.

Program satisfaction
The lion's share of teacher responses about mobiLLab in general were positive, with about half of the teachers specifically saying that they would like to have mobiLLab visit their classroom again. Teachers think the program operates well, as exemplified by this (paraphrased) teacher's statement:

> 'The mobiLLab team members, including student coaches, are professional. Even though the program obviously involves a lot to bring the experiments into schools, it runs very smoothly.'

Teachers say mobiLLab is valuable to them because it offers experimentation with equipment and materials the schools do not have and because pupils can develop and implement their own ideas. One teacher said mobiLLab has changed for the better over the past several years and is glad to see that there is less emphasis on theory and enough coaches.

Several teachers said pupil feedback after the mobiLLab visit was positive. Several teachers thought that the Highspeed Camera and Infrared Camera posts were the most popular with pupils. One teacher reflected that pupils who select posts like the Microwave Synthesis and IC Chromatograph are usually the ones who are really interested and really engage.

Teachers continue (this was also mentioned during Background Investigation interviews) to mention that it makes the most sense to have mobiLLab visit a second year class, because the pupils are about to make their apprenticeship choice.

Preparation
Teachers offered some specific comments about how preparation for a mobiLLab visit, for teachers, pupils and the mobiLLab team, is time-consuming but that it is worth the effort. Other teachers said that the preparation is sometimes difficult to integrate into their teaching plans. About half of the teachers noted a conflict with time to prepare pupils for Stellwerk, a test which pupils take each May, which has learning objectives that are largely different than mobiLLab's.

An effective preparation, according to teacher interviews, 1) uses key resources such as the E-Learning and Post Instructions, 2) relates mobiLLab to pupils' interest, which was often related to encouraging pupils to bring their own materials for testing at the experimental posts, 3) relates classroom activities and assignments to mobiLLab, 4) orients pupils to the plan for the day, and 5) helps pupils lose their timidity about working with mobiLLab equipment.

Gender and tinkering

Several teachers commented that pupils' experimental post choices fall along gender lines, with girls drawn to health-related posts and boys liking something more sensational or something with more buttons and knobs.

Some teachers talked about how important it is for pupils to become comfortable with, or 'lose their fear of,' the experimental equipment, and one teacher noted that it is helpful when pupil are focused on a particular experiment. One teacher noted how, in his classroom, pupils organize themselves so that those who are good at working with technology and help those who are not so good at working with technology.

Coaches

Teachers offered mostly positive comments about the mobiLLab pre-service student coaches, such as how they helped to bring the material to the appropriate level for the pupils. One teacher expressed concerns about students moving pupils away from posts when they finished early with the major tasks at the posts, before the post session time had expired, rather than encouraging them to continue experimenting and playing.

Conclusions and implications for the main mobiLLab study

The most striking result from the mobiLLab pilot study is the strong link (medium MANCOVA effect) identified between pupils' tendency to explore technology and changes in their S&T outcomes. Qualitative data also points to pupils comfort with equipment as important. That is, pilot study teacher interviews, as well as perspectives from PHSG faculty (Cors, 2013), suggest that improving pupils' comfort and familiarity with the mobiLLab visit plan and the equipment helps them to engage in the mobiLLab experience. Somewhat similarly, Luckay and Collier-Reed (2011a) found that, when compared with Art students, "Engineering students are statistically more likely to … interact with technological artefacts with less fear and more self-initiation (Tinkering)."

The mobiLLab research-faculty team considered the possibilities for a more in-depth main study that focused either on pupils' novelty factors, particularly technological capability, or on classroom preparation. Pilot data collected from teachers through a survey and brief interviews produced very little, or more often no, significant variation about classroom preparation practices. A study to better understand classroom preparation would require classroom observation, longer teacher interviews, and ideally pupil interviews, activities to which the mobiLLab team anticipated there were barriers. Evidence of this was how teachers explained during pilot study interviews that were happy to participate in the study, but that because it was time-consuming, they hoped they would not be involved in multiple years of survey research.

On the other hand, data about novelty could be collected relatively comfortably and easily through pupil surveys. Therefore, the focus for the main study was to better understand how the development of pupils' interest in the science related to mobiLLab was affected by both pupil novelty influence factors (NEFs) and their novelty experience factors (NEFs), and the relationship between NIFs and NEFs. That is, data were to be collected about pupils' 'traits,' such as how technologically capable they perceive themselves to be, and also about their at-visit novelty 'state,' such as their feeling of familiarity with the equipment.

Pilot study results supported program improvements
Based on teacher interview data, the mobiLLab team managers identified a list of ideas for program improvement. Some improvements were made immediately, for the 2015-2016 school year (indicated by a "√" indicates the improvement has already been made).

- √ Reorganize the website.
- √ Tell teachers Firefox works better for E-Learning.
- √ Convert the Introductory PowerPoint presentation (*Einführung ins mobiLLab*):
    - Include more photos of the mobiLLab.
    - Use a regular PowerPoint format that makes editing by teachers possible.
- √ Simplify the Journalblätter, so that the contents are more learner-created.
- Generally, make more references to everyday uses.
- Include specific content that encourages pupils to formulate their own questions and to bring their own materials for testing.
- Ensure that all teachers who will have a mobiLLab visit, not just the teachers who ordered it, receive mobiLLab program communications.
- Update the introductory brochure for teachers.
- Consider producing a video that provides pupils with a virtual experience of the mobiLLab-visit.

Another result is that the mobiLLab team managers now continuously seek feedback from participating teachers, giving them further ideas about how to support teachers. For example, starting in the 2014-2015 school year, teachers received a USB-Stick that contains all classroom preparation documents.

5 From New Theoretical Understandings to Main Study Hypotheses

The review of theory and literature in chapters 3 and 4 led to new and broader theoretical understandings about novelty and how it relates to development of learner interest in S&T through OSLeP experiences. Described in this chapter is a refined definition of novelty in the context of informal learning. A key observation is that there are two types of novelty factors that have been shown to relate to educational outcomes at OSLePs: novelty influence factors (NIFs) and novelty experience factors (NEFs). For the mobiLLab study, a subset of these factors was selected. This chapter also outlines how, based on new theoretical understandings and insights from related previous work, NIFs and NEF can be characterized and how one would expect that NIFs would predict NEFs. Following this is a description about how NIFs and NEFs would be expected to relate to pupils' affective S&T educational outcomes. To examine these relations, hypotheses were generated for the mobiLLab main study, which are presented in a list and also through a relational illustration. Finally, a research purpose statement summarizes how the direction for research was established, what the study intended to accomplish, and how these research objectives were pursued.

5.1 A refined definition of the novelty construct

The Merriam-Webster dictionary defines something novel as something "new and different from what has been known before." Berlyne (1960) distinguished between absolute and relative novelty. Something is absolutely novel when some of its features have never been experienced before, whereas it is relatively novel if it has familiar features but they occur in a different combination than previously encountered. However, Berlyne's explanation gives rise to the idea that just about any experience, no matter how new, can be related to something familiar:

> "Any new experience, even if it does not seem to be a combination of familiar experiences, must have some definite degree of resemblance to experiences that have occurred before. It will inevitably be possible to insert it into an ordering of familiar stimuli or to assign to it values among dimensions that are used to classify them" (p. 19)

Novelty as something overwhelming that requires effort to process. The process of relating novel stimuli with the familiar is central to how educational psychologists have described novelty; they portray this process as something that requires effort and distracts from learning. Specifically, they describe how people process the novel experiences in order to associate them with the familiar, so that they can attend to the task at hand. For example, Falk et al. (1978) described how learners at OSLePs deal with novelty, and the disorientation it introduces, by following an adaptation process that starts with itemizing or naming objects, then grouping or clustering them, and then finally generalizing (Falk et al., 1978). Only then, can learners direct their attention to assigned tasks. More recently, based on a definition of novelty as 'not previously experienced or lack of familiarity,' Förster et al. (2010) formulated a Novelty Categorization Theory (NCT), which "attempts to predict when people perceive events as novel and how they process novel events across different domains" (p. 736). They assert that by using broad mental categories, people reduce the perception of an event being novel through inclusion processes, whereas when people use narrow categories, novelty increases as a result of exclusion processes. Over time, people develop a 'when-novel-then-process-globally' routine that activates when they encounter novelty.

Novelty as an appealing trigger for situational interest. In contrast, some informal learning researchers have, through inductive approaches, discovered novelty as an appealing variable that triggers situational interest at OSLePs. For example, in a study of high school pupils visiting an aquarium, Dohn (2010) discovered several novelty-related triggers of pupils' situational interest. That is, when coding interview data about triggers for pupil's situational interest, Dohn (2010) identified four sub-categories having to do with novelty: 1) Novelty: Something new, 2) Unusual: Things that are different from daily practice, 3) Suspense: Not knowing what was going to happen, and 4) Variety: Change in activity. Similarly, Sandifer (2003) found that technological novelty was one of four exhibit characteristics of science museum exhibits that best attracted and held visitor attention. An exhibit was considered to be technologically novel if it met at least one of the following criteria: 1) The exhibit contained visible state-of-the-art devices, or 2) The exhibit, through the use of technology, illustrated phenomena that would otherwise be impossible or laborious for visitors to explore on their own.

Two types of novelty factors. As described in section 4.2, studies of novelty at OSLePs have focused almost exclusively on novelty factors such as previous knowledge, which prepare learns to feel more familiar with the OSLeP. While many of these studies suggest how these factors should relate to reduced novelty at an OSLeP visit, few have studied indicators of learners' at-visit experience. Therefore, to explore the role of novelty at OSLePs more deeply, the mobiLLab study was designed to examine two types of novelty factors. The first, a 'novelty influence factor' (NIF), refers to pupil factors such as their disposition, previous experience, and previous knowledge, which are thought influence learners' at-visit novelty experience. For example, Falk et al. (1978) compared pupils who were more and less familiar with a wooded area, to see if this NIF made a difference in their post-field trip test scores. A list of NIFs examined by other studies of novelty at OSLePs is Table 11 on page 58. A second factor is called a ´novelty experience factor' (NEF), which indicates how a learner actually perceives novelty during an OSLeP visit. It is based on the description of perceived novelty experience from Anderson and Lucas (1997) as "a state of mind experienced by individuals when they are exposed to, or in a context where, new or unusual sensory information is received" (p. 486). As an example, Kubota and Olstad (1991) studied pupils' exploratory behavior at a science center as an indicator of perceived novelty. They found that pupils who watched in an orienting video exhibited more on-task exploratory behavior than pupils who did not watch the video. A description of how other studies of novelty at OSLePs have measured exploratory behavior is provided in Table 12 on page 59, followed by a discussion of other potential, as of yet unmeasured, NEFs.

5.2 Selecting novelty factors for the mobiLLab study

The mobiLLab study involved a subset of novelty factors identified by other studies of novelty at OSLePs. Novelty impact factors (NIFs) were selected from the full list of NIFs in Table 11, based on which most closely related to the mobiLLab goal of getting pupils interested in S&T (section 4.3.1), and on the resources available for the study. As described in Figure 14, the three NIFs investigated by the mobiLLab study were pupils' technological capability, their previous experiences with OSLePs, and their content knowledge. Novelty experience factors (NEFs) are based on insights from previous studies described in section 4.2.8. The NEFs investigated by the mobiLLab study were exploratory behavior, oriented feeling, curiosity state and cognitive load. The focus of the mobiLLab main study is to test how NIFs predict NEFs and to test how both NIFs and NEFs predict pupils' core S&T outcomes, which are also defined in Figure 14.

Novelty impact factors (NIFs) were pupil factors that affect how familiar they find an OSLeP to be. The mobiLLab study design included three NIFs: their previous experiences with OSLePs, their technological capability, and their content knowledge.
Novelty experience factors (NEFs) were indicators of how pupils perceive novelty at the mobiLLab visit: exploratory behavior, oriented feeling, curiosity state and cognitive load.
Core S&T outcomes were indicators of pupils' affective learning, or their interest in, attitude to, and self-concept to S&T.

Figure 15: Definitions for the three core constructs of the mobiLLab main study: pupils' novelty impact factors (NIFs), their novelty experience factors (NEFs), and core S&T outcomes.

5.3 Links among selected novelty factors and educational outcomes at OSLePs

Previous studies of novelty at OSLePs and related research offer insights into how to study novelty factors and educational outcomes, and explore the relations among them. The resulting new theoretical understandings about NIFs, NEFs, and pupils' core S&T outcomes, and how they relate to one another, are summarized in this section. First is a description of the NEFs exploratory behavior, oriented feeling, cognitive load, and curiosity feeling. Next is a description of the NIFs technological capability, previous OSLeP experiences, and previous knowledge, which were tested by the mobiLLab pilot study, as described in section 4.3.2. This discussion articulates how, based on theories and previous studies, NIFs are expected to relate to NEFs. Next is a description of the expected impact on NEFs from a novelty-reducing video. Next is a discussion of the how it was expected that NIFs and NEFs would predict pupils' S&T interest. Based on other studies, several control variables were also measured that have been found to confound these predictions. Finally, is a discussion of insights about how people develop interest in S&T, particularly at OSLePs.

5.3.1 Novelty Experience Factors (NEFs)

Insights about novelty experience, or novelty perceived by learners at OSLePs, and how it relates to their behavior, comes from the motivation model called Social Determination Theory (SDT) (Deci et al., 1991). According to SDT, the quality with which humans are motivated to engage in an activity is driven primarily by conditions supporting a learner's experience of autonomy, competence, and relatedness. The quality of engagement, in turn, affects the quality of learner performance, persistence, and creativity. Indeed, several studies of science learning at OSLePs have considered how learners' basic needs are fulfilled and relate to their situational interest, such as Glowinski (2007) and Pawek (2009). However, only three studies of novelty at OSLePs characterize learner engagement with activities, which was measured as exploratory behavior (see summary in Table 12).

Identifying novelty experience factors (NEFs). Clues about how to understand the quality of pupil engagement at the mobiLLab lie in the theories behind, and findings from, studies of OSLePs. For example, theoretical views of learning suggest that perceived novelty is closely linked to exploratory behavior and curiosity (Anderson & Lucas, 1997; Berlyne, 1951). Indeed, findings from at least one study describe how data about exploratory behavior indicated how much novelty learners perceived

(Falk & Balling, 1982). And while no studies of novelty at OSLePs have measured curiosity, curiosity has been linked to novelty, through a questionnaire that asked more than 700 university students about their tendency to approach or avoid novel stimuli (Litman & Spielberger, 2003). Also, some studies describe how too much novelty causes disequilibrium, or an overload with working memory, in learners (Falk et al., 1978), something that has been studied by educational psychologists as cognitive load (de Jong, 2009; Paas et al., 2010). Finally, since several studies of novelty at OSLePs organized 'orienting' classroom preparation to reduce novelty (Anderson & Lucas, 1997; Kubota & Olstad, 1991; Orion & Hofstein, 1991b), it would be interesting to learn how much of a difference these interventions made in how oriented learners actually feel during the OSLeP visit. In summary, *theory and studies about learning science point to the value of better understanding four aspects of pupils' novelty experience: exploratory behavior, oriented feeling, cognitive load, and curiosity state.*

Specific versus diversive engagement. Berlyne (1954) describes two types of exploration: specific exploration to reduce uncertainty produced by a particular, novel stimulus, and diversive exploration to generally reduce the uncertainty of a novel environment. During mobiLLab pilot study interviews, teachers said that pupils engage most in mobiLLab activities if they are more comfortable with the mobiLLab equipment. As such, exploratory behavior should be examined in relation to pupils' specific exploration, or how comfortable they feel exploring mobiLLab equipment, rather than their general exploration of, for example, the room. In parallel fashion, at-visit curiosity should relate to specific, stimulus-driven curiosity about mobiLLab equipment and themes. In other words, for the mobiLLab study, *it would be most meaningful to examine pupils' specific curiosity and exploration, which reflect a drive to know more about a specific object or stimulus, namely mobiLLab equipment and science themes.*

5.3.2 Novelty Influence Factors (NIFs) and NEFs

Studies of novelty at OSLePs have explored how five different types of novelty impact factors (NIFs), described in Table 11, affect learner at-visit behavior and learning. For the mobiLLab study, two NIFs were selected based on previous studies: previous knowledge and ability to navigate the setting. A third NIF, technological capability, was selected based on a desire by the mobiLLab team to better understand pupils' experiences with the high-technology nature of mobiLLab experimental posts. This section describes the theoretical underpinnings of each NIF, how each was measured during the mobiLLab pilot study, and how each NIF was expected to relate to novelty experience. These relations are described in terms of whether each NIF would predict that pupils would have a more positive novelty experience: exhibiting more exploratory behavior, feeling better oriented to the visit, feeling less cognitive load, and feeling more curious.

NOTE: An additional predictor, *dispositional curiosity*, was also of interest. Even though it has not been described or investigated in the context of OSLeP studies, curiosity researchers have thought that dispositional curiosity (curiosity trait) relates significantly to curiosity feeling (curiosity state), as described on page 32. Because dispositional curiosity is not of direct interest as a novelty influencing factor, yet is possibly predictive of curiosity state, it could be a confounding or interacting variable. Therefore, it was important to consider it as a possible covariate.

Technological capability describes someone's tendency to 'poke around' and tinker with technology, rather than seek direction, to work with it. A detailed description of theory about technological capability, and why it was selected as a mobiLLab study NIF, is on page 53. Findings from the pilot mobiLLab (section 4.3.2) study showed technological capability related significantly to how pupils S&T outcomes changed. This was supported by teachers' suggestions that pupils who are more comfortable with mobiLLab equipment are more apt to engage in experimental post activities. As such, it was expected that those pupils who described themselves as more technologically capable would feel more curious, explore more, feel more oriented to the setting and perceive less cognitive load. In other words, *more technologically capable pupils would have a more positive at-visit novelty experience.*

Setting orientation. Several studies of novelty at OSLePs hypothesized, and found, that pupils who had more previous experiences with similar or the same OSLePs (Anderson 2007, Cors 2015), or had a vicarious experience through a classroom preparation (Kabuto, 1991), showed more positive educational outcomes. This is probably because previous experiences with OSLePs prepares learners for navigating OSLePs, which have physical layouts and schedules that are different from classrooms and from everyday life. This ability to navigate an OSLeP has been called "museum savvy" (Falk & Dierking, 2011, p. 80). Examining learners' museum savvy could be explored by asking them about their experience with different types of OSLePs, which have been described by Falk et al. (2012a). It was expected, then, that *pupils who have more previous experience with OSLePs would experience more positive at-visit novelty.*

Previous relevant content knowledge, measured in studies of novelty at OSLePs through a pre-visit knowledge test, has been found to be a predictor of at-visit engagement at OSLePs. For example, Falk et al. (1978) found that pupils who scored better on a pre-visit test about knowledge of wooded areas exhibited more on-task exploratory behavior. Also, Orion and Hofstein (1991a) found that knowledge of the (geology) content related to a field trip explained 10 percent of pupils´ attitude toward learning. For the pilot mobiLLab study, a gage of their knowledge of electromagnetic concepts, which relate to about three-quarters of the experimental posts, was interesting. It was expected that *pupils who know more about electromagnetic spectrum concepts would experience more positive at-visit novelty.*

5.3.3 A novelty-reducing intervention and NEFs

During mobiLLab pilot study interviews, teachers said that if pupils can be supported in feeling more comfortable with mobiLLab equipment, then they would better engage in experimental post activities (Cors et al., 2015a). For this reason, the mobiLLab faculty-research team designed an intervention in the form of novelty-reducing videos. Development of these videos, which were aimed at orienting pupils to mobiLLab equipment, is described on page 91. It was hypothesized that *pupils who watched the mobiLLab novelty-reducing videos would report more positive at-visit novelty experience factors (NEFs).*

5.3.4 Relating NIFs and NEFs to pupils' educational outcomes

A core focus of the mobiLLab study was to examine how pupils' core S&T outcomes were affected by both their novelty influence factors (NIFs) and by their perceived novelty experience (NEFs).

Technological capability and pupils' S&T outcomes. The mobiLLab pilot study findings, summarized starting on page 53, showed that whether or not pupils described themselves as technologically capable, that is, whether they tend to tinker or seek direction when interacting with technology, related significantly to changes in their core S&T outcomes related to technology. The effect that technological capability had on changes in the combined 'group' of outcomes (from the multivariate tests) related to technology outcomes was medium (η_p^2=.05); univariate results show that interest in technology decreased less for direction seekers (η_p^2=.03), attitude to technology was insignificantly affected, and self-concept to technology decreased less for tinkerers (η_p^2=.02). There were no significant relations between technological capability and natural science outcomes. Even though the primary interest for the mobiLLab study was in learning about what factors explained variations in changes in S&T outcomes, it is worth noting the large overall differences between tinkerers and directions seekers for core S&T outcomes (between-subject differences). These results are shown in the top section of Table 15 on page 68. The table shows that tinkerers had much (large effect) more overall positive outcomes related to technology (η_p^2=.34). Univariate statistics, not shown in the table, show that this effect was large for interest in (η_p^2=.26), attitude to (η_p^2=.15) and self-concept (ηp^2=.32) to technology. Tinkerers also had more positive overall outcomes related to natural science (η_p^2=.17). Univariate effect sizes for interest in (η_p^2=.04) and attitude to (η_p^2=.04) natural science were small-to-medium, while overall variations for self-concept to natural science were large (η_p^2=.15). Since the survey items about technological capability from the pilot study were used in the main study survey, similar results were expected. That is, it was expected that *pupils who described themselves as more technologically capable would have more positive S&T outcomes that remain more positive from before to after a mobiLLab visit.*

Setting orientation and pupils' S&T outcomes. Early insights from Orion and Hofstein's novelty space framework (1989) and more recent reflections by Falk and Dierking (2011, p. 80), suggest that whether learners have the know-how to navigate an OSLeP setting will affect learning. This same idea of giving participating pupils an orientation to the setting through a vicarious experience, often through a video and/ or photos of the setting, was behind novelty-reducing preparations for studies of novelty at OSLePs, described in section 4.2. Findings provided evidence that learners who experienced a pre-visit orientation had better test scores, improvements in test scores, greater enthusiasm for science, and decreased anxiety about science (Anderson & Lucas, 1997; Jarvis & Pell, 2005; Kubota & Olstad, 1991; Orion & Hofstein, 1991a). And, whether learners previously visited the OSLeP before the study, or visited a similar place, has also been related to more on-task behavior, to more positive attitudes towards science and technology, and to improvements in test scores (Anderson & Lucas, 1997; Cors et al., 2015a; Falk & Balling, 1982; Falk et al., 1978).

Findings from the mobiLLab pilot study showed that setting orientation predicted differences in pupils' core S&T outcomes overall, but did not explain variations in changes from pre- to post-visit survey. Interestingly, the *type* of OSLePs that pupils frequented related significantly to their overall affective outcomes. That is, core S&T outcomes relating to *technology* were rated much (large effect) higher by pupils who more often visited technology-related informal learning settings, such as science centers, before and after the mobiLLab visit, $F(3,195)=25.2$, ($p<.001$), η_p^2=.28. However, technology core S&T outcomes were not significantly affected by the amount of previous visits pupils made to natural science OSLePs, such as nature centers. $F(3,195)=2.0$, ($p=.114$). Similarly, pupils who had more previous experience with natural science-related OSLePs had overall more positive *natural science* educational outcomes, $F(3,193)=8.3$, ($p<.001$), η_p^2=.15. Natural science outcomes were also significantly greater for pupils more previous experiences with technology-related OSLePs, $F(3,193)=11.4$, ($p<.001$), η_p^2=.11. Since the survey items about setting orientation from the pilot study were used in the main study survey, similar results were expected. That is, it was expected that, *pupils who have previously visited more OSLePs would have more positive core S&T outcomes both before and after the mobiLLab visit, but not show more improvements, than pupils who visited less OSLePs.*

Content knowledge and pupils' S&T outcomes. The novelty space framework from Orion and Hofstein (1991, 1994), based on theory about learning at OSLeP put forth by Falk (1978), explicitly hypothesized that pupils with better previous content knowledge would have a more optimal learning experience. Since then, pre-visit knowledge scores about the science content related to OSLeP activities, have been linked to more on-task behavior, test score improvements, and a better attitude about the field trip (Falk et al., 1978; Orion & Hofstein, 1991a). Therefore, results for the mobiLLab main study were expected to be similar. That is, it was expected that *pupils with better pre-visit knowledge test scores would show more improved core S&T outcomes.*

Findings from the mobiLLab pilot study show that pupils with better math and science grades did not have significantly different changes in S&T outcomes (Cors et al., 2015a). However, pupils with better grades had better overall core S&T outcomes. That is, according to between-subjects results, pupils with better science grades had more positive core S&T outcomes, before and after the mobiLLab visit, related to technology, $F\ (3,194)=4.2$, ($p=.007$), $\eta_p^2=.06$, and related to natural science, $F\ (3,192)=11.0$, ($p<.001$), $\eta_p^2=.15$. Similarly, pupils with better math grades had more positive core S&T outcomes, related to technology, $F\ (3,195)=4.0$, ($p=.008$), $\eta_p^2=.06$, and related to natural science, $F\ (3,193)=5.2$, ($p=.002$), $\eta_p^2=.07$. Based on these findings, it was expected that *pupils with better science and math grades would have more positive S&T outcomes, but not have significantly different changes in core S&T outcomes.*

Exploratory behavior and pupils' S&T outcomes. As described in section 4.2, findings from studies of novelty at OSLePs provide evidence that there are links between specific, object-focused and on-task exploratory behavior and knowledge gain (Falk & Balling, 1982). No studies provide evidence of links between exploratory behavior and improved affective outcomes. However, interviews with teacher participating in the mobiLLab program suggested that pupils who are more comfortable with the mobiLLab equipment would benefit more from the program. Based on these ideas and evidence, it was expected for the mobiLLab study that *pupils who explore the mobiLLab equipment more would show more improved core S&T outcomes.*

Oriented feeling and pupils' S&T outcomes. Some studies of novelty at OSLePs have linked a more complete classroom preparation, which is designed to orient learners to the OSLeP setting and schedule, to better knowledge test scores, improvements in knowledge gain, and attitudes about science (Anderson & Lucas, 1997; Kubota & Olstad, 1991; Orion & Hofstein, 1991a). Other studies of novelty at OSLePs show that pupils who were expected to be more familiar with an OSLeP, because of previous experiences with the same or with similar OSLePs, had better knowledge test scores and better attitudes toward the learning activity (Anderson & Lucas, 1997; Falk et al., 1978). Based on these findings, it was expected for the mobiLLab main study that *pupils who feel better oriented at the mobiLLab visit will show more improved core S&T outcomes.*

<u>Relating cognitive load and curiosity to pupils' S&T outcomes.</u> When considering peoples' experiences with unfamiliar objects, events and settings, existing studies and common experience suggest that novelty elicits one of three types of responses, or has 'three faces.' This holds true for experiences in general and for learning contexts in particular, and very specifically for novelty as an aspect of the OSLeP experience. Both Förster et al. (2010) and Falk et al. (1978, 1982) describe how novelty of events can elicit interest and increase curiosity, be threatening because it is overwhelming or carries some risks, or be boring, causing an off-task search for stimulation.

It is not surprising, then, that Falk and Balling (1982) used an inverted-U function appropriate for describing pupils' behavior and learning in wooded settings. That is, they found that pupils' learning was lower when they were bored, a low cognitive load situation, and also when they were overwhelmed, a high cognitive load situation. Based on these findings it was expected that, for the mobiLLab main study, *pupils who experienced moderate at-visit cognitive load would have more positive S&T outcomes*.

Similarly to cognitive load, at-visit curiosity is also thought to promote educational outcomes when it is moderate. That is, feeling curious at an OSLeP is thought to relate to more positive educational outcomes when that state of curiosity is moderate (Anderson & Lucas, 1997). The idea is that, low or high levels of perceived novelty at an OSLeP results in less curiosity, which, in turn, results in less learning. Based on these understandings, it was expected for the mobiLLab study that *pupils who experience moderate at-visit curiosity will have more positive S&T outcomes.*

5.3.5 Control Variables

An aim of (quasi-) experimental research is to show how an independent variable predicts variations in a dependent variable. The degree to which one can feel confident in the predictive relationships identified through the research, also called internal validity, is to eliminate likely alternative causes or explanations. The following control variables were interesting for the mobiLLab study because other studies suggested that they could influence the results of tests that relate novelty to interest, and therefore confound predictions by independent variables of pupil interest.

Gender. Studies at German education laboratories and studies of PISA data provide evidence that interest for boys and girl is different, depending upon what science discipline they are asked about (Brandt et al., 2008; Bybee & McCrae, 2011). And several studies at OSLePs have found that knowledge gain differed depending upon gender (Dowell, 2011; Kubota & Olstad, 1991). Moreover, attitudes to technology have been shown to differ for boys and girls (Heitzmann & Güdel, 2014).

Grade level. Several studies at OSLePs have shown that older pupils are less interested in S&T than pupils who are just one or two grade levels lower (Barmby et al., 2005; Guderian, 2007).

School track. Observations from mobiLLab coaches (faculty and students) suggested that because Vocational Track pupils often seemed to know more about the science behind the experiments, they could engage more in experiments than General Track pupils. The assumption behind this hypothesis, that Vocational Track pupils know more about science, is supporting by PISA data, which show that school track in St. Gallen relates significantly to math knowledge (Buccheri et al., 2014, p. 56).

Home language. Some researchers who study OSLePs suggest that home language may also affect learning (Jarvis & Pell, 2005; Tran, 2011). One sees evidence of a significant relation between home language and test performance, and with socioeconomic status, in PISA test results (PISA, 2014). That is, for every test between 2003 and 2012, pupils who spoke the language of the test as their home language have a greater average math score (page 13) and have a higher socioeconomic status (page 16). This suggests that pupils who speak primarily German at home would have an easier time engaging in mobiLLab activities, which require one to follow instructions that are in German, than pupils who speak another language at home.

Technology at home. For the mobiLLab study, it was thought that the amount of technology pupils have access to at home would influence their technological capability, a NIF and an independent variable in the mobiLLab study. Technology at home is also measured by PISA surveys, which include a list of 'technology at home' items that characterize possessions at home and has to do with socioeconomic status (OECD, 2009, p. 43).

5.3.6 New understandings about how people develop an interest in science

The mobiLLab study was also guided by new understandings about how people develop an interest in science. For example, studies that have explored interest development also examined self-concept of ability and attitude. In fact, some studies show that interest in, attitude to, and self-concept to science and/or math are closely coupled during learning (Denissen et al., 2007; Dresel & Lämmle, 2011; Potvin & Abdelkrim, 2014). Based on this I decided that *pupils' affective educational S&T outcomes would be expressed through interest, attitude, and self-concept*.

It is also worth noting that studies have found that interest in science differs for learners depending upon whether one refers to soft sciences like biology or technology-related sciences like physics (Bybee & McCrae, 2011). Moreover, interest in science during an OSLeP experience has been shown to be different from interest in experimenting and in technology (Itzek-Greulich et al., 2015; Pawek, 2009). Therefore, for the mobiLLab study, it was thought that *pupils' interest in science would differ from their interest in technology.*

5.4 Main study hypotheses

With a refined definition of novelty, and broader understandings of novelty and interest, a focus for the mobiLLab study became clear. The research was to explore the role of novelty at OSLePs, with a focus on the question, *What role does novelty play in how pupils develop interest in S&T through a mobiLLab visit?* I had a specific interest in examining the relations among three constructs: 1) pupil novelty influence factors (NIFs), 2) pupils' at-visit novelty experience factors (NEFs), and 3) their attitudes towards science and technology (pupil core S&T outcomes).

The variables that were part of these main study constructs are shown in Figure 15. A first step in the investigation was to characterize pupils' perceived at-visit *novelty experience,* shown as EX1 ('exploration 1'), in Figure 15. Then it was possible to explore the relations among three constructs: pupils' *novelty impact factors (NIFs)*, their at-visit perceived *novelty experience (NEFs)*, and their core *S&T outcomes*. The study also involved testing the effects of a novelty-reducing video intervention on pupils' NEFs. The specific hypotheses that were tested are listed below in this section and labeled in Figure 15.

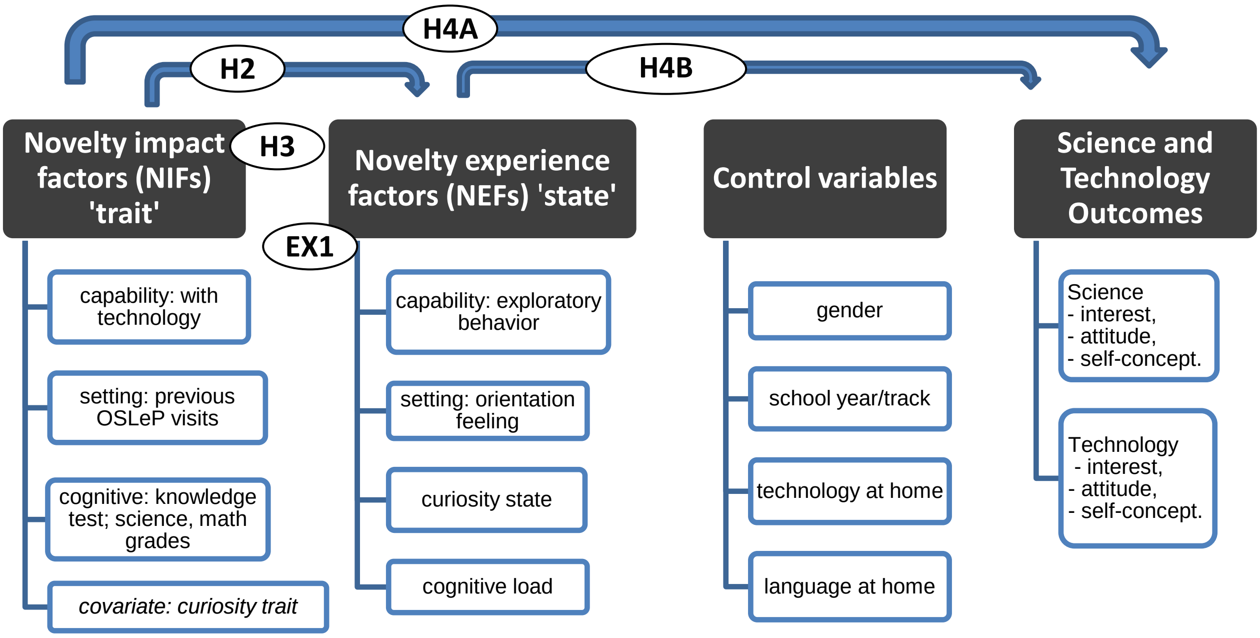


Figure 16: MobiLLab study variables.

Hypothesis group 2: The relation between pupil novelty influence factors (NIFs) and their novelty experience (NEFs).

H2A: More technologically capable pupils will experience more positive at-visit novelty.

H2B: Pupils who have previously visited more OSLePs will experience more positive at-visit novelty.

H2C: Pupils with more relevant pre-visit content knowledge will experience more positive at-visit novelty.

Hypothesis 3: Testing the intervention.
H3: Pupils who watch more novelty-reducing videos will experience more positive at-visit novelty.

Hypothesis group 4A: The relation between pupils' NIFs and their affective S&T outcomes.
H4A1: More technologically capable pupils will have more positive pre-visit core S&T outcomes that remain more positive after the visit.
H4A2: Pupils who have previously visited more OSLePs will have more positive core S&T outcomes, both before and after the mobiLLab visit, but show no greater improvements that their peers.
H4A3: Pupils with better pre-visit knowledge test score will show more improved core S&T outcomes.
H4A4: Pupils with better science and math grades will have more positive pre-visit core S&T outcomes that remain more positive after the visit.

Hypothesis group 4B: The relation between pupils' NEFs and their affective S&T outcomes.
H4B1: Pupils who explore the mobiLLab equipment more will show more improved core S&T outcomes.
H4B2: Pupils who feel better oriented to the mobiLLab visit will show more improved core S&T outcomes.
H4B3: Pupils who experience moderate at-visit curiosity will have more positive S&T outcomes.
H4B4: Pupils who experience moderate at-visit cognitive load will have more positive S&T outcomes.

5.5 Summary: research purpose statement

Creswell (2009) describes how a research purpose statement articulates three aspects of a study: 1) establishes the direction for the research, 2) indicates the reasons for conducting the study and the aims of the study, and 3) outlines the objectives, the intent, and the major idea of a proposal or a study.

The purpose of the mobiLLab study was to better understand the how novelty, or unfamiliarity, affects development of pupil interest in science and technology (S&T) at a mobile laboratory. The study was carried out through investigation of the mobiLLab program in Eastern Switzerland. The impetus for the study was an initiative by the mobiLLab team to improve their program based on its goals and priorities, which were identified during a background investigation. Based on results from the background investigation, a pilot investigation was designed to explore the how pupil novelty factors, classroom preparation, and teacher attitude related to pupils' (affective) core S&T outcomes. Core S&T outcomes were defined as interest in, attitude to, and self-concept to S&T. A critical part of the investigation was exploring what novelty is, what research frameworks about novelty can guide the research, and how to measure it. A parallel goal was to collect informative data to evaluate program performance. During a mixed-methods pilot study, three types of data were collected: 1) pre- and post-visit surveys were used to track changes in pupil S&T interest, 2) teacher surveys and interviews allowed for characterization of pre-visit activities, teacher use of website resources, and teacher attitudes, and 3) observations at mobiLLab visits. An intervention involved giving treatment teachers access to additional preparation material. Pilot study results showed that pupils' technological capability, or how comfortable they felt interacting with technology, and length of preparation explained variations in changes in pupils' core S&T outcomes. Similarly, teacher interview responses indicated that how comfortable pupils are with mobiLLab equipment affected their ability to engage in the mobiLLab activities. Teacher interview data also provided actionable ideas for immediate program improvements. These results suggested that for the mobiLLab main study, measurements of pupil novelty impact factors (NIFs), such as previous knowledge, and studying at-visit novelty experience factors (NEFs), such as exploratory behavior, would yield a yet deeper understanding of the role of novelty in pupils' mobiLLab experience.

Based on these pilot study findings, the main study focused on examining the relations among NIFs, NEFs, and pupils' core S&T outcomes. Data was collected through three pupil surveys. Through a pre-visit survey, pupils described their NIFs and their S&T interest. Through an at-visit survey, pupils responded to items about their perceptions of novelty, and related behaviors at the mobiLLab visit. And, through a post-visit survey, pupils reported about their interest in S&T and about their program satisfaction. In a first phase of analysis, a factor analysis was used to validate scalar measures of NEFs: exploratory behavior, oriented feeling, curiosity feeling, and cognitive load. Comparisons of pre- and post-visit data revealed changes in pupil interest measures. Then, in a second phase of analysis, multivariate statistical analysis was used to examine how well NIFs predicted NEFs, and how NIFs and NEFs related to pupils' core S&T outcomes.

III. METHODS

6 Design and Data Collection Methods

This chapter describes activities carried out to develop the study research design and to collect data. A first section describes how a background investigation and pilot study supported development of main study design and data collection strategies. A second section describes research design elements: the research setting, pupil sample, the novelty-reducing video intervention, and the sampling plan. A final section describes development and testing of instruments to collect data.

6.1 Grounded in real-world challenges, priorities, and voices

The main study was preceded by a background investigation (page 60) and pilot study (page 66), activities carried out to support external, construct and internal validity, as defined on page 192. This section describes how the results to these activities enabled me to design a study whose results were more strongly linked to the challenges and activities of both mobiLLab in the field and of similar programs. A section part of this section describes how, similarly, involvement of mobiLLab faculty and staff in development of research instruments was aimed at eliciting authentic responses from study participants.

6.1.1 Inquiry strategy

As Figure 16 shows, the inquiry strategy was a three-step process that involved an explorative background investigation to define a research focus, a mixed-methods pilot study to test study variables and methods, and a main study to measure and relate novelty factors and pupil interest.

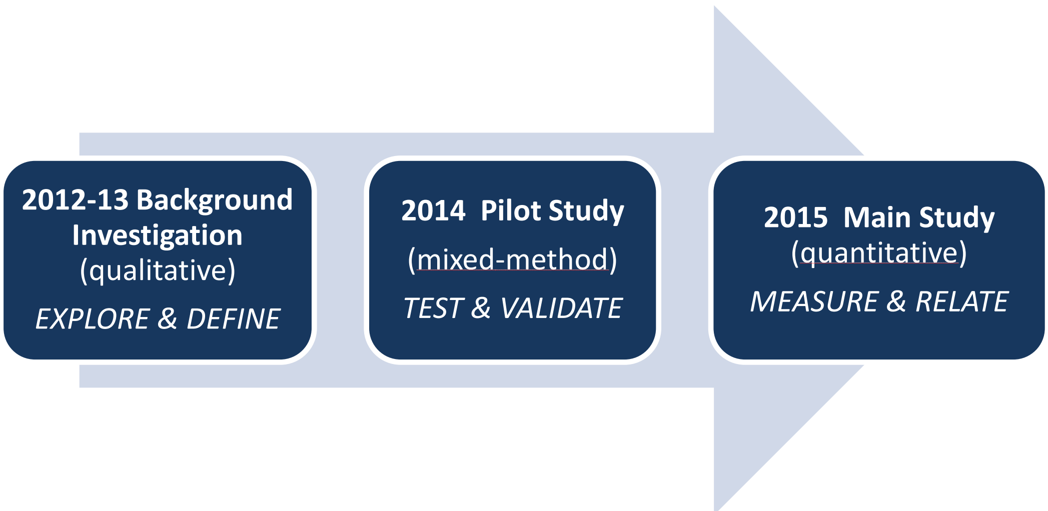


Figure 17: The focus for the mobiLLab investigation was developed through a qualitative, explorative background investigation and then tested through a mixed-methods pilot study.

To ensure that the mobiLLab study was tied to mobiLLab challenges, it was appropriate to begin the investigation with a background investigation that involved open, discovery-focused inquiry to uncover salient themes and challenges. Section 4.3.1 describes how the mobiLLab background investigation employed qualitative methods, including stakeholder interviews and school visit observations, which supported construction of a ‘logic model’ map of the program’s resources, products, and desired outcomes. An important activity for the mobiLLab team was a synthesis of and reflection on their theory of change, described in a logic model chart that illustrated their vision for how the program can optimally function. In this way, several of the program goals from their theory of change became foundational drivers of the mobiLLab research investigation. This intent was to focus the research on real-world challenges, multiple-methods, and produce results that can be used in the field, an approach described as having a pragmatic worldview (Cresswell, 2009). Based on the results of the background investigation, preliminary research questions and hypotheses were identified, which supported development of research instruments and design elements that could be tested through a pilot study. The pilot study design, sample, and results are described in section 4.3.2. Based on results of the pilot study, a purely quantitative main study investigation was designed, which measured and related three constructs: novelty impact factors (NIFs), novelty experience factors (NEFs), and pupils affective outcomes.

6.1.2 Iterative involvement from mobiLLab faculty and staff

The author sought to align study and program aims through regular consultation with mobiLLab faculty and staff. A list of research activities that involved mobiLLab faculty and/or staff is shown in Table 15. Because some faculty had been with the mobiLLab program for several years before the research effort began, their input was important for developing instruments that would elicit meaningful responses from study participants. For example, faculty had specific suggestions for formulating survey items using language appropriate to the region and to program literature. In this way, involvement of mobiLLab team members contributed to the construct validity of the study. For example, involvement by mobiLLab staff and faculty in survey item development was important for ensuring that translating the study constructs, such as perceived novelty, into measures, such as Novelty Experience Factors (NEFs), which are truly a good reflection of how pupils perceive novelty.

Table 16: Dates and type of inputs from mobiLLab team members, which were important for developing study design and instruments, and for analyzing the data.

Dates	Type of involvement from mobiLLab team members
October 2012 – April 2013	MobiLLab team members participated in informal interviews that contributed as part of a background investigation of the program to identify factors that influence development of pupils' science and technology interest, attitude and knowledge development. PRODUCT: October 2013 Background Investigation Report (Cors 2013).
February 5, 2013 and September 4, 2013	During these two mobiLLab team meetings, and during individual follow-up discussions with several members, we reviewed and refined a logic model of desired program outcomes, which was developed from data collected during the qualitative background investigation. PRODUCT: List of mobiLLab "hotspot" priorities, which are areas of greatest concern and possible impact," summarized in Cors (2013).
January – April 2014	Development of documents for communication with teachers, schools, and parents and also surveys with regular reviews and recommendation from the mobiLLab program manager. PRODUCTS: Schedule for study instruments for teachers (*Befragungsablauf*), pre- and post-survey for teachers, pre-and post-surveys for pupils. Related letters and emails to teachers, schools, parents.
August 15, 2014	MobiLLab faculty meeting to review pilot study data. PRODUCTS: 1) List of (possible) improvements to mobiLLab and 2) Discussion of possibilities for measuring the STATE (situational) aspect of the construct "tendency to tinker" at a mobiLLab school visit.
September 12 and 23, 2014	Discussion of how to measure novelty STATE.
September 23, 2014	Discussion of Intervention for the main study. PRODUCTS: plan for intervention video and for data collection during the mobiLLab visit to measure novelty experience (state).
November 2014 – February 2015	Development of main study surveys with the mobiLLab program manager. PRODUCTS: Schedule for study instruments for teachers (*Befragungsablauf*), pre-and post-surveys for pupils. Related letters and emails to teachers, schools, parents.
August 2015 – December 2015	Series of meetings to review preliminary results by research with mobiLLab faculty. PRODUCT: Interpretations of results that relate to mobiLLab in the field.

6.2 Research design

This section describes how a research design to explore the mobiLLab study hypotheses listed in section 4.3.1 was developed. First, it explains how the research setting shaped the study. Then it provides basic information about the pupils sample for the main study: gender, school year and school track are provided. About half of the pupils watched a novelty-reducing video intervention that was designed to improve their comfort level with mobiLLab equipment could be improved. The sampling plan for the main study, which consisted of pre-, at-, and post-visit surveys is also described.

6.2.1 The research setting

When the mobiLLab study began in 2012, the program had already been in operation for four years. Additionally, mobiLLab faculty had recently made some major changes to the program, including two major additions 1) E-Learning tutorials for each experimental post, meant to be viewed by pupils before the visit, and 2) production of simplified, step-by-step instructions for carrying out activities at each post. MobiLLab faculty had the feeling that they had good relationships with participating teachers and pupils, had a good reputation in Eastern Switzerland, and thought school visits ran smoothly. The team was interested an evaluation of program operations to get some feedback. However, ideas to collect data through pupil interviews were considered too time consuming for teachers to organize and observations of classroom preparation were considered too intrusive for the teachers. Also, asking a teacher to skip classroom preparation to act as a control group was not an option, as teachers were customers.

6.2.2 Pupil sample

The sample consisted of pupils who participated in the mobiLLab program in spring 2015. These pupils were distributed among 21 class groups and 15 teachers, which means that some teachers participated with multiple classes. Table 16 below shows the number of pupils who responded to the surveys, along with data about gender, school year and school track. Of the 366 pupils who responded to the pre-visit PU1 survey, 215 pupils responded to all three surveys: the pre-visit survey PU1, at-visit survey PU2, and the post-visit survey PU3. About half of the pupils who responded to all three surveys were girls and about half were boys (girls: 102, 47%; boys: 109, 51%). However, for the school level and school track sub-groups, the group sizes are relatively unequal.

Table 17: Descriptions of pupil sample number, gender, school year and school track.

	Pre-visit survey PU1	Pre- At- & Post-visit PU1 & PU2 & PU3
Sample Size (*N*)	366	215
Gender		
Girls	167 (46%)	102 (47%)
Boys	193 (53%)	109 (51%)
School year		
2nd (ages 13-15)	310 (85%)	176 (82%)
3rd (ages 14-16)	66 (15%)	39 (18%)
School track		
General Track(ISCED2A)	82 (22%)	46 (21%)
Vocational Track (ISCED2B)	284 (78%)	169 (79%)

Survey responses

As sample sizes show, not all pupils completed all of the surveys. For example, data show that 35 (6%) pupils, who completed the pre-visit survey PU1 and at-visit survey PU2, did not complete the post-visit survey PU3. Also, some pupils (68, 13%) apparently completed only the post-survey PU3. There are two major reasons for this, which were described by teachers through informal conversational interviews during school visits.

- Pupils were sometimes not present to complete all three surveys. Several times when teachers received the post-surveys in person (so that they could have their pupils fill them out later), they mentioned individual absences or even school events that prevented pupils from attending the mobiLLab visit or completing the first survey.
- Pupils sometimes wrote different versions of the identification code on each survey. This identification code was used to match the surveys. During data entry, there were sometimes uncertainties about whether a handwritten letter was, for example, a 'u' or a 'v.' Even though the identification codes for 32 cases were corrected to match because just one letter or digit was different, some other surveys from the same pupils were likely coded too differently to be matched.

About school track

Attendance at the 'Volksschule,' or elementary school, is mandatory for all children in Switzerland. Since the curriculum at a private school is almost identical to the public school, students may also graduate from there. Elementary school begins at the age of seven and lasts at least eight, but usually nine, years. Some schools offer an additional (tenth) year for kids who either have not yet decided what to do after school, have not found an apprenticeship or have not yet reached the age at which they may start training in their chosen profession. The Volksschule is divided into 'Primarschule' and 'Oberstufenschule' for the Canton of St. Gallen as follows:

'Primarschule' lasts six years. Usually one teacher covers all subjects. At the end of the sixth grade, pupils move to the Gymnasium (secondary school level 2), which prepares them for higher education, or to the Oberstufenschule (secondary school level 1), which prepares pupils to begin a vocation.

'Oberstufenschule' lasts three years, during which two specialized teachers share the lessons, and the International Standard Classification of Education (ISCED) code is ISCED2 (Bundesamt für Statistic, 2008). Typically, one teacher teaches languages and humanities, the other math and science. There may be other teachers for some special subjects like gym, needlework, cooking and so on. A pupil in Oberstufenschule is enrolled in one of two different tracks, a Vocational Track and a General Track.

- A Vocational Track is called 'Sekundarschule' in St. Gallen, Switzerland. Some apprenticeships and entrance to the Gymnasium require completion of this level of schooling. This curriculum includes math, geometry, German, French, English, geography, history and more. Students may also add other subjects, such as a third foreign language, (usually Italian) or a computer course. The code for this track is ISCED2B.

- A General Track is called 'Realschule' in St. Gallen, Switzerland. The same subjects are taught, but at a more measured pace and with less depth. The code for this track is ISCED2A.

The mobiLLab study involved teachers and pupils in the General and Vocational Tracks in the Swiss Canton of St. Gallen.

6.2.3 Intervention

At the mobiLLab research-faculty team discussion held on *23. September, 2014,* the group discussed how 30-120 second videos should be developed for up to six mobiLLab experimental posts that would promote pupils' comfort with mobiLLab equipment. The following decisions about the design of, and pupil access to, the video were made.

- The videos will be positioned early in the E-learning sequence.
- Actors are to be one boy and one girl, who are the age of mobiLLab pupils.
- The videos should focus on one or more questions or problems frequently posed by pupils. The videos should also show pupils finding solutions using the mobiLLab equipment (not software – needs to be focused on machines). Examples of orienting and how-to text can be drawn from Kubota (1991): orienting remark : "the lever is at the back"; how-to explanations: " lift the lever to the second bar to prepare the machine."
- The video needs a catchy name, like 'Minute Physics' which will 1) draw pupils' attention to it and make it feel nice to watch and 2) which will enable them to remember it when asked on a survey whether they watched it (to measure the strength of the intervention).
- The video should be sandwiched between a few seconds of video with a logo/ sound/ catchy name before and after the video itself.
- The group identified six experimental posts for video development: X-ray Fluorescence, UV Radiation, IR Camera, IR Spectroscope, Food Analysis, and Highspeed Camera.

Video Development

For six weeks in September and October each year, the mobiLLab experimental posts are set up at a PHSG laboratory so that pre-service student teachers and other coaches can learn first-hand about the equipment before they coach pupils at school visits during the regular school year. In September 2014, the author conducted informal interviews with mobiLLab staff and faculty while working with experimental equipment to identify common problems that pupils encountered at experimental posts. The results was a list of questions and concerns that pupils frequently have (from previous years and also expected questions for new posts), about how to work with the equipment and avoid breaking it, for each of the six posts selected for the intervention. Next, an example video script was created for the X-ray Fluorescence post, which addressed two common problems in working with the equipment. Through a series of drafts and reviews by mobiLLab faculty, and later rehearsal of the video by mobiLLab staff, scripts were developed for the six designated posts.

A boy and girl, who were the age of mobiLLab pupils, were engaged for filming the videos. Even though they volunteered, they received gift certificates to a local bookstore in appreciation for their work. During the filming of the video, several decisions were made about making the videos feel as authentic as possible for the pupils who would watch them.

- The structure of "how-to" videos for the six mobiLLab experimental posts should have a natural feel and yet sometimes go slowly or present things very obviously.
- Pupils-actors should articulate their steps more than they usually would, to illustrate exploring activities like "looking around" and "finding something." These activities were shown in a bold box in each script.
- Actors do not have to read the script verbatim, but rather are encouraged to use their own words, rather than something memorized and unnatural.

– The actors will be asked to speak in their natural dialect of German, so that the video sounds genuine. This introduced a possible risk that trying to understand a dialect will be a confounding factor for the roughly 5% of pupils who speak High German at home and especially for the 14% or so of pupils who speak a language other than German at home.

Video accessibility

The novelty-reducing videos were posted on the mobiLLab website as part of the E-Learning tutorials about half-way through the school visits included in the study. Data, presented in Figure 17, show that after 37 percent of the pupils who participated in the study had a visit with mobiLLab, the mobiLLab manager posted the novelty-reducing videos on the e-Learning. Data from informal conversational interviews with teachers show that an additional 13 percent of pupils did not view E-learning when the videos were available. This means that, based on the number of pupils who planned to participate in the study, our best estimate was that 51 percent of the pupils viewed the E-Learning when the novelty-reducing video was posted as part of it.

NOTE: Because it was not feasible to randomly assign pupils to treatment and control groups, the research can be described as employing a quasi-experimental design. To improve the robustness of the investigation design, difference between pupil outcomes based on class level (second and third grade) and school track (Vocational versus General Track) were measured to determine whether pupil learning varied with these factors, as described on page 128.

mobiLLab visit		Number of pupils planned to attend visit		
		Videos not posted	Videos Posted	
			Teacher report	
			Pupils didn't watch E-learning	Pupils watched E-Learning
19.01.2015	Morning	17		
19.01.2015	Afternoon	25		
20.01.2015	Morning	23		
11.02.2015	Morning	14		
11.02.2015	Afternoon	15		
17.02.2015	Morning	15		
17.02.2015	Afternoon	16		
18.02.2015	Morning	15		
06.03.2015	Morning			15
06.03.2015	Afternoon		12	
17.03.2015	Morning			20
17.03.2015	Afternoon			17
18.03.2015	Morning		19	
18.03.2015	Afternoon			19
19.03.2015	Morning		18	
19.03.2015	Afternoon			17
20.03.2015	Morning			19

mobiLLab visit		Number of pupils planned to attend visit		
		Videos not posted	Videos Posted	
			Teacher report	
			Pupils didn't watch E-learning	Pupils watched E-Learning
12.05.2015	Morning			22
12.05.2015	Afternoon			22
02.06.2015	Morning			22
02.06.2015	Afternoon			21
TOTALS IF ALL PUPILS PRESENT		**140**	**49**	**194**
		37%	13%	51%

Figure 18: Schedule of mobiLLab visits, showing when the novelty-reducing video was posted.

Figure 18 shows how the E-Learning looks on a typical computer screen for the Highspeed Camera Post. Here the video appears as the eighth menu item, called "Gewusst wie."

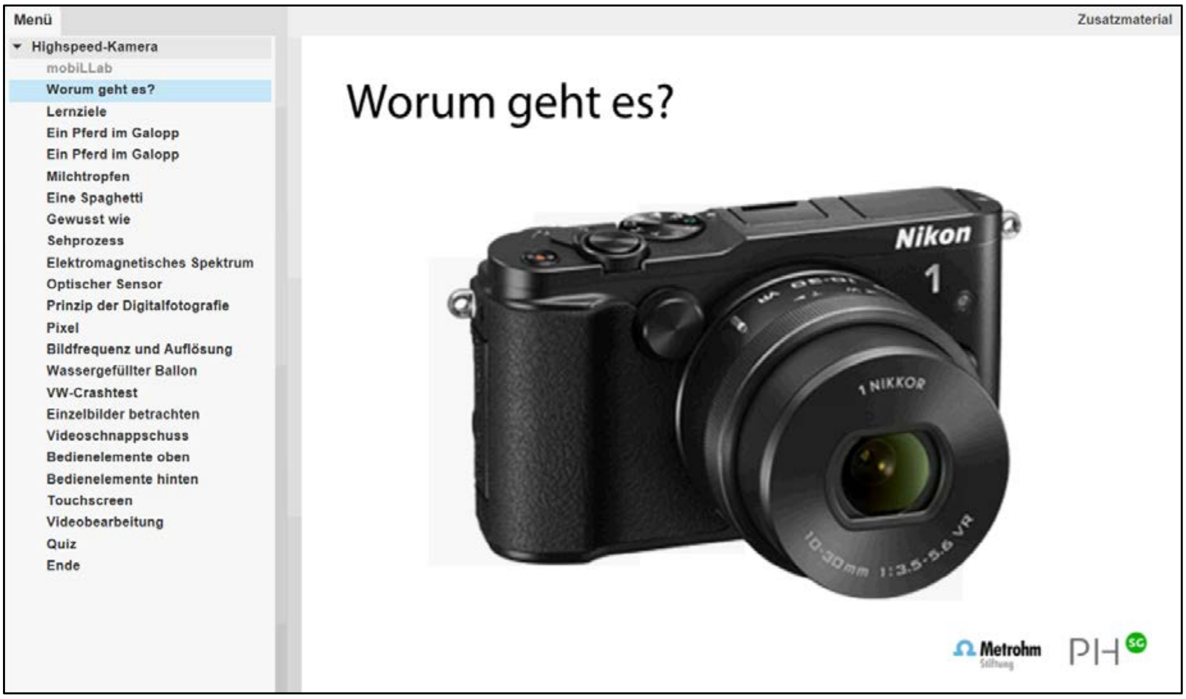


Figure 19: MobiLLab E-Learning tutorial as seen by the pupils. The "Gewusst Wie" novelty reducing videos were added after about half of the pupils visited mobiLLab.

RESULTS SHOW EVIDENCE OF VALDITY: Pupils' reports match expectations
As data in Table 17 shows, pupils did not report seeing any of the six videos before they were posted on the mobiLLab website as part of the E-Learning tutorial, which suggests they were indeed reporting about the videos and not just about having watched the E-Learning tutorials. For the period of the study when the videos were posted, the distribution of the number of videos pupils reported watching does not show a random pattern. This reflects how pupils were not assigned to certain posts as part of the research design. Instead, pupils were generally assigned to work at certain experimental posts by their teachers; however, in some cases, pupils selected some of their own post assignments. These results also show that pupils indeed reported watching different numbers of videos. This is also expected because, even though a pupil works at four posts during a visit, it was possible that they would work with no posts, or just one or two posts, for which a video had been prepared.

Table 18: As expected, pupils reported watching different numbers of videos.

	# videos pupils reported watching						TOTAL
	0	1	2	3	4	6	
0 'videos not yet available'	70	0	0	0	0	0	70
1 'videos posted on E-learning'	46	18	29	24	8	20	145
TOTAL	116	18	29	24	8	20	215

RESULTS ARE VALIDITY CONCERN: Some pupils may have confused the videos with the E-Learning
Twenty pupils reported watching all six videos, which is highly unlikely, because they are assigned to prepare for only four experimental posts. A likely reason for pupils to report watching six videos is that they do not remember exactly which videos they watched, so they blindly filled out all six boxes and gave all of them ratings. Another possible reason is that the pupils confused the novelty-reducing videos and the E-Learning.

NOTE: These 20 pupils came from 6 different class groups, so this phenomenon of pupils reporting watching six videos, rather than the maximum of four that they are required to, is independent of class group.

6.2.4 Sampling plan

Data was collected for the mobiLLab main study from participating pupils through three surveys: a pre-visit survey, an at-visit survey, and a post-visit survey. As shown in Figure 19, data collection ran from December 2014 to June 2015. In December 2014, all pupils completed a pre-visit survey, which asked pupils to respond to items about NIFs, control variables such as gender and home language, and their S&T outcomes, such as their attitude towards science and their attitude towards technology. Then, before their mobiLLab visit, pupils experienced a classroom preparation led by their teacher, who is assumed to have used preparation materials posted on the mobiLLab website. Control group pupils watched a version of the E-Learning tutorial that did not include the novelty-reducing videos and treatment group pupils watched the E-Learning tutorials with the videos. At the mobiLLab visit, after working at two experimental posts, pupils completed a short survey of items about their how they perceived novelty at the visit. Finally, about one week after the mobiLLab visit, teachers organized pupil completion of a post-visit survey that included items about pupils' educational outcomes and program satisfaction. Survey instruments are shown on page 208.

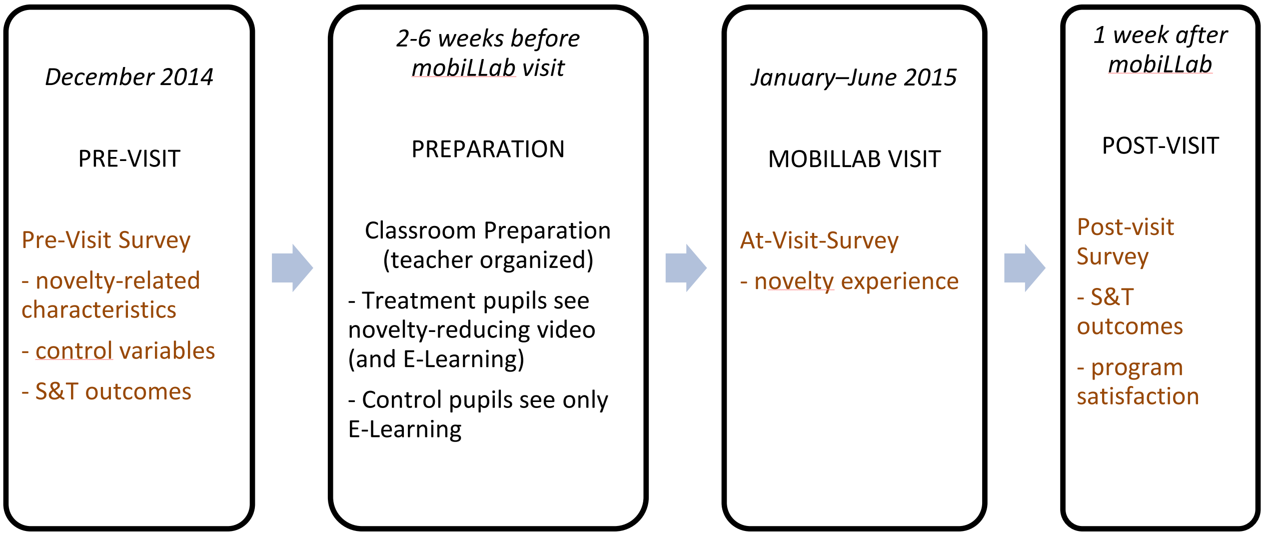


Figure 20: Sampling plan for the mobiLLab main study.

6.3 Instrument development and testing

The instruments used to collect data from mobiLLab teachers (pilot only) and pupils are listed in Table 18, which describes the format and purpose of each. The conceptualization of specific constructs and variables that would enable exploration of mobiLLab study research questions is described in the synthesis of theory and previous research, starting on page 74, and is illustrated in Figure 15. To define survey items that would produce measures these variables, the author turned to previous studies, listed in the Variable Operationalization Matrix on page 98. The development and testing of each instrument is described below in this section. Data was collected and managed in an effort to minimize the effort of teachers and to maximize database quality.

Table 19: MobiLLab study instruments: formats, audience, purpose.

Instrument	Format	Who completed?	Purpose(s)
Teacher pre-visit survey	Online	Teachers (pilot only)	Profile of teachers' educational (*Ausbildung*) and professional training (*Weiterbildung*) background for use in selecting balanced treatment and control groups. Explore how teachers use classroom preparation resources posted on the mobiLLab website. Gage the degree to which teachers value situated and constructivist learning
Teacher post-visit survey	Online	Teachers (pilot only)	Characterize classroom preparation practices. Gage the degree to which teachers value situated and constructivist learning
Teacher interview.	In-person	Teachers (pilot only)	Identify which preparation resources from the mobiLLab website teachers used. Characterize these resources based on teacher feedback from teachers about the clearness, age-appropriateness, usefulness and interestingness Ask how teachers see the influence of preparation on pupil behavior during the mobiLLab visit.
Observation protocol	1-page form	mobiLLab staff and	Characterize pupil engagement, behavior, and mood.

		faculty (pilot only)	Describe teachers´ roles during visit.
Pupil pre-visit survey	Paper-and-pencil	Pupils (pilot and main study)	Measure pupils´ novelty-related factors, such as grade, control variables such as gender. Measure pupils´ S&T interest.
Pupil post-visit survey	Paper-and-pencil	Pupils (pilot and main study)	Measure pupils´ post-visit S&T interest. Gage pupils´ program satisfaction.
Pupil at-visit survey	Paper-and-pencil	Pupils (main study only)	Characterize pupils´ at-visit novelty experience.

6.3.1 Lessons learned from the pilot study about pupil surveys

Carrying out the mobiLLab pilot study produced some lessons learned that improved pupils suruvey for the main study. Some positive feedback from teachers showed that the research instruments were well received. That is, during interviews teachers were asked for feedback about the survey length, experience of filling it out and sending the pupil (paper) surveys back to the PHSG. Teachers had no major complaints about managing completion of the teacher and pupil surveys. Several teachers reported that pupils took about 20 minutes to fill out the survey; one teacher reported that pupils took 30 to 40 minutes to fill out their surveys. Teachers also said that paper and pencil surveys are preferable for pupils, explaining that online surveys introduce problems of computer room availability and logging into the survey.

Another lesson learned from the pilot study, was that the ordinal survey scales and data management supported reliable responses for variable scales, as evidenced by the Chronbach's alpha statistics in the section, Appendix: Variable frequencies and scale reliability. That is, all survey scales were implemented as 4-step ordinal scale, from 'not at all true' = 1' to 'completely true = 4.' Also, data management conducted based on guidelines adapted from the World Health Organization STEPS protocol for data collection and entry (WHO, 2008) were found to be effective. For example, dates for sending and receipt of surveys were logged on a protocol spreadsheet, creating an effective system for tracking surveys and preventing data loss.

Pilot results also showed that the dependent variable scales adapted from Pawek for science and technology interest and self-concept, from PISA for attitude to technology were reliable (all $\alpha > .69$). These scales were selected because they offered several advantages: 1) they were developed based on interest theories from Krapp (1999), 2) the scales have already been tested with a German-speaking subject group, and 3) the scales have been shown to be reliable for two similar German-speaking pupil groups. The mobiLLab study pilot results show that all three scales were reliable for the mobiLLab pupil population, offering yet another case of reliability for the scales.

Pilot study results also revealed some improvements that should be made to pupil surveys. For example, some teachers suggested that text in the survey introduction explain that some questions are similar to each other and this is because the mobiLLab team wants to understand their attitude towards natural science versus technology. Teachers also suggested that some pupil survey items include examples of, for example, of natural science phenomenon in comparison with technology phenomenon. There was also an interest in getting an indicator of pupils' program satisfaction. For example, how much fun did they have and what did they learn.

6.3.2 Operationalizing quantitative variables

For the quantitative variables included in the main mobiLLab study design, measurement tools could be adapted from previous studies, as described in Chapter 5, and from mobiLLab program resources. Each variable, the number of items included in its scale, the definition and the source for the items is shown in Table 19. The variables that serve as Novelty Influence Factors (NIFs) and Novelty Experience Factors (NEFs) are labeled.

Table 20: Variable Operationalization Matrix

Variables	Keyword	# items	Variable Type	Definitions and Scales (Source) Pu=pupil; ML= mobiLLab; O=Ordinal; D=Dichotomous; I=Interval.	Surveys PRE	AT	POST
Independent Variables					Est. time (sec)*		
1) Tink NIF	Perceived technological capability	6	O	Whether Pu tinkers, or seeks direction, to interact with technology (Luckay & Collier-Reed,	120	0	0
2) V_NS NIF	Frequency science OSLeP visits	11	O	How often Pu visits natural science-related OSLePs (Falk et al., 2012a)	100	0	0
3) V_Tech NIF	Frequency technology OSLeP visits	11	O	How often Pu visits technology-related OSLePs (Falk et al., 2012a)	100	0	0
4) CurT	Curiosity trait	6	O	Pu dispositional curiosity (trait) (Litman & Spielberger, 2003; Naylor, 2007)	0	0	120
5) GrS NIF	Science grade	1	I	Pu grade in science (Natur und Technik) course.	20	0	0
6) GrM NIF	Match grade	1	I	Pu grade in math course.	20	0	0
7) ExpB NEF	Exploratory behavior	5	O	How much Pu explores equipment at ML visit (Luckay & Collier-Reed, 2011a)	0	10	0
8) OF NEF	Oriented feeling	3	O	How oriented Pu feels at ML visit (Orion et al., 1997b)	0	60	0
9) CurS NEF	Curiosity state	5	O	How curious Pu feels at ML visit (Litman & Spielberger, 2003; Naylor, 2007)	0	80	0
10) CL NEF	Cognitive load	4	O	How much workload Pu experiences at ML visit (Hart & Staveland, 1988)	0	80	0
11) VidNo	Intervention strength	6	N	Number of novelty-reducing videos Pu watched before ML visit	0	0	20
12) Know NEF	Knowledge	4/2/5	N	Pu pre-visit score on test about electromagnetic concepts (Schütz 2009; Barder 2007)	40	0	40
13) RA	Reality/ authenticity	6	O	How closely Pu thought their ML experience related to everyday life (Jochen Kuhn et al., 2008)	0	0	120
Dependent Variables							
14) Tint	Interest in technology	7	O	Pu dispositional interest in technology, from Pawek (2009)	120	0	120
15) Sint	Interest in natural science	7	O	Pu dispositional interest in natural science, from Pawek (2009)	120	0	120
16) Tatt	Attitude to technology	5	O	Pu attitude towards technology, from PISA (2006)	100	0	100
17) Satt	Attitude to natural science	5	O	Pu attitude towards natural science, from PISA (2006)	100	0	100
18) Tsc	Self-concept to technology	8	O	Pu self-concept to high-technology, from Pawek (2009)	160	0	160
19) Ssc	Self-concept to. natural science	8	O	Pu self-concept to natural science, from Pawek (2009)	160	0	160
20) CA	Career aspiration	1	O	Pu career aspiration with respect to S&T (Güdel, 2014, p. 306)	20	0	20
21) PSat	Program satisfaction	3	O	Pu satisfaction with ML visit, from Rennie (1994, p. 266)	0	0	60
Control Variables					0	0	0
22) Gen	Gender	1	N	Pu Gender	10	0	0
23) SY	School year	1	N	Pu school year	20	0	0
24) ST	School track	1	N	Pu school track (General versus Vocational)	20	0	0
25) HT_IC	Internet technology at home	4	O	Information & communication technologies at pupil's home, from OECD (2006)	60	0	0
26) HT_Mech	Mechanical technology at home	2	O	Mechanical technologies at pupil's home, from OECD (2006)	60	0	0
27) HL	Home language	1	N	Language spoken most often by pupil at home, from OECD (2006)	20	0	0
28) EXP_G	Experiment in small groups	1	O	How often pupil experiments in small groups in their classroom, from Engel (2004)	20	0	0
29) EXP_T	Observe teacher experiments	1	O	How often pupil observes experiments conducted by their teacher, from Engel (2004)	20	0	0

NIF = Novelty Influence Factor; NEF= Novelty Experience Factor.

6.3.3 Instruments to collect data from teachers (pilot study only)

6.3.3.1 Teacher online surveys (pilot study): pre- and post-visit

The pre- and post-visit pilot surveys for teachers were scripted in German by the author, reviewed with a language editor, then reviewed by the research team (Prof. Dr. Müller and Dr. Robin) and finally by the manager of the mobiLLab program. The author programmed the survey using *Artologik Survey & Report* software and then sent a draft of the online survey to a group of 10 testers including pre-service teachers, teachers, researchers and faculty at the University of Teacher Education in St. Gallen. The mobiLLab manager gave final approval of all survey text.

6.3.3.2 Teacher interviews (pilot study)

The teacher interview guide was developed with several main goals in mind: 1) identify which preparation activities teachers used; 2) collect feedback from teachers about the clearness, age-appropriateness, usefulness and interestingness of preparation resources posted on the mobiLLab website; 3) explore teachers' opinions about factors that support pupil at-visit engagement and positive post-visit outcomes.

The interview guide was developed to support a *standard open-ended interview* with several elements of a *general interview*, as described by Patton (2002). A detailed description of strategies used to develop the interview guide, and examples of elements of the interview guide, are described in Table 54 and on page 207. The guide was drafted in German with the support of a native speaker. A structured format for the interview guide supported quality of the instrument in the following respects.

- The research team and mobiLLab team project manager could review a draft of the specific questions that would be asked (and provide improvement suggestions) before interviews took place.
- Enabled collection of some identical (semi-quantitative) data about particular preparation resources.
- Was focused so that the interviewer had a good chance of collecting a lot of information in the half an hour allotted for the interview.
- Produced many responses that were easy to find and compare during analysis. The author/interviewer conducted a practice interview with a fellow researcher, which allowed her to identify further areas for improvement.

Teacher interviews took place at schools where teachers worked and lasted 30 to 40 minutes. Interviews were conducted in a semi-structured manner, which involved following a scripted list of questions and sometimes diverging from the script when opportunities arose to talk with teachers about study-relevant details. It was clear beforehand that there would not be enough time for teachers to comment on each of the preparation resources available on the mobiLLab website. In anticipation of the limited time, interviewer Rebecca Cors planned asked all teachers about some main resources - the introduction, called the 'Einführung ins mobiLLab;' the E-Learning, the 'Journalblätter' worksheets, and the post step-by-step instructions, called the 'Kurzanleitung.' Detailed conversations about other resources were generally initiated by the teacher.

6.3.4 Pre- and post-visit pupil surveys

6.3.4.1 Pupil paper-and-pencil pre- and post-visit surveys (pilot study and main study)

The pre- and post-visit pilot survey for pupils were scripted in German by the author, reviewed with a German language editor, and then reviewed by the research team (Prof. Dr. Müller and Dr. Robin) and the manager of the mobiLLab program. A group of eight testers, including four teens, completed a draft of the pilot survey and provided feedback for improvement. The mobiLLab manager gave final approval of all survey text. Based on feedback from teachers during pilot study interviews about how surveys could be made more understandable to pupils, several revisions to survey text were made.

6.3.4.2 At-visit survey (main study)

To measure indicators of how pupils perceived at-visit novelty, a short survey was developed for pupils to complete during their mobiLLab visit. MobiLLab team members recommended that completion of the survey would be least disruptive to their mobiLLab experience if pupils completed it half-way through their mobiLLab visit; that is, during the break that typically takes place after they worked through first two experimental posts and before their two remaining posts. A test of the survey took place during a mobiLLab school visit in December 2014. Based on variation of pupil responses on ordinal survey items and on written feedback, several survey items were revised.

Approach

A test of the survey took place during a mobiLLab school visit in December 2014 with 40 pupils from two class groups. The goals of the test were to ensure that pupils could understand the survey, that pupils had relatively similar understandings of survey items, and that filling it out would take no more than 10 minutes and not disrupt pupils´ mobiLLab experience. After the first two experiments and before their break, the teacher and author asked for the pupils' attention (we moved to a separate classroom). During the first two minutes, the author described to pupils how to fill out the survey and the feedback box at the end of the survey. In both the morning and afternoon groups, most pupils needed 4-6 minutes to fill out the survey. The author watched the pupils as they filled out the survey and noticed that some of them did not realize that there were items on the back of the A4 paper, so she mentioned this to the entire class. After eight or nine minutes, it looked like all of the pupils were finished filling out the survey. The author then asked them to take a minute to write feedback about how it was to fill out the survey in the 'feedback box,' where they should list and describe any difficult items or other remarks. After the survey, the pupils returned to the mobiLLab to work through their last two experimental posts.

Results

Results of an analysis of survey data are shown in Table 20. Because three pupils wrote concerns about comprehension for items 2 and 15, an analysis for these two items is also shown.

Table 21: Means and standard deviations of items from tester responses for the at-visit survey suggest pupils had similar understanding of all but one item (N=40).

scale or item	exploratory behavior with equipment	exploratory behavior with experiments	oriented	curiosity	cognitive load	Nr2	Nr15
number of items	5	3	3	3	4	1	1
M	3.1	3.0	3.2	2.9	3.1	3.1	3.2
SD	0.4	0.5	0.4	0.6	0.7	0.6	1.2

As Table 20 and Figure 20 show, the means for each item are not extreme, nor surprising (note that all scales except cognitive load run from 1 to 4, while cognitive load ranges from 1 to 6). Standard deviations for all scales are less than one rating point, suggesting that pupils' interpretation of the items varied little. However, Nr15 has a standard deviation that is double many of the others, suggesting that pupils had different understandings of the item.

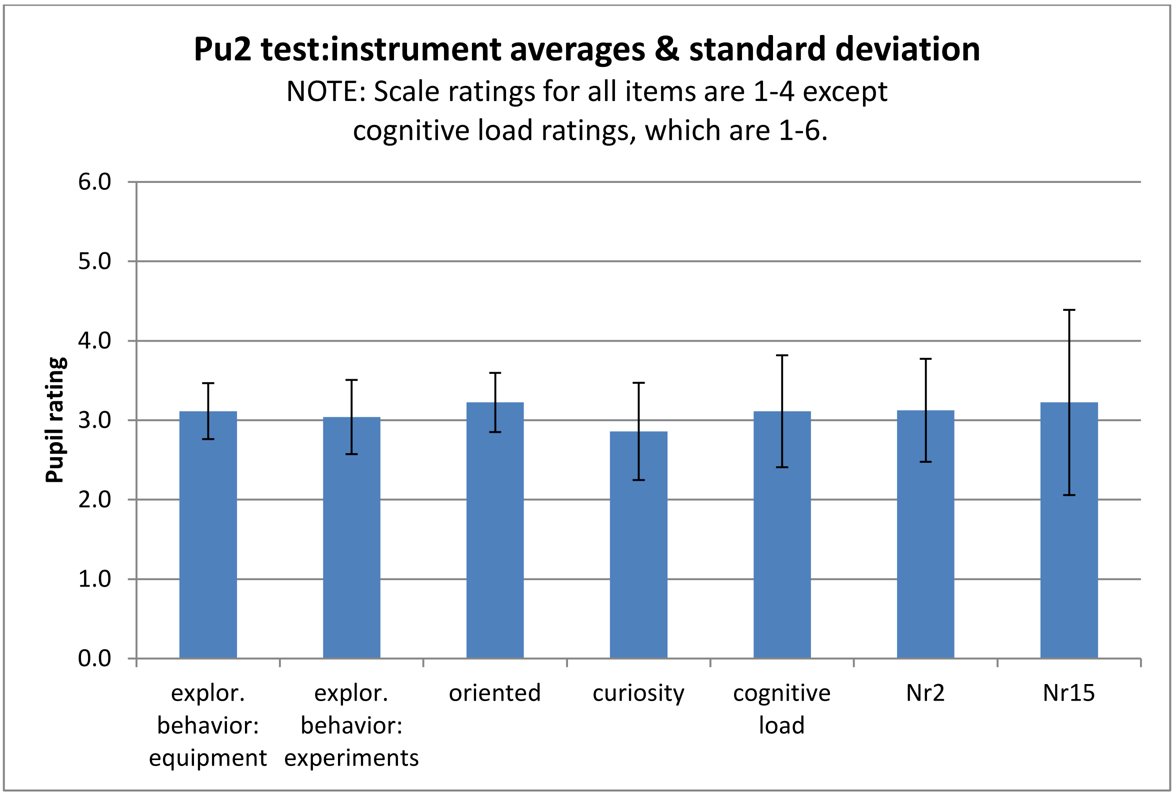


Figure 21: Means and standard deviations of tester responses to the prototype at-visit survey.

Written feedback from pupils about the at-visit survey is summarized in Table 21 below. Three pupils each expressed concerns about understanding items Nr2 and Nr15. The pupil who tested the at-visit survey were enrolled in the Vocational Track, and were in the second grade level, so it was thought that they should have should have above average reading comprehension skills compared to the average mobiLLab pupil. Therefore, these items will likely be even more challenging to pupils enrolled in the General track or in the first grade level of the Vocational Track school track.

Table 22: Typology and examples of written responses from testers about the at-visit survey prototype.

Type of comment	Occurrences	Representative example
Survey was understandable	5	It was not difficult or strenuous to fill out the survey. *Es war nicht schwer oder anstrengend um den Fragebogen auszufüllen*.
Redundancies	3	On the front, the questions were all about the same thing. *Auf der Vorderseite, handelten sich die Fragen fast immer um das gleiche.*
Q2 comprehension	3	Question 2 was a bit unclear for me. *Die Frage 2 war ein bisschen unklar formuliert, dass man es nicht so ganz versteht.*
Q14 comprehension	1	I don't exactly understand Questions 2 and 14. *Frage 2 verstehe ich nicht richtig, und Frage 14 ebenfalls.*
Q15 comprehension	3	I don't understand Question 15. *15 chegge ich nicht.*
I like the mobiLLab visit (unsolicited)	7	The team explained everything very well and the experiments were really interesting. Thank you! *Das Team hat alles gut erklärt und die Experimente waren sehr spannend :)! Vielen Dank!*

Based on analysis of observations and survey data, a few changes were made to the instrument. First, on the bottom of the front page, writing indicated that there were more questions on the back side. Also, two items were reformulated based on written feedback from pupils.

6.3.5 Observation protocol (pilot only)

An observation instrument was developed to allow for characterization of pupil engagement, behavior, and mood and to describe teachers´ roles during visit. Because mobiLLab faculty and staff did not want to be too distracted from their work of managing and coaching the visit, they requested that a one-page protocol be developed. The instrument was drafted and tested by different members during three mobiLLab visits during the fall of 2013 and revised based on input.

6.4 Data collection and management

Collection and management of both pilot and main study survey data was conducted in a manner intended to make the process transparent for teachers and to minimized their efforts. To promote data quality, data management was based on standard protocols from the World Health Organization STEPS protocol for data collection and entry (WHO, 2008).

6.4.1 Permissions and survey data collection (main study)

Teachers supported survey data collection by organizing pupil completion of pre- and post-visit surveys and by organizing pupils to gather during the mobiLLab visit to fill out the at-visit surveys. Therefore, survey data collection was conducted in a manner intended to make the process transparent for teachers and minimized their effort.

Communication with participating teachers, school leaders, parents
Through letters and emails, teachers, school leaders and parents were informed in advanced about the study surveys and interviews. These materials explained that the aim of the study is to better understand and improve how pupils' interest and motivation is piqued by mobiLLab, welcomed questions and comments about the study and ensured that all data collected would be handled anonymously.

Paper-and-pencil pupil surveys (main study description)
A pre-visit pupil paper survey was sent to teachers in early December 2014, asking them to have their pupils complete them before their mobiLLab preparation activities and then to return it by mail using an addressed, stamped envelope. The author delivered the post-visit pupil survey to teachers at their school visit, asking for a return of one to two weeks. To promote anonymity, teachers were asked to refrain from answering content questions from pupils and pupils returned their surveys to teachers in a sealed envelope. In pilot study interviews, most teachers estimated that the surveys took about 20 minutes for the pupils to fill out. Several teachers commented that a paper-and-pencil format is preferable to an online format for the pupil survey, but that an online is most convenient for teacher surveys.

6.4.2 Survey data management

Handling of pupil survey data followed guidelines adapted from a World Health Organization (WHO) (2008) data handling protocol.

- Logged dates for sending and receipt of surveys in a MS Excel protocol spreadsheet. This spreadsheet was created in cooperation with the PHSG IFN secretary, who organized pupil surveys mailings.
- Created a data entry spreadsheet in MS Excel for each pupil survey. These MS Excel files are backed up daily by the PHSG computer server.
- Supported data entry accuracy by creating laminated item coding cards and a decision table for g data and other anomalies in cooperation with data entry operator (a PHSG student). At least once per week during data entry, the investigator and the data entry operator worked through any new questions, anomalies and workflow issues.
- Established a data entry tracking system by numbering surveys as their data was entered and including this number and the data entry operator name and entry date in the database.
- Established an instrument filing system that involved storing pupil surveys from the same schools in cardboard mailing boxes that were labeled with the school name.
- Conducted random checks of one or two surveys per 50 to check data entry accuracy for quality assurance.

6.4.3 Journal of school visits for main study

During the main study, the author kept a journal about how each participating class group was described by the teacher. The main purpose of the journal was to document whether or not the teacher said that their pupils looked at the E-Learning. Knowing whether pupils looked at the E-Learning was a way of gathering data to confirm (or contrast with) survey data from pupils about whether they saw the novelty-reducing videos, which were integrated in E-Learning, as described on page 93. This triangulation allowed for calculation of an estimate of how many pupils were exposed to this intervention, shown in Figure 17 on page 93. During these informal conversations with teachers, they sometimes offered additional descriptions of the class groups, but no patterns emerged.

7 Data Analysis Methods

This chapter describes the data analysis strategies employed for each phase of the mobiLLab investigation. First, is a discussion of strategies used to analyze main study survey data, which involved an exploratory factor analysis, multivariate regression, and multivariate analysis of variance (MANOVA) tests. These tests were conducted with statistical analysis software SPSS. Second, is a description of how, for interview data from pilot teacher interviews, a basic qualitative analysis approach was employed to identify recurrent and striking themes. Finally, comes a description of how observation data from pilot study mobiLLab visits were analyzed using several basic statistical tests.

7.1 Analysis of survey data (main study)

The section explains how multivariate tests were used to test main study hypotheses. Analysis of pupils' responses to the main study surveys followed the process illustrated in Figure 21. As a first step, descriptive tests were used to assess pupils' school and home factors and their novelty impact factors (NIFs), such as how technological capability they report that they are. In a second step, a factor analysis was used to verify proposed dimensions of pupils' perceived novelty at the mobiLLab visit, which served as novelty experience factors (NEFs) in tests of hypotheses.

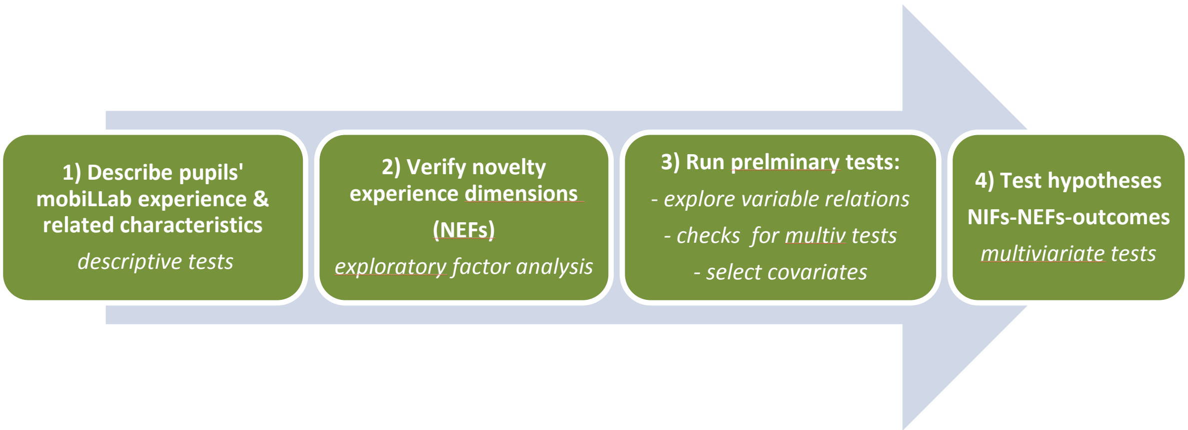


Figure 22: Overview of the process to analyze survey data.

In a third step, before testing mobiLLab study hypotheses, some additional preliminary analysis work was required. Correlations, tests of sample normality and some other tests were important to ensure that preconditions for multivariate tests were met. Also, a small battery of tests was used to screen potential covariates for use in tests of research questions. Finally, multivariate tests were employed to test main study hypotheses. Statistical tests used to test survey data collected during the main study are listed in Table 22, which describes the purpose of each test and lists the page number where the results can be found.

Table 23: Summary of statistical tests used to analyze main study survey data.

Statistical Tests	Purpose (reference to results)	Reference
Reliability test	Assess the internal consistency of scalar variables (groups of survey items). Shown in section 11.8.	(Field, 2013)
Correlation analysis	Explore whether & how strongly pairs of study variables are related. Multivariate test precondition: Dependent variables should be moderately correlated.	(Tabachnick & Fidell, 2013)
Paired t-test	Compare before- and after- visit pupil core S&T outcomes (interest, attitude, self-concept, knowledge). Page 116.	(Field, 2013)
Item analysis for multiple-choice knowledge questions and tests	Assess knowledge item difficulty, item discriminatory power (between pupils), item reliability, and discriminatory power of a test. Page 110.	(Ding & Beichner, 2009)
Analysis of variance (ANOVA)	Assess whether core S&T outcomes vary significantly depending upon sample groups defined by control variables. Page 213. Test the independence of the CV (curiosity trait) from the IVs. Page 218.	(Field, 2013)
Linear regression	Assess relation between the number of novelty-reducing videos pupils watched and the S&T outcomes. Page 120.	
Factor Analysis	Verify the dimensions of pupils' novelty experience. Page 124.	(Field, 2013)
Kolmogorov-Smirnov test	Multivariate test precondition: Assess normality of sample distribution for some of the main DVs. Page 208.	(Tabachnick & Fidell, 2013)
Additional checks for multivariate test problem-makers	Additional multivariate test preconditions (described on page 131). – Similar sample sizes work best for multivariate tests. – Relatively few missings works best for multivariate tests. – CVs should be measured before treatment. – Non-linear relationships between DV and CV reduce power of test.	(Tabachnick, 2013)
Multivariate Regression	Assess whether the number of novelty-reducing videos that pupils watched (dosage of intervention) explained variations in novelty experience factors. Page 157. Assess the significance of the following relations: – NIFs and NEFs. Page 145. – NIFs and pupils' core S&T outcomes. Page 159. – NEFs and pupils' core S&T outcomes. Page 167. NOTE: When repeated-measures regression tests were significant, MANCOVA tests were used to further describe univariate results, as described below.	(Field, 2013)
Multivariate analysis of (co)variance MAN(C)OVA	For significant repeated-measures multivariate regression results, MAN(C)OVAs were used to create graphs that show the nature of the univariate relations between predictor IVs and DVs. The IV was first transformed into a categorical variable using a median split. Pages 159 and 167.	(Field, 2013)
Effect size, Cohen's d	Assess the magnitude of significant effects identified through t-tests. Page 116.	(Cohen, 1988)
Effect size, partial eta squared, η_p^2	Assess the magnitude of significant effects identified through (M)AN(C)OVA tests. Pages 159 and 167.	(Cohen, 1988)

DV=dependent variable. IV=independent variable. CV=covariate. NIF=novelty influence factor. NEF=novelty experience factor.

7.1.1 Describing pupil school, home, and, novelty-related factors

Home language

As shown in Figure 22, 85 percent of pupils who participated in the mobiLLab main study spoke primarily German or a dialect of German at home, which is the language of the mobiLLab program materials and of the investigation surveys. One percent spoke primarily another national language of Switzerland at home, that is, they spoke either French, Italian, or Retroromanisch. The remaining 14 percent spoke a non-national language.

This wording of the survey items about home language was based on the PISA 2006 survey (OECD, 2006). The categories used for grouping languages three categories, German or other Swiss (CH) language or not a CH language, comes directly from the PISA Codebook (OECD, 2007).

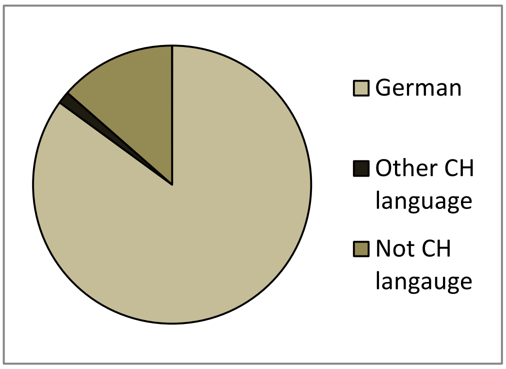


Figure 23: Home language of participating pupils (N=214).

Technology at home
As shown in Figure 23, the majority of pupils have more technology at home than expected, particularly mobile phones, computers, and bikes, for which many selected the response "three or more." Most pupils reported having three or more mobile phones (192, 89%) or and three or more bicycles (192, 89%) at home. Almost half of pupils indicated they have three or more computers at home (104, 48%). Reports about other technology indicate that most pupils have access to between 1 and 2 of the following devices: televisions (*M*=1.7, *SD*=.8), tablets (*M*=1.2, *SD*=1.0), cars (*M*=1.7, *SD*=.7).

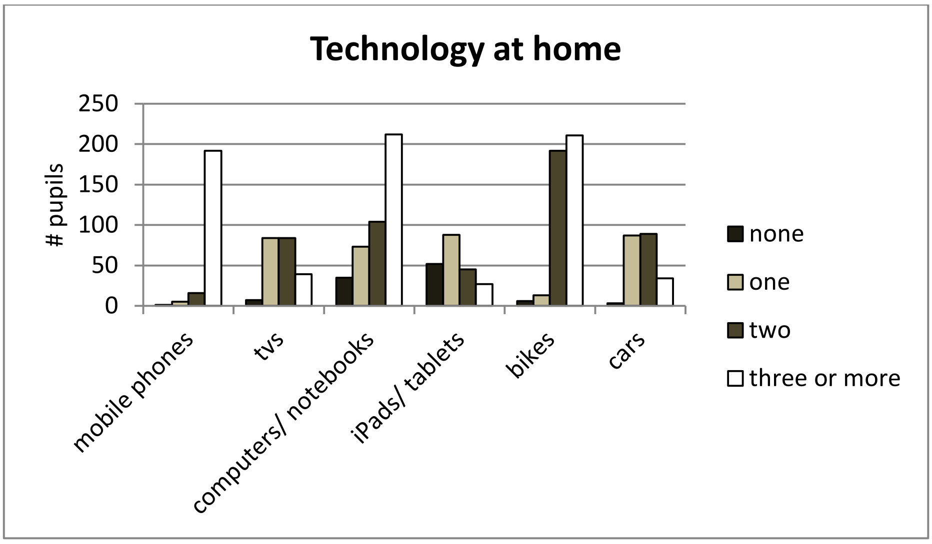


Figure 24: Participating pupils have more technology at home than expected.

Collapsed variables about technology related to the internet, which are mobile phones, televisions, computers/ notebooks, iPads/ tablets, HT_IC (*M*=2.0, *SD*=.5), and technology related to machines, which are bikes and cars, HT_Mech (*M*=2.3, *SD*=.4) were calculated, so they could be considered as possible covariates in tests to answer research questions.

Because many pupils had more technology at home than the measurement scales accounted for, the data were likely exhibiting a ceiling effect. That is, since so many pupils reported that they had '3 or more' of some technologies, these data probably not reveal significant differences in core outcomes between pupils from technology-rich and technology-poor households. Evidence for this is in several relatively high skew and kurtosis statistics, seen in Table 72, for smartphones (-3.7, 14.7) and bicycles (-3.6, 12.4), which indicate an asymmetry (weighted high in this case) and a high peak in these data, respectively.

Experimenting in the classroom

Pupils were asked how often they conduct experiments in their science class (German: *Natur und Technik)* with a small peer group and how often they watch their teacher conduct experiments in their science class. They could respond with 1='very seldom,' 2='seldom,' 3='often,' 4='very often.' As shown in Figure 24, the average pupil reported that they sometimes, more than seldom but less than often, conducted experiments in small groups (*M*=2.6, *SD*=.8) and that a bit more often they watch their teacher conduct experiments in the classroom (*M*=2.8, *SD*=.7). This is comparable to results from a study that indicated that *Oberstufenschulen* (secondary level) physics teachers in the Swiss canton of Bern spend about half of their classroom time conducting experiments (Börlin, 2011).

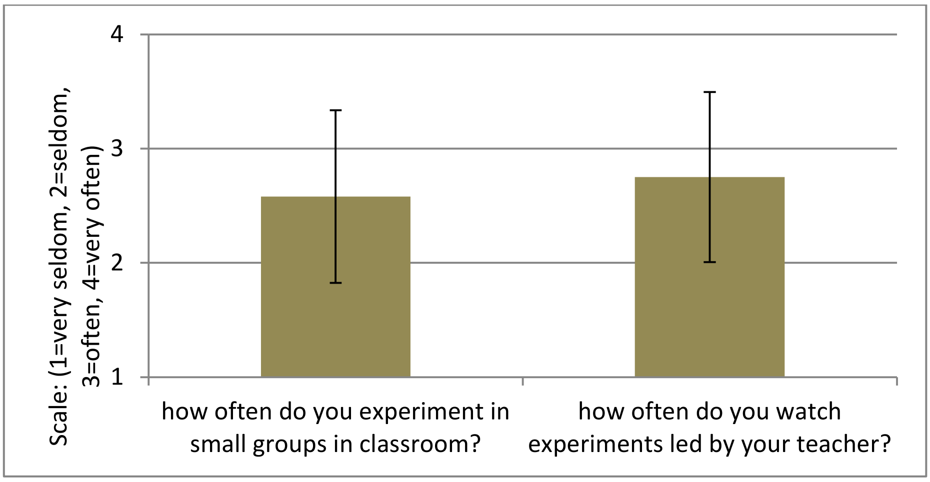


Figure 25: Pupils reported experimenting with moderate frequency in small groups and by watching teacher demonstrations.

Technological capability, course grades, curiosity

Before the mobiLLab visit, pupils responded to survey items about novelty influence factors (NIFs). Data in Table 23 show that pupils describe themselves as somewhat technologically capable (*M*=2.9, *SD*=.6) and report average performance in science (*M*=4.7 (of 6); SD=.5) and math (*M*=4.6 (of 6); SD=.6) class. When responding to an item on the post-visit survey, pupils describe themselves as being somewhat curious people (*M*=2.8, *SD*=.5).

Table 24: Pupils describe themselves as relatively capable with technology, as having moderate science and math grades, and as being somewhat curious people.

Dispositional traits and school performance measures as NIFs	**Variable Label**	***N***	***M***	***SD***	**Skew**	**Kurtosis**
Capability NIF: technological capability	Tink	207	2.9	.6	-.167	-.266
Knowledge NIF: science grade	GrS	213	4.7	.5	-.234	-.298
Knowledge NIF: math grade	GrM	215	4.6	.6	-.299	-.148
Covariate: curious trait	CurT	203	2.8	.5	-.148	.144

Previous experiences with out-of-school learning places (OSLePs)

Pupils were asked about how often they visit OSLePs that relate to natural science, such as zoos and botanical gardens, and how often they visit OSLePs that relate to technology, such as science centers. Frequencies of their reported visits are shown in Figure 25 and Figure 26. Similar to common experience, most pupils visited OSLePs that generally involve exhibits and an entry fee such as museums, zoos, aquariums, and science centers, once or several times per year. In contrast, pupils visited OSLePs with freer access, such as botanical gardens, vegetable gardens, flower gardens, and forests more frequently. A full list of the frequencies that pupils reported is shown on page 221.

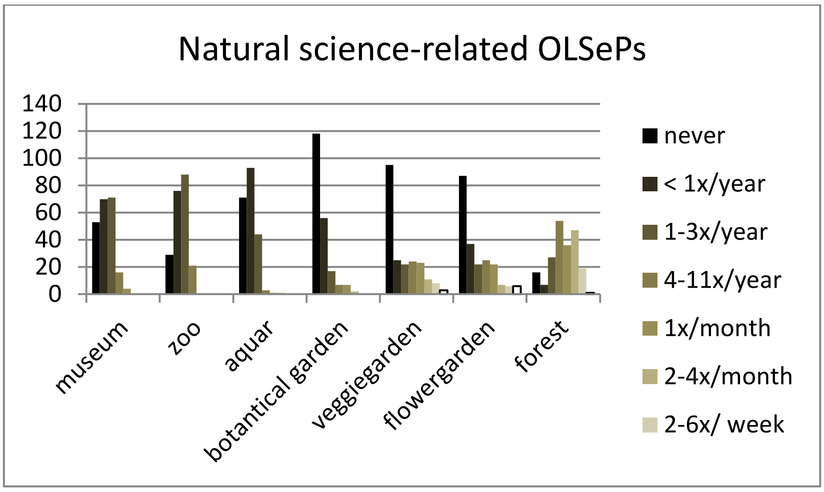


Figure 26: Pupil reported about how frequently they visited natural science-related OSLePs.

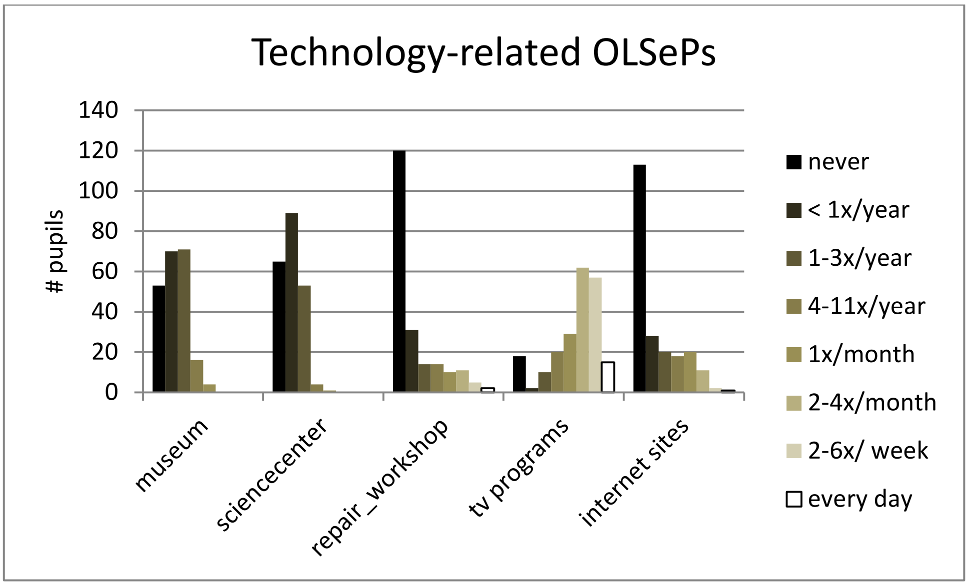


Figure 27: Pupil reported about how frequently they visited technology-related OSLePs.

Collapsed variables representing natural science OSLePs, V_NS (*M*=6.4, *SD*=.9), and technology-related OSLePs, V _Tech (*M*=6.2, *SD*=09), were calculated, so they could be used in the analysis of data to answer research questions.

- V_NS: museum, zoo, aquarium, botanical garden, vegetable garden, flower garden, forest.
- V_Tech: museum, science center, hobby workshop, S&T television programs, S&T internet sites.

SUMMARY

- About half of the pupils who responded to all three surveys were girls and about half were boys (girls: 102, 47%; boys: 109, 51%). However, for the school level (82% second grade; 18% third grade) and school track (78% Vocational Track; 22% General Track) sub-groups, the group sizes are relatively unequal.
- Eighty-five percent of pupils speak primarily German or a dialect of German at home, which is the language of mobiLLab program materials and of the investigation surveys.
- The majority of pupils have a lot of technology at home, particularly mobile phones, computers, and bikes. These data are likely exhibiting a ceiling effect.
- The average pupil reported that they sometimes conducted experiments in small groups in their classroom and that a bit more often they watch their teacher conduct experiments.
- Pupils describe themselves as being relatively capable of dealing with technology, of having moderate science and math grades, and as being somewhat curious people.
- Similar to common experience, most pupils visited OSLePs that generally involve exhibits and an entry fee such as museums once or several times per year, and visited OSLePs with freer access, such as forests, more frequently.

7.1.3 Exploring pupils' knowledge about electromagnetic radiation concepts

Even though the mobiLLab program's core goal is to pique the *interest* of Swiss youth in S&T, program leaders saw value in learning about pupils' knowledge about electromagnetic radiation, the science behind three-quarters of the mobiLLab experiments. Specifically, they wanted to explore their understanding of some basic concepts and to see if their knowledge related to their novelty experience. On the pre-and post-visit surveys, pupils responded to four questions about electromagnetic radiation. The at-visit survey, due to time constraints, included only the first two questions. The post-visit survey also included a fifth question. While these items, described in detail on page 202, do not constitute a test instrument, they helped the mobiLLab team gain some insight into pupils´ knowledge.

Item analysis results

*Difficulty, measured as the percent of pupils who answered correctly, p. R*esults from an item analysis (Table 24) showed that some items 1 and 2 were easiest to answer. Some pupils knew (pre-visit p=.68) and some learned (post-visit p=.82) that radiation energy transports light and energy (Question 1). Most pupils knew and that some waves are visible and some not (Q2). Because this item was so easy for most pupils during the pre-survey (pre-visit p=.93), there was little room left for learning, or a ceiling effect. Many pupils found it difficult to tell the difference between longer & shorter wavelengths (Q3) before the mobiLLab visit (p=.12) and after the visit (p=.15), suggesting the question was too difficult and no learning occurred, or a floor effect. Some pupils knew (pre-visit p=.26), and some learned (post-visit p=.56), that only a small part of the ES spectrum is visible (Q4). Most pupils knew the UV post used UV waves and the Microwave posts most used microwaves (Q5). This may have been too easy to guess from the post name; they found other posts to be quite difficult.

Discrimination index, D. The extent to which an item discriminated (elicited different responses) between pupils who know the material well in comparison with pupils who do not is called the discrimination index. Calculation of a discrimination index, *D* in Table 24*,* shows that only items 1 and 4 from the pre-visit survey, and 5a discriminate very well between pupils' knowledge (*D*>0.3). *Such discrimination power is not evident in at- and post-survey data. This could indicate that classroom preparation eliminates big differences between pupils' knowledge.*

Item reliability is a correlation between the item and the total score and is measured by the point biserial coefficient. It is worth noting that this statistic was calculated by through a corrected correlation, r_{pbi}, recommended by SPSS in a white paper (SPSS, 1998); "A more useful correlation is the overall test performance computed excluding the particular test item in question. This measure is called the corrected point biserial correlation of a test item" (p. 3).

Item reliability was low, which was expected because this was item-wise exploration of knowledge, not instrument. One sees how the values for r_{it} in Table 24 for items 1-4 were all less than .270, which is less than the lower threshold of .2. An explanation for this is probably that the items had differing levels of difficulty for the pupils.

Table 25: Item analysis results for knowledge questions.

Nr.	Item		Survey/ Wave	*P*	*D*	*corrected r_{pbi*}*
			Desired Values:	***(0.3 – 0.9)***	***≥ 0.3***	***≥ 0.2***
1	Concept: *What does radiation transport?*		PU1	**0.68**	**0.92**	.199
	G=.43 (knowledge gain)		PU2	**0.75**	0.16	.198
			PU3	**0.82**	0.16	.240
2	Concept: *Which waves are visible?*		PU1	0.93	0.19	.103
	G=-.13		PU2	0.94	0.19	.198
			PU3	0.92	0.04	.171
3	Concept: *Which is a longer wavelength?*		PU1	0.12	**0.39**	**.215**
	G=.03		PU3	0.15	0.25	.142
4	Concept: *How much of electromagnetic spectrum is visible?*		PU1	0.26	**0.82**	**.225**
	G=.41		PU3	**0.56**	0.23	**.263**
5	Application (PU3 only): *Which waves are relevant to which post?*	a	infrared waves	**0.40**	**0.49**	**.218**
		b	ultraviolet waves	**0.56**	-0	**.227**
		c	visible light	**0.31**	0.18	.143
		d	microwaves	**0.67**	-0.1	**.252**
		e	radio waves	0.27	0.16	.044
		f	x-rays	**0.49**	0.2	**.334**

Note. #5 sub-items are based on a smaller sample. *Reported as the corrected point biserial correlation of test item (recommended by SPSS white paper (1998)) given for knowledge items 1-4.

<u>Calculating knowledge gain using pre- and post-test difficulty data</u>

Knowledge gain about science and technology topics from pre-instruction to post-instruction scores, also called normalized gain, can be calculated as the change in score from pre- to post-test divided by the maximum possible increase in score (Coletta & Phillips, 2005; Hake, 1998):

$$G = \frac{postscore\,\% - prescore\,\%}{1 - prescore\,\%}$$

Knowledge gain was calculated for the first four knowledge questions from the mobiLLab survey, using the pre- and post-visit survey item scores, or item difficulty (*P*), from Table 24. For question 1 about radiation energy transport (Q1), labelled as 'xport,' G=(0.82-0.68)/(1-0.68)=0.14/0.32=.43. This statistic appears to represent a strong knowledge gain, when compared with the knowledge gains from a sample of more than 6000 students, who were in a control situation (G=.23) and after experiencing an interactive-engagement method to learn physics (G=.48) (Hake 1998, p. 64). Knowledge gain for Q2 (G=-.13) and Q3 (G=.03) were weak, reflecting floor and ceiling effects described above, respectively. Knowledge gain for Q4 (G=.41) appears to be strong. Even though knowledge gain was not the central focus of the study, these results provide evidence of some learning.

Average of item difficulty

Average of item difficulty statistics, shown in Table 25, shows that the test is more difficult for the pupils before the visit (p=0.5) than at the visit (p=0.8), and also that the post-visit test was easier than the pre-visit test, but more difficult than the at-visit test (p=0.6). These findings suggest that pupils are learning some things from preparation and from the mobiLLab visit, and retain some of this knowledge after the visit.

Table 26: An average of the item difficulty statistics shows that pupils learn about the electromagnetic spectrum from the classroom preparation, but then forget some of what they learned after the mobiLLab visit.

Test statistics	Test	Values*	Desired values
Average item difficulty $\overline{P}$	pre-visit	**0.5**	(0.3 – 0.9)
	at-visit	**0.8**	
	post-visit	**0.6**	

Knowledge gain significance tests

MANCOVA results listed in Table 26 show that pupils' scores on two of four knowledge questions changed significantly over time. The questions had to do with radiation energy transport (Q1), 'xport,' and visibility (Q2), 'see.' Changes in knowledge item scores did not generally depend upon their gender, whether pupils watched the video (TG), and their school year (SY). Only scores for the second question were significantly different for year two than for year three pupils.

Table 27: Pupils' scores on two of four knowledge questions changed significantly over time.

Source	Knowledge Question	Df	df error	*F*	*p*	η_p^2
Pre to post (survey)	Xport	1	176	6.22	**.014**	.03
	See	1	176	6.96	**.009**	.04
	Size	1	176	0.07	.795	.00
	Part	1	176	1.52	.219	.01
Survey * gender	Xport	1	176	0.07	.791	.00
	See	1	176	0.49	.486	.00
	Size	1	176	0.00	.958	.00
	Part	1	176	0.24	.627	.00
Survey * SY	Xport	1	176	2.12	.147	.01
	See	1	176	5.76	**.017**	.03
	Size	1	176	0.01	.907	.00
	Part	1	176	0.01	.928	.00
Survey * TG	Xport	1	176	0.70	.403	.00
	See	1	176	2.74	.100	.02
	Size	1	176	2.03	.156	.01
	Part	1	176	0.39	.536	.00

SUMMARY

- Pupils' performance on four questions about electromagnetic spectrum concepts shows evidence of knowledge gain, from classroom preparation and from the mobiLLab visit. These data can be useful to the mobiLLab team in further improving preparation materials for teachers and for developing a future knowledge test.
  - Significantly more pupils answered a question correctly about how radiation waves transport light and energy (Q1) on the post-visit survey than on the pre-visit survey. A knowledge gain calculation also provides evidence for pupil learning (G=.43).
  - Pupils found a question about whether all radiation waves are visible (Q2) to be pretty easy on the pre-visit survey. Scores on the post-visit survey showed a significant improvement and were near 100%, suggesting a ceiling effect.
  - Pupils found questions about the length of radiation waves (Q3) to be difficult, on both pre-visit and post-visit surveys, which likely reflects a floor effect.

  - Pupils found a question about which waves of the electromagnetic spectrum are visible (Q4) to be somewhat difficult on the pre-visit survey and easier on the post-visit survey. A knowledge gain calculation also provides evidence for their learning (G=.41).
- That discrimination power for items Q1 and Q4 disappears after the pre-visit survey could be because classroom preparation eliminates big differences between pupils' knowledge.

7.1.4 Describing pupils core science and technology (S&T) outcomes

On pre-visit and post-visit surveys, pupils responded to items about their interest in, attitude to, and self-concept related to science and technology (S&T), the core outcomes for the study. They also responded to an item about their career aspirations related to S&T. Results of paired t-tests, Figure 27, show significant changes in core S&T outcomes between pupils' pre-visit and post-visit survey responses. There was no significant change in pupils' interest in technology (p=.070), yet interest in natural science became less positive, and this was a moderately strong change (effect) (p=.000, d=.52). Attitude about both technology (p=.042, d=.29) and natural science (p=.013, d=.35) became significantly more positive, albeit with small effect. Pupils' self-concept with respect to technology (p=.000, d=.53) and towards natural science (p=.000, d=.79) became significantly less positive, with moderately strong effect. Finally, there was no significant change in pupils' aspirations to choose a career related to S&T, which perhaps reflects the relatively great standard deviation for these responses.

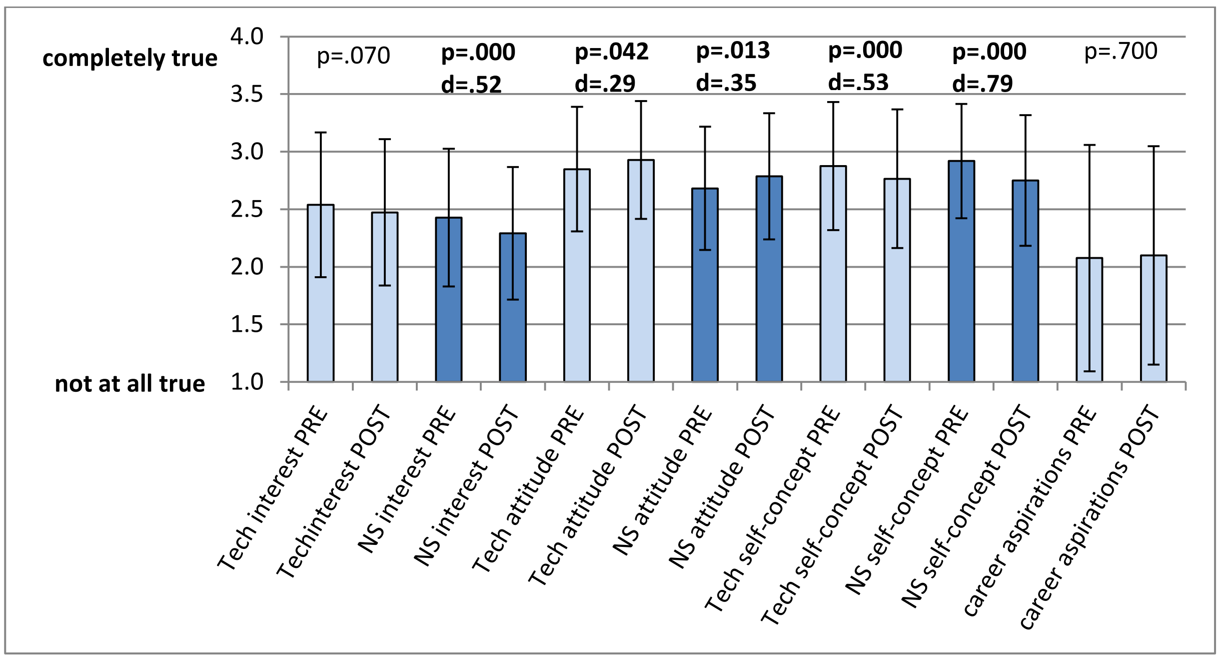


Figure 28: There were some significant changes between pupils' pre-visit and post-visit responses to core outcome survey items.

Table 27 provides additional detail about paired t-test results.

Table 28: There were some significant changes in core outcomes from the pre-visit to post-visit survey.

Variable	Label	*N*	*M*	*SD*	Mean difference	*t*	*df*	95% confidence interval lower	upper	p (two-tailed)	d
Tech interest PRE	TI_t1	203	2.5	0.6	-0.07	1.82	202	-0.01	0.14	.070	0.26
Tech interest POST	TI_t2	203	2.5	0.6							
NS interest PRE	NSI_t1	201	2.4	0.6	-0.14	3.68	200	0.06	0.21	**.000**	0.52
NS interest POST	NSI_t2	201	2.3	0.6							
Tech attitude PRE	TAT_t1	200	2.8	0.5	0.08	-2.04	199	-0.16	0.00	**.042**	0.29
Tech attitude POST	TAT_t2	200	2.9	0.5							
NS attitude PRE	NSAT_t1	201	2.7	0.5	0.11	-2.51	200	-0.19	-0.02	**.013**	0.35
NS attitude POST	NSAT_t2	201	2.8	0.5							
Tech self-concept PRE	TSC_t1	202	2.9	0.6	-0.11	3.78	201	0.05	0.17	**.000**	0.53
Tech self-concept POST	TSC_t2	202	2.8	0.6							
NS self-concept PRE	NSSC_t1	199	2.9	0.5	-0.17	5.55	198	0.11	0.23	**.000**	0.79
NS self-concept POST	NSSC_t2	199	2.8	0.6							
career aspirations PRE	carrer_t1	211	2.1	1.0	0.02	-0.39	210	-0.14	0.10	.700	0.05
career aspirations POST	career_t2	211	2.1	0.9							

.

Boys and girls differ in their affective outcomes

Boys gave on average significantly more positive responses than girls to survey items about core S&T outcomes. Results of one-way ANOVA tests (Figure 28) show how responses to items about technology discriminated more, that is, had a larger effect size, between boys and girls than did questions about natural science, where effect sizes are small to medium. For only one variable, natural science interest, was there a significant difference in groups over time. That is, girls' interest in natural science decreased significantly more than boys', albeit with small effect ($p=.045$, $\eta_p^2=.02$), Table 60 on page 213.

There were almost no significant differences between other control groups: second versus third year pupils, General versus Vocational Track pupils, and pupils with a German home language versus other language (detailed results start on page 213).

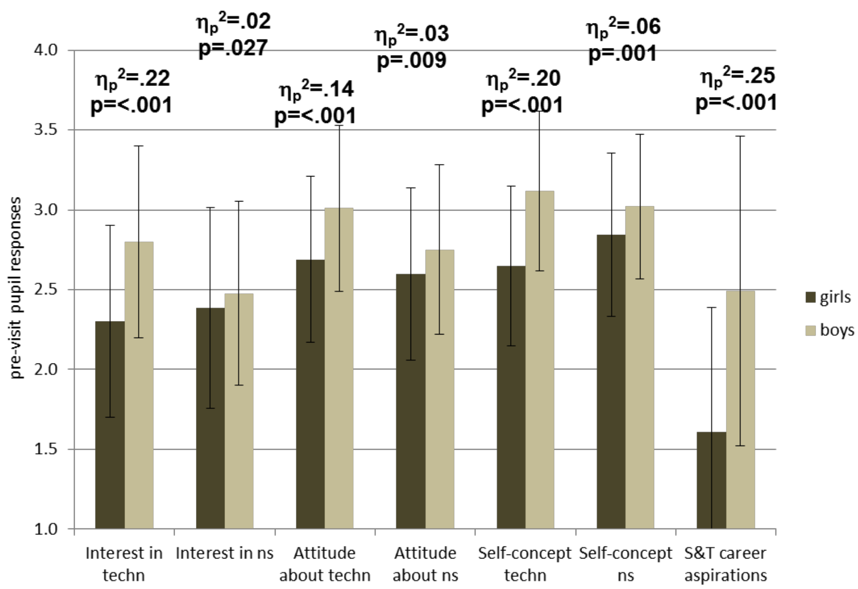


Figure 29: Boys gave significantly more positive responses to survey items about S&T interest, attitude and self-concept, as well as S&T career aspirations.

Gender gap greater for technology than natural science, widens slightly

While the change from the pre-visit to post-visit survey in interest for boys and girls is not significantly different (Figure 28), a closer look at data (Table 28) shows that the difference between girls' and boys' interest widens slightly from pre- to post-visit survey. That is, girls' interest in both science and technology decreased more from pre-visit survey to post-visit survey than boys' interest.

Table 29: The gap for interest between girls and boys widens slightly from before to after the mobiLLab visit.

Interest measure	Girls	Boys	Difference
Pre-visit interest in TECH	2.3	2.8	.5
Post-visit interest in TECH	2.2	2.8	.6
Pre-visit interest in NS	2.4	2.5	.1
Post-visit interest in NS	2.2	2.4	.2

Boys are tinker more than girls

Data also show that more boys (65 percent) tend to tinker, or describe themselves as more technologically capable, than girls (29 percent), as seen in Table 29. That is, more boys are tinkerers and more girls are direction seekers.

Table 30: More boys tinker, more girls ask for direction.

		seeks direction		tends to tinker		Total
gender	Boys	49	35%	90	65%	139
	Girls	87	71%	35	29%	122
Total		136	52%	125	48%	261

SUMMARY

- MobiLLab data show moderate, significant decreases in pupils' natural science interest and S&T self-concept, form pre- to post-visit, and also slightly significant increases in pupils' S&T attitude.
- Boys show significantly more positive responses for all of these core S&T outcomes. This gender gap was greater for technology than for natural science outcomes and widened slightly, albeit not significantly, from pre-visit to post-visit.
- More boys describe themselves as pretty technologically capable, as 'tinkerers,' and more girls described themselves as direction seekers.

7.1.5 Relating the intervention to pupils' core S&T outcomes

Results: Number of videos watched has a mostly insignificant relation to core S&T outcomes
Results of a regressions (Table 31) show that, for all but one core S&T outcome, the number of novelty-reducing videos pupils reported watching had no significant effect. A small effect was found for the relation between the number of videos pupils watched and the variation in Attitude about Natural science; only two percent of the variation was explained (R^2=.02). This suggests that pupils who watched more novelty-reducing videos had a slightly better attitude about natural science after the mobiLLab visit than those who watched fewer videos.

Table 31: The number of videos pupils watched appears to slightly influence their attitude about natural science.

			Number of Videos Watched				
Dependent Variable (post-visit survey)	R^2	*Adjusted* R^2	*df*	*df error*	*F*	*p*	*B*
Interest in techn POST	0.01	0.01	1	182	2.3	.135	.038
Interest in ns POST	0.00	0.01	1	182	0.1	.796	.006
Attitude about techn POST	0.01	0.01	1	182	2.5	.114	.031
Attitude about ns POST	0.02	0.02	1	182	4.0	**.046**	.042
Self-concept techn POST	0.01	0.00	1	182	1.0	.322	.023
Self-concept ns POST	0.00	-0.01	1	182	0.1	.713	-.008
S&T career aspirations POST	0.01	0.00	1	182	1.0	.325	.036

7.1.6 Describing choice of experimental posts and program satisfaction

During the half-day mobiLLab visit pupils worked at four of the twelve experimental posts. According to pilot study teacher interviews and survey responses, pupils are often involved in selecting at least two of four posts they work. Based on the posts at which pupils worked, the most popular experimental posts were the Infrared Camera and Highspeed Camera, which were chosen by more than 90 pupils or more than 44%. Least popular were Microwave Synthesis and Infrared Spectroscope experimental posts, visited by 34 pupils or 16% each. During an interpretive session, mobiLLab faculty said their experience suggests that the Highspeed camera is the most popular and they wondered whether some pupils confused the Infrared and Highspeed cameras when filling out the survey. It is worth noting that these technologies help one to see things the naked eye cannot and, therefore may have a certain 'mystique.' For two posts, responses suggest a strong gender preference. That is, the Food Analysis post was visited by one-quarter of the girls (25%) and only 14% of boys. And, the Exhaust Gas Analysis post was visited by almost one-quarter of boys (24%) and only by 7% of girls.

Table 32: Number of boys and girls who worked at each experimental post (N=211).

Post		Girls		Boys		Total	
English	German	N	%	N	%	N	%
Infrared camera and IR thermometer	Wärmebild-Kamera	46	22%	53	25%	99	47%
Highspeed camera	Highspeed-Kamera	39	18%	55	26%	94	45%
Household microwave	Haushaltsmikrowelle	37	18%	52	25%	89	42%
Food analysis	Lebensmittelanalyse	52	25%	29	14%	81	38%
X-ray fluorescence	Röntgenfluoreszenz	30	14%	48	23%	78	37%
Visible light analysis	Farben/ Spektren	40	19%	30	14%	70	33%
Exhaust gas analysis	Abgasmessung	14	7%	50	24%	64	30%
UV radiation	UV-Strahlung	40	19%	24	11%	64	30%
Spiro-ergometer	Spiroergometrie	28	13%	19	9%	47	22%
Ion cromatograph	Ioncromatografie	19	9%	18	9%	37	18%
Microwave synthesis	Mikrowellenynthese	15	7%	19	9%	34	16%
Infrared spectroscope	Infrarot-Spektroskopie	15	7%	19	9%	34	16%

SUMMARY

- The most popular experimental posts were the Infrared Camera and Highspeed Camera, which were also named by teachers as most popular during pilot interviews.
- Post choices sometimes reflected gender preferences: girls like the Food Analysis post much more; boys like the Exhaust Gas Analysis post more.

Program satisfaction

When asked to give mobiLLab a grade, pupils gave on average a 4.8 of 6.0 (*SD*=0.9), which is more than a full grade greater than pupils' responses to the same question in 2010 (*M*=3.2, *SD*=1.5) (see Figure 29). MobiLLab team members attributed pupils' improved grade largely to new items developed for each post for the 2011-2012 school year: 1) 12-minute introductory E-Learning sequences viewed during classroom preparation and 2) a laminated step-by-step procedural guide (Kurzanleitung) for use at the visit. MobiLLab team leaders also point to other improvements to the program that could contribute to this increased program satisfaction. They explain that there are more teachers each year who have already worked with mobiLLab in a previous year, who can therefore deliver a more thorough classroom preparation. New posts, such as the Food Analysis post, are easier to operate and can test more items from home; added materials to, for example the Visible Light post, such as a prism were thought by mobiLLab staff to be more popular with pupils.

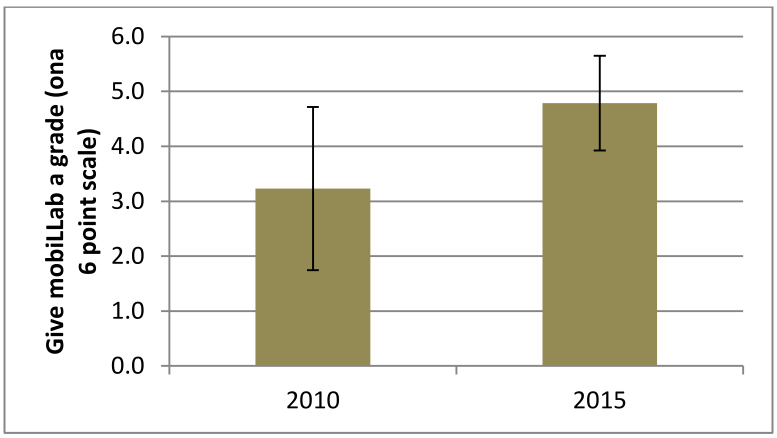


Figure 30: Pupils gave mobiLLab a higher grade in 2015 than in 2010.

Pupils' responses to three questions about their satisfaction with their mobiLLab experience were also encouraging. The average pupil gave a pretty positive rating for liking the program (*M*=3.1, *SD*=0.8). Responses were more neutral and more mixed about whether they would like to participate in another mobiLLab visit (*M*=2.7, *SD*=1.0). Also, they reported that they had to work about as hard during the mobiLLab visit as they do in science class (M=2.4, SD=0.8). This is evidence that pupils worked about as hard during the mobiLLab visit as they do in their regular science class, and still liked the mobiLLab day very much.

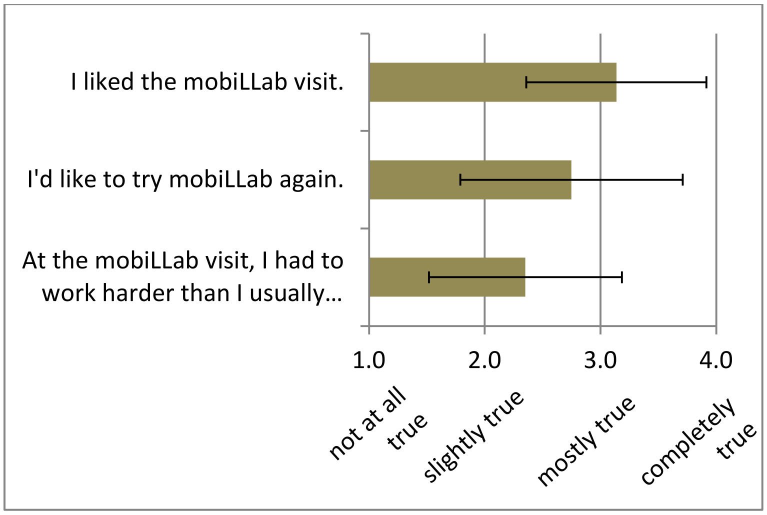


Figure 31: Pupils' responses to program satisfaction questions were neutral to positive.

SUMMARY

- Pupils graded the mobiLLab program with more than a full grade higher than they did in 2010. The mobiLLab team attributed this improvement primarily to program improvements made in for the 2011-2012 school year.
- Pupils reported that they worked about as hard during the mobiLLab visit as they do in their regular science class, and still liked the mobiLLab day very much.

7.1.7 Identifying NEFs with factor analysis

Pupils completed the at-visit survey during the mobiLLab visit after working at two experimental posts and before working at their remaining two posts. The at-visit surveys consisted of items that were developed based on previous studies and theories, as summarized in section 5.3.1. By synthesizing information from these studies and theories about at-visit novelty experience at OSLePs, I developed a refined theoretical understanding of four novelty experience factors: exploratory behavior, oriented feeling, curiosity state and cognitive load. Table 53, page 204, lists the original 20 survey items and theoretical sources from which they were adapted. Because the items were adapted from existing studies and used in a new combination, I wanted to explore how the items would describe dimensions of pupils' novelty experience at the mobiLLab visit. It was important to distinguish which items were eliciting responses that represented, for example, curiosity state, from for example, those items that characterized exploring behavior. By revealing how responses to certain survey items have common variance, exploratory factor analysis helps researchers to identify groups of items, or scales, which reliably represent a characteristic about a population.

A factor analysis was conducted with the 20 items of the at-visit survey to explore for distinct dimensions of pupils' at-visit experience, as it relates to perceived novelty. Specifically, principal axis factoring was chosen to explore the items about how pupils perceived novelty at the mobiLLab visit. Because it is an exploratory approach, results are descriptive of the study sample, rather than generalizable to a broader population (Field, 2013, p. 674).

Prelminary tests

Several tests were conducted to screen items for inclusion in the factor analysis.

- Standard deviations of items were not extreme (*SD*=0.6 to 0.8), suggesting pupils responses varied somewhat, yet they answered each item somewhat similarly.
- Likewise, means were not extreme (*M*=1.8 to 3.6).
- All together, the list of items has a scale reliability of r=.71.
- Correlations results generated during the scale reliability test show weak to moderate correlations (from no correlation up to r=.5) among items, suggesting factor analysis may be appropriate. Tabachnick and Fidell (2013) recommend correlation coefficients greater than r=.3.

Preliminary Analysis

Preliminary analysis indicates no assumptions were violated.

- The determinant of the correlation matrix (determinant=.010 for first run; determinant=.005 for final run) is greater than the threshold ($p>.001$), indicating reasonably good correlation among items, and also that correlations are not too strong, so multicollinearity is not an issue.
- The Kaiser-Meyer-Olkin measure (KMO=.857 for first run, KMO=.871 for final run) is greater than .5, suggesting sampling adequacy is meritorious, which means very good.
- Bartlet's measure is significant ($p<.001$), indicating that the original correlation matrix is not an identity matrix.

Results
An initial principal analysis factoring, with orthogonal (Varimax) rotation, was run to with the 20 items shown in Table 53 to produce factors eigenvalues, which represents the amount of variation explained by that factor. Four factors had eigenvalues greater than 1.1 and these same four factors were identified also by Oblique (Oblimin and Promax) rotations; a fifth factor also had an eigenvalue greater than 1, but was eliminated because included only one item with factor loadings greater than 0.3. The four factors in combination explained 47% of the variance in pupil responses. The scree plot was somewhat ambiguous and the inflection supported selecting three or four factors. Given the moderate sample size and confirmation by Oblimin and Promax rotations, I retained three factors. The items that clustered on the same factor suggested that factor 1 represented pupils' curiosity state, factor 2 represented pupils' cognitive load, and factor 3 represented pupils' exploratory behavior with mobiLLab equipment. A fourth factor, about how oriented pupils felt, showed only two items with factor loadings greater than 0.3, which together gave a Chronbach's alpha of α=.534, too low to warrant their use as a reliable scale. However, one of the items loaded at lambda=.694, so it was used to represent the Novelty Experience Factors (NEF) oriented feeling when conducting multivariate tests to explore research questions.

A forced three-factor analysis was conducted to identify which survey items contributed to scales for the remaining three NEFs: curiosity state, cognitive load and exploratory behavior. Chronbach's alphas for these three groups helped determine that two items were not contributing to reliability of the three strong factors. The item cls2 had a loading < .300, so it was eliminated. Chronbach's alpha statistics for the three strong factors showed that the exploratory behavior scale had a Chronbach's alpha greater than .700 when exex1 was eliminated and texs4 was used in reverse form. A final principal axis was run with Varimax rotation and 18 items (eliminated cls2 and exex1). Results are shown in Table 32, which lists factor loading and communalities for each item and lists Chronbach's Alpha and Eigenvalues for each factor. The scree plot is shown in the Appendix on page 205. For this final test (N=205), three factors were identified through loadings and only these factors had eigenvalues greater than 1. The factors are Curiosity State, which explains 29% of the variance, Exploratory Behavior, which explains 12% of the variance, and Cognitive Load, which explains 8% of the variance.

NOTE: Communality values are mixed. With a sample size of 205, they should not be much less than $\hat{h}$=.5. For the curiosity items, communalities are acceptable, but some exploratory behavior and cognitive load items are less than $\hat{h}$=.5.

SUMMARY: Describing pupils' perceived novelty at the mobiLLab visit
Results of the factor analysis provide the first ever psychometric validation of groups of questions (scales), which are grounded in novelty theory, that describe how pupils´ perceive novelty while visiting a mobiLLab. That is, *one can describe pupils´ perceived novelty in terms of reported curiosity state, exploratory behavior, oriented feeling, and cognitive load.*

These instruments inform us about how learners perceive novelty at other technology-related OSLeP. That is, through factor loadings, we gained insight into ways that pupils perceived novelty. First, pupils do not separate the feeling of being oriented with the feeling of being able to explore the equipment, evidenced by how items sett1 and sett2 and sett3, which were developed to describe feeling oriented, loaded for the exploratory behavior factor. Also, pupils saw cognitive load as something having to do with conducting experiments, as seen by how items exex2 and exex3, about pupils´ ease in try out experiments. Finally, the switch of item texs5 from the proposed exploratory behavior scale to the curiosity scale, suggests that pupils associate fun with curiosity more than with exploratory behavior.

Understanding factor analysis test results

Exploratory factor analysis was useful for examining a list of items from the mobiLLab survey about pupils´ perceived novelty. It helped me to determine that there were several common themes, or explanatory factors, under which the items can be grouped as viable scales (measurement instruments), namely Curiosity state, Exploratory Behavior and Cognitive Load. Below are the terms used when reporting result from a factor analysis test.

Communality ($\hat{h}$) — The communality value indicates the common variance shared by an item with the rest of the items involved in the factor analysis. For example, the first item in the curiosity state list has a communality of $\hat{h}$ =.659, which describes how well it correlates with the rest of the items in the factor analysis. With a sample size of 205, they should not be less than $\hat{h}$=.5.

Eigenvalue — The eigenvalue associate with each factor represents the variance (among the responses to all of the items included in the factor analysis) explained by that factor. It is reported as percentage. For example, curiosity state explained 29 percent of the total variance among the responses from pupils about their perceived novelty (the items included in the factor analysis).

Factor — A cluster of items that correlate highly with each other.

Factor loading — A factor loading indicates the relative contribution of an item to a factor. It can be thought of as the Pearson correlation between a factor and an item and is a gage of the importance of an item to a given factor. For example, the factor loading for curs1 is 0.078, which describes how well it correlates with the rest of the items in the curiosity state scale.

Reliability (α) — The reliability of a scale (group) of items/ questions is a measure of its internal consistency. This refers to the degree to which the items that make up the scale ´hang together.´ That is, are the items measuring the same underlying construct? The Chronbach´s alpha (α) coefficient of a scale should be greater than .7, which indicates strong reliability.

Table 33: Four novelty factors characterize pupils' at-visit mobiLLab experience.

Item	Factor Loadings			ĥ	a
	Curiosity State	Exploratory Behavior	Cognitive Load		
curs1: Die Erfahrung mit mobiLLab weckt meine Neugier auf die dort behandelten Themen.	**0.78**	<.30	<.30	.659	.818
curs2: Es interessiert mich, wie die Geräte an den verschiedenen Posten funktionieren.	**0.70**	<.30	<.30	.527	.832
curs5: Ich möchte die in den mobiLLab behandelten Themen besser verstehen.	**0.70**	<.30	<.30	.522	.849
curs4: Die in den mobiLLab-Versuchen behandelten Themen haben mich persönlich angesprochen.	**0.69**	<.30	<.30	.558	.831
curs3: Ich möchte mehr über die mobiLLab-Themen erfahren.	**0.67**	<.30	<.30	.474	.840
texs5: Es hat mir Spass gemacht, die mobiLLab-Geräte auszuprobieren.	**0.59**	<.30	<.30	.457	.847
texs1: Ich habe keine Probleme, die mobiLLab-Geräte selbst zu bedienen.	<.30	**0.51**	<.30	.355	.653
setts3: Für den mobiLLab-Besuch bin ich gut vorbereitet.	<.30	**0.48**	<.30	.272	.669
texs4: Ich konnte rasch mit der Bedienung der mobiLLab-Geräte beginnen.	<.30	**0.47**	**0.33**	.342	.658
texs2: Aufgrund der Vorbereitung habe ich keine Angst, bei der Bedienung der mobiLLab-Geräte Fehler zu machen.	<.30	**0.46**	<.30	.232	.669
setts1: Der zeitliche Ablauf des mobiLLab-Tages ist mir bekannt.	<.30	**0.46**	<.30	.286	.702
setts2: Der mobiLLab-Besuch ist gut organisiert.	<.30	**0.43**	<.30	.265	.673
texs3: Ich bin in der Lage mit den mobiLLab-Geräten zu „spielen" um zu sehen, was sie alles können.	<.30	**0.39**	<.30	.262	.666
cls3: Wie sehr musstest du dich anstrengen, um die Experimente durchzuführen?	<.30	<.30	**-0.53**	.290	.680
cls1: Wie hoch war die geistige Belastung bei den Versuchen insgesamt (zuviel Unbekanntes, zuviel auf einmal)?	<.30	<.30	**-0.52**	.275	.666
exex3: Ich konnte mich gut auf die Experimente konzentrieren, ohne mit den Geräten "kämpfen" zu müssen.	<.30	0.34	**0.52**	.431	.638
cls4: Wie verunsichert, entmutigt, oder verärgert warst du während der Experimente?	<.30	<.30	**-0.47**	.326	.662
exex2: Die Experimente waren schwierig.	<.30	<.30	**-0.45**	.288	.663
cls2: Wie empfindest du die Zeit, die für Experimente zur Verfügung stand? (eliminated in final factor analysis)	NA	NA	NA	NA	NA
exex1: Wir haben genügend Informationen, um die Experimente durchführen zu können. (eliminated in final factor analysis)	NA	NA	NA	NA	NA
Chronbachs α	0.86	0.70	0.70		
Eigenvalue Total	5.21	2.11	1.36		
% of Variance	29	12	8		
Cumulative Variance	28.93	40.65	48.21		

NA=These items were not included in the final factor analysis because loadings on these items were too low. ĥ= communalities. a=Chronbach's alpha if item deleted.

7.1.8 Screening potential covariates

Covariates (CVs) are variables that are not part of the main experimental manipulation but are thought to have an influence on the dependent variable(s). Based on studies about potential control variables for OSLePs (Pawek, 2009; Tran, 2011) and how different groups, such as girls and boys, vary in their interest in S&T (Bybee & McCrae, 2011); PISA report for Switzerland, 2012), a short list of control variables was identified for the mobiLLab study: gender, school year, school track, and technology at home. And based on studies about curiosity (Litman & Spielberger, 2003; Naylor, 2007), dispositional curiosity was selected as an additional potential covariate, because it has been thought to explain variances in people's curiosity experience, or curiosity state. A more detailed description of the theoretical basis for selecting potential covariates is on page 5.3.5.

It is important to choose a small set of covariates that are uncorrelated with each other but moderately correlated with the dependent variable. "As a general rule, one wants a very small number of CVs, all correlated with the DV and none correlated with each other. The goal is to obtain maximum adjustment of the DV with minimum loss of degrees of freedom for error" (Tabachnick & Fidell, 2013, p. 279). "When too many CVs are used and they are correlated with each other, a point of diminishing returns in adjustment of the DV is quickly reached. Power is reduced because the numerous correlated CVs subtract degrees of freedom from the error term while not removing commensurate sums of squares for error. … Preliminary analysis of the CVs improves chances of picking a good set {of CVs}" (Tabachnick & Fidell, 2013, p. 302).

Covariate Screening Tests for Possible Covariates

Four tests are commonly used to evaluate the utility of covariates in statistical tests:

1. Reliability.

   NOTE: This test is only relevant for the potential covariate dispositional curiosity, TCURT, because it is the only scalar variable.

2. Significant relationship with DV (univariate tests). "Significance tests for CVs assess their utility in adjusting the DV. If a CV is significant, it provides adjustment of DV scores." (Tabachnick and Fidell, 2013, page 302). ANOVA performs as well as any other test for selection of covariates (Steiner 2010).

3. Significant, moderate correlation with DV(s) (Mayers, 2013, p. 382) and non-correlation with other CVs.

   NOTE: This is only relevant for the potential covariate dispositional curiosity, TCURT, because it is the only scalar variable.

4. Independence of treatment. The covariate should not vary with the independent variables. (Field, 2013, p. 484; Tabachnick & Fidell, 2013, p. 279)

RESULTS show gender and curiosity trait should be covariates

Gender (Gen) was the only control variable for which dependent variables differed significantly and the detailed test results are shown on page 213. This is consistent with some studies of novelty at OSLePs that show how gender makes a difference for cognitive and (Kabuto, 1991) affective (Cors, 2015) outcomes. Also identified as a covariate was curiosity trait (CurT), which was a strong predictor of curiosity state, as shown in regression results on page 148. However, curiosity trait was shows to be a covariate that should be handled with some caution, because it was shown by an independence test (ANOVA results on page 218) to vary significantly with predictors technological capability and frequenting technology-related OLSePs.

Table 34: Evaluation tests for selection of covariates.

Potential Covariate	Evaluation Tests				Selection Decision
	Reliability	Significant as predictor of DV(s)*	Correlation with DV(s)	Independence from predictors	
Gender	NA	Significant ANOVA results for all core S&T outcomes	NA	NA	Use as a covariate with all tests involving core DVs.
School year	NA	Significant ANOVA results for one DV: S&T career aspirations.	NA	NA	Use as a covariate with tests where career aspiration is DV.
School track	NA	Not significant for core S&T outcomes		NA	Do not use as a covariate.
Home language	NA	Not significant for core S&T outcomes	NA	NA	Do not use as a covariate.
Technology at home	NA	Not significant for core S&T outcomes	NA	NA	Do not use as a covariate.
Experimentation in the classroom	NA	Regression sign. for only one DV: 18% of variance with natural science interest explained by teacher demonstration.	Correlations all ns except one: between IV *teacher demonstration* and DV *natural science interest.* r=.18.	NA	Do not use as a covariate.
Dispositional curiosity	.84	Linear regression shows that CURT significantly predicts DVs: cognitive load, curiosity state, exploratory behavior.	Significant and moderate correlations to DVs: cognitive load, curiosity state, exploratory behavior.	Varies significantly with IVs: techn capability, techn-OSLePs.	Use with caution as a covariate where curiosity state is a DV.

DV=dependent variable. IV= independent variable. NA=not applicable because these variable are non-scalar. ns=not significant. sign=significant.

For the remaining control variables, dependent variables did not vary significantly, and so these variables were not employed as covariates in the mobiLLab study. Detailed results are shown starting on page 213. For the control variable school year (SY), only the dependent variable career aspirations (CA) varied significantly. This contrasts with findings from other studies about science learning at OSLePs that showed that interest and attitude outcomes decreased with age (Barmby et al., 2005; Guderian, 2007). Also unexpected was that core S&T outcomes did not vary significantly with school track (ST), as suggested by mobiLLab coaches and staff during informal conversational interviews. Perhaps because the teachers who sign up for the mobiLLab program, whether they are teaching General or Vocational Track, are enthusiastic about science. Home language (HL), or whether pupils spoke German as a main language at home, also made no significant difference in core S&T outcomes. The other 'home' variable,' technology at home (HTECH) also made no significant difference in pupils' core S&T outcomes. In this case, it appeared to be because many pupils have a lot of technology and so there was a ceiling effect with the data.

These results suggest that the mobiLLab is robust over some socio-economic factors, namely school track and home language, which were developed by PISA to explore socio-economic factors.

7.1.9 Methods for testing hypotheses

Preceded by exploring variable relations

Before running multivariate tests, data were explored to get an overview of relations among variables and to ensure that the databased met preconditions for multivariate test. In addition to meeting the preconditions describe below, several aspects of the data supported confidence in conducting multivariate tests with the main study database. For example, there was moderate correlation among dependent variables. That is, correlations among dependent variables were virtually all significant and most are medium, with some variation: $.12 <= r <= .76$. Also, multivariate test works best when Chronbach's alpha for the covariate is relatively high. For the mobiLLab study, the only covariate that could be tested for reliability was curiosity trait, whose reliability was relatively high ($\alpha = .84$). It is worth noting that, although the covariate dispositional curiosity was measured after the mobiLLab visit rather than before, which is meant to prevent intervention effects, this variable was thought to be stable over time.

Sample size

Results are generalizable if the sample size is big enough. About 15 participants per predictor variable are needed for a reliable equation: $N>50+8m$, where m=number of independent variables (Tabachnick, 2013 page 123). Multivariate tests were performed with just one or two IVs at a time, so the sample size minimum should be 66 (calculation: 50+8*2), which is exceeded by far by the mobiLLab study sample, N= 215. Sub-groups, such as boys and girls, were shown to have relatively equal variances. That is, Levene's and Box's M test results were almost all non-significant for sample sub-groups – gender, school year, school track, home language.

Normality of sample

Multivariate statistical tests assume that the distribution of scores on the dependent variable is normal. Normality was found for core S&T outcomes for the full sample and for sub-groups based on gender, school year, school track, home language (test results starting on page 208). Because normality results were sometimes mixed, Greenhouse-Geyser results were reported because they use a more conservative value for degrees of freedom to reduce Type I error (Field, 2013, page 548). Following is a list of indicators of sample normality:

- Mostly significant results from Kolmogorow-Smirnov (K-S) tests. Because K-S test results can be significant even when scores are only slight different from a normal distribution, results should be interpreted in conjunction with histograms, Q-Q plots and skew and kurtosis (Field, 2013, page 188).
- Histogram distribution of scores all looked reasonably normally distributed and Normal Q-Q plots confirmed this.
- Boxplots showed very few extreme values, all of which were in-range.
- The original mean and 5% trimmed mean for each variable are very similar, suggesting that extreme scores are having little influence on the mean.

- For smaller groups, such as General Track pupils or 3rd year pupils, Shapiro and Wilks' normality test results were often non-significant, suggesting normality.
- All but several dependent variables showed skewness or kurtosis for pupil sub-groups, which should not affect the results of an analysis with the mobiLLab study sample because it is greater than 200 (Tabachnick & Fidell, 2013, p. 80).

Multicollinearity and singularity

Multicollinearity occurs when independent variables are highly correlated with each other. Multicollinearity coefficients for tolerance, which indicates how much of the variability in an independent variable is not explained by the other independent variables in the model, were all within range, or nearly within range. Singularity is violated when one independent variable is actually a combination of other independent variables. Since multiple regressions were conducted with just one IV at a time, or two different IVs, this minimized risk of singularity.

Sphericity

Sphericity is the assessment of whether differences between group variances are too extreme 1) among IVs, if there are three or more IVs and 2) variances over time, if there are three or more sampling times (Mayers, 2013, p. 343). Thus sphericity is not relevant to mobiLLab study tests, which involved a maximum of two IVs and two sampling times for repeated measures tests. Therefore, multivariate tests did not produce a sphericity statistic. (In cases were sphericity is relevant, a desirable statistic is significant, $p<.001$).

Two types of multivariate tests

Multivariate tests were used to test mobiLLab study hypotheses. These tests show whether an independent variable significantly relates to a group of dependent variables (the term ´multivariate' tells us that more than one DV is involved). If one would test the same hypothesis through a number of univariate tests, one for each dependent variable, one increases the risk of false positives, or Type I errors. Multivariate regression and multivariate analysis of (co)variance (MAN(C)OVA) are the two main tests used to test hypotheses of the mobiLLab study. A comparison of these approaches is provided in Table 34.

Regression and MA(C)NOVA are based on two different basic statistical concepts. The purpose of a MANOVA test is to determine if means of two or more groups are statistically different from each other. The Regression tests are based on the concept of correlation, which shows if two variables are significantly related to one another. If they are, then a regression test can be used as a predictive model to examine impact of one variable on another (Field, 2013).

Table 35: Comparison of two methods for testing mobiLLab study hypotheses: multivariate regression and multivariate analysis of variance (MANOVA).

	Multivariate Regression	**Multivariate Analysis of Variance (MANOVA)**
Shows joint effect of IVs	✓	✓
Shows which IVs predict DVs	✓	✓
Decreases Type I error (false positive)	✓	✓
Test for relationship	Through correlations	Through comparison of means
Independent variables (IVs)	At least one IV is metric (continuous)	All IVs are categorical variables
Advantages	Shows relative contribution of each IV through β coefficients, which are standardized to units of standard deviation	Excellent for comparing groups.

DV=dependent variable. IV=independent variable.

Interpreting multivariate test

Below are the terms used when reporting results from a multivariate test.

S&T Outcomes — Multivariate tests assess the relation between one or more predictors (independent variables (IVs)) and a small group of dependent variables (DVs). Testing the multiple dependent variables is accomplished by creating new dependent variables that maximizes group differences. This artificial DV is a linear combination of the original DVs. For the mobiLLab study, there were two core groups of dependent variables (DVs): 1) interest, attitude, and self-concept related to technology and 2) interest, attitude, and self-concept related to natural science. For multivariate tests, I first report results between predictors and these two groups. For any results that were significant for these dependent variable ´groups,´ the univariate test results are also reported. Multivariate tests can use time (from per- to post-survey, for example) as a nested independent variable, giving results that indicate how IVs predict the change in dependent variables.

F-ratio (F) — The F-ratio is the main output of a (M)ANOVA output. It compares the ratio of systematic variation, or that explained by the IVs, with the amount of unsystematic variation, explained by other factors outside of the study parameters.

NOTE: The F-ratio compares the mean squares for the model (MSM) with the residual mean squares (MSR) to determine whether the model has improved the prediction of the outcome compared to a baseline model, such as the mean. These mean squared values are found by dividing the sum of squares by the degrees of freedom. MSM represents the variation among means explained by the data, also called the systematic variation, and MSR represents the variation explained by extraneous variables (unsystematic variation).

n_p^2	The partial eta squared value is a measure of the effect size. That is, it tells us the magnitude of significant result, or the proportion of variance in the DV explained by an IV. These values can be interpreted using Cohen´s scale: small=.01, medium=.06, large=.14 (Cohen, 1988).
R^2	R^2 is the main output of regression analysis. R^2 represents the amount of variation in the DVs explained by the IVs, and is a ratio of the variation explained by the model (SS_M) relative to the total variation (SS_T), which are both sums of squares. This represents the proportion of improvement due to the model (from the data) and can be interpreted as a percent. For example, if R^2=0.10 it means that this predictor explains 10 percent of the variation for the DV. NOTE: The model sum of squares (SS_M) is the improvement in prediction that comes from using the regression model, rather than the mean. It, is calculated as the difference between total sum of squares (SS_T) and the residual sum of squares (SS_R). SS_T comes from the difference between observed data and the mean values of observations. SS_R comes from the differences between observed data and the 'best fit' line, or regression line. Further detail about determining these sums of squares is described and illustrated in Field, 2013, p. 301.
Adjusted R^2	The adjusted R^2 value takes into account the loss of predictive power that comes from collecting data from a sample, rather than a whole population. When a small sample is involved, the R^2 value tends to be rather optimistic. With small study samples, the adjusted R^2 value is often reported because it represents the variance accounted for if the model (results) had been determined for the population from which the sample is taken. If the adjusted R^2 value is near the value of R^2, it is a good cross-validation that the R^2 value is accurate. Further detail is provided in Field (2013, p. 336).
b	The b-values, also called unstandardized coefficients, from a regression test allow us to assess individual predictors. The t-statistic for each b-value tells whether that predictor significantly contributes to our ability to estimate the DVs.
b SE	The b SE values indicate to what extent b-values vary across different samples and are used to determine whether a b-value differs significantly from 0.
β	The standardized b-values, called beta (β) values, tells us the number of standard deviations that the outcome will change as a result of one standard deviation of change in the predictor. β-values are all measured in standard deviation units, and so they are directly comparable among predictors.
df	Degrees of freedom represents the number of scores used to compute the mean, adjusted for the fact that we are estimating for the population. Therefore it is N-1. A common way to think of degrees of freedom is as the number of independent pieces of information available to make an estimate. More concretely, the number

of degrees of freedom is the number of independent observations in a sample of data that are available to estimate a parameter of the population from which that sample is drawn. For example, if we have two observations, when calculating the mean we have two independent observations; however, when calculating the variance, we have only one independent observation, since the two observations are equally distant from the mean.

In fitting statistical models to data, the vectors of residuals are constrained to lie in a space of smaller dimension than the number of components in the vector. That smaller dimension is the number of degrees of freedom for error.

p — The p-value tells us whether the results of the results of a test are significant. That is, if the p-value is equal to or smaller than the significance level (α), which for this study was .05, it suggests a significant difference between groups. For between-subjects results the difference is between sample groups, such as boys and girls. For within-subjects results, difference is between events, such as survey time one and survey time two.

Repeated-measures Tests — Measures of pupils' core S&T outcomes, the dependent variables, were taken once before and once after the mobiLLab visit. Relations between predictor variables and changes in these dependent variables were explored using repeated-measures multivariate regressions, a special case of mixed- model regression, where time is a nested prediction factor. For each significant multivariate regression result, exploration of the relations between novelty factors and individual dependent variables (univariate results) is interesting. To do this, a MANCOVA test was conducted using a categorical version of the predictor variable that was created using a median-split. One product of MANCOVAs is the pilot plot graphs, such as the one shown in Figure 31.

BETWEEN-GROUPS

Between-groups output for the F-ratio tells whether the mean difference for two groups, such as girls and boys, or treatment and control group, is significant. For example, in Figure 31, the mean value for attitude to technology for tinkerers, the solid line, is visibly higher on the graph (greater than) than for direction seekers.

WITHIN-SUBJECTS

Within-subjects output for the F-ratio indicates whether the difference between how values for two groups of subjects change over time is significant. For example, in Figure 31, the change in attitude towards technology for each group changes from the pre-survey to the post-survey in different directions: tinkerers' attitudes becomes slightly less positive, direction seekers' attitudes becomes more positive.

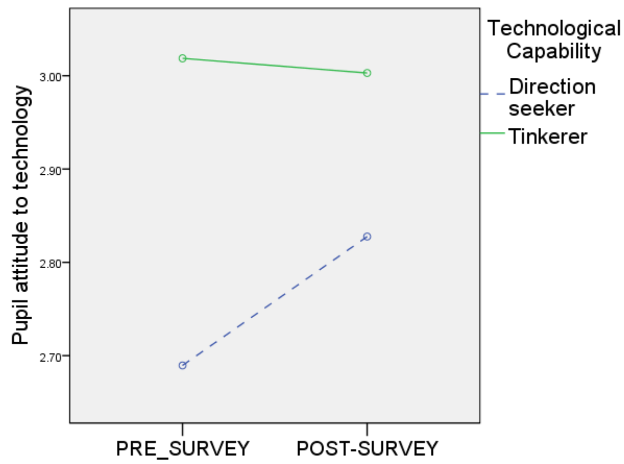


Figure 32: Example plot of MANOVA results to illustrate the difference between between-group and within-subject output.

7.2 Interpretation of survey results

A review of selected survey results was conducted with a group of informal learning researchers and practitioners attending an informal learning conference in 2016, in order to check findings against other perspectives. Such an 'expert audit review' involves experts in reviewing the results in the form of a meta-analysis, something that adds credibility of results (Patton, 2002, p. 562). This interpretive session was held at the Mobile Laboratory Coalition Conference, held July 13-16, 2016 in Columbus, Ohio. Conference participants were science teachers, managers and instructors from informal learning programs such as mobile laboratories, science laboratory educational programs, and university faculty involved with science learning and related research. Given their experiences, these conference participants are experts about informal learning, particularly as it relates to mobile laboratory programs. A group of about 25 conference participants attended the interpretive session.

Participants in the interpretive session listened to a 20-Minute presentation about the mobiLLab study, which covered the inquiry strategy, study variables, hypotheses, sampling plan, and example survey items. The description of the research also included an overview of descriptive results and results of tests of study hypotheses. The presentation also provided a detailed description of findings about how technological capability related to core S&T outcomes and about how exploratory behavior related to core S&T outcomes.

After the presentation, participants were asked to form groups of three to five people and to conduct focused discussions about how useful the results are for improving informal science learning. They were specifically asked to pose critical questions about the study and the results and to describe how they might use results in their own informal learning programs.

7.3 Analysis of teacher interview data (pilot study only)

Interview data was collected during the pilot study for two reasons: 1) to better understand preparation practices and use of preparation materials posted on the mobiLLab website and 2) to explore teacher ideas about what factors promote development of pupil interest in S&T. Because interviews were not focused on testing study hypotheses, but employed for program evaluation and exploration, a general inductive approach was used to analyze the data. The general inductive approach has been recognized as one that "provides an easily used and systematic set of procedures for analyzing qualitative data that can produce reliable and valid findings" (Thomas, 2006, p. 237). The goals of this approach are to condense raw textual data into a brief, summary format and to establish clear links between the research objectives and the summary findings derived from the raw data.

Interpretation of interview data was conducted in consideration of quality criteria. Quality criteria for interview data relate to the conditions for the interview (the room, the surroundings), rapport with interviewees, finding time to reflect on interview content immediately after they were conducted, ability to follow up with interviewees regarding ambiguities, and whether one learns what one seeks to learn (Patton, 2002).

Reflection and follow-up on interview content

For about two-thirds of the nine teacher interviews conducted for the pilot 2014 study, other work prevented the interviewer from reviewing the interview notes immediately after the interview. Through email, some facts could be clarified, such as exactly when their classes experienced mobiLLab. However, email communication was not used to clarify, for example, ambiguities in teacher responses, nor follow up on points of interest.

Scheduling and interview location in classroom

All teachers responded promptly to scheduling a time to meet for the interview and accommodated requests to speak somewhere without interruption and to be tape recorded. When meetings took place in the teachers' classroom, sometimes postings of mobiLLab program-related material were visible 1) preparation resources from the mobiLLab website and 2) homework products from after the mobiLLab visit.

Rapport with teachers

Teachers seemed cooperative and in most cases eager to share their experiences and suggestions for the mobiLLab program. Most teachers made positive comments about the program overall and about half specifically mentioned that they would like to have mobiLLab visit their class again. One teacher was not as talkative as the others and his demeanor was neutral and suggested little about his attitude about the interview and the mobiLLab program.

As a native speaker of English with proficient, but not fluent, German language skills, interviewer strategies for dealing with difficult to understand responses were limited. Fortunately, all teachers spoke standard "high" German with me, rather than their dialect, and were agreeable and accommodating, offering clarifications to any follow-up questions.

Were interview goals achieved?

Through interviews, the interviewer largely met goals of 1) learning about how teachers use classroom resources and 2) eliciting suggestions for program improvement. The cards that represent mobiLLab preparation resources seemed to make my requests to talk about certain resources more concrete and also supported data collection, as some teachers moved them around or wrote on them, making them useful data recording tools. After several interviews, it became clear that asking teachers about the novelty factors and about their role at the mobiLLab visit did not add much new information. Therefore, subsequent interviews shifted to questions about 1) pupil products from after-visit homework (what they assigned and why), 2) how teachers integrated ML in their curriculum and 3) (when time allowed) ask teachers to draw their preparation activities on a Timeline.

Validity of teacher responses

Teacher responses to surveys and interviews should be interpreted with consideration for their motivations. Teachers consider the mobiLLab program valuable for their teaching and said they would like to work with mobiLLab in the future. Their role as a customer of the program, which involves building a positive professional relationship with mobiLLab program representatives, could have been at odds with their role as an interviewee, who is asked to provide objective and critical feedback to a member of the mobiLLab team. As such, the validity of teacher comments was likely skewed, because teachers likely chose more positive responses and may have, for example, inflated their reports of preparation times. MobiLLab faculty had this very concern, expressing suspicions of over-positive comments and inflated estimates of preparation time from teachers during a group during the 15. August, 2014 review of pilot data. An example of teachers' tendency to be more positive than constructive could be interpreted from how, even though all teachers said things went smoothly with the study survey distribution and send-back, they also expressed hopes that they would not have to deal with the surveys next year.

7.4 Analysis of school visit observation data

The author conducted observations at 14 of the 15 school visits involved in the pilot mobiLLab study.

Observation Data Quality

During four of the 14 observed school visits, two mobiLLab faculty members filled out the observation sheet. Correlation tests compared these observations of pupil behavior to check for inter-rater reliability. Large (>= .500), positive Person product-moment correlation coefficients indicate a strong match (Table 35). Looking at the Coefficients of Determination (r^2), it is clear that the raters' scores shared between 25 percent (.50 x .50) to .88 percent (.94 x .94) of their variance.

Table 36: Strong correlations between observations of pupil behavior (N=6 behaviors) by two different mobiLLab faculty, suggest high inter-rater reliability.

	Faculty M1	Faculty M2	Faculty U3	Faculty N5
Faculty R1	.88*			
Faculty R2		.55**		
Faculty R3			.94***	
Faculty R5				.50**

* p<.05 (two-tailed); **not significant ***p<01 (2-tailed); Faculty Xx=Faculty {letter code and school visit number}.

A Cohen's ĸ was calculated to determine the degree of agreement between mobiLLab faculty observations regarding the mood of the class group, for which they chose descriptive adjectives such as "interested " or "wild." Inter-rater reliability was weak, ĸ = .167, .226, .226 and .400 with no statistical significance (Table 36). This aligns with comments during observations from some faculty about how interpretation of the adjectives to describe mood was quite subjective. They sometimes had questions about the terms and/or did not have time to fill them out, as they took more time because of their ambiguity.

Table 37: Inter-rater reliability between observations from two different mobiLLab faculty for class mood (N=12 adjectives that describe class mood) was low (never significant).

	Faculty M1	Faculty M2	Faculty U3	Faculty N5
Faculty R1**	.167*			
Faculty R2		.400*		
Faculty R3			.226*	
Faculty R5				.226*

*not significant; Faculty Xx=Faculty {letter code and school visit number}.

Results about pupils' engagement

Results of observations were used to characterize pupils' engagement. They were also used to test several sub-hypotheses posed by mobiLLab staff.

Observation of pupil behavior

MobiLLab faculty indicated on an observation form, and teachers on a post-visit survey, the percentage of pupils who were engaging in behaviors of experimentation, goal directed behavior, talking about mobiLLab, socializing, drawing attention to themselves, or were distracted during a mobiLLab visit. As shown in Figure 32 and Table 37, both mobiLLab faculty and teachers indicated that more than half of pupils exhibited the first three, more "desirable" behaviors and that less than half exhibited the remaining, "less desirable" behaviors. Teachers tended to indicate that more of their pupils were exhibiting each behavior than mobiLLab staff. For most behaviors, particularly "drawing attention," teacher responses were widely distributed, suggesting some teachers interpreted the item differently than others.

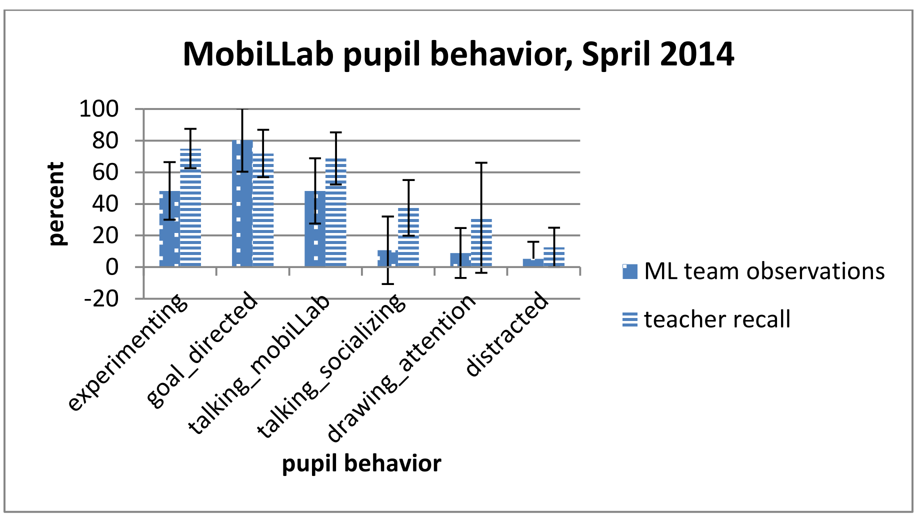


Figure 33: MobiLLab staff observations and teacher recall of pupil behaviors at the mobiLLab visit.

Table 38: MobiLLab staff observations and teacher recall of pupil behaviors at the mobiLLab visit.

Variable Name	Type of Behavior	*M* from ML Faculty	*SD*	*M* from Teacher	*SD*
beh_explore	exploratory and experimental behavior	48%	18%	75%	13%
beh_goal	goal-directed behavior	80%	20%	72%	15%
beh_talkml	talking about mobiLLab	48%	21%	69%	17%
beh_socialize	talking to socialize	11%	21%	38%	18%
beh_attention	attention-seeking behaviors	9%	16%	31%	35%
beh_distract	distracted or withdrawn behaviors	5%	11%	13%	13%

A comparison could only roughly be made between mobiLLab faculty observations at each school visit and teachers' recalled pupil behavior during a post-visit survey, which was for all of their classes that visited mobiLLab. Pearson Product-moment correlations are relatively high (with one exception, $0.73 < r < 0.98$), indicating a strong match (Table 38) for the six behaviors.

Table 39: The match between mobiLLab faculty observations ('mobiLLab x') and teacher recall ('Tex') of pupil behavior (N=6 behaviors) is relatively strong.

	Te1	Te3	Te5	Te7	Te8	Te9	Te10	Te11	Te12
mobiLLab 1	.74*								
mobiLLab 3		.82**							
mobiLLab 5			.****						
mobiLLab 7				.98***					
mobiLLab 8					.81**				
mobiLLab 9						.73*			
mobiLLab 10							.07*		
mobiLLab 11								.81*	
mobiLLab 12									.25*

*no significance info; **p<.05 (two-tailed); ***p<01 (two-tailed); ***missing teacher data. Tex=recall (all of their classes) from teacher who was at school visit x; mobiLLab x=mobiLLab observation for school visit x.

Observation of class mood

When observing class mood, mobiLLab faculty chose among a list of adjectives on the protocol worksheet. In a post-visit survey, teachers also chose among these same adjectives to describe how they remembered the class mood during the mobiLLab visit. As Figure 32 shows, the adjectives "excited," "concentrated," and "curious" were most often chosen by both mobiLLab faculty and teachers. Many teachers chose "industrious," "motivated," "interested," showing they perceived pupils' behavior to be relatively focused and engaged. Teachers tended to choose more positive adjectives to describe class mood at school visits than mobiLLab faculty.

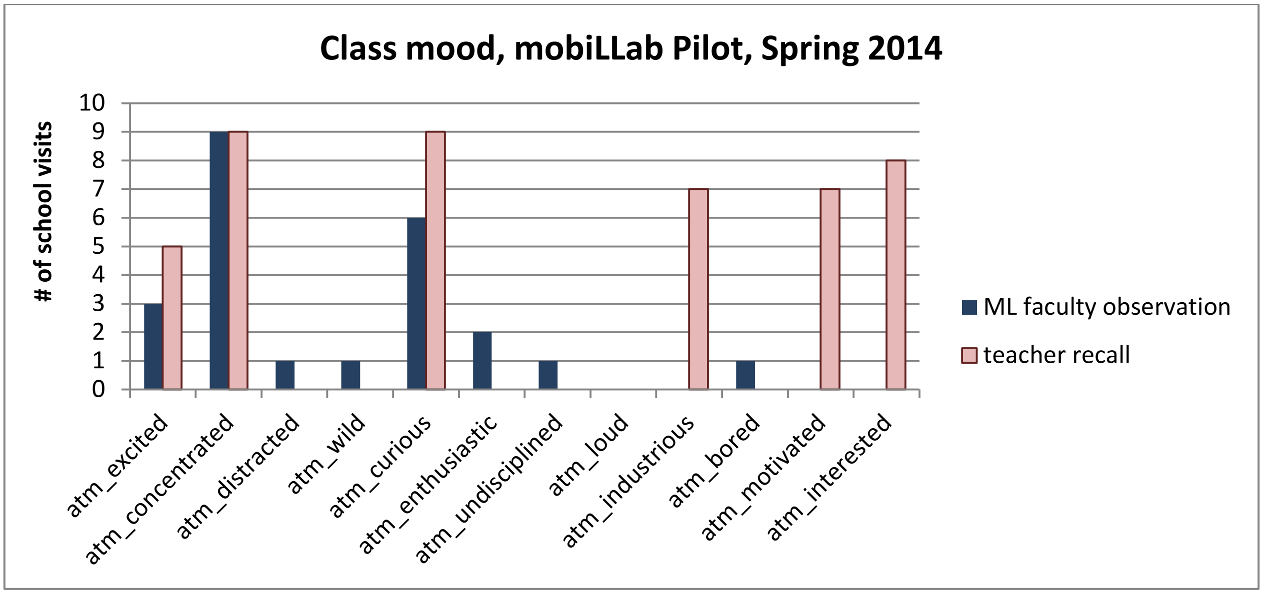


Figure 34: Adjectives chosen by mobiLLab faculty and teachers to describe class mood at school visits.

Again, comparison could only be roughly made between observations made by the mobiLLab team faculty (the author) at school visits and teachers' recall about class mood when responding to a survey. Again, the comparison was a rough one because mobiLLab faculty conducted observations at each school visit and teachers recalled pupil behavior during a post-visit survey for all of their classes that had a mobiLLab visit. Inter-rater reliability between mobiLLab and teacher adjectives was weak: Cohen's Kappa (k) values were between .167 and .408 with no statistical significance.

HYPOTHESIS: Pupils whose schedule is posted were more engaged.
All teachers posted a schedule showing which pupils worked at which posts, so the data could not be used to test this hypothesis.

HYPOTHESIS: Pupils who fill out the Journalblätter worksheets brought more objects to test
While pupils brought objects to mobiLLab visit to test with fairly high consistency (*M*=60; *SD*=19), they varied much more in whether they fill out the *Journalblatt* worksheet during the school visit (*M*=49; SD=40). As Figure 35 illustrates, comparison for each visit of how many pupils filled out the worksheets and how many pupils brought objects to test showed few matches. Therefore, this relationship was not explored further.

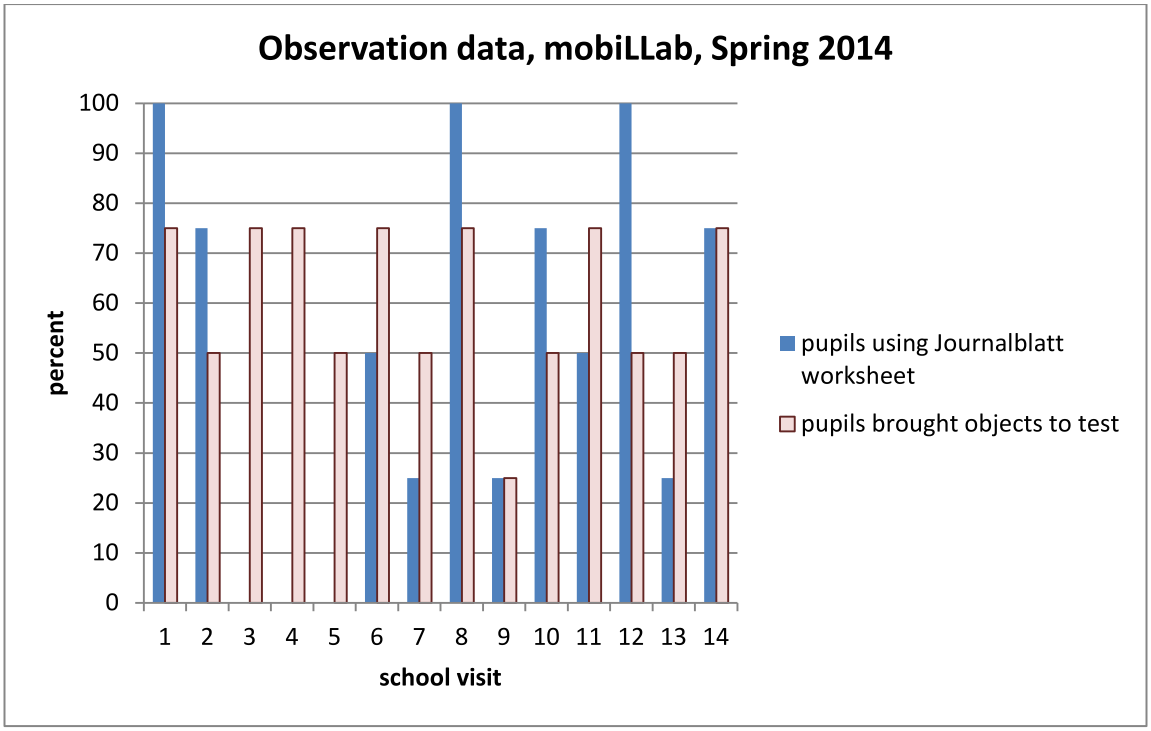


Figure 35: Filling out the 'Journalblätter' worksheets during a mobiLLab visit did not predict whether pupils brought objects to test.

SUMMARY

- MobiLLab staff and teachers (recalled in survey responses) observed pupil groups' behavior as usually on-task: 'experimenting,' 'goal-directed,' and 'talking about mobiLLab.' Observations between different mobiLLab staff, and between mobiLLab staff and teachers, were reliable.
- MobiLLab staff described class mood most often with the following adjectives: "excited," "concentrated," and "curious," suggesting pupils' behavior was relatively engaged. Teachers tended to choose more positive adjectives to describe class mood at school visits than mobiLLab faculty. Class mood observations from mobiLLab staff were different enough from teacher survey (recalled) observations that inter-rater reliability was insignificant.
- The number of objects pupils brought to mobiLLab visit to test did not match data about whether they filled out the *Journalblatt* during the school visit.
- Observers expressed concerns about ratings for a group not applying to all pupils.
- It is worth noting that when the type of class behavior was used as an independent variable during the mobiLLab pilot study, it was not a predictor of differences in pupils' affective S&T outcomes.

IV. RESULTS AND DISCUSSION

8 Examining the Role of Novelty in Pupils' Interest Development at mobiLLab

What role did novelty play in how pupils experienced the mobiLLab visit and in their affective educational outcomes? This chapter explores this question by presenting results of tests of the mobiLLab study hypotheses, which are listed in section 5.4. It begins with a review of novelty experience factors (NEF), variables that characterize how pupils perceived novelty at the mobiLLab visit. It then presents results about how novelty influence factors (NIFs) related to NEFs. Further analysis shows how the covariate variable, dispositional curiosity, is also linked to their NEFs. Following is a discussion about how the intervention, watching novelty-reducing videos about the mobiLLab experimental posts, related to pupils' NEFs. Next is a section about how NIFs related to pupils' core S&T outcomes. The next section describes how differences in the NEFs exploratory behavior and oriented feeling account for variations in how pupils' core S&T outcomes change. A final section describes how pupils' at-visit curiosity and cognitive load relate significantly to positive post-visit S&T outcomes. The statistical analysis approaches employed for these tests are described in detail in section 7.1.9.

When reviewing repeated-measures results about changes in pupils' core S&T outcomes, described in sections 8.4 and 8.5, the reader should keep the following points in mind.

- The text first describes results for within-subjects changes over time, followed by group comparisons.
- Each test is run once with technology outcomes and once with natural science outcomes, as described in section 5.4.
- The time between pre-visit and post-visit test completion varied from seven weeks to twenty-four weeks, depending upon when each class had their mobiLLab visit.
- Unlike other tables of regression results in this chapter, tables show independent variables in rows.
- For univariate results that are significant, a graph illustrates how pupil core S&T outcomes changes over time. These graphs were generated by running a MANCOVA test with a categorical version of the predictor variable, which was created using a median-split. The graphs show a pupil response scale (Y-axis) ranging from 2.0 to 4.0.

8.1 Pupils' novelty experience factors (NEFs)

Four factors that characterize pupils' novelty experience , called novelty experience factors (NEFs), were identified by drawing on the results of a factor analysis of pupil responses to at-visit survey items (analysis described on page 124). These four factors were oriented feeling, exploratory behavior, curiosity state, and cognitive load. According to means and standard deviations for these variables, shown in Figure 35, the average pupil described themselves as feeling pretty well oriented to the mobiLLab visit (*M*=3.6, *SD*=0.5, *N*=215), feeling pretty able to explore mobiLLab equipment (*M*=3.2, *SD*=0.4, *N*=211), feeling somewhat curious (*M*=2.9, *SD*=0.6, *N*=212), and having a somewhat low cognitive load (*M*=1.8, *SD*=0.4, *N*=213).

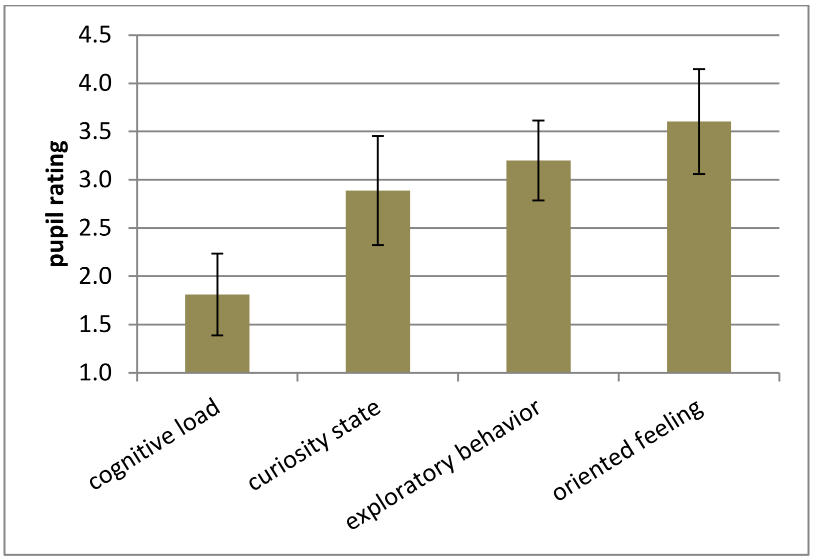


Figure 36: Pupils´ (perceived) novelty experience factors (NEFs) at the mobiLLab visit are reported cognitive load, curiosity state, exploratory behavior, and oriented feeling.

Probable floor effect with cognitive load data. It is worth noting that cognitive load responses have a relatively low rating and small variation, suggesting a possible floor effect. This means that responses were on average low enough to indicate that most pupils did not perceive very much cognitive load during the mobiLLab visit. One explanation for this is that the mobiLLab is presented to pupils, by both mobiLLab staff and their teachers, as a day to ´try things out´ and not a performance-demand day, where they should learn certain content to perform a task or test. This means that there was probably not enough variation among pupils´ responses about cognitive load to produce significant results for some regression tests.

Possible ceiling effect with oriented feeling data. Similarly, responses about how oriented pupils felt at the visit have a relatively high rating and small variation, suggesting a possible ceiling effect. This means that responses were on average high enough to indicate that most pupils felt the mobiLLab visit was well organized. It is possible that there was not enough variation among pupils´ responses about their oriented feeling to produce significant results for some regression tests.

8.2 Relating novelty influence factors (NIFs) to novelty experience factors (NEFs)

A central set of hypotheses for the mobiLLab study states that pupils with stronger novelty influence factors (NIFs) would have more positive novelty experience factors (NEFs). Pupils are described as having *stronger* NIFs if they perceived themselves as more technologically capable, visit natural science- and technology-related OSLePs more often, and scored higher on a pre-visit knowledge test. Pupils at-visit novelty experience was considered *more positive* when they reported feeling more comfortable with the mobiLLab equipment and conducting experiments (exploratory behavior), feeling more oriented to the mobiLLab visit, wanting to know more about mobiLLab equipment and science topics (curiosity state), and feeling less overwhelmed (cognitive load).

8.2.1 H2A RESULTS: Pupils' who describe themselves as more technological capability reported more positive NEFs

A multivariate multiple regression was run to examine the relation between technological capability and NEFs. The test involved the following variables:

TEST: Predictor: Tink = pupils' technological capability
DV1: ExpB: degree to which pupils explore ML equipment
DV2: OF: degree to which pupils feels oriented
DV3: CL: cognitive load
DV4: CurS: curiosity state
CV: CurT: curiosity trait

MAIN RESULTS

Table 39 shows results of the multivariate regression run with only techological capabilty as a predictor. These results indicate that pupils who described themselves as more technologically capable (Tink) reported more positive at-visit novelty experience in the form of more exporatory behavior (ExpB) ($p<.001$), less cognitive load (CL) ($p=.001$), and more curiosity state (CurS) ($p=.001$). According to the R^2 values, technological capability explained 10% of the variation in responses about exploratory behavior, 6% of the variation in responses about cognitive load and 5% of the variation in responses about curiosity state.

Table 40: Pupils' technological capability is a significant predictor of variations in their at-visit exploratory behavior, cognitive load, and curiosity state.

N=198			**Technological capability (Tink)**					
Dependent Variable	***R²***	***Adjusted R²***	***df***	***df error***	***F***	***p***	***b***	**β**
exploratory behavior	.10	.09	1	196	20.8	**<.001**	.21	.13
oriented feeling	.00	.01	1	196	0.0	.866	-.01	-.01
cognitive load	.06	.06	1	196	12.5	**.001**	-.17	-.10
curiosity state	.05	.05	1	196	10.5	**.001**	.22	.13

Table 40 shows results when both the predictor technological capability (Tink) and the covariate curiosity trait (CurT) are part of the regression model. These results indicate that, together, technological capability and curiosity trait explained 8% of the variation in responses about exploratory behavior, 26% of the variation in responses about oriented feeling, 13% of the variation in responses about cognitive load, and 5% of the variation in responses about curiosity state. Because these predictors are both significantly related to exploratory behavior, we can compare their standardized coefficients to determine which contributed more to the variations in exploratory behavior. Results shows that curiosity trait is a slightly stronger predictor of exploratory behavior (β=.10) than technological capability (β=.08). Comparisons of the standardized coefficients related to other NEFs was not possible, because each of these NEFs had only one significant predictor. That is, curiosity trait is the sole predictor of predictor of variations in oriented feeling and curiosity state and technological capability is the sole predictor of variations in cognitive load.

Table 41: Pupils' technological capability and dispositional curiosity predicted differences in some NEFs.

N=186			Technological capability (Tink)						Curiosity trait (CurT)					
Dependent Variable	***R^2***	***Adjusted R^2***	***df***	***df error***	***F***	***P***	***b***	**β**	***df***	***df error***	***F***	***P***	***b***	**β**
exploratory behavior	.08	.07	1	183	7.2	**.008**	.14	.08	1	183	10.8	**.001**	.18	.10
oriented feeling	.26	.25	1	183	2.8	.099	-.12	-.07	1	183	8.3	**.004**	.22	.12
cognitive load	.13	.12	1	183	7.1	**.008**	-.15	-.09	1	183	3.6	.059	-.11	-.06
curiosity state	.05	.04	1	183	0.0	.877	.01	.01	1	183	54.1	**<.001**	.51	.27

Two phenomena are worth noting when comparing Table 39 and Table 40. First, as a lone predictor in the regression (Table 39) technological capability explains 10% (R^2=.10) of the variation in pupils' responses about their exploratory behavior. When both technological capability and curiosity are included predictors in the regression (Table 40), one would expect this statistic to increase, as it did for the other dependent variables. Instead, the combined predictors explain slightly less, that is 8% (R^2=.08), of the variation in exploratory behavior. These unexpected results can be explained by the fact that the regression tests were conducted with a slightly different set of pupils, mostly because there were some missing responses. That is, the regression test with technological capability as the sole predictor was conducted with 198 pupil records and the regression test with both technological capability and curiosity trait as predictors was conducted with 186 pupil records.

Second, technological capability (Tink) became an insignificant predictor of curiosity state (CurS) when curiosity trait (CurT) was included in the regression model. A possible cause of this was multicollinearity between the independent variable, technological capability, and the covariate, curiosity trait; however, the regression test output show no collinearity (VIF<2). If curiosity trait were exerting a classical suppressor effect, it would have zero correlation with the dependent variable (Lancaster, 1999). However, the correlation between curiosity trait and curiosity state is significant and moderate (r =.49).

Therefore, it was thought that curiosity trait may be mediating the strength of the ability of technological capability to predict curiosity state. Further analysis to explore the role of dispositional curiosity follows.

FURTHER ANALYSIS: *The role of curiostiy trait in predicting NEFs*
Even though curiosity trait was not a direct predictor in the mobiLLab study design, but rather a covariate predictor, results above showed that it significantly predicted curiosity state, and also exploratory behavior and oriented feeling. This warranted further analysis of the relation between curiosity trait and the other NEFs. In fact, results of a multivariate regression presented in Table 41 indicate that curiosity trait as a lone preditor is linked significantly to all NEFs. A look at the R square values (R^2) show that how dispositionally curious pupils said they were accounted for 10% of the variation in their exploratory behavior, 3% of the variation in their oriented feeling, 5% of their cognitive load, and almost one-quarter of the variation in their curiosity state at the mobiLLab visit.

Table 42: Curiosity trait is a significant predictor of variations in perceived novelty experience indicators: curiosity state, exploratory behavior, oriented feeling and cognitive load.

N=186			**Curiosity trait**		
Dependent Variable	R^2	**p**	**B**	**B SE**	**ß**
exploratory behavior	0.10	**<.001**	.238	.051	.36
oriented feeling	0.03	**.017**	.167	.070	.17
cognitive load	0.05	**.002**	-.164	.054	-.21
curiosity state	0.24	**<.001**	.499	.064	.49

Curiosity trait as a predictor of curiosity state is mediated by technological capability
Because the stregth of the prediction by curiosity trait (CurT) of curiosity state (CurS) (β=.49) becomes smaller when the covariate technological capability (Tink) is part of the regression model (β=.27), a mediator effect was explored. A first step in the process was to consider the causal order of Tink and CurT. The more plausible causal order is that curiosity trait predicts technological capability. This is reflected in survey items of studies that ask people about their curiosity, which sometimes describe someone interacting with technology (Litman & Spielberger, 2003; Naylor, 2007). In contrast, survey items do no refect the less likely causal order, that technological capability predicts curiosity trait. That is, survey items to measure technological capability do not ask respondents about their curiosity (Luckay & Collier-Reed, 2012). Another theoretical argument for curiosity trait as a predictor of technological literacy comes from Self-Determination Theory (SDT), where curiosity and intrinsic motivation are described as precursors to effort and action (Deci & Ryan, 2000b). Finally, that people with a curious nature tend to be more comfortable interacting with technology is also more intuitive than vice-versa.

Results of tests for the presence of a mediator variable indeed provided evidence for this causal order. They indicate that, even though pupils' curiosity trait predicts at-visit curiosity state, the covariate technological capability mediates this relation. This means that, rather than directly predicting variations in curiosity state, shown as path ´c´ in Figure 36, the relation operates partially through the mediator variable technological capability, shown as the path formed by ´a´ and ´b.' This is evidence that instead of a direct link between dispositional curiosity and feeling curious at the mobiLLab visit, participating pupils who reported having a curious disposition also saw themselves as technologically capable. Many of these tinkerers, in turn, tended to feel more curious than their direction seeking peers. It is worth noting, however, that here and in the following discussion, results for the presence of the mediator variable are presented as an indication for future research possibilities; a detailed mediation analysis proper was beyond the scope of the thesis and was not carried out.

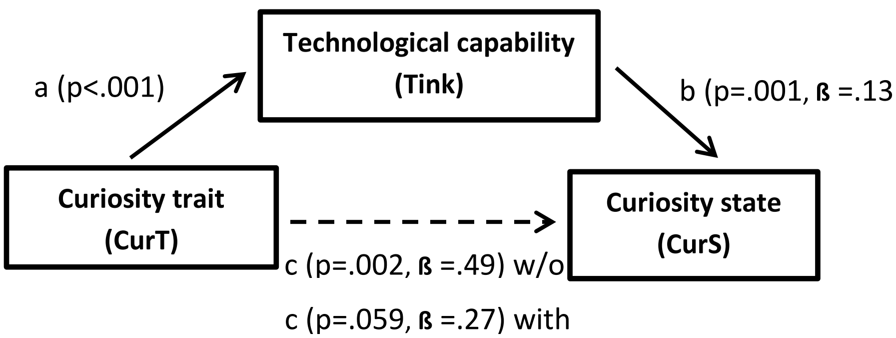


Figure 37: The ability of pupils´ dispositional curiosity to predict their at-visit curiosity state operates indirectly through the mediator technological capability (adapted from Baron and Kenny (1986)).

Mediation test detail. The four conditions of mediation (Baron & Kenny, 1986), listed here, were met.

1. The predictor (CurT) significantly predicts the outcome variable (CurS) ($p<.001$), Table 41.
2. The predictor (CurT) significantly predicts the mediator variable (Tink), $F(1, 194)=3.62$, $p<.001$, Table 67.
3. The mediator (Tink) significantly predicts the outcome (CurS) ($p=.001$, ß =.13), Table 39.
4. The predictor variable (CurT) predicts the outcome variable (CurS) less strongly when both predictor and mediator are used in a regression model with the outcome variable (CurS), revealed by comparison of Table 40 ($p<.001$, ß =.27) and Table 41 ($p<.001$, ß =.49).

Curiostiy trait as a predictor of at-visit cognitive load is mediated by technological capability.
The ability of curosity trait to predict cognitive load, (p=.002 in Table 41) becomes insignificant when technological capability is part of the regression model (p= .059 in Table 40), so a mediation effect was explored. Mediation test results, illustrated in Figure 37, indicate that, even though curiosity trait predicts pupils' at-visit cognitive load, the covariate technological capability mediates this relation. This is evidence that, rather than directly predicting variations in cognitive load, path 'c' in Figure 37, the relation operates indirectly, and completely, through the mediator variable technological capability, shown as the path formed by ´a´ and ´b.' However, carrying out a detailed mediation analysis was beyond the scope of the thesis.

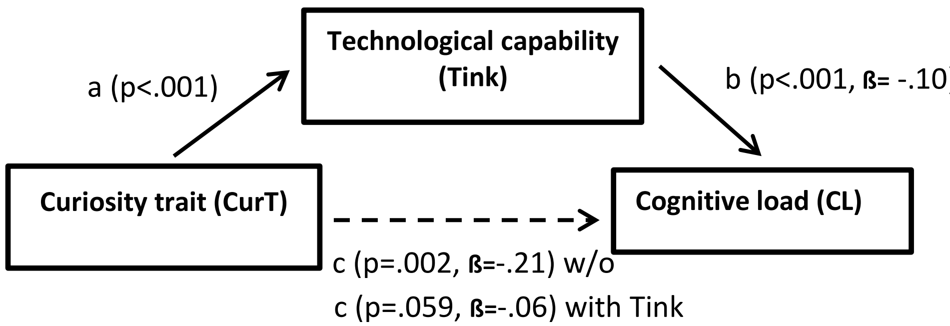


Figure 38: The ability of pupils´ dispositional curiosity to predict their at-visit cognitive load operates indirectly (and completely) through the mediator technological capability (adapted from Baron and Kenny, 1986).

Mediation test detail. The four conditions of mediation (Baron & Kenny, 1986), listed here, were met.

1. The predictor (CurT) significantly predicts the outcome variable (CL) (p=.002), Table 41.
2. The predictor (CurT) significantly predicts the mediator variable (Tink), F(1, 194)=3.62, p<.001.
3. The mediator (Tink) significantly predicts the outcome (CL) (p=.001), Table 39.
4. The predictor variable (CurT) predicts the outcome variable (CL) less strongly when both predictor and mediator are used in a regression model with the outcome variable (CURS), revealed by comparison of Table 41 (significant p=.002), and Table 40 (insignificant p=.059).

FURTHER ANALYSIS: *NIF-NEF correlations*
The regression and mediation analysis above showed that the covariate curiosity trait confounds the relation between technological capability and two NEFs. This was grounds to examine correlations between pairs of NIFs and NEFs to see if any strong paired relationships existed. While there are no strong correlations, several pairs are moderately correlated, as shown by the correlation coefficients in Table 43. For example, technological literacy (r=.22) and curiosity trait (r=.49) both correlate with curiosity state. Moreover, curiosity trait is correlates with exploratory behavior (r=.32) and technoligcal capability (r=.28), indicating curiosity trait plays a strong role in several aspects of pupils' at-vist novelty experience.

Table 43: Correlations between NIFs and NEFs show several moderately strong associations.

Variable	NIFs					NEFs			
	Tink	V_NS	V_TECH	Know	CurT	ExpB	OF	CL	CurS
Technological capability (Tink)	--	ns	-.38*	.24*	.39*	.28*	ns	-.25*	.22*
Previous natural science OSLeP visits (V_NS)	--	--	.45*	ns	-.17**	ns	ns	ns	ns
Previous technology OSLeP visits (V_TECH)	--	--	--	.21*	-.37*	-.31*	ns	ns	-.26*
Pre-visit knowledge (Know)	--	--	--	--	.20*	ns	ns	ns	.18**
Curiosity trait (CurT)	--	--	--	--	--	.32*	.17*	-.21*	.49*
Exploratory behavior (ExpB)	--	--	--	--	--	--	.56	-.56*	.43*
Oriented Feeling (OF)	--	--	--	--	--	--	--	-.30*	.28*
Cognitive Load (CL)	--	--	--	--	--	--	--	--	-.35*
Curiosity state (CurS)	--	--	--	--	--	--	--	--	--

*ns=not significant. *p<.01 (two-tailed); **p<05 (two-tailed); significance values for these multiple comparisons were examined for false positives (Type I errors) according to Benjamini and Hochberg (1995), http://www.biostathandbook.com/multiplecomparisons.html.*

<u>H2A RESULTS SUMMARY</u>

This subsection provides a summary interpretation of results in light of the original hypothesis, correlation statistics, and mediation results.

Hypothesis supported: technological capability predicts positive novelty experience. More specifically, pupils who describe themselves as more technologically capable reported more positive novelty at the mobiLLab visit in the form of more exploratory behavior, more curiosity state, and less cognitive load. A new, related finding was about the strong link between the covariate, curiosity trait, and technoloical capability. Together, techological capability and curiosity trait predict positive novelty for all four NEFs: more exploratory behavior, better oriented to the setting, more curiosity state, and less cognitive load.

Interpretation of correlation analysis

Several of the correlation statistics parallel other research about curiosity.

> *Curiosity state and exploratory behavior correlate*. A correlation analysis shows that pupils at mobiLLab who feel curious report more exploratory behavior (r=.43). While the correlation does not show that feeling curious at an OSLeP causes exploratory behavior, it shows co-existence of the two factors, which is in line with how Berlyne (1960) emphasizes curiosity as a motivational state that stimulates exploratoy behavior.

Curiosity trait and curiosity state. A moderate correlation between curiosity trait and curiosity state (r=.49) is evidence for the concept put forward by Naylor (2007) that curiosity trait predicts curiosity state.

NOTE: The variables technological capability (Tink) and how oriented the pupils were (ORIENT) were not significantly correlated (p=.631), so significant results were not expected.

Interpretation of Mediation Tests

The results of mediation tests, shown in Figure 36 and Figure 37, are consistent with a mediation effect. That is, they indicate that the strength of curiosity trait to predict curiosity state and cognitive load is mediated by technological capability. These results are evidence that technological capability and curiosity trait are both strong influencers of novelty experience at OSLePs. Results also support a causal order beginning with curiosity trait, which is mediated by technological capability. That is, they support the idea that pupils with a curious disposition tend to tinker with technology, a tendency that is linked to feeling more curious and less cognitive load at the mobiLLab visit.

8.2.2 H2B RESULTS: Pupils who frequent technology OSLePs reported more positive NEFs

Results of a multivariate multiple regression (Table 43) show that pupils who more frequently visited OSLePs experienced more postive at-visit novelty. According to the R^2 values, how often pupils frequented OSLePs explained 15 percent of the variations in responses about their exploratory behavior, 3 percent of the varation in their oriented feeling, 3 percent of the variation in their cognitive load, and 9 percent of the varation in their curiosity state. A look at the significance and β values for each NEF tells us how much visiting each type of OSLeP contributed to these predictions. Results show that technology-related OSLePs (V_Tech), such as science centers, is the only significant predictor, relating to greater exporatory behavior (ExpB) ($p<.001$), better oriented feeling (OF) ($p=.027$), and feeling more curiosity (state) (CurS) ($p<.001$) during the mobiLLab visit. No significant relations were found between how often pupils visited natural-science related OSLePs (V_NS) and NEFs. For a detailed description of what types of OSLePs the the pupils frequented, see page 109.

<u>THE TEST VARIABLES</u>

The following variables were involved in the test:

Predictor: V_NS = how often pupils frequent OSLePs related to natural science
Predictor: V_TECH = how often pupils frequent OSLePs related to technology
DV1: ExpB: degree to which pupils explore ML equipment.
DV2: OF: degree to which pupils feels oriented.
DV3: CurS: curiosity state
DV4: CL: cognitive load

Table 44: Pupils who frequent technology-related OSLePs reported greater at-visit exploratory behavior, better oriented feeling and greater curiosity state.

N=164			**OSLEP - natural science (IV)**						**OSLEP - technology (IV)**					
Dependent Variable	***R^2***	***Adjusted R^2***	***df***	***df error***	***F***	***p***	***b***	**β**	***df***	***df error***	***F***	***p***	***b***	**β**
exploratory behavior	.15	.14	1	171	1.9	.164	.05	.04	1	171	28.3	**<.001**	-.20	-.12
oriented feeling	.03	.02	1	171	0.7	.390	.04	.04	1	171	4.9	**.027**	1.40	-.05
cognitive load	.03	.01	1	171	1.0	.328	.04	.03	1	171	1.5	.222	.86	.01
curiosity state	.09	.08	1	171	2.2	.142	.04	.07	1	171	17.0	**<.001**	.98	-.07

<u>H2B RESULTS SUMMARY</u>

Hypothesis supported: museum ´savvy´predicts variations in novelty experience. These results support the hypthesis that pupils who more often visit OSLePs, such as science centers and hands-work workshops, experienced more positive novelty at the mobiLLab visit in the form of more exploratory behavior, feeling better oriented and feeling more curious. Similarly, Kabuto and Olstad (1981) and Falk et al. (1978) describe how learners who have more knowledge about how to navigate a given OSLeP, a skill Falk and Dierking call ´museum savvy´ (2011, p. 80), helps learners feel less anxious and more oriented, and is linked to their exploratory behavior at OSLePs.

NOTES: Previous experience with natural science-related OSLePs had no significant effect on novelty indicators, probably because these OSLePs are less like mobiLLab.

The absence of a significant relation between frequenting similar OSLePs and cognitive load may be due to the floor effect with cognitive load responses.

8.2.3 H2C RESULTS: Pupils with more pre-visit knowledge reported mixed NEFs

Results of a multivariate regression (Table 44) show that pupils who scored better on a pre-visit test about electromagnetic spectrum concepts (Know) reported feeling significantly more curious (curiosity state, CurS) (p=.015) at the mobiLLab visit. According to the R^2 value, pre-visit knowledge predicted three percent of the variation in pupils' responses about their curiosity state at the mobiLLab visit. There was an insignificant relation between previous knowledge (Know) and the remaining novelty experience factors: exploratory behavior (ExpB) (p=.171), oriented feeling (OF) (p=.758), and cognitive load (CL) (p=.146). The following variables were involved in the test:

Predictor: Know: pupils´ score on 4-question test about electromagnetic radiation concepts.
DV1: ExpB: degree to which pupils explore ML equipment.
DV2: OF: degree to which pupils feels oriented.
DV3: CurS: curiosity state
DV4: CL: cognitive load

Table 45: Pupils with greater pre-visit knowledge of electromagnetic spectrum concepts reported significantly greater curiosity state at the mobiLLab visit.

N=205	Pre-visit knowledge (IV)							
Dependent Variable	***R^2***	***Adjusted R^2***	***df***	***df error***	***F***	***p***	***b***	**β**
exploratory behavior	.01	.01	1	190	1.9	.171	.05	.05
oriented feeling	.00	.01	1	190	0.1	.758	-.01	.00
cognitive load	.01	.01	1	190	2.1	.146	-.05	-.05
curiosity state	.03	.03	1	190	6.0	**.015**	.11	.08

H2C RESULTS SUMMARY: *Hypothesis partially supported: better knowledge predicts curiosity state*

Pupils with greater previous knowledge of electromagnetic concepts felt more curious at the mobiLLab visit, which could be explained by their better base of relevant knowledge. This could reflect a situation at the mobiLLab visit where less knowledgeable pupils were somewhat distracted by trying to understand electromagnetic concepts, while their better-scoring peers already had this knowledge and could therefore focus on their motivations to learn and experience more through the mobiLLab activities. These desires for acquiring new knowledge and new sensory experience have been described as curiosity by Berlyne (1960). These findings about how better content knowledge related significantly to curiosity are parallel to findings from von Stumm et al. (2011), who identified a link between intellectual curiosity and academic performance. Through a meta-analysis, investigators showed that intellectual curiosity is a predictor of academic performance, measured primarily through grade point average.

Probable reasons that a good pre-visit test score did not predict variations in other NEFs are as follows.

- The insignificant relation between cognitive load (CL) and pre-visit knowledge (Know) can be explained by the floor effect with the variable cognitive load. Also, a significant result was not expected because the variables were not significantly correlated (p=.105).
- Because pre-visit knowledge (Know) and oriented feeling (OF) were not significantly correlated (p=.862), a significant result was not expected.
- Because pre-visit knowledge (Know) and exploratory behavior (ExpB) were not significantly correlated (p=.163), a significant result was not expected.

8.3 The intervention: watching more novelty-reducing videos did not affect NEFs

Results from a multivariate regression, Table 45, showed no significant relations between the number of novelty-reducing videos that pupils watched (VidNo) and at-visit novelty experience indicators (NEFs): exploratory behavior (ExpB), oriented feeling (OF), cognitive load (CL), and curiosity state (CurS). The following variables were involved in the test.

Predictor: VidNo=number of novelty-reducing videos pupil watched.
DV1: ExpB: degree to which pupils explore ML equipment.
DV2: OF: degree to which pupils feels oriented.
DV3: CurS: curiosity state
DV4: CL: cognitive load

Table 46: The number of novelty-reducing videos pupils watched during preparation did not significantly relate to at-visit novelty indicators.

N=205			**Number of Videos Watched***				
Dependent Variable	***R^2***	***Adjusted R^2***	***df***	***df error***	***F***	***p***	***b***
exploratory behavior	0.01	0.01	1	203	2.1	.152	.027
oriented feeling	0.01	0.00	1	203	0.9	.333	.025
cognitive load	0.00	0.00	1	203	0.5	.460	.015
curiosity state	0.00	0.00	1	203	0.2	.632	.013

* when pupils reported watching 6 videos, it was assumed that they watched 4 videos.

H3 SUMMARY: *Hypothesis not supported: watching videos did not affect pupils' novelty experience.*
These results do not support the hypothesis that pupils who watched more novelty-reducing videos would experience more positive novelty at the mobiLLab visit. Researchers may have overestimated the expected effect of the treatment. Novelty-reducing videos were developed for 6 of the experimental posts and lasted about 120 seconds each. This is relatively short in comparison with the preparation that both the treatment and control group experienced, which according to mobiLLab teacher reports lasts about six hours (Cors, 2013). The 120-second novelty reducing videos were also short in comparison to the 12-minute E-Learning sequences for each post, which were also available to both treatment and control pupils. A detailed description about how pupils accessed the novelty-reducing videos via the mobiLLab online E-Learning is on page 91.

FURTHER ANALYSIS: *technological capability did not moderate effects of novelty-reducing video*
The purpose of the novelty-reducing videos was to help pupils feel less inhibited about working with the mobiLLab equipment. One could guess that the pupils who describe themselves as less technologically capable (Tink) would report a bigger change in exploratory behavior (ExpB) if they watched more videos (VidNo) than their more technologically capable pupils. To explore the relationship between these three variables, a multiple regression was conducted. The following variables were involved in the test:

TEST: Predictor: VidNo = number of novelty-reducing videos pupil watched.
Predictor: VidNoxTink = interaction of VidNo and Tink (technological capability).
DV1: ExpB: degree to which pupils explore ML equipment.

NOTE: Correlation among the three variables showed there was no reason for concern about possible multicollinearity from creating the interaction variable, VidNoxTink.

Results of a multiple regression, Table 46, showed no significant relation between the interaction variable, VidNoxTink, and exploratory behavior ExpB (p=.221). That is, pupils' technological capability did not moderate, or explain the strength of the effect of, watching the novelty-reducing videos on their exploratory behavior. This underscores the conclusion that researchers overestimated the effect that the 120-second novelty-reducing videos would have on pupils' at-visit novelty experience.

Table 47: The technological capability of a pupil does not explain variations in the effect of watching novelty-reducing videos on exploratory behavior (multiple regression).

				Number of videos watched (VidNo)				**Technological Capability (Tink)**				**Interaction (VidNoxTink)**			
Dependent Variable	**R^2**	**Adj R^2**	***P***	***B***	***B SE***	**ß**	***p***	***B***	***B SE***	**ß**	***p***	***B***	***B SE***	**ß**	***p***
exploratory behavior (ExpB)	.092	.078	**<.001**	-.088	.093	-.315	.345	.141	.063	.199	**.026**	.038	.031	.422	.221

8.4 Relating NIFs to changes in pupils' core S&T outcomes

To examine the relations between NIFs and changes in pupils' core S&T outcomes from pre-visit to post-visit, multivariate regression tests were run.

WITHIN-SUBJECT RESULTS: *Technological capability related to how outcomes change*
A summary of multivariate test results presented in Table 47 shows how NIFs related to two groups of pupils' core S&T outcomes: outcomes related to technology and outcomes related to natural science. The bottom half of the table lists within-subjects statistics that indicate how NIFs account for variations in changes in outcomes from pre-visit to post-visit. Here one sees that pupils' technological capability (Tink) accounts for significant variations in changes in technology outcomes (p=.017) and natural science outcomes (p=.035). Also, whether a pupil frequents natural science-related OSLePs (V_NS), significantly explains variations in changes in natural science outcomes (p=.022). Following the table are descriptions of univariate results, which describe the nature of these relations. Gender did not play a role in the strength of the significance of within-subject predictions. Frequenting technology-related OSLePs, pre-visit knowledge test scores, and science and math grades were not significant predictors of variations in changes in S&T core outcomes.

NOTE: Unlike the results that are presented in other tables in this chapter, the repeated-measure multivariate regression results in Table 47 are reported with independent variables in the rows. This is done to be consistent with other reporting of repeated measures for OSLePs (Kubota and Olstad, 1991; Anderson & Lucas, 1997).

DIFFERENCES BETWEEN GROUPS
Between-groups statistics, listed in the top half of Table 47, also show differences between sample groups. First, results show that predictors of more overall positive technology outcomes were technologically capability (p<.001) and frequency of technology-related OSLeP visits (p<.001). And predictors of more overall positive natural science outcomes were more technologically capability (p<.001), frequency of technology-related OSLeP visits (p<.001) and natural science-related (p=.017) OSLePs visits, and better science grades (p<.001). However, pupils with different pre-visit knowledge and math grades did not have significantly different S&T core outcomes.

Table 48: Pupils´ technological capability and how often they visit natural science-related OSLePs significantly accounted for variations in changes for some core S&T outcomes.

	technology outcomes						natural science outcomes					
Independent Variable	*df*	*df error*	*F*	*p*	η_p^2	CV	*df*	*df error*	*F*	*p*	η_p^2	CV
Between-groups comparisons: multivariate effects (p<0.05)												
technological capability	3	167	32.06	**<.001**	0.37	a	3	166	8.73	**<.001**	0.14	b
frequent techn OSLePs	3	147	13.58	**<.001**	0.22	a	3	142	3.50	**.017**	0.07	b
frequent NS OSLePs	3	147	0.33	.802	0.01	a	3	142	3.44	**.019**	0.07	b
pre-visit knowledge	3	162	1.52	.211	0.03	a	3	162	1.52	.211	0.03	b
science grades	3	169	2.77	.044	0.03	a	3	168	8.60	**<.001**	0.13	a
math grades	3	169	1.79	.152	0.03	a	3	168	0.30	.824	0.01	a
Within-subjects changes over time, from pre- to post-survey: multivariate effects (p<0.05)												
technological capability	3	167	3.49	**.017**	0.06	b	3	166	2.94	**.035**	0.05	b
frequent techn OSLePs	3	147	1.69	.171	0.03	a	3	142	2.55	.058	0.05	b
frequent NS OSLePs	3	147	0.34	.797	0.01	a	3	142	3.30	**.022**	0.07	b
pre-visit knowledge	3	162	0.20	.896	0.00	b	3	162	0.90	.445	0.02	b
science grades	3	169	0.65	.585	0.01	b	3	168	0.73	.535	0.01	b
math grades	3	169	0.70	.552	0.01	b	3	168	1.79	.150	0.03	b

techn = technological-related, NS = natural science related. CV= covariate. [a] gender was a significant covariate. b gender was not a significant covariate.

TEST VARIABLES

The tests involved the following variables:

Predictor: Tink = pupils' technological capability
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Tint: Pupil interest in technology
DV2: Tatt: Pupil attitude towards technology
DV3: Tsc: Pupil self-concept with respect to technology
CV: Gen: Gender (1=girl; 0=boy)

Predictor: Tink = pupils' technological capability
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Sint: Pupil interest in natural science
DV2: Satt: Pupil attitude towards natural science
DV3: Ssc: Pupil self-concept with respect to natural science
CV: Gen: Gender (1=girl; 0=boy)

Predictor: V_NS = how often pupils visit natural science OSLePs
Predictor: V_TECH = how often pupils visit technology OSLePs
Repeated measurement of DVs: Survey (pre-visit, post-visit)

DV1: Tint: Pupil interest in technology
DV2: Tatt: Pupil attitude towards technology
DV3: Tsc: Pupil self-concept with respect to technology
CV: Gen: Gender (1=girl; 0=boy)

Predictor: V_NS = how often pupils visit natural science OSLePs
Predictor: V_TECH = how often pupils visit technology OSLePs
Repeated measurement of DVs: Survey (pre-visit, post-visit)
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Sint: Pupil interest in natural science
DV2: Satt: Pupil attitude towards natural science
DV3: Ssc: Pupil self-concept with respect to natural science
CV: Gen: Gender (1=girl; 0=boy)

Predictor: (Between subjects): Know
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Tint: Pupil interest in technology
DV2: Tatt: Pupil attitude towards technology
DV3: Tsc: Pupil self-concept with respect to technology
CV: Gen: Gender (1=girl; 0=boy)

Predictor: (Between subjects): Know
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Sint: Pupil interest in natural science
DV2: Satt: Pupil attitude towards natural science
DV3: Ssc: Pupil self-concept with respect to natural science
CV: Gen: Gender (1=girl; 0=boy)

Predictor: (Between subjects): GrS=grade in science class
Predictor: (Between subjects): GrM=grade in math class
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Tint: Pupil interest in technology
DV2: Tatt: Pupil attitude towards technology
DV3: Tsc: Pupil self-concept with respect to technology
CV: Gen: Gender (1=girl; 0=boy)

Predictor: (Between subjects): GrS=grade in science class
Predictor: (Between subjects): GrM=grade in math class
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Sint: Pupil interest in natural science
DV2: Satt: Pupil attitude towards natural science
DV3: Ssc: Pupil self-concept with respect to natural science
CV: Gen: Gender (1=girl; 0=boy)

8.4.1 H4B1 UNIVARIATE RESULTS: Technologically capable pupils have more positive & more resilient core S&T outcomes

This section describes significant univariate results from the repeated measures tests, which show how pupils' technological capability related to how individual core S&T outcomes changed. Within-subjects results show that differences in pupils' technological capability accounted for variations in changes in their attitude to technology and interest in natural science from pre- to post-visit. After the within-subject results, is a description of between groups results, which show that pupils who describe themselves as more technologically capable have more positive core S&T outcomes overall.

WITHIN-SUBJECTS RESULTS: *Less technologically capable pupils show more improved attitude to technology*

Univariate results show that mobiLLab supports development of a more positive attitude towards technology among less technologically capable pupils, from the pre- to the post-visit survey, in comparison with their more technologically capable peers, $F(1,169)=1.26$, $p=.003$. This is illustrated in a MANCOVA graph shown in Figure 38, where one sees how more technologically capable pupils started with a better attitude towards technology, an attitude remained virtually unchanged after the visit. Meanwhile, less technologically capable pupils' attitude towards technology improved significantly more, with small effect ($\eta_p^2=.03$).

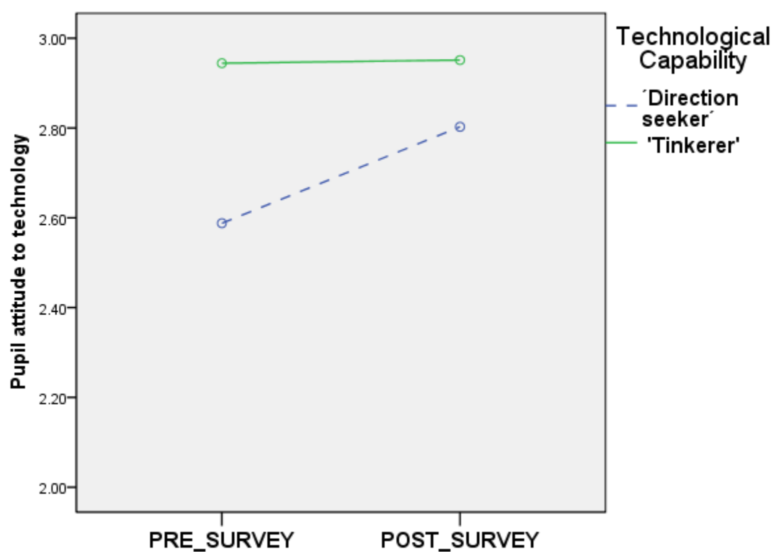


Figure 39: Direction seekers experienced a moderately greater improvement in attitude towards technology than their more technologically capable peers.

WITHIN-SUBJECTS RESULTS: *More technologically capable pupils have a more positive and more resilient interest in natural science*

Univariate results from the regression showed no significant difference between tinkerers and direction seekers for natural science outcomes. However, results of a MANCOVA analysis, Figure 39, showed that interest in natural science decreases significantly more (with small effect) more for less technologically capable pupils than for ´tinkerers,´ who had almost no decrease in interest $F(1,168)=5.24$, $p=.023.$, $\eta_p^2=.03$.

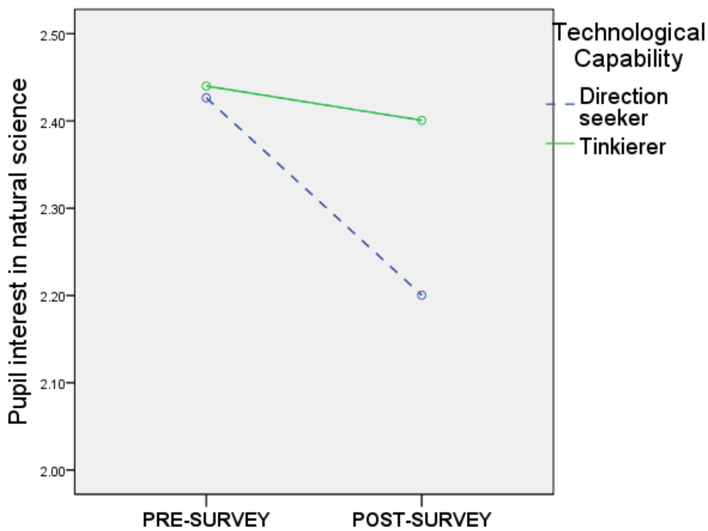


Figure 40: Direction seekers showed a significantly greater decrease in interest in natural science than their more technologically capable peers.

H4A1 RESULTS SUMMARY: *Hypothesis supported: More technologically capable pupils will have more positive pre-visit core S&T outcomes that remained more positive after the visit.*

Results from the mobiLLab pilot study, page 66, also showed technological capability as a predictor of how pupils' core S&T outcomes changed from before to after the mobiLLab visit. Depending upon whether pupils described themselves as tinkerers (more technologically capable) or direction seekers (less technologically capable), their core S&T outcomes were as follows.

- Tinkerers' S&T outcomes are more resilient. Tinkerers showed less change in their (above average) attitude towards technology than their direction-seeking peers, which could reflect that their interest in and self-concept to technology is a relatively strong dispositional trait, whereas direction seekers interest is less ingrained. The difference between how outcomes for the two groups changed is small (small effect sizes).

- Tinkerers generally have more positive S&T outcomes. Between-subjects findings provide evidence that pupils who describe themselves as more technologically capable report more positive interest, attitude and self-concept, both before and after the mobiLLab visit.
- For direction seekers, the mobiLLab experience supports development of a more positive attitude to technology.
- Direction seekers' also show a significantly greater decrease in natural science interest than their technologically capable peers. These results most likely reflect how the mobiLLab program is designed to support development of more positive attitudes towards working with technology but not towards the discipline of natural science.

DIFFERENCES BETWEEN GROUPS

Between-group univariate results show significant differences between groups. That is, pupils who described themselves as more technological capability had more positive technology-related outcomes: interest, $F(1,169)= 27.5$, $p<.001$, attitude, $F(1,169)= 15.5$, $p<.001$, self-concept, $F(1,169)= 37.7$, $p<.001$. Likewise, between-subject univariate results show significant relations between technological capability and all natural science outcomes: interest, $F(1,168)= 8.8$, $p=.003$, attitude, $F(1,168)= 6.3$, $p=.013$, self-concept, $F(1,168)=25.1$, $p<.001$.

8.4.2 H4B2 UNIVARIATE RESULTS: Frequenting technology OSLePs was linked to how pupils' natural science interest changed

This section describes significant univariate results from the repeated measures tests for predictors about the frequency with which pupils visit OSLePs. Within-subjects results show that differences in how often pupils frequented OSLePs accounted variations in how their interest in natural science changed from pre- to post-visit. Between-group results show significant differences in pupils' outcomes depending upon which types of OSLePs they frequent.

<u>WITHIN-SUBJECT RESULTS:</u> *How often pupils frequented OSLePs accounted for how their interest in natural science changed*

Univariate regression results indicate a significant relation between frequenting natural science-related OSLePs and pupils natural science interest, $F(1,144)=6.17$, $p=.014$. The graph from a MANCOVA analysis, shown in Figure 40, illustrates how pupils who more often visited natural science-related OSLePs started out with more interest in natural science, but show a significantly greater decrease in interest in natural science. The MANCOVA analysis shows that this was a slight difference (small effect, $\eta_p^2=.02$).

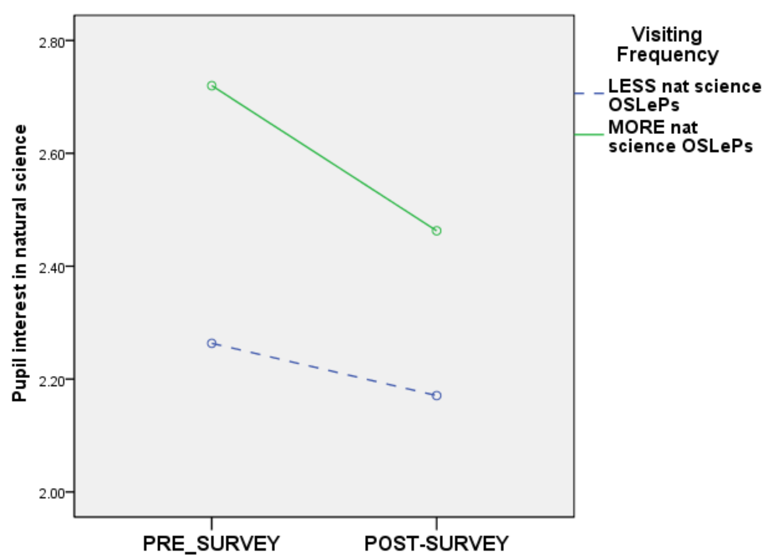


Figure 41: Pupils who more frequently visited natural science OSLePs start with greater interest in natural science, but lose significantly more interest from before to after the visit.

<u>DIFFERENCES BETWEEN GROUPS</u>

Between-subject univariate results show significant differences in changes in pupils' outcomes depending upon whether they frequented certain types of OSLePs. This is evident in how pupils who frequent technology-related OSLeP, such as science centers, have more positive technology outcomes and more positive natural science outcomes. Similarly, pupils who frequent natural science OSLePs, such as nature centers, had more positive natural science interest in and self-concept to natural science. However, pupils who frequent natural science OSLePs did not have significantly different technology outcomes. Detailed univariate statistics are as follows.

- Pupils who reported that they frequented more technology OSLePs had more positive technology-related outcomes: interest, F(1,149)= 37.5, p<.001, attitude, F(1,149)= 17.8, p>.001, self-concept, F(1,149)= 21.5, p<.001.
- Pupils who reported that they frequented more technology OSLePs had more positive natural science outcomes: interest, F(1,144)=9.2 , p=.003, attitude, F(1,144)= 3.9, p=.050, self-concept, F(1,144)=7.1 , p=.008.
- Pupils who reported that they frequented more natural science OSLePs had no significant differences between their overall technology outcomes.
- Pupils who reported that they frequented more natural science OSLePs, had no more significant attitude, F(1,144)= 3.5, p=.063, but had a greater interest, F(1,144)= 10.3, p=.002, and a more positive self-concept to natural science , F(1,144)= 4.4, p=.027, than their peers who visited them less often.

H4A2 RESULTS SUMMARY

Hypothesis partially supported: Frequenting similar OSLePs predicted more positive outcomes AND, unexpectedly, also predicted changes in outcomes. That is, results support the hypotheses that pupils who more often visit natural-science OSLePs had more positive interest in natural science, overall, a between-subjects phenomenon. However, the data also show that pupils who more often visit natural science OSLePs experienced a greater decrease in natural science interest than their peers who have less experience with natural-science OSLePs. This decrease in natural science interest by those pupils who more frequently visit other OSLePs could be explained by unmet expectations. That is, perhaps due to their experiences with places like natural history museums and botanical gardens, these pupils imagined working with, for example, plant materials and animals, rather than the equipment at the mobiLLab visit, which left them feeling less interest in the science having to do with mobiLLab.

The type of OSLeP visited makes a difference. It is noticeable from between-subjects results that pupils who more often visited natural science-related OSLePs had more positive natural science-related outcomes, but not more positive technology-related outcomes. Similarly, results from the mobiLLab pilot study also show that the *type* of OSLSEP experience (Cors, 2015) was a strong predictor (large effect) of overall outcomes. That is, pupils who previously visited technology-related OSLePs, such as science centers and science YouTube films, had significantly more positive technology-related outcomes (η_p^2 =.28;) and, likewise, pupils who frequented natural science-related OSLePs, such as nature centers, had significantly greater natural science outcomes (η_p^2 =.15).

8.4.3 H4B3 RESULTS: Pupils' pre-visit content knowledge did not relate significantly to how their core S&T outcomes change

8.4.4 H4B3 RESULTS: Pupils' math and science grades did not relate significantly to how their core S&T outcomes change

8.5 Relating exploratory behavior & oriented feeling to core outcomes

Results of a repeated-measures multivariate regression, provided in Table 48, show pupils' exploratory behavior and oriented feeling are significant predictors of variations in how pupils´ core S&T outcomes changed (within-subject results). That is, exploratory behavior was significantly linked to changes in natural science S&T outcomes (p=.015) and oriented feeling was significantly linked to changes in technology-related S&T outcomes (p=.044). Univariate results described in this section provide insight into the nature of these significant relationships.

NOTE: Unlike the results that are presented in other tables in this chapter, the repeated-measure multivariate regression results in Table 47 are reported with independent variables in the rows. This is done to be consistent with other reporting of repeated measures for OSLePs (Kubota and Olstad, 1991; Anderson & Lucas, 1997).

Table 49: Pupils´ exploratory behavior and oriented feeling explained changes in some S&T outcomes.

	technology outcomes						**natural science outcomes**					
Independent Variable	***df***	***df error***	***F***	***p***	η_p^2	**CV**	***df***	***df error***	***F***	***p***	η_p^2	**CV**
Between-groups comparisons: multivariate effects (p<0.05)												
exploratory behavior	3	171	6.93	**<.001**	.11	a	3	169	6.63	**<.001**	.11	b
oriented feeling	3	172	0.89	.449	.02	a	3	171	0.66	.581	.01	a
Within-subjects changes from pre- to post-visit survey: multivariate effects (p<0.05)												
exploratory behavior	3	171	1.58	.196	.03	b	3	169	3.59	**.015**	.06	b
oriented feeling	3	172	2.75	**.044**	.05	b	3	171	0.23	.873	.00	b

CV= covariate. [a] gender was a significant covariate. [b] gender was not a significant covariate.

<u>DIFFERENCES BETWEEN GROUPS</u> *(between-subject results)*

Between-subjects statistics show significant differences between groups. That is, results show that pupils who explored more had overall more positive technology (p<.001) and natural science (p<.001) outcomes. Whether or not pupils felt oriented to the mobiLLab did not significantly predict variations in their overall outcomes.

TEST VARIABLES

The tests involved the following variables:

TESTS: Predictor: ExpB = exploratory behavior
Predictor: OF = oriented feeling
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Sint: Pupil interest in natural science
DV2: Satt: Pupil attitude towards natural science
DV3: Ssc: Pupil self-concept with respect to natural science
CV: Gen: Gender (1=girl; 0=boy)

Predictor: ExpB = exploratory behavior
Predictor: OF = oriented feeling
Repeated measurement of DVs: Survey (pre-visit, post-visit)
DV1: Sint: Pupil interest in natural science
DV2: Satt: Pupil attitude towards natural science
DV3: Ssc: Pupil self-concept with respect to natural science
CV: Gen: Gender (1=girl; 0=boy)

8.5.1 H4B1 UNIVARIATE RESULTS: Explorers have more positive & more resilient core S&T outcomes

This section describes significant univariate results the repeated-measures tests that show how the degree to which pupils explored mobiLLab equipment related to changes in their responses about individual core S&T outcomes. Within-subjects results show that differences in exploration significantly accounted for how pupils' interest in and self-concept to natural science changed from pre- to post-visit survey. Between groups results show that pupils who explored more were those pupils who had more positive S&T outcomes before and after the mobiLLab visit.

WITHIN-SUBJECT RESULTS: *Explorers' interest and self-concept in natural science decreases less*

Univariate results show a significant link between exploratory behavior and interest in and self-concept to natural science: interest, $F(1,171)=7.99$, $p=.005$; self-concept. $F(1,171)=4.60$, $p=.003$. MANCOVA analysis, Figure 41, illustrates how pupils who reported more exploratory behavior maintained their interest in and self-concept to natural science, while their peers who explored less, reported a significantly greater decrease in these outcomes. The MANCOVA analysis shows that the strength of the relations between exploratory behavior and as a predictor of interest in natural science and of self-concept are small (both effect sizes are $\eta_p^2=.02$).

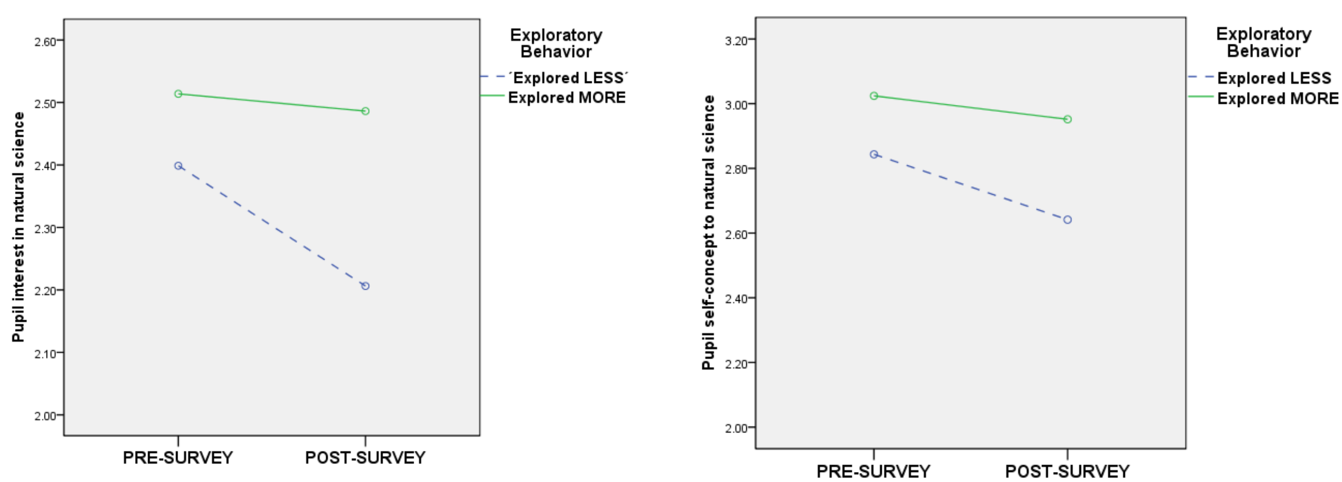


Figure 42: Pupils who reported more exploratory behavior had significantly greater interest and self-concept related to natural science, which decreased less from pre- to post-visit survey.

NOTEWORTHY: *Univariate results show significant link between exploratory behavior and self-concept to technology.* That is, even though multivariate regression results were insignificant, univariate results show a significant relation between exploring and self-concept to technology, $F(1, 173)=4.66$, $p=.032$, $\eta_p^2=.02$. This means that the relation between exploratory behavior and self-concept to technology is expressed only at univariate level and that the combined group of core S&T outcomes does not relate significantly to exploring behavior. However, a MANCOVA analysis did not show that exploratory behavior related significantly to self-concept to technology.

<u>DIFFERENCES BETWEEN GROUPS</u>

Results also indicate that pupils who reported more overall exploratory behavior reported more positive core S&T outcomes, a between-subjects phenomenon, (multivariate results for technology outcomes: p=<.001, η_p^2=.11; for natural science outcomes: p=<.001, η_p^2=.11). Univariate results show these results are relevant for most individual core S&T outcomes.

- Pupils who explored more had more positive technology-related outcomes: interest, F (1,169)=11.88, p=.001 η_p^2=.06, attitude, F (1,169)=8.53, p=.004 η_p^2=.06, self-concept, F (1,169)=17.80, p<.001 η_p^2=.09.
- Pupils who explored more had more positive interest and self-concept related to natural science, interest , F (1,171)=9.18, p=.003 η_p^2=.05, self-concept, F (1,171)=6.37, p=.012, η_p^2=.04. However, their attitude about natural science was not significantly different than their peers who explored less, F (1,171)=0.02, p=.899.

<u>H4B1 SUMMARY</u>: Hypothesis partially supported: how much pupils explored at the mobiLLab visit explained variations in how many of their core S&T outcomes changed.

- Exploratory behavior explained variations in changes in pupils' interest and self-concept to natural science and in their self-concept to technology. Both relations were small effects (η_p^2=.02).
- Pupils who reported more exploratory behavior at the mobiLLab visit also reported more positive pre-visit interest, attitude and self-concept to S&T than pupils who explore less, and they maintained these outcomes after the visit.
- Pupils who reported less exploratory behavior exhibited significantly greater decreases in interest and self-concept to natural science.

8.5.2 H4B2 UNIVARIATE RESULTS: Better oriented pupils have more stable self-concept to technology

This section describes univariate results from the repeated measures test, which showed how the degree to which pupils felt oriented to the mobiLLab visit related to their responses about individual outcomes. Within-subjects results show that differences in how oriented pupils felt to the mobiLLab visit accounted for how pupils' self-concept to technology changed. Because multivariate regression results did not show a significant difference between more and less oriented pupils for their natural science outcomes, univariate results are not explored.

<u>WITHIN-SUBJECT RESULTS</u>

Univariate results show that pupils who reported feeling more oriented at the mobiLLab visit were more apt to maintain their self-concept related to technology from before to after a mobiLLab visit, while their less oriented peers show a significantly greater decrease in their self-concept. This is evident in univariate results, which show a link between more oriented feeling and self-concept related to technology, $F(1,174)=5.24$, $p=.023$. How oriented a pupil was did not relate significantly to their interest in nor their attitude to technology.

A MANCOVA analysis was conducted to illustrate the nature of this relation, Figure 42. The graph shows how pupils all started with virtually the same level of self-concept to S&T, but those who reported feeling more oriented maintained their self-concept slightly better (small effect, $\eta_p^2=.02$) than those pupils who felt less oriented.

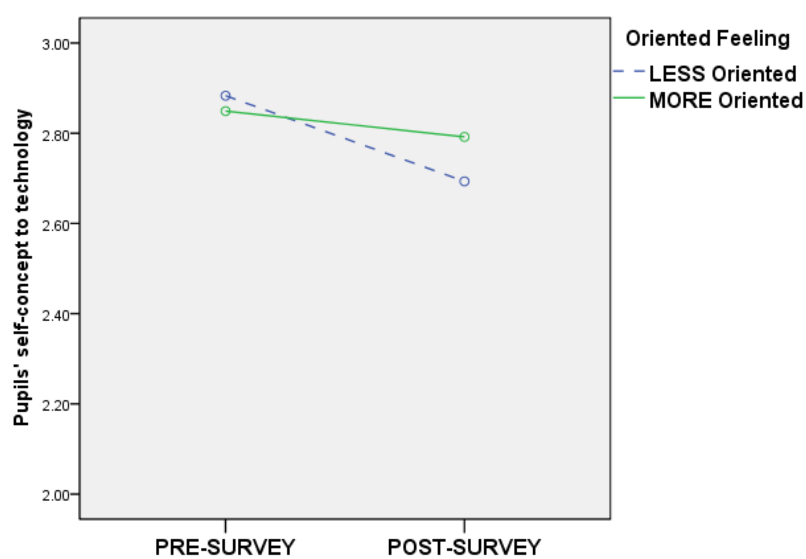


Figure 43: Less oriented pupils experienced a significantly greater decrease in self-concept related to technology.

H4B2 SUMMARY: *Hypothesis partially supported: oriented feeling explained changes in self-concept to technology*

While these results do not show any improvement in self-concept to technology for more oriented pupils, it does show that they are better able to maintain their (above average) self-concept to technology. This probably reflects that better oriented pupils feel less anxious, a variable related to better classroom preparation by Jarvis and Pell (2005).

8.6 Relating curiosity state and cognitive load to pupils' affective outcomes

The mobiLLab study proposed two new indicators for at-visit novelty, curiosity state and cognitive load. It was hypothesized that when these predictors were moderate, pupils' core S&T outcomes would be more positive. As a first test to explore the relation between the predictors and pupils´ core S&T outcomes, multiple linear regression tests were conducted. The following variables were involved in the tests:

Predictor: CurS = (at-visit) curiosity state
Predictor: CL = cognitive load
DV1: Tint: Pupil interest in technology POST
DV2: Tatt: Pupil attitude towards technology POST
DV3: Tsc: Pupil self-concept with respect to technology POST
DV4: Sint: Pupil interest in natural science POST
DV5: Satt: Pupil attitude towards natural science POST
DV6: Ssc: Pupil self-concept with respect to natural science POST

Multiple regression results (Table 49) show that, together, curiosity state and cognitive load account for about 10-20% (based on R^2) of variation in post-visit responses about their interest, attitude and self-concept of ability related to S&T.

8.6.1 H4B3 RESULTS: Curiosity state predicts variations in post-visit core S&T outcomes

Regression results (Table 49) show a significant relation between curiosity trait and all core S&T outcomes. This predictor explains all of the variation in post-visit S&T interest and attitude in the model.

8.6.2 H4B4 RESULTS: Cognitive load predicts variations in post-visit self-concept to S&T

Regression results (Table 49) show a significantly negative relation between cognitive load and self-concept to science. Both how curious pupils felt and how much cognitive load pupils felt explain, to about the same degree, variations in their post-visit responses about their self-concept related to technology (β=.22 for curiosity; β=-.026 for cognitive load) and their self-concept related to natural science (β=.27 for curiosity; β=-.027 for cognitive load).

Table 50: There was a strong linear relation between pupils' curiosity state and core S&T outcomes and also a strong linear relation between cognitive load and S&T self-concept.

				Curiosity State (CurS)				Cognitive Load (CL)			
Dependent Variable	**R^2**	**Adj R^2**	***P***	***B***	***B SE***	**ß**	***p***	***B***	***B SE***	**ß**	***p***
Interest in techn POST	.198	.190	**<.001**	.445	.077	0.39	**<.001**	-.183	.103	-0.12	.077
Interest in ns POST	.199	.191	**<.001**	.470	.069	0.46	**<.001**	.042	.093	0.03	.647
Attitude about techn POST	.123	.114	**<.001**	.325	.064	0.36	**<.001**	.031	.086	0.03	.720
Attitude about ns POST	.099	.090	**<.001**	.285	.067	0.30	**<.001**	-.048	.090	-0.04	.596
Self-concept techn POST	.155	.146	**<.001**	.231	.072	0.22	**.002**	-.361	.096	-0.26	**<.001**
Self-concept ns POST	.201	.193	**<.001**	.269	.067	0.27	**<.001**	-.363	.090	-0.27	**<.001**

H4D&E RESULTS SUMMARY: *Hypothesis not supported, but strong linear relations found*
While these results do not support the original hypothesis that moderate levels of curiosity and cognitive load predict higher S&T outcomes, they show a strong, linear predictive relation. For the first time, more curiosity state at an OSLeP has been linked to more positive learners´ S&T interest, attitude and self-concept, and less cognitive load at an OSLeP has been linked to more positive learners´ self-concept.

Curiosity and cognitive load moderately correlated. MobiLLab study data also indicate that pupils who feel more curious (CurS) experience less cognitive load (CL) (r=-.35). As yet there have been no studies that have shown a significant relation between curiosity state and cognitive load at an OSLeP.

NOTE: Residual plots and scatterplots indicate the quality of the linear regressions are very good (see Appendix on page 219). In this case, statisticians generally accept the linear relationship; therefore, non-linear tests, which provide neither significance tests, nor validity checks (http://www.multivariate.de/nichtlineare-regression.html) were not conducted.

9 Discussion and Conclusions

The mobiLLab main study sought to give us a better understanding of the role of novelty in informal learning. This chapter provides a review of central research findings, which show links among individual and setting novelty factors, pupils' mobiLLab experience, and their affective educational outcomes. Results also provide a profile for tinkerers, or those pupils who describe themselves as more technologically capable. The last two sections in this chapter are discussions about how curiosity is linked to exploration and novelty and about what was learned about participating pupils' knowledge about the electromagnetic spectrum.

9.1 Summary of main results

For the full main study sample, data show both significant increases and decreases in pupils' affective educational outcomes – S&T interest, attitude, self-concept – from before to after the visit. These results are not unexpected, as previous studies have also found mixed results (R. Cors, 2013; Priemer & Pawek, 2014). The central aim of the mobiLLab study was to identify which novelty factors make a difference in theses educational outcomes, which would point to ways to optimize mobiLLab and similar OSLePs.

This subsection begins with a description of a main contribution of the mobiLLab study: development of a more comprehensive theoretical framework for studying novelty at OSLePs. Following is a discussion of the mobiLLab study intervention, which was in the form of a novelty-reducing video. Next is a synthesis of central study findings, which provide evidence for links between individual and setting factors, called pupils' novelty influence factors (NIFs), their experience at the mobiLLab visit, called novelty experience factors (NEFs), and pupils' affective educational outcomes. A key finding here is how tinkerers and explorers – pupils who described themselves as more technologically capable and who report that they explored mobiLLab equipment more, respectively – have more positive outcomes that change less than their direction-seeking, less explorative peers. The section closes with a discussion about how results confirm trends about boys showing more interest in science than girls and for gender preferences related to different types of science.

A more comprehensive theoretical framework for studies about novelty in informal learning

A main contribution of the mobiLLab study is that it describes a broader set of factors that contribute to novelty at OSLePs, something that can guide other studies. Many existing studies about classroom preparation designed to reduce novelty during OSLeP experiences have led to development of some research models about novelty at OSLePs. Some studies refer to Orion and Hofstein's novelty space model (Orion, 1989), which describes three pre-visit factors that are most important for supporting performance and learning during a field trip: previous content knowledge, familiarity with the field trip area, and previous experience with field trip events. However, the guiding models and variables to define novelty and learning used by studies of novelty at OSLePs have varied considerably. For example, Falk et al (1978) based their investigation of how novelty affected pupils' test scores and behavior during a nature center field trip on Piaget's cognitive adaption concepts of assimilation, adaptation and accommodation (Piaget, 1952). In another example, to investigate how novelty at a science center affected learner behavior and test scores, Anderson and Lukas (1997) proposed their own theory, which linked curiosity, novelty and educational outcomes. Their investigation explored how learning was affected by novelty factors of pre-visit orientation and previous visits to the science center.

The mobiLLab study produced tools that can guide research about novelty at OSLePs. First, it produced a typology of novelty influence factors (NIFs) that can be investigated, shown in Table 11. Second, it proposed and measured four indicators of pupils' at-visit perceptions and behaviors that relate to novelty, called novelty experience factors (NEFs), Figure 15. Finally, the mobiLLab study is the first case study that relates NIFs and NEFs to pupils' affective outcomes at OSLePs. As such, offers first insights into what relations are significant and into what methodological aspects of a research design are effective.

Intervention

MobiLLab main study findings show that watching novelty-reducing videos did not affect pupils' novelty experience nor did it relate significantly to their core S&T outcomes. This contrasts with findings from Anderson and Lukas (1997), Falk et al. (1978), Kubota and Olstad (1991), and from Orion and Hofstein (1994), which showed that (more complete) preparation led to better performance and related to positive interest. Similarly, Jarvis and Pell (2005) showed that 'type' of preparation is important for supporting pupils' enthusiasm for science. Also along these lines, Glowinski (2011) found pre-visit instruction promotes competence and social relatedness, which promote interest. The ineffectiveness of the intervention on mobiLLab pupils' novelty experience probably has to do with researchers overestimating the expected effect of the treatment. Novelty-reducing videos were developed for six of the twelve mobiLLab experimental posts and each lasted about 120 seconds. This is relatively short in comparison with the preparation that both the treatment and control group experienced. Classroom preparation lasts about six hours (R. Cors, 2013) and, for each of the four posts they select, pupils looked at an E-Learning sequence that last about 12 minutes.

Novelty factors matter

A significant accomplishment of the research was identifying a suite of factors that describe pupils' at-visit novelty experience, called novelty experience factors (NEFs): curiosity, exploratory behavior, oriented feeling, and cognitive load. Main study results show that novelty influence factors (NIFs), technological capability, and frequenting OSLePs, played a role in how pupils perceived novelty at the mobiLLab visit and in how their affective outcomes changed. Also all NEFs significantly related to core S&T outcomes. What is striking is that pupils who describe themselves as tinkerers and as explorers had more positive interest in, attitudes about, and self-concept to S&T that remained virtually unchanged by the mobiLLab experience. Meanwhile, their direction seeking and less explorative peers showed both increases and decreases in affective outcomes, suggesting that these pupils have the greatest potential to be influenced by OSLeP experiences.

NIFs and NEFs. A look at relations between NIFs and NEFs offer insight into how pupil characteristics affect their novelty experience. Pupils who perceived themselves as more capable with technology reported more exploratory behavior, lower cognitive load, and feeling more curious at the mobiLLab visit. Interestingly, the covariate curiosity trait was a predictor of all four NEFs: more exploratory behavior, feeling better oriented, lower cognitive load, and a greater curiosity state at the mobiLLab visit. In combination, the NIF technological capability and the covariate curiosity trait are stronger predictors of exploratory behavior and of cognitive load, and in both cases curiosity was the stronger predictor.

How often pupils frequented other technology-related OSLePs, another NIF, also related to positive NEFs: more positive exploratory behavior, more oriented feeling and more curiosity state. These results support the hypthesis that pupils who more often visit OSLePs, such as science centers and hands-on workshops, feel more positive novelty at the mobiLLab visit in the form of more exploratory behavior, feeling better oriented and feeling more curious. Similarly, Kabuto and Olstad (1981) and Falk et al (1978) attribute similar more exploratory behavior to feeling less anxious and more oriented, and having more knowlegde about how to navigate a given OSLeP, a skill Falk and Dierking call ´museum savvy´ (Falk & Dierking, 2011, p. 80).

Finally, results show that pre-visit knowledge predicted at-visit curiosity, but was not a predictor of other NEFs.

NIFs and pupils' core S&T outcomes. Difference in NIFs also accounted for variations in changes in pupils S&T outcomes, all with small effect. For example, how pupils perceived their capability with technology significantly predicted how their attitude towards S&T changed and how their interest in natural science change. Specifically, tinkerers' core S&T outcomes were more positive and remained virtually unchanged from pre- to post-visit, in comparison with their direction-seeking peers. In contrast, direction seekers started with less positive S&T outcomes and had gains in attitude to technology, but losses in their interest in natural science.

Another NIF, how often pupils frequented natural science-related OSLePs accounted for differences how pupils' natural science interest changed from before to after the mobiLLab visit. Data show that pupils who more often visit natural science OSLePs had more positive pre-visit interest in natural science and experienced a significantly greater decrease in natural science interest than their peers who have less experience with natural-science OSLePs. One explanation is that these pupils who more often visit natural science-related OSLePs had expectations that they would encounter earth and life science themes at the mobiLLab visit, such as soil and plants. In contrast, the mobiLLab program is about doing science with technology, which could have disappointed these pupils, causing them to feel less connected and interested in science in general.

What was also noticeable is that the type of OSLeP that pupils frequented makes a difference. For example, pupils who more often visited natural science-related OSLePs had more positive natural science-related outcomes, but not more positive technology-related outcomes, a between-groups phenomenon. Similarly, results from the mobiLLab pilot study also show that the *type* of OSLeP experience (Cors et al., 2015) was a strong predictor of overall outcomes. Specifically, pupils who previously visited technology-related OSLePs, such as science centers and science YouTube videos, had slightly more positive technology-related outcomes. Likewise, pupils who frequented natural science-related OSLePs, such as nature centers, had slightly greater natural science outcomes. Similarly, a handful of studies about novelty at OSLePs have shown a link between positive learner outcomes at OSLePs and their familiarity with the setting. This familiarity was a result of either pupils' previous visits to an OSLeP (Anderson & Lucas, 1997), because they gained virtual experience through videos during classroom preparation (Jarvis & Pell, 2005; Kubota & Olstad, 1991; Orion & Hofstein, 1991a), or were assumed to have knowledge of the setting because of where they lived or went to school (Falk & Balling, 1982; Falk et al., 1978).

Finally, results show that pre-visit knowledge, measured as science and math grades and scores on pre-visit knowledge test, did not predict how pupils' core S&T outcomes changed. These findings are different from those of similar studies. For example, Orion and Hofstein (1994) showed that pre-visit knowledge related to a better attitude by pupils towards a field trip and Jarvis and Pell (2005) showed that a more thorough preparation, which included content, related to greater science enthusiasm.

NEFs and pupils' core S&T outcomes. MobiLLab main study results also significant links between all NEFs and pupils' core S&T outcomes (all small effects). One NEF, exploratory behavior, had previously been measured through observation by other investigations of novelty at OSLePs (Falk & Balling, 1982; Falk et al., 1978; Kubota & Olstad, 1991). For the mobiLLab main study, pupil responded to survey questions about how comfortable they felt using mobiLLab equipment. How much exploratory behavior pupils reported was found to explain differences in changes in self-concept to technology and interest in, and self-concept to, natural science. Data show that explorers started with more positive S&T outcomes that changed little from before to after the mobiLLab visit. Meanwhile, pupils who explore less had significant decreases in the interest in and self-concept to natural science. Somewhat similarly, in their study of pupils at science center, Kubota and Olstad (1991) also found a link between exploratory behavior and pupils' content knowledge.

Another NEF, pupils' oriented feeling, predicted a more positive self-concept to technology, which changed less between the pre- and post-visit than for less oriented pupils. These results are similar to the link that Orion and Hofstein (1994) found between how organized pupils found a field trip to be and their attitude towards the field trip. The oriented feeling variable in the mobiLLab study is based on a question about how well organized the mobiLLab visit is from Orion and Hofstein's SOLEI (Science Outdoor Learning Environment Inventory) (1997). In a preliminary test of the instrument, Orion and Hofstein (1994), found that pupils had more positive attitudes about a field trip if they thought that it was well organized. Findings from the mobiLLab study also show that pupils' oriented feeling did not relate significantly to pupils' natural science outcomes.

The NEF curiosity state was linked to more positive core S&T outcomes from post-visit surveys. Here a strong linear relation shows that pupils who reported feeling more curious at the mobiLLab visit also had more positive post-visit S&T outcome scores. Similarly, a lower cognitive load was linked to learners' post-visit self-concept to S&T. While these results do not support the original hypothesis that moderate levels of curiosity and cognitive load predict higher S&T outcomes, they show a strong, linear predictive relation. An additional result was that curiosity state and cognitive load moderately correlated (r=-.21), indicating that pupils who felt more curious were the ones who felt less mentally overloaded at the mobiLLab visit.

Breaking new ground. To the best of the author's knowledge, technological capability, curiosity, and cognitive load have not been tested as novelty factors in studies about learning at OSLePs.

Tinkerers' and explorers' affective outcomes are more resilient

MobiLLab main study findings show that tinkerers and explorers had more positive and more resilient, or unchanging, educational outcomes than their direction-seeking and less explorative peers, respectively. This is based on several significant results between technological capability and core S&T outcomes and also between exploring and core S&T outcome.

Three significant relations were identified between technological capability and core S&T outcomes. First, data show that, before the mobiLLab visit, tinkerers described themselves as more interested in, more positive about, and more confident with both natural science and with technology then their direction-seeking peers. For tinkerers, these outcomes changed little or not at all. For two core S&T outcomes, analyses showed significant differences in how direction seekers' outcomes change. First, pupils who describe themselves as direction seekers had an improvement in attitude from pre- to post-visit survey. However, other findings show that directions seekers' interest in natural science decreases from pre- to post-visit survey. One could assert that the first results about attitude to technology are more relevant to mobiLLab, a program that employed technology to do science.

Data about pupils' reported exploratory behavior and core S&T outcomes followed a similar pattern. That is, pupils who described themselves as feeling more comfortable with exploring mobiLLab equipment were significantly more interested in, had a more positive attitude about, and greater self-concept to technology, and also were more interested in and had a more positive self-concept to natural science. These outcome ratings remained virtually the same from pre- to post-visit survey. In contrast, pupils who explored less had a significantly greater decrease in interest in and self-concept to natural science.

One could surmise from these findings that pupils who are less interested in, have a worse attitude about, and are less confident with S&T are more influenced by the mobiLLab experience. Similarly, a study of the MdBioLab in Maryland found that a school visit most strongly affected the attitudes of pupils who were unsure about their science interest and ability; these pupils become more confident with their competence to conduct experiments (Dowell, 2011).

Gender gap for S&T interest

For both the pilot study and the main study, boys reported more positive affective S&T outcomes than girls. This gender gap was greater for technology than for natural science outcomes and widened slightly, albeit not significantly, from pre-visit to post-visit surveys. These findings contrast with results from a recent study about Swiss youth who experienced a hand-on 'EXRETU' classroom unit designed to promote their technological affinity (Güdel, 2014; Heitzmann & Güdel, 2014). Results provided evidence that girls had improvements in technology interest, attitude and self-efficacy, while boys' affective outcomes showed no change. However, the comparison between the half-day mobiLLab visit and EXRETU, a 12-lesson intervention designed to support development of competencies in scientific and technological problem-solving, are limited.

Gender preferences for the way science and technology are presented

MobiLLab main study results indicated that some experiments were more popular with girls and others with boys. Before the mobiLLab visit, pupils are often able to choose some or all of the experimental posts at which they will work, according to teachers. For some posts, one sees a gender preference. For example, the Food Analysis post was visited by one-quarter of the girls (25%) and only 14% of boys. And, the Exhaust Gas Analysis post was visited by almost one-quarter of boys (24%) and only by 7% of girls. This echoes comments from mobiLLab teachers during pilot study interviews that pupils' experimental post choices fell along gender lines, with girls drawn to health-related posts and boys liking something more sensational or something with more buttons and knobs. These results are similar to findings from PISA surveys, which also indicated that gender preference for science depended on how science is presented (Bybee & McCrae, 2011):

> "It is evident that females expressed much more interest than males in learning about health-related issues in general, though in part this is probably due to some of the issues (e.g. milk components, ultrasound examinations) being regarded by females as having more personal relevance. Interestingly, males showed much more interest than females in learning about issues involving atmospheric pollution, but this finding is confounded by some of the issues being as much about technological solutions. Once again, similar findings applied in OECD and non-OECD countries" (p. 23).

Here it is worth noting that, similarly to how PISA results indicate that boys are more interested in themes that relate to technology, mobiLLab study findings show that boys describe themselves as being more technologically capable.

9.2 Tinkerers

Who are tinkerers, or pupils who describe themselves as more technologically capable? This section reviews the origins of this concept and how it was operationalized for the mobiLLab study. A closer look at mobiLLab data describes a profile for these youth and their experiences at OSLePs and in society.

Who are tinkerers?

The existence and importance of a technological capability characteristic for the mobiLLab study first surfaced during Background Investigation interviews with mobiLLab faculty and staff, who described an aim to foster ‘technophilia,’ or an attraction to working with science through technology (R. Cors, 2013). Similarly, a technological capability characteristic emerged during mobiLLab pilot study interviews with teachers, who described differences among their pupils’ abilities to work with technology. One teacher described how, in his classroom, pupils organize themselves so that each pupil who is good at working with technology pairs up with a pupil who is not so good at working with technology.

For the mobiLLab study, the technological capability survey items were based on two constructs identified by the Technological Profile Inventory (TPI) from Luckay & Collier-Reed (2011a) about how people interact with technological artefacts. These two TPI scales indicate whether people tend to tinker with technological artifacts, ‘Interaction with a technological artefact is through tinkering,’ or whether they tend to seek direction when working with technological artefacts, ‘Interaction with a technological artefact is through direction. ’ MobiLLab survey data show that even though about half of the pupils described themselves as tinkerers, about two-thirds of boys identify as tinkers, while only about one-third of girls did (Table 29).

Tinkerers have and maintain more positive S&T outcomes. Between-subjects findings from the mobiLLab study provide evidence that the pupils who describe themselves as more technologically capable also report a significantly more positive S&T interest, attitude and self-concept, both before and after the mobiLLab visit. This means that tinkerers came to the mobiLLab visit with more positive affective educational outcomes. And, as described above on page 175, these outcomes remain virtually unchanged by their experience.

Tinkerers have more internet and communication technology

MobiLLab study findings show that tinkers tend to have more access to internet and communication technology, mobile phones, televisions, computers, and tablets (r=.21) than their direction-seeking peers (r=not significant). These pupils are perhaps those who have embraced ever-increasing number and types of technological objects and processes in our lives, and may have earned their generation labels such as the ‘Net Generation’ or ‘Digital Natives.’ Other research supports the idea that the increasing prevalence of technology in our societies is affecting the learning styles of today’s youth, who are more adept at working with technology for information and communication (Jones & Shao, 2011):

> “The complex changes that are taking place in the student body have an age related component that {relates} most obviously with the newest waves of technology. Prominent amongst these are the uses made of social networking sites (e.g. Facebook), uploading and manipulation of multimedia (e.g. YouTube) and the use of handheld devices to access the mobile Internet… Demographic factors interact with age to pattern students’ responses to new technologies. The most important of these are gender, mode of study (distance or place-based) and the international or home status of the student” (p. 2).

Tinkerers were more intrinsically motivated at mobiLLab

Results provide evidence that tinkerers felt more self-directed, or more intrinsically motivated than their direction-seeking peers during the mobiLLab visit. This assertion is based on the Cognitive Evaluation (sub)Theory (CET) of Self-Determination Theory (Deci & Ryan, 2000b), which describes how autonomy and competence and the appeal of something novel or challenging are needed to support intrinsic motivation. The theory is discussed in more detail on page 25. In other words, mobiLLab study results provide evidence that the mobiLLab experience supported feelings of competence and autonomy in tinkerers, which could be argued to have catalyzed their intrinsic motivation to engage in working with experimental equipment. CET proposes that humans who feel competent and autonomous in a situation will flourish, or feel that their intrinsic motivation is supported, in that situation. The evidence, which includes some assumptions, is as follows:

- *Tinkerers felt competent.* Many pupils who describe themselves as technologically capable also reported a higher pre-visit self-concept to technology (r=.64). One could assume that tinkerers brought this feeling of competence to the mobiLLab visit.
- *Pupils felt autonomous*. At the mobiLLab visit, pupils worked in pairs without frontal instruction in a self-directed manner, an environment which, according to CET theory, supports feelings of autonomy. While at-visit feelings of pupil autonomy were not measured, observations confirm that they worked without frontal instruction.
- *Tinkerers engaged.* Results show that tinkerers tend to explore mobiLLab equipment more and felt more curious at the mobiLLab visit Table 39.
- *Tinkerers and explorers maintained their feelings of competence.* There is evidence that tinkers had greater self-concept to S&T before and after the mobiLLab visit. Also, explorers, who are more often tinkerers (r=.28), had more positive self-concept, which stayed virtually the same from pre- to post-visit. This could be explained by the absence rewards and threats at the mobiLLab visit, such as tests and deadlines, which CET says would undermine pupils' feelings of competence.

Tinkerers are more technologically literate

MobiLLab main study results and interview findings from the mobiLLab pilot study confirm the existence of technological capability as a human characteristic and provide evidence that it is linked to learning at OSLePs. The survey items about technological capability used for the mobiLLab study were based on survey items from the Technological Profile Inventory (TPI) (Luckay & Collier-Reed, 2011a). Development of the TPI was based on the idea that technological capability, understanding the nature of technology, and being able to think about technology are three core dimensions of technological literacy. Luckay and Collier-Reed confirmed the existence of these dimensions of technological literacy through inductive analysis of data from interviews and surveys from students at a university in South Africa.

Development of the TPI was based in part on early work by the US National Academy of Engineering (NAE) and US National Research Council (NRC) to define and assess technological literacy (G. Pearson & Young, 2002). Similarly, they described technological literacy as having dimensions of capabilities, knowledge, and critical thinking. They explain how technological literacy has become a critical aspect of how people function in and support the economy of today's society (Garmire & Pearson, 2006):

> "There are a number {of benefits of technological literacy} … some of the most important relate to improving how people—from consumers to policy makers— think and make decisions about technology; increasing citizen participation in discussion of technological developments; supporting a modern workforce, which requires workers with significant technological savvy; and

ensuring equal opportunity in such areas as education and employment for people with differing social, cultural, educational, and work backgrounds" (p. 22).

They describe technological literacy as something similar to scientific literacy or mathematical literacy in that people are not expected to be experts about technology, but are comfortable enough to understand a newspaper article that includes information about that field and apply that knowledge in their daily lives. Also, being technologically literate does not require that one have a specific position on controversial issues. They give the example of knowing that a car needs regular maintenance. If someone is technologically literate, they explain, they have the tools to participate intelligently and thoughtfully in the world around them. These tools, or the characteristics of a technologically literate person are listed in Table 50. According to the authors, the capabilities dimension refers to how well people can take advantage of technology in their personal lives and how effective they can be in the workplace. MobiLLab study findings support these ideas in that they show links between technological capability and pupils' at-visit engagement and their affective educational outcomes.

Table 51: Characteristics of a Technologically Literate Person (from Gamire and Pearson (2006)).

Knowledge
Recognizes the pervasiveness of technology in everyday life.
Understands basic engineering concepts and terms, such as systems, constraints, and trade-offs.
Is familiar with the nature and limitations of the engineering design process.
Knows some of the ways technology has shaped human history and how people have shaped technology.
Knows that all technologies entail risk, only some of which can be anticipated.
Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits.
Understands that technology reflects the values and culture of society.
Critical Thinking and Decision Making
Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.
Weighs available information about the benefits, risks, costs, and trade-offs of technology in a systematic way.
Participates, when appropriate, in decisions about the development and uses of technology.
Capabilities
Has a range of hands-on skills, such as operating a variety of home and office appliances and using a computer for word processing and surfing the Internet.
Can identify and fix simple mechanical or technological problems at home or at work.
Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits.
Can use a design-thinking process to solve a problem encountered in daily life.
Can obtain information about technological issues of concern from a variety of sources.

9.3 Curiosity

According to findings from the mobiLLab study, curiosity plays an important role in how learners experience novelty at OLSePs and in how the experience affects their educational outcomes. This section discusses how, more than any other individual or setting novelty influence factor in the mobiLLab study, curiosity trait predicted pupils' at-visit experience. Then comes a discussion of how curiosity state appears to serve as a link between technological capability and educational outcomes at OSLePs. This section closes with a discussion about how mobiLLab study findings offer new insights about longstanding ideas about relations between these constructs.

A curious disposition fosters more postive at-visit novelty

A main goal of the mobiLLab study was to characterize pupils' novelty experience at the mobiLLab visit. What is striking is how prominent their at-visit curiosity was. That is, findings, listed in Table 32 on page 127, show that curiosity state accounts for more than one-quarter of the variance in pupils´ novelty experience, more than any of the other novelty experience factors (NEFs). This is consistent with the predominance of curiosity in learning theory (Berlyne, 1954, 1960).

Findings also indicate there is a significant link between dispositional curiosity (trait) and at-visit feelings of curiosity (state). This supports the assertion by Naylor (2007) that curiostiy trait ´C-Trait,´ predicts curiosity state, which he calls ´C-State.´ His hypothesis was based on the idea that, 'C-Trait' refers to individual differences in the capacity to experience curiosity. He presumed that people possessing more C-Trait perceive curiosity in a wider range of situations than do people with less C-Trait. He also presumed that those possessing more C-Trait experience greater intensities of C-State" (2007, p. 173).

Another interesting finding of the mobiLLab study was that pupils' dispositional curiosity, called curiosity trait, was a strong predictor of novelty experience factors (NEFs). Curiosity trait was introduced in the study as a covariate predictor and analyses showed that it confounded the relation between technological capability and both curiosity state and cognitive load. Further analyses show that curiosity trait is a predictor of technological capability, and also a stronger predictor of NEFs than technological capability. The mediator effects identified through the mobiLLab study (section 8.2.1) provide evidence that the prediction by dispositional curiosity of cognitive load (complete mediation) and curiosity state (partial mediation) is mediated by technologically capability. That is, pupils who are more curious by nature see themselves as more capable of interacting with technology. More technologically capable pupils have less cognitive load and feel more curious at the mobiLLab visit. This is called an indirect relation (Eid et al., 2011) and it is illustrated in Figure 44.

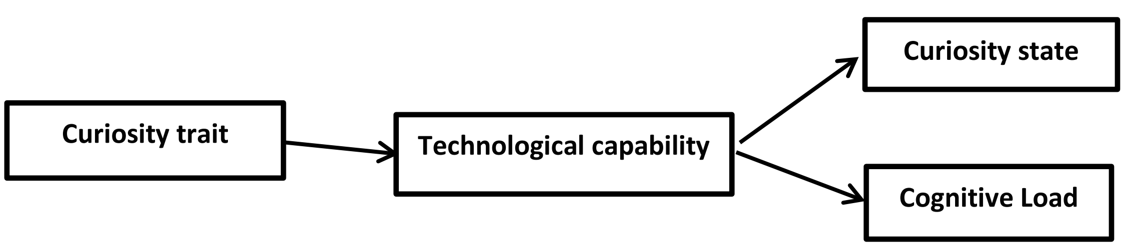


Figure 44: Findings support the idea that the prediction of curiosity state and cognitive load by curiosity trait is mediated by pupil's technological capability.

At-visit curiosity is a link between factors that influence novelty and educational outcomes at OSLePs
Findings from the mobiLLab study show that novelty influence factors (NIFs) were linked to at-visit curiosity, which, in turn, was linked to pupils' affective educational outcomes at mobiLLab. That is, pupils who saw themselves as more technologically capable, who more often frequented technology-related OSLePs, and had better pre-visit knowledge scores also reported feeling more curious at the mobiLLab visit. These pupils who felt more curious at the mobiLLab visit reported more positive S&T interest, attitude and self-concept on the post-visit survey. This portrays curiosity as a vehicle for learning for mobiLLab pupils. It also establishes an argument for tracking learners' feelings of curiosity as an outcome of informal learning by taking measurements before, during, and after an informal learning experience. Similarly, informal learning researchers describe motivation and a willingness to engage as important outcomes of OSLePs that support development of more positive learner attitudes (Rennie, 1994):

> "Motivation and willingness to engage in further instruction are most likely to be the important affective outcomes of a visit. In terms of other affective outcomes relating to science, a short visit is more likely to raise students' awareness about science, scientists and future careers than to result in a fundamental change of attitude with respect to these things, although this may also occur" (p. 263).

Curiosity, exploration and novelty
MobiLLab main study results offer new evidence about the relation between curiosity, novelty, and exploration. In this way, it responds to calls from researchers, who say that "to clarify the nature of curiosity as a psychological construct, it is essential to examine the emotional states that motivate exploratory behavior and to consider how individual differences in curiosity as a personality trait influence exploration" (Litman and Spielberger, 2003, p. 84). Even though mobiLLab findings provide evidence of links between curiosity, novelty, exploratory behavior at OSLePs, they also show how difficult it is to untangle the effects of these constructs on educational outcomes from one another.

Curiosity state and exploratory behavior. MobiLLab data show evidence of a link between curiosity state and exploratory behavior, variables who have a strong moderate correlation (r=.43). While the correlation does not show that feeling curious at an OSLeP causes exploratory behavior, it shows co-existence of the two factors, which is in line with how Berlyne (Berlyne, 1960) emphasizes curiosity as a motivational state that stimulates exploratoy behavior.

Curiosity trait predicts exploratory behavior. MobiLLab data also show evidence of a link between curiosity trait and exploratory behavior. According to mobiLLab data, dispositional curiosity explained 10 percent of the variation in exploratory behavior (see Table 41).

Technological capability and curiosity trait both predict exploratory behavior. A confounding element is pupils' technological capability, or a tendency to explore. Specifically, pupils with a greater perceived technological capability, or a tendency to explore, and those who have a more curious disposition both reported feeling more comfortable exploring mobiLLab equipment.

Based on standardized coefficient values, finding provide evidence that curiosity trait is a slightly stronger predictor.

Are curiosity, novelty, exploration defined circularly? Some analyses of novelty, curiosity and exploratory behavior suggest relations among these constructs are difficult to characterize because they are often defined in terms of each other (Edelman, 1997):

> "This is a difficult topic to conceptualize because of the circular nature of the terms and the contradiction and inconclusiveness of the research. Curiosity, exploration, motivation and drive are defined, described, explained and operationally defined in terms of one another, and thus become embedded and intertwined."

However, a comparison of how the variables curiosity trait, curiosity state, technological capability, and exploratory behavior were operationalized for the mobiLLab study, presented in Table 51, shows distinct definitions and weak to moderate correlations. This offers evidence that it is possible to study these constructs as distinct phenomena.

Table 52: Definitions for and correlations among curiosity trait, curiosity state, technological capability, and exploratory behavior.

Variable	Definition from mobiLLab study	Correlations (r)			
		CurT	CurS	Tink	ExpB
Curiosity trait (CurT)	A group six of survey items for which pupils described their dispositional drive to know about "a broad range of new information," called diversive epistemic curiosity by Litman and Spielberg (2003).	--	.49	.39	.32
Curiosity state (CurS)	A group of survey items that describe pupils' interest in knowing more about mobiLLab equipment (two items) and related science themes (four items).	--	--	.22	.43
Technological capability (Tink)	A group of six survey items through which pupils described whether, when interacting with technology, they usually tinker or seek direction/ support from others.	--	--	--	.28
Exploratory behavior (ExpB)	A group of six survey items through which pupils reported their comfort exploring mobiLLab equipment (four items) and how prepared and organized things felt (three items.)	--	--	--	--

Curiosity trait and technological capability not independent

A covariate is used in a multivariate test to reduce the within-group error variance by allowing the covariate to explain some of this error variance. For a variable to be a true covariate, it should be independent of the variables used as predictors in the investigation (Field, 2013, p. 144). Ideally, the covariate shares its variance with the error, or unexplained variance, from prediction by an independent variable of a dependent variable. One-way ANOVAs tests, run for each predictor variable as shown in

Table 66, were used to test whether different sample groups differ on the covariate. In this case, technological capability and frequenting technology-related OLSePs vary significantly with the covariate curiosity trait. This means, for example, that pupils who describe themselves as technologically capable, tend to be more curious by nature. Therefore, it is questionable as to whether curiosity trait ‘controls for’ or ‘balances out’ differences between groups, as a covariate should.

9.4 Knowledge

Several survey items of the mobiLLab main study explored what pupils knew about electromagnetic radiation concepts, concepts which it was thought could have helped them to engage at activities at three-quarters of the experimental posts. Their knowledge was explored through four questions developed based on mobiLLab preparation materials and on a basic physics test. Results show that pupils who had a better pre-visit score on these knowledge items felt more curious at the mobiLLab visit. This indicates that pupils who know more about the electromagnetic spectrum were more curious about mobiLLab experiments and themes. Also, pupils’ performance on these four questions about electromagnetic spectrum concepts shows evidence of improvement from before preparation to the visit, which is likely due to classroom preparation, and then more improvement after the visit, which is likely due to learning at the mobiLLab visit. These findings are evidence that pupils who knew more about the electromagnetic spectrum before the mobiLLab visit felt more curious at the mobiLLab visit and, in turn, pupils who felt more curious at the mobiLLab visit, in turn, had more positive core S&T outcomes after the visit. While encouraging, evidence of a direct link between pupils’ knowledge about the electromagnetic spectrum and their affective educational outcomes is lacking.

Other studies have also produced mixed results about links between science knowledge positive attitudes towards science. Moreover, some question which measures of attitudes and of science understanding are important. For example, a study of a 10-day environmental science course showed that “…{high school} students having higher knowledge scores had more favorable environmental attitudes compared with students with lower knowledge scores ” (Bradley et al., 1999, p. 17). Other researchers say that “understanding of science is weakly related to more positive attitudes in general: but, more significantly, it is also associated with more coherent and more discriminating attitudes“ (Evans & Durant, 1995). In a meta- analysis of science attitudes and knowledge, Allum et al. (2008) concluded that “Although many studies, both quantitative and qualitative, have examined this issue, the results are at best diverse and at worst contradictory” (p. 35). Finally, some researchers say studies of the relation between understanding of and attitudes about science need to be conducted with more valid measures (Bauer et al., 2000):

> “Research on the public understanding of science has measured knowledge as acquaintance with scientific facts and methods and attitudes as evaluations of societal consequences of science and technology. The authors propose alternative concepts and measures: knowledge of the workings of scientific institutions and attitudes to the nature of science. The viability, reliability, and validity of the new measures are demonstrated on British and Bulgarian data” (p. 30).

9.5 Summary

Findings from the mobiLLab study provide new insights into how learners experience and profit from high-technology OSLePs. Clearly, pupils' technological capability is a key factor. The degree to which pupils saw themselves as technologically capable related to how novel they perceived the mobiLLab experience to be, with more technologically capable pupils reporting more exploratory behavior and curiosity and less cognitive load at the visit. Technological capability also related to how interested pupils were in S&T and how this interest changed from before to after a mobiLLab visit. Study results also provide evidence that tinkerers, or the more technologically capable pupils, were more motivated about mobiLLab visit activities and more engaged. Taking a broader view, it is worth noting that experts see technological capability as a skill that helps people participate in today's workforce and in societal decisions. Theories and studies suggest that the cumulative experience of engaging in multiple OSLeP experiences will support development of technological capability among direction seekers.

Findings of the mobiLLab study also provide evidence that studying both dispositional curiosity and at-visit curiosity can help us better understand learners' experiences high-technology OSLePs. Results suggest that dispositional curiosity predicts more positive at-visit novelty, such as lower cognitive load, more at-visit curiosity and more exploratory behavior. Findings also demonstrate strong relations among curiosity, exploratory behavior, and novelty at OSLePs. Also, pupils with greater knowledge of the electromagnetic spectrum were more curious at the mobiLLab visit. To help us better understand and manage OSLePs to promote S&T interest, future studies should attempt to replicate these findings and further explore the role of curiosity in OSLeP experiences and achieving related educational outcomes.

10 Reflections and Recommendations

This chapter describes the major accomplishments of the mobiLLab study and some important lessons learned during the investigation that could benefit future studies. It also describes several limits of the research. The chapter closes with suggestions for managing informal learning programs and for future research about informal learning.

10.1 Accomplishments and lessons learned

The mobiLLab study is grounded in real-world challenges of a mobile laboratory program, produced data from a moderately large sample, and bridges research written in German and in English. The work produced a broader theoretical framework for investigating novelty at OSLePs, which consists of individual and at-visit factors that were shown to be linked to pupils' educational outcomes.

Grounded research in real-world aspects of informal learning

Researchers can ensure that their research framework, design, and variables are tied to OSLeP challenges by working closely with program managers. Input from the mobiLLab team was invaluable for supporting the meaningfulness of mobiLLab study results. For example, insights from the mobiLLab team elicited during the background investigation lead to crafting of a research design to examine factors thought to most impact pupils' visit experience and S&T interest: preparation and novelty of technology. Also, the close review of survey items by mobiLLab team members ensured that the text would be appropriate for the pupils' age level and cultural background. Another useful contribution of mobiLLab team members was during data interpretation. For example, when reviewing pilot data from teachers, mobiLLab team leaders were skeptical about whether teacher responses about preparation, for example, classroom time for preparation, were inflated.

Broader theoretical framework for studying novelty at OSLePs

A main contribution of the mobiLLab study was identification of a broader suite of novelty factors that were identified by drawing from other studies. Some of these factors represented individual and setting factors thought to influence novelty, or feelings of unfamiliarity at mobiLLab visits, and others factors were indicators of at-visit novelty. This enabled results to demonstrate, for example, that pupils who more often frequent OSLePs, felt more oriented to the visit. This new framework, and how it links theoretical understandings from previous studies to the current study, is described in chapter 5.

The mobiLLab study was designed to test a new (synthesized) framework, shown in Figure 45 below, which was development based on existing models about the impact of novelty on educational outcomes at OSLePs. The novelty space model from Orion (1993), which theorizes a link between individual and setting factors and educational outcomes, has been a basis for several studies about novelty at OSLePs (Cotton & Cotton, 2009; Jarvis & Pell, 2005; Orion & Hofstein, 1994). The mobiLLab study framework calls these factors Novelty Influence Factors (NIFs). Other studies about novelty at OSLePs have suggested and/or examined how at-visit factors of feeling overwhelmed, exploratory behavior (Falk & Balling, 1982; Falk et al., 1978; Kubota & Olstad, 1991) and curiosity (Anderson & Lucas, 1997) relate to their NIFs and/or educational outcomes. For the mobiLLab study, these at-visit factors are called Novelty Experience Factors (NEFs).

The mobiLLab study combines these approaches, based on an argument for identifying the effect of individual and setting factors on at-visit perceived novelty. Such an analysis also reduces the uncertainty about whether reduced novelty due to preparation indeed led to more positive educational outcomes, rather than other factors in learners' lives.

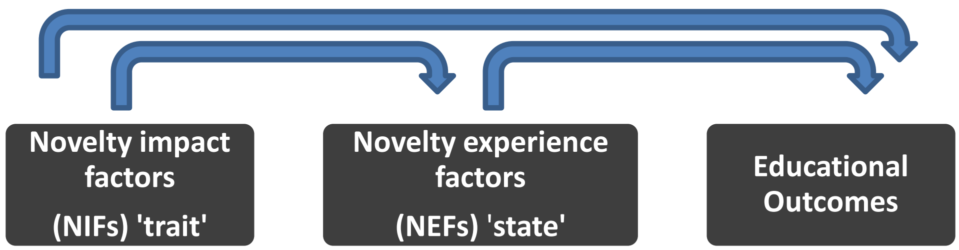


Figure 45: The mobiLLab study was designed to test new, hybrid a model that relates both individual and at-visit variables for OSLePs to educational outcomes.

Testing of the relations among NIFs and NEFs led to the first ever psychometric validation of groups of questions (scales), which are grounded in novelty theory, that describe how pupils´ perceive novelty while visiting a mobiLLab. That is, one can describe pupils´ perceived novelty in terms of reported curiosity state, exploratory behavior, oriented feeling, and cognitive load. These instruments inform us about how learners perceive novelty at other technology-related OSLeP. For example, we learned that pupils do not separate the feeling of being oriented to the visit with the feeling of being able to explore the equipment. Also, pupils saw cognitive load as something having to do with conducting experiments. Finally, results suggest that pupils associate fun with curiosity more than with exploratory behavior.

Control variables

One contribution that the mobiLLab study makes to research about novelty at OSLePs is identification and screening of control variables. A control variable is a variable, other than the independent variables, that is thought to explain some of the variation in the dependent variable (DV). Control variables are measured concurrently with the independent variables before an experiment and then held constant during an experiment. In the case of the mobiLLab study, a short list of possible control variables was identified based on previous studies. These variables were curiosity trait, gender, teacher attitude, school grade level, school track, home language, and amount of technology at home.

As summarized in Table 33, screening tests showed that curiosity trait and gender were the only variables that were linked to differences in the DVs. Dispositional curiosity was shown to be a significant predictor of NEFs cognitive load, curiosity state and exploratory behavior. Therefore, it was included in the study as a covariate predictor. MobiLLab study findings, in fact, showed that dispositional curiosity was a stronger predictor of at-visit exploratory behavior and curiosity feeling than technological capability was. Moreover, the strength of the ability of dispositional curiosity to predict at-visit curiosity state and cognitive load were shown to operate through the mediator variable technological capability. These are, as far as the author knows, the first findings that link curiosity, both state and trait, to OSLeP experiences.

The other interesting control variable, gender, was significantly linked to differences in all core (affective) S&T outcomes: interest in science, interest in technology, attitude to science, attitude to technology, self-concept to science, and self-concept to technology. This echoes findings from other studies about how boys have greater affect for science than girls and show these differences also exist for technology. However, as with many other studies, mobiLLab study findings showed that gender did not predict how these DVs changed from before to after the mobiLLab visit.

Improvements to mobiLLab program

The mobiLLab study also led to several program improvements. These included reorganization of the website materials that teachers and pupils use for classroom preparation and improvements to the introductory PowerPoint presentation on the website, such as more photos of the mobiLLab equipment. Specific feedback from teachers led to simplification of a worksheet for use at the mobiLLab visit, so that the contents are more learner-centered. Another improvement is that, starting in the 2014-2015 school year, teachers receive a USB-Stick that contains all classroom preparation documents.

Bridges research written in German and in English

The mobiLLab study looked to two groups of studies about science learning at OSLePs. One was evaluations conducted over the past decade about mobile laboratory programs in Europe and the United States. Even though these programs are situated in English-speaking cultures, they offer pupils a similar experience to mobiLLab and therefore provide important insight into factors that influence science learning at mobile laboratories in particular. Also reviewed were studies conducted over the last 12 years about pupil visits to school laboratories in Germany, some of them in university and/or research settings, such as those established by the German Centers for Air and Space (DLR). Even though these programs offer experiences that were sometimes different than a mobiLLab experience, they provide valuable insights into studying interest development at OSLePs in German-speaking youth.

Intervention

The novelty-reducing videos were developed as an intervention that was meant to improve pupils' comfort level with mobiLLab equipment. A product of this process was the identification of some common questions and problems pupils have with mobiLLab equipment, something that is being used to make improvements to some experimental posts. Even though the 120-second novelty-reducing videos were not shown to significantly reduce pupils' at-visit novelty, it was nonetheless an accomplishment to create videos that were well received by pupils. It appears that, since all pupils had a relatively thorough preparation of about six classroom hours, this probably eclipsed any effects of the videos. A future study about pupils' comfort with mobiLLab equipment should introduce these videos separately from classroom preparation.

Evidence of knowledge gain

Even though affective educational outcomes were the focus of the mobiLLab study, an exploratory investigation of participating pupils' knowledge gain showed some interesting and useful results. Specifically, findings provide evidence that pupils learned something about electromagnetic spectrum concepts from the mobiLLab preparation and also from the visit, demonstrating at least short-term knowledge gain. It also provides information to the mobiLLab team about what aspects of the electromagnetic spectrum are easier and more difficult for pupils to grasp, information that can be used further improve preparation materials and communication with teachers. Finally, the mobiLLab study created a baseline of scores for several questions that are a good gage of pupils' knowledge and can be used in the future.

10.2 Limitations

While having accomplished a lot, several aspects of the investigation were limited. These limitations are discussed within the context of three types of validity:

- *External validity* refers to the degree that the results of an experiment can be generalized to other settings, times, and participants.
- *Internal validity* is the degree to which an experiment establishes a direct cause-and-effect relationship between the independent and the dependent variable.
- *Construct validity* is the extent to which an experiment measures the independent and dependent variables that it claims to measure. An experiment would be low in construct validity if it claimed to measure self-esteem, but in reality measured confidence.

Self-reported data. Survey data from pupils was a form of self-reporting. Self-reports from pupils could have been biased, because they were describing how interested they felt about technology after experiencing a program that was obviously meant to promote technology use. More positive responses about interest in technology could have been in part a response to the expectation that their experience improves their interest. This expectation could come from the questionnaires themselves or from the excitement of the mobiLLab visit, which may be a social desirability bias or an interest in feeling part of the excitement among their peers about mobiLLab. Social cues may also have been introduced during the administration of questionnaires, which was done by the teacher in a classroom situation, where pupils were among their peers. Informal learning practitioners and researchers who participated in a session to interpret findings, described in section 7.2, also questioned whether self-reporting offers an accurate measure of interest. The mobiLLab surveys were designed with forced-choice items in an attempt to address self-report bias, which can threaten construct validity. Other strategies used to mitigate the effects of social desirability are to check the neutrality of items, rotate random items in surveys and isolating subjects when they complete a questionnaire (Nederhof, 1985).

Similarly, some mobiLLab team members suspected teachers, who are customers of the program and have an interest in its success and their future participation, were eager to describe the program positively and perhaps inflate estimates of classroom preparation time. This is similar to what psychologists describe as self-selecting or volunteer bias, which describes subjects who for one reason or another are more positively biased about the results of the study (Brownell et al., 2013). It is probably true that teachers who make the effort to organize a mobiLLab visit may be more enthusiastic about science and informal learning and may not represent science teachers in Eastern Switzerland. However, they are probably representative of those teachers who participate in mobiLLab and similar informal learning programs.

Access. Because access to program participants was limited, the author could not pursue certain methodological and design strategies. Interviews with pupils would have supported an exploration of, for example, what made them feel curious at the mobiLLab visit. These data would have been useful for triangulating with survey responses about their at-visit experiences. However, access to pupils for interviews was considered to be too intrusive and also logistically problematic. Additionally, it could have been helpful in interpreting some survey responses. For example, speaking with pupils would have helped clarify whether they indeed watched the novelty-reducing videos and what they took away from watching them, something that wasn't clear from survey responses. Similarly, in order to maintain good relations with teachers, the mobiLLab team was reluctant to suggest classroom observation as a data collection method and so a picture of preparation activities came from teacher interviews and surveys only. By providing a third source of teacher data, that was not self-reported, classroom observations may have helped to check whether teachers provided overly-positive reports in interviews and survey.

No comparison group. The design of the mobiLLab study included some elements of rigor, such as pre-screening survey items with a test group of youth, and offers some evidence of content learning and about affective educational outcomes. However, without a control group of pupils who instead learned the content in the classroom, conclusions cannot be made about whether learning at a mobiLLab visit is different than classroom learning. When considering novelty, there was no control group of pupils who did not have a classroom preparation, which would have allowed for a test of the effectiveness of the preparation in reducing novelty. Science education researchers recognize that generalizations made from the results of a study without a comparison group might wrongly attribute the gains in educational outcomes to the specific intervention, thus presenting a threat to external validity (Brownell et al., 2013).

Non-random sample. Participating pupils and teachers were not randomly chosen, but were selected because they happened to participate in the mobiLLab program while the study took place. Therefore, the research design is based on an assumption that there is an even distribution of characteristics within the population. An example is how data was collected for both the pilot and main study during the spring, so the findings may not apply to pupils who participate in the mobiLLab program in the fall semester. This could make a difference if, late in the fall semester, pupils experienced lessons that prepared them to better deal with the science content of the mobiLLab. In this scenario, pupils whose mobiLLab visit took place earlier during the fall semester would have perhaps felt less familiar with the science concepts of mobiLLab.

Limits of Within Subjects-Designs. Comparisons of pupils' pre-visit and post-visit responses about educational outcomes, namely S&T interest, attitude and self-concept of ability, were critical for identifying predictors of changes in these outcomes. However, because of the unique experience of study participants, results may not apply to other learners at other OSLePs, threatening external validity.

For example, pupils at other OSLePs will experience a different program, with different coaches and different materials, thus limiting the generalizability of mobiLLab study results to other school districts and other OSLePs. Also, there was, albeit not very much, evidence that the within-subject design could have introduced a fatigue bias. This was noticeable in several remarks from teachers, and also written comments from pupils, about how the survey items were repetitive, suggesting some pupils were becoming annoyed and fed up with filling out the surveys. However, sarcastic remarks were detected in less than ten surveys, suggesting this fatigue bias was minimal.

Another aspect of within-subject designs that can be problematic is the other experiences besides the program/treatment that take place in subjects' lives between measurements, which can also influence the dependent variables and threaten the internal validity of research. The time between pupils' completion of the pre-visit survey and the post-visit survey was anywhere from seven to twenty-four weeks, depending upon when their mobiLLab visit took place. The differences in this time span time between pre- and post-visit survey for different class groups could have differently affected how their memory of the visit was, leading to different responses about, for example, their program satisfaction. With a substantial timespan between pre- and post-visit survey, the possible influence of other events in the subjects' lives on the dependent variables of the study is greater. That is, other factors besides the mobiLLab visit, such as other OSLeP visits or S&T lessons that occurred between these times, could have affected how pupils' S&T interest, attitude and self-concept changed. Practitioners who reviewed mobiLLab study results at an interpretive session (described in section 7.2) observed that untested individual factors, such as learning styles, may have also played a role in how pupils' affective outcomes changes. Another example they offered was which experiments pupils worked at; they explained that, if some pupils worked at more difficult experiments than others, it would likely be reflected in their self-concept to science and technology.

Limited Scope of Design. Practitioners who reviewed the results at an interpretive session (described in section 7.2) observed that the study did not explore the effects of social factors, which seem relevant to pupils at-visit experience, given that the pupils worked in pairs. They explained that factors, such as whether they chose their partner or whether their partner was technologically capable, would have affected the pupils' experience at the mobiLLab visit.

Lack of longitudinal data. Because sustained interest development can only be demonstrated if it is maintained over time, a limitation of the study was the lack of temporal breadth that would have come from a longer timespan for the study. Resources for the mobiLLab study were instead invested in identifying and validating variables that characterize novelty for learners when they are at OSLePs. This choice was in large part based on the mobiLLab team priority to better understand how classroom preparation and pupils' interaction with technology affect how pupils engage in mobiLLab visit activities. While the study identified and tested some interesting new variables related to novelty at OSLePs, and produced results that inform us about how they interact with mobiLLab equipment, it is unclear whether there were any long-term effects. Whenever possible, studies about how OSLeP factors relate to educational outcomes should make measurements over the long term. Also, a longitudinal study with multiple measures of the covariate predictor curiosity trait and of at-visit novelty factors would provide clearer evidence about the relation among these variables.

Language barriers. As a native speaker of English with proficient, but not fluent, German language skills, strategies for dealing with difficult-to-understand interview responses were sometimes limited. In the view of the mobiLLab team leaders, such limits were minimal to none. Still, while participating teachers were generally accommodating and friendly, some points may have been misinterpreted or missed. The language barrier may also have limited the understanding of program materials and some terminology used in pupil surveys items.

10.3 Looking forward

10.3.1 Suggestions for OSLeP managers

Give that technological capability is a skill experts recognize as important for success in work and society, OSLeP managers should pay attention to this aspect of learners' identity. MobiLLab study findings showed that pupils' technological capability related to pupils' engagement at the visit and to how their S&T educational outcomes changes. Direction seekers' S&T outcomes changed more than tinkerers' S&T outcomes from before to after a mobiLLab visit. This points to an opportunity to explore the variable of technological capability more deeply. It appears that direction seekers are less decided about their interest, attitude, and self-concept, pointing to an opportunity. The question then becomes, *How can we better support direction seekers in engaging in informal learning activities that involve technological equipment?*

Practitioners who reviewed the results at an interpretive session (described in section 7.2) discussed mobiLLab study results about technological capability. They said that results of the mobiLLab study made them curious about how to support learners in exploring their own technological capability. One specific approach the practitioners suggested was to develop a meta-lesson, where learners could become aware of how they interact with technology. A first activity would involve completion of the six mobiLLab survey items in order to score their own technological capability. Then, they could discuss what it means to be a direction-seeker or a tinkerer, and the direction seekers could try out the approaches of tinkerers. A second proposal from the practitioner expert group was to pair a tinkerer and a direction-seeker during a mobile laboratory visit. This could be supported by specific instructions for the tinkerer to mentor the direction seeker. They explained that it would be interesting to learn about whether such a pairing supported learning or was frustrating to one or both learners.

10.3.2 Suggestions for further research

MobiLLab findings point to directions for future studies.

Links among novelty factors and outcomes

Findings from the mobiLLab study results provide evidence that there are links between individual and novelty factors and at-visit novelty factors, which, in turn are linked to S&T educational outcomes. These findings indicate, for example, that pupils' technological capability does indeed influence their at-visit exploratory behavior, and that frequenting technology related OSLePs explains variations in how oriented pupils were to the mobiLLab visit. Studies can further contribute to our understanding of the role of novelty at OSLePs by identifying, operationalizing and relating NIFs and NEFs to educational outcomes.

The opportunity: Directions seekers

MobiLLab findings show that tinkerers, or pupils who see themselves as less technologically capable, explored equipment more. A major question that has come out of the mobiLLab study is, How to get non-tinkerers exploring? For example, mobiLLab study teacher interviews revealed that, at least in some classrooms, pupils are aware of who is more technologically capable and, in some cases, the tinkerers and direction seekers independently pair up. Future research could examine the effects of pairing of pupils with different levels of technological capability.

MobiLLab study results provide some quantitative evidence that tinkerers are more engaged at the mobiLLab visit. Exploratory research through interviews and focus groups could help us better understand just what less technologically capable people need to feel more comfortable interacting with technology. Self-Determination Theory provides a lens for such research, which should examine learners' motivation factors, such as feelings of competence and curiosity, and relate it to their indicators at-visit engagement, such as exploratory behavior. Teacher interviews may also produce some relevant insights.

Specific variables

MobiLLab study findings provided insights into how several variables should be handled when included in future studies of novelty at OSLePs.

Measuring technology at home

Study findings show that the scale used to ask mobiLLab study pupils how much technology they had access to at home should be adjusted. It appears that this population has access to more technology at home than youth worldwide, particularly mobile phones, computers, and bikes. This becomes clear when one considers how the survey items about 'technology at home' were developed. The items for 'technology at home' for the mobiLLab survey are adapted from the PISA questionnaire (OECD, 2006). The PISA study looks at technology at home for the purposes of understanding affluence (wealth). That is, PISA shows these 'technology at home' items as Q14 (OECD, 2006, p. 43), which are part of a longer list of items to characterize possessions at home and are mixed with items about other possessions and home situation items to calculate a variable called WEALTH. When pupils complete the questionnaire, they indicate how many of the given technological object they have at home by marking one of the boxes on the scale to indicate either 'none,' 'one,' 'two,' or 'three or more.' However, it is clear from the results of the mobiLLab study, that the endpoints for the scales represented fewer objects than many pupils have at home. For studies in Switzerland, the scale should be broadened to a range of 'none' to 'five' and then tested with a focus group.

Curiosity trait (covariate) and curiosity state (DV)

Findings suggest that pupils with a curious disposition tend to tinker with technology, a tendency that is linked to feeling more at-visit curiosity and less cognitive load at the mobiLLab visit. This clearly demonstrates that dispositional curiosity is an important covariate in studies of novelty at OSLePs. To further explore the role of dispositional curiosity in how learners perceive novelty in informal learning settings, more rigorous studies are needed. First, it would be important to measure curiosity trait concurrently with other predictors, before an OSLeP visit/ intervention. Second, longitudinal data about mediators and outcomes would provide more solid evidence to characterize the relation between these two variable types.

At-visit curiosity was also shown to play a major role in pupils' informal learning experiences. In fact, curiosity state accounts for more than one-quarter of the variance in pupils´ novelty experience, more than any of the novelty experience factors (NEFs). According to findings from the mobiLLab study, curiosity state appears to be a link between technological capability and educational outcomes at OSLePs. By exploring which informal learning program design elements, such as experiment and exhibit characteristics or unfamiliarity/ novelty, support learner at-visit curiosity and how, in turn, curiosity state relates to learners' educational outcomes, future studies help us better understand the role of this variable. Also, mobiLLab study findings show that there is a significant link between dispositional curiosity (trait) and at-visit feelings of curiosity (state). Any studies of curiostiy state should be sure to include curiosity trait as a covariate. It would be interesting to explore how stimuli, such as written matierals or exhibit factors, could be developed to pique the curiousity of learners who are less dispositionally curious.

Gender

Several studies with big samples (Bybee and McCrae, 2011; Jarvis and Pell, 2005) show that girls tend to be more interested in science topics related to health and well-being, while boys are more interested with topics that have to do with cars and 'destructive technologies.' Similarly, during mobiLLab pilot study interviews, several teachers described how boys seem more attracted to experiments that have to do with action and with cars. Also, mobiLLab main study data shows that about twice as many girls visited the food analysis experimental post, while more than three times as many boys visited the exhaust gas experimental post. Future studies could help us better understand how to designs of informal learning settings support each gender to develop their interest in science. Other researchers agree. For example, Potvin and Abdelkrim (2014) suggests that how science lessons are presented is as important as their content: "…the pedagogy that is traditionally used in physics teaching might possess distinctive features that would explain why some students are less interested in it" (p. 109). Similarly, context-based approaches for teaching science have been shown to reduce the gap between girls' and boys' attitudes to science (Bennett, 2006).

Authenticity of setting, learner participation in society
Other individual and setting factors that affect learning at OSLePs were identified during the background investigation, but were beyond the scope of this investigation. Some experts (Bybee and McCrae, 2011) say that youth may put off by science when it does not relate to their personal experience. For example, authenticity of experience at a biology educational laboratory was linked to learner outcomes at an OSLeP (Glowinski & Bayrhuber, 2011). It would also be interesting to find out how pupils' participation in informal learning programs relates to their participation in society, including choices for environmentally sustainable behaviors, understanding and participation in social issues, and anticipated career choice. Such studies would provide evidence for how well informal learning environments can address the PISA agenda for promoting interest in science, support for scientific enquiry, and responsibility towards resources and environments (Bybee and McCrae, 2011).

Path analysis
MobiLLab study findings indicate that some variables had moderator and mediator relationships. For example, how technologically capable pupils think they are may have explained the strength of the novelty-reducing preparation. Also, curiosity trait was shown to indirectly predict curiosity state and cognitive load, through the mediator technological capability.

Future studies about OSLePs that aim to characterize the relations among a group of novelty factors and educational outcomes should consider a path analysis approach. Results of path analysis would assign comparable values to more variable relations and help us better understand what really drives learners' engagement at OSLePs and improvements in their educational outcomes. Studies using path analysis could, for example, try to replicate findings by suggested by Glowinski and Bayrhuber (2011) that self-concept predicts interest development among pupils with less S&T interest: "Participants with low interest profit from support and quality of instruction as well as from their self-concept and the degree of pre-visit instruction, while for students with high individual interest, self-concept and quality of instruction became the most prominent significant predictors for feeling competent in the student lab" (p. 385).

Skills for informal learning… and for life
The mobiLLab study provides evidence of the importance of skills for participation in OSLeP activities, particularly with technology, something more and more important in our Digital Age societies. Findings show a link between skills with technological objects and educational outcomes at OSLePs. That is, pupils who saw themselves as more technologically capable, and pupils who reported more exploratory behavior, had more positive affective educational outcomes that remained positive from before-to-after the mobiLLab visit. Similarly, Jarvis and Pell (2005) attribute better attitudes to science to skill-building before the OSLeP visit. This focus on technological capability was also articulated by representatives of mobile laboratory programs worldwide during the background investigation as a central mandate for their programs. That is, an important outcome of the program was not only that pupils would be more likely to consider careers in science and technology workforce, but also participate in societal decisions about important issues related to S&T. To better understand these program outcomes, future studies

should examine how S&T experiences and learning at OSLePs relate to pupils' habits, intentions, and around social issues such as conserving the earth's resources.

On the potential of informal learning

By reducing overwhelming novelty and leveraging intriguing novelty, OSLePs are uniquely positioned to bring us closer to realizing the benefits of discovery learning. That is, by encouraging learner autonomy and engagement in learning, thus promoting creativity and problem-solving skills, we develop a more agile workforce that our globalized, Digital Age societies need (Castranova, 2002; Cors et al., 2003). Moreover, these education approaches have been recognized as critical for developing skills needed for businesses and societies to move forward sustainably (R. Cors, Matsubae, K., Street, A. , 2013; Scholz, 2011).

Eleanor Roosevelt suggested once that we all do one thing each day that scares us. Equipped with tools for managing and leveraging novelty, OSLeP managers can offer safe, stimulating environments for people to try something new and explore the edges of their interests, knowledge and abilities. These experiences are important for engaging more youth in the sciences and for supporting their ability to act as informed, responsible global citizens.

V. APPENDIXES AND REFERENCES

11 Appendixes

11.1 Appendix: Selection of balanced teacher subject groups (pilot study)

A main purpose of the 2014 mobiLLab pilot investigation was to characterize teachers' preparation for a mobiLLab visit. Of the nine teachers participating in the pilot study, only treatment group teachers were given access to these materials and the hypothesis is that they would therefore conduct a more complete preparation than control teachers. To diminish effects by factors having to do with gender, education and professional training, and experience, teacher subjects were selected for treatment and control groups in an effort to balance the groups based these factors.

The criteria for balancing teacher groups were Gender, Education, Class level taught, Years of teaching, Professional development, Participation in mobiLLab training course, and Previous experience with mobiLLab. Data about these parameters were collected through the mobiLLab online pre-visit teacher survey (Artologik online software), February 6-16, 2014 (*Erste mobiLLab-Befragung von Lehrpersonen (Te1)*). Additionally, to test whether treatment group teachers were sharing access to "treatment" preparation materials with control group teachers at their schools, one multiple-teacher school was with both treatment and control group teachers.

Several criteria variables did not exhibit enough variation to warrant taking them into account for balanced sample assignments. First, all of the 9 teachers were male. Second, all but one teacher taught Vocational Track classes (one taught General Track*)*. Third, only one teacher has an additional degree other than their teaching degree (education).

With assignments of study subjects to treatment and control groups as shown in Table 52 below, variability for the remaining criteria is represented as evenly as possible between the treatment and control groups. In addition, of the four teachers at the secondary school in Wittenbach, Switzerland, two are in the treatment group and two in the control group, allowing for a test about possible "resource sharing".

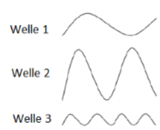
Table 53: Criteria for teacher assignment to control and treatment groups.

Teacher ID	Sample Group Assignment	School	Experienced ML Before?	Took ML Training Course	Degree	PD in the last four years?	Years teaching?
1	treatment	Bad Ragaz	yes	yes	SekundarLP phil II	yes	10-20
2	treatment	Gommiswald	yes	yes	SekundarLP phil II	no	more than 20
4	treatment	Necker	no	yes	SekundarLP phil II	yes	5-10
6	treatment	Wittenbach	no	no	RealLP	yes	10-20
8	treatment	Wittenbach	no	no	SekundarLP phil II	yes	10-20

Teacher ID	Sample Group Assignment	School	Experienced ML Before?	Took ML Training Course	Degree	PD in the last four years?	Years teaching?
3	Control	Gommiswald	yes	yes	SekundarLP phil II	no	5-10
5	Control	Necker	yes	yes	SekundarLP phil II	yes	10-20
7	Control	Wittenbach	no	no	SekundarLP phil II	no	more than 20
9	Control	Wittenbach	no	yes	SekundarLP phil I	yes	more than 20

OZ= Oberstufenzentrum; LP=Lehrperson (teachers); PD=professional development

11.2 Appendix: Knowledge Question Coding

Keyword	Variable label	Question Text	Possible answers	Code
transport	kn_xport_tx	1. Strahlung, zum Beispiel Radiowellen, Mikrowellen oder das Licht einer Glühbirne, transportiert _____. *Radiation waves, such as radiowaves, microwaves or the light from a lightbulb, transport __________.*	Energie UND Licht (*Energy* AND *Light*) – both answers marked	2
			Energie (*Energy*) Licht (*Light*)	1
			Stoff (*Material*) Post (*Mail*) Keine von den genannten Lösungen (*none of these answers*) Das weis ich nicht (*Don't know*)	0
visible	kn_see_tx	2. Alle Arten von Strahlung sind sichtbar. *All kinds of radiaion waves are visible.*	Nein UND Einige sind sichtbar und einige nicht (*No* AND *Some are visible and some are not*) – both answers marked	2
			Nein Einige sind sichtbar und einige nicht (*Some are visible and some are not*)	1
			Ja (*Yes*) Das weiss ich nicht (*Don't know*)	0
Wavelength	kn_size_tx	3. Welche Welle hat die grösste Wellenläng e? *Which wave has the longest wavelength?* 	Welle 1 (*Wave 1*)	1
			Welle 2 (*Wave 2*) Welle 3 (*Wave 3*) Alle haben die gleiche Wellenlänge (*all have the same wavelength)* Das weiss ich nicht (*Don't know*)	0
Spectrum	kn_part_tx	4. Der Teil des elektromagnetischen Spektrums, den wir mit unseren Augen wahrnehmen können, ist: *The part of the electromagnetic spectrum that we can see with our eyes is:*	ein ganz winziger Teil (a very tiny part) weniger als ein Zehntel (less than one-tenth)	1
			mehr als die Hälfte (*more than one-half*) fast alles (*almost the entire spectrum*) Ich weiß nicht, was das elektromagnetische Spektrum (ES) ist (*I don't know what an electromagnetic spectrum (ES) is*) Ich weiß , was das ES ist, kann aber die Frage nicht beantworten (*I know what an ES is, but still don't knwo the answer*) Das weiss ich nicht (*Don't know*)	0
5. Gib für die folgenden Strahlungsarten an, bei welchem der von dir bearbeiteten Posten sie hauptsächlich verwendet wurden.				
infrared waves	irpost_check_t3	Infrarot-Strahlung	IR-Spectroskopie (Infrared Spectroscope), Wärmebildkamera (Infrared Camera)	1
			Other answers are incorrect	0
Microwaves	mwpost_check_t3	UV-Strahlung	UV-Strahlung (Ultraviolet radiation)	1
			Other answers are incorrect	0
radio waves	radpost_check_t3	Sichtbares Licht	Keine von den genannten Posten (?) (*None of the posts*)	1

Keyword	Variable label	Question Text	Possible answers	Code
			Any post name is incorrect	0
ultraviolet waves	uvpost_check_t3	Mikrowellen	Mikrowellensynthese (Microwave synthesis), Haushaltmikrowelle (Household microwave)	1
			Other answers are incorrect	0
visible light	vispost_check_t3	Radiowellen	Farben und Spektren (Visible light analysis)	1
			Other answers are incorrect	0
x-rays	xrfpost_check_t3	Röntgenstrahlung	Rontgenflorezenz (X-ray fluorenscence)	1
			Other answers are incorrect	0

11.3 Appendix: Factor Analysis Detail

Table 54: Original list of perceived novelty questions, which were used in a factor analysis, and their theoretical basis.

Item	Variable name	Hypothesized Construct	Source
Ich habe keine Probleme, die mobiLLab-Geräte selbst zu bedienen.	TEXS1	Explores ML equipment	Adapted from Luckay, 2011; tested in Cors, 2013
Aufgrund der Vorbereitung habe ich keine Angst, bei der Bedienung der mobiLLab-Geräte Fehler zu machen.	TEXS2		
Ich bin in der Lage mit den mobiLLab-Geräten zu „spielen“ um zu sehen, was sie alles können.	TEXS3		
Ich konnte rasch mit der Bedienung der mobiLLab-Geräte beginnen.	TEXS4		
Es hat mir Spass gemacht, die mobiLLab-Geräte auszuprobieren.	TEXS5		
Der zeitliche Ablauf des mobiLLab-Tages ist mir bekannt.	SETTS1	Feels oriented	Adapted from Luckay, 2011, tested in Cors, 2013
Der mobiLLab-Besuch ist gut organisiert.	SETTS2		
Für den mobiLLab-Besuch bin ich gut vorbereitet.	SETTS3		
Wir haben genügend Informationen, um die Experimente durchführen zu können.	EXEX1	Explores ML experiments	Adapted from Luckay, 2011 and Orion et al, 1997.
Die Experimente waren schwierig.	EXEX2		
Ich konnte mich gut auf die Experimente konzentrieren, ohne mit den Geräten “kämpfen” zu müssen.	EXEX3		
Die Erfahrung mit mobiLLab weckt meine Neugier auf die dort behandelten Themen.	CURS1	Curiosity state	Adapted from Littman, 2003; Naylor, 2007.
Es interessiert mich, wie die Geräte an den verschiedenen Posten funktionieren.	CURS2		
Ich möchte mehr über die mobiLLab-Themen erfahren.	CURS3		
Die in den mobiLLab-Versuchen behandelten Themen haben mich persönlich angesprochen.	CURS4		
Ich möchte die in den mobiLLab behandelten Themen besser verstehen.	CURS5		
Wie hoch war die geistige Belastung bei den Versuchen insgesamt (zuviel Unbekanntes, zuviel auf einmal)?	CLS1	Cognitive load	Adapted from Hart, 1988
Wie empfindest du die Zeit, die für Experimente zur Verfügung stand?	CLS2		
Wie sehr musstest du dich anstrengen, um die Experimente durchzuführen?	CLS3		
Wie verunsichert, entmutigt, oder verärgert warst du während der Experimente?	CLS4		

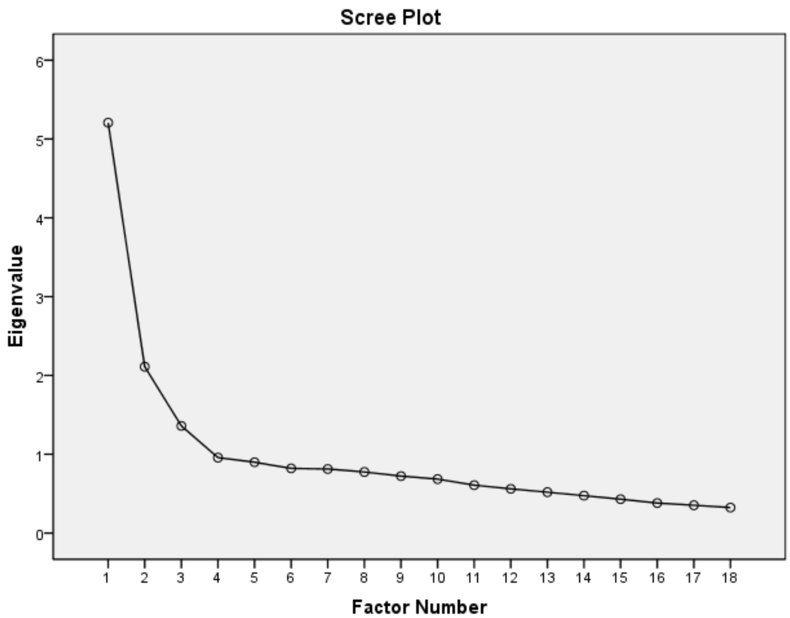


Figure 46: Scree plot from final factor analysis.

11.4 Appendix: Examples of teacher interview elements and their purpose

An interview introduction was developed to describe the purpose of the mobiLLab evaluation-investigation, to establish ignorance of the interviewer, to explain what type of information the interviewer hoped to discuss, to convey that data from the interview would be handled anonymously and to ask about whether the interviewee would consent to having the conversation tape recorded (Bloomberg school of health and other source?). Interview items were developed to be truly open by using "how" and "what" questions, rather than dichotomous. Items were mostly about teachers' experience, behavior, and opinions and they were formulated to explore one idea at a time. To avoid leading questions, neutrality was observed by avoiding any assumptions about teachers in interview items (Patton, 2002). Table 54 shows specific examples of items developed for the survey according to these strategies. In addition to interview content, attention was given to interview process. That is, a conscious effort was made to give reinforcing and elaboration cues when interviewees did not speak very much and, on the other hand, to give re-directing feedback when interviewees spoke for a long time or went off-topic (Patton, 2002).

Interviews drew from strategies of expressing ignorance and use of cards to represent preparation materials that are posted on the mobiLLab website. Carla Willig (2013), describes the value of such strategies:

> "A good way to obtain detailed and comprehensive accounts from interviewees is to express ignorance. A naïve interviewer encourages the interviewee to 'state the obvious' and thus give voice to otherwise implicit assumptions and expectations. This can be extremely enlightening. Another way to encourage interviewees to elaborate is to ask for {oral} illustrations of events or experiences. This is particularly helpful when abstract concepts or general opinions are being referred to. For instance, having heard the interviewee say that people do not take him or her seriously, the interviewee can ask the interviewee for a concrete example of when (s)he felt this way and how (s)he dealt with it.
>
> Another way of encouraging interviewees to produce rich and varied accounts is to use a stimulus such as a film clip, a newspaper cutting or a photograph in order to stimulate and focus the discussion. Alternatively, interviewees can be invited to bring along their own images or items of significance so that they can then talk about what these mean to them during the interview… In this way, the data produced during the interview are likely to be richer in detailed description of interviewees' experiences, memories and feelings, and less likely to remain at the abstract, impersonal level." (p. 39).

Table 55: Examples of teacher interview elements and their purpose.

Element Type (source)	Purpose	Example
Introduction: Purpose of study statement (Willig)	Reminds interviewee of purpose of interview.	I am conducting a study to learn about how the mobiLLab program is working and how it could be improved. *Ich führe eine Untersuchung durch, um herauszufinden, wie das mobiLLab in der Praxis angewendet wird und wie man es weiter verbessern könnte.*
Introduction: Purpose of interview statement (Willig)	Establish ignorance of interviewee, articulate information sought.	We do not know what preparation resources the teachers use and do not know how helpful they are for pupils' experimentation and engagement. Anything you can tell me about which resources were used and how effective you think they were would be interesting. *Wir wissen derzeit weder, welcher Ressourcen sich die Lehrerpersonen zur Vorbereitung bedienen noch wie diese die SuS beim Experimentieren unterstützen und ihr Engagement wecken. Alles, was Du mir über die Verwendung der Ressourcen und ihre Wirksamkeit erzählen kannst, ist wertvoll für uns.*
Item: Preface statement (Patton 2001)	Alerts interviewee to what is about to be asked.	Through the following questions, I want to ask your opinion about how useful the preparation resources were and about what could be improved. *Mit den folgenden Fragen, möchte ich von dir erfahren wie nützlich die jeweiligen Ressourcen waren oder was verbessert werden könnte.*
Item: Structured experience/ behavior question (Patton 2001)	Collect data about classroom preparation practices (behavior) that can quickly be compared with data from other interviewees	*Could you put the cards (that represent each classroom preparation resource) into two piles, one for the resources you used and one for the resources you did not know about or did not use? If you used any additional resources – from our website or of your own – please fill out an additional card.* *Könntest Du sie <u>in zwei Stapel einordnen</u>: der eine Stapel soll die Ressourcen, die Du verwendet hast enthalten, der andere Stapel jene Ressourcen, die du nicht verwendet hast. Falls Du <u>zusätzliche Ressourcen</u> benutzt hast, schreib die Namen der Ressourcen auf leere Karten.*
Item: Semi-structured opinion question (Patton 2001)	Ask about interviewee opinion with specific reference to study lens and pupil behavior	*Now I want to ask about your opinion.* Looking *at things now that the mobiLLab visit has taken place, and considering the ML-NST model, which aspects of a preparation are most effective to help pupils engage in experimentation during a mobiLLab visit?* *Nun möchte ich dir nach deiner Meinung fragen. Im Hinblick auf das Verhalten des Sus während des zurückliegenden mobiLLab-Einsatzes, und unter Berücksichtigung des ML-NST-Modells, welche Aspekte der Vorbereitung sind am wirksamsten, um die Sus während dem mobiLLab Einsatz zu engagieren und zum Experimentieren anzuregen?*
Probe: detail and elaboration (Patton 2001)	Further explore teachers' experience with preparation resources (if time, flow allow)	*How useful were the resources for you yourself (rather than for the pupils)? What additional resources would you like to have available?* *Wie nützlich war dieses Material für dich selbst? Was würdest du dir sonst noch für Ressourcen wünschen?*
Probe: exploration through simulation (Patton 2001)	Puts the teacher in the role of planner/ expert	If you were supposed to plan and develop the preparation and resources, how would you do it? *Wenn du die Vorbereitung und Ressourcen selbst planen müsstest, <u>wie würdest du</u> es machen?*
Item: open question (Patton 2001)	Ask teachers to elaborate on a related area	How do you see your role in the mobiLLab program? *Wie siehst du <u>deine Rolle</u> im mobiLLab-Programm?*

11.5 Appendix: Normality of pupil scalar variables

For each dependent variable in the mobiLLab study, a check for normality was made by reviewing the Kolmogorov-Smirnov significance test results, histograms and Q-Q plots, and skew and kurtosis. The first table below, Table 55, lists these data for the full sample of pupils. The subsequent tables list these data for subgroups split by gender, school year, school track, and home language. In these split sample tables, the Shapiro-Wilk significance is also given, because it is relevant to samples smaller than 50.

Table 56: Normality tests for dependent variables – full sample group.

Construct	Label	L	M	5% Trimmed Mean	Kolmogorov-Smirnov significance	Histogram, Q-Q Plot	Boxplot: # of outliers	Skew	Kurtosis
Pupil interest in techn PRE	Tti_t1	210	2.5	2.5	.046	Normal, straight	0	-.114	-.238
Pupil interest in techn POST	Tti_t3	208	2.5	2.5	.000	Normal, straight	6	.067	-.092
Pupil interest in ns PRE	Tnsi_t1	205	2.4	2.4	.047	Normal, straight	3	.050	-.089
Pupil interest in ns POST	Tnsi_t3	209	2.3	2.3	.000	Normal, straight	1	-.088	-.184
Pupil attitude techn PRE	Ttat_t1	207	2.8	2.9	.000	Normal, straight	1	-.352	.400
Pupil attitude techn POST	Ttat_t3	207	2.9	2.9	.000	Normal, straight	1	-.055	.039
Pupil attitude ns PRE	Tnsat_t1	206	2.7	2.7	.000	pointy, straight	8	-.322	.729
Pupil attitude ns POST	Tnsat_t3	210	2.8	2.8	.000	Normal, straight	7	-.142	.484
Pupil self-concept techn PRE	Ttsc_t1	207	2.9	2.9	.011	Normal, straight	1	-.224	-.211
Pupil self-concept techn POST	Ttsc_t3	210	2.8	2.8	.038	Normal, straight	0	.061	-.520
Pupil self-concept ns PRE	Tnssc_t1	209	2.9	2.9	.007	Normal, straight	2	-.281	-.041
Pupil self-concept ns POST	Tnssc_t3	205	2.8	2.8	.000	Normal, straight	0	-.239	-.273
S&T career aspiration PRE	career_t1	214	2.1	2.0	.000	+ skew, straight	0	.526	.758
S&T career aspiration POST	career_t3	212	2.1	2.1	.000	+skew, straight	0	.478	.639

Table 57: Normality tests for dependent variables – split into gender groups: 1) 'girl' and 2) 'boy'.

Variable Label	Group	N	M	5% Trimmed Mean	Kolmogorov-Smirnov significance	Histogram, Q-Q Plot	Boxplot: # of outliers	Skew	Kurtosis
Tti_t1	girl	100	2.3	2.3	.094	Normal, straight	3	.006	-.163
	boy	106	2.8	2.8	.068	Normal, straight	3	-.469	.489
Tti_t3	girl	101	2.2	2.2	.000	Normal, straight	9	-.75	.226
	boy	103	2.8	2.8	.200*	Normal, straight	1	-.175	-.064
Tnsi_t1	girl	98	2.4	2.4	.200*	Normal, straight	0	.053	-.237
	boy	103	2.5	2.5	.005	Normal, straight	1	.049	.0392
Tnsi_t3	girl	101	2.2	2.2	.002	Normal, straight	0	-.042	-.592
	boy	104	2.4	2.4	.040	Normal, straight	0	-.146	.268
Ttat_t1	girl	98	2.7	2.7	.009	Normal, straight	2	-.361	.647
	boy	105	3.0	3.0	.001	Normal, straight	3	-.469	.535
Ttat_t3	girl	100	2.7	2.7	.000	Normal, straight	1	-.078	.465
	boy	103	3.1	3.1	.008	Normal, straight	1	-.095	-.269
Tnsat_t1	girl	96	2.6	2.6	.000	Normal, straight	1	-.674	.825
	boy	106	2.8	2.8	.000	Normal, straight	4	-.003	.344
Tnsat_t3	girl	99	2.7	2.7	.000	Normal, straight	1	-.210	.442
	boy	107	2.9	2.9	.000	Normal, straight	13**	-.197	.603
Ttsc_t1	girl	98	2.6	2.7	.036	Normal, straight	1	-.399	.271
	boy	105	3.1	3.1	.011	Normal, straight	0	-.355	-.347
Ttsc_t3	girl	100	2.5	2.5	.112	Normal, straight	1	.097	-.229
	boy	106	3.0	3.0	.074	Normal, straight	0	-.049	-.839
Tnssc_t1	girl	100	2.9	2.9	.151	Normal, straight	1	-.358	.545
	boy	105	3.0	3.0	.022	Normal, straight	0	-.176	-.766
Tnssc_t3	girl	98	2.6	2.6	.000	Normal, straight	0	-.227	-.360
	boy	103	2.9	2.9	.011	Normal, straight	3	-.413	.109
career_t1	girl	101	1.6	1.5	.000	+ skew, straight	2	1.088	.420
	boy	109	2.5	2.5	.000	Normal, straight	0	.133	-.942
career_t3	girl	100	1.7	1.6	.000	+ skew, straight	2	.947	.522
	boy	108	2.5	2.5	.000	Normal, straight	0	.060	.898

.* This is a lower bound of the true significance. ** extreme values are within range of item scale.

Table 58: Normality tests for dependent variables – split into school year groups: 1) 'year 2' and 2) 'year 3'.

Variable Label	Group	N	M	5% Trimmed Mean	Kolmogorov-Smirnov significance	Shapiro-Wilk	Histogram, Q-Q Plot	Boxplot: # of outliers	Skew	Kurtosis
Tti_t1	year 2	172	2.6	2.6	.047	.191	Normal, straight	0	-.101	-.030
	year 3	38	2.5	2.5	.200*	.386	point, straight	0	.017	-.938
Tti_t3	year 2	171	2.5	2.5	.001	.029	Normal, straight	5	.082	-.082
	year 3	37	2.5	2.5	.033	.394	Normal, straight	2	.020	-.057
Tnsi_t1	year 2	168	2.4	2.4	.067	.113	Normal, straight	0	.067	.075
	year 3	37	2.5	2.5	.200*	.404	Normal, straight	0	-.043	-.605
Tnsi_t3	year 2	172	2.3	2.3	.000	.010	Normal, straight	0	-.250	-.306
	year 3	37	2.3	2.3	.145	.137	Normal, straight	0	.449	.256
Ttat_t1	year 2	169	2.8	2.8	.001	.007	Normal, straight	1	-.349	.447
	year 3	38	2.9	2.9	.000	.036	Normal, straight	7	-.432	.482
Ttat_t3	year 2	169	2.9	2.9	.000	.003	Normal, straight	0	.187	-.225
	year 3	38	2.9	2.9	.102	.326	Normal, straight	1	-.542	.163
Tnsat_t1	year 2	167	2.7	2.7	.000	.000	Normal, straight	7	-.411	1.023
	year 3	39	2.7	2.7	.200*	.374	Normal, straight	0	.110	-.644
Tnsat_t3	year 2	173	2.8	2.8	.000	.000	Normal, straight	18**	-.077	.572
	year 3	37	2.6	2.6	.123	.302	Normal, straight	2	-.233	.119
Ttsc_t1	year 2	170	2.9	2.9	.015	.023	Normal, straight	1	-.340	-.021
	year 3	37	2.8	2.8	.200*	.491	Normal, straight	0	.173	-.721
Ttsc_t3	year 2	171	2.8	2.8	.036	.042	Normal, straight	0	.125	-.536
	year 3	39	2.7	2.7	.200*	.369	Normal, straight	0	.034	.809
Tnssc_t1	year 2	170	2.9	2.9	.001	.007	Normal, straight	1	-.393	.028
	year 3	39	3.0	3.0	.200*	.379	pointy, straight	0	.251	-.795
Tnssc_t3	year 2	167	2.7	2.7	.002	.037	Normal, straight	0	-.305	-.347
	year 3	38	2.8	2.8	.200*	.420	Normal, straight	0	.180	.036
career_t1	year 2	175	2.0	2.0	.000	.000	Normal, straight	0	.511	-.678
	year 3	39	2.3	2.3	.000	.000	Normal, straight	0	.321	-1.387
career_t3	year 2	174	2.0	2.0	.000	.000	+skew, straight	0	.470	-.575
	year 3	38	2.4	2.4	.000	.000	Normal, straight	0	.228	-1.368

.* This is a lower bound of the true significance. ** extreme values are within range of item scale.

Table 59: Normality tests for dependent variables – split into school track groups: Vocational and General.

Variable Label	Group	N	M	5% Trimmed Mean	Kolmogorov-Smirnov significance	Shapiro-Wilks p	Histogram, Q-Q Plot	Boxplot: # of outliers	Skew	Kurtosis
Tti_t1	General	44	2.5	2.5	.200*	.434	Normal, straight	0	.066	-.614
	Vocational	166	2.5	2.6	.021	.077	Normal, straight	0	-.146	-.291
Tti_t3	Real	43	2.4	2.4	.200*	.200	Normal, straight	0	.292	.408
	Vocational	165	2.5	2.5	.000	.009	Normal, straight	0	.018	-.033
Tnsi_t1	General	43	2.3	2.3	.200*	.712	Normal, straight	0	.028	-.422
	Vocational	162	2.5	2.5	.047	.119	Normal, straight	3	.069	.028
Tnsi_t3	General	45	2.2	2.2	.002	.055	Normal, straight	0	-.484	-.488
	Vocational	164	2.3	2.3	.018	.115	Normal, straight	1	-.006	-.165
Ttat_t1	General	46	2.7	2.8	.073	.472	Normal, straight	0	-.266	.297
	Vocational	161	2.9	2.9	.000	.009	Normal, straight	3	-.369	.499
Ttat_t3	General	44	2.8	2.8	.000	.000	+ skew, straight	5	1.117	1.257
	Vocational	163	2.9	2.9	.000	.014	Normal, straight	1	-.276	.001
Tnsat_t1	General	44	2.6	2.6	.137	.830	Normal, straight	2	-.032	.211
	Vocational	162	2.7	2.7	.000	.000	Normal, straight	6	-.373	1.046
Tnsat_t3	General	46	2.8	2.8	.007	.025	Normal, straight	1	.542	.386
	Vocational	164	2.8	2.8	.000	.000	Normal, straight	7	-.234	.407
Ttsc_t1	General	43	2.8	2.8	.200*	.226	Normal, straight	1	-.519	.666
	Vocational	164	2.9	2.9	.015	.037	Normal, straight	0	-.120	-567
Ttsc_t3	General	45	2.7	2.7	.200*	.756	Normal, straight	0	.175	-.342
	Vocational	165	2.8	2.8	.069	.065	Normal, straight	0	.029	-.545
Tnssc_t1	General	43	2.8	2.8	.200*	.026	Normal, straight	1	-.635	.711
	Vocational	166	3.0	3.0	.050	.089	Normal, straight	0	-.144	-.474
Tnssc_t3	General	43	2.6	2.7	.108	.210	Normal, straight	0	-.169	-909
	Vocational	162	2.8	2.8	.002	.135	Normal, straight	2	-.201	-.064
career_t1	General	46	1.9	1.9	.000	.000	Normal, straight	0	.806	-.281
	Vocational	168	2.1	2.1	.000	.000	Normal, straight	0	.463	-.820
career_t3	General	45	2.0	1.9	.000	.000	Normal, straight	0	.373	-844
	Vocational	167	2.1	2.1	.000	.000	Normal, straight	0	.466	-.750

.* This is a lower bound of the true significance.

Table 60: Normality tests for dependent variables – split into home language (HLANG) groups: 1) 'German' and 2) 'Other' language.

Variable	Group	N	M	5% Trimmed Mean	Kolmogorov-Smirnov significance	Shapiro-Wilk p	Histogram, Q-Q Plot	Boxplot: # of outliers	Skew	Kurtosis
Tti_t1	German	178	2.5	2.5	.090	.128	Normal, straight	2	-.027	-.302
	Other	31	2.6	2.6	.200*	.350	Normal, straight	1	-.656	.930
Tti_t3	German	175	2.5	2.5	.000	.005	Normal, straight	5	1.60	-.067
	Other	32	2.5	2.5	.200*	.264	Normal, straight	0	-.517	.014
Tnsi_t1	German	174	2.5	2.4	.024	.061	Normal, straight	3	.023	-.069
	Other	30	2.4	2.4	.200*	.874	Normal, straight	0	.278	.040
Tnsi_t3	German	177	2.3	2.3	.000	.027	Normal, straight	1	-.122	-.215
	Other	31	2.2	2.2	.200*	.683	Normal, straight	0	-.113	-.601
Ttat_t1	German	176	2.9	2.9	.000	.002	Normal, straight	5	-.451	.575
	Other	30	2.8	2.8	.043	.180	Normal, straight	0	.280	-.699
Ttat_t3	German	175	2.9	2.9	.000	.011	Normal, straight	1	-.089	-.048
	Other	31	2.9	2.9	.036	.143	Normal, straight	2	.294	1.313
Tnsat_t1	German	177	2.7	2.7	.000	.001	Normal, straight	6	-.385	.821
	Other	28	2.8	2.8	.200*	.939	Normal, straight	0	.062	.103
Tnsat_t3	German	177	2.8	2.8	.000	.000	Normal, straight	7	-.206	.430
	Other	32	2.7	2.7	.200*	.001	Normal, straight	2	.130	2.032
Ttsc_t1	German	176	2.9	2.9	.000	.939	Normal, straight	1	-.268	-.205
	Other	30	2.8	2.8	.036	.000	Normal, straight	0	.250	-.788
Ttsc_t3	German	178	2.8	2.8	.016	.029	Normal, straight	0	.055	-.549
	Other	31	2.7	2.7	.041	.045	Normal, straight	0	.026	-.666
Tnssc_t1	German	178	2.9	2.9	.039	.155	Normal, straight	1	-.352	.086
	Other	30	2.8	2.7	.169	.035	Normal, straight	0	.022	-.683
Tnssc_t3	German	173	2.8	2.8	.018	.715	Normal, straight	0	.283	-.261
	Other	31	2.7	2.7	.200*	.015	Normal, straight	0	.054	-.590
career_t1	German	181	2.1	2.0	.000	.000	Normal, straight	0	.536	-.730
	Other	32	2.1	2.1	.000	.000	Normal, straight	0	.564	-.762
career_t3	German	179	2.1	2.1	.000	.000	+skew, straight	0	.428	-.844
	Other	32	2.0	1.9	.000	.000	+skew, straight	5	.919	1.338

.* This is a lower bound of the true significance.

11.6 Appendix: Detailed Results from Potential Covariate Selection and Screening

This appendix shows the detailed results of one-way analyses of variance (ANOVAs) tests, which were used to explore the relations between some potential covariates and pupils' core S&T outcomes. It also shows the results of regression used to screen several potential covariates for the mobiLLab study.

GENDER (Gen)

- All core S&T outcomes were significantly difference between boy and girls (shown as bolded between group values for p.
- For one core S&T outcome, interest in natural science, gender accounted for significant differences in changes from pre- to post-visit survey (p=.045).

Table 61: Comparison of pupil core S&T outcomes from girls and boys.

Dependent Variable	Group	N	Pre-visit *M*	Pre-visit *SD*	Post-visit M	Post-visit SD	ANOVA Test	*df*	*df error*	*F*	p	ηp^2
Interest in techn	girls	99	2.3	0.6	2.2	0.5	Between groups	1	197	54.0	**0.000**	0.215
	boys	100	2.8	0.6	2.8	0.6	Group * time	1	197	0.4	0.507	0.002
Interest in ns	girls	97	2.4	0.6	2.2	0.6	Between groups	1	195	5.0	**0.027**	0.025
	boys	100	2.5	0.6	2.4	0.6	Group * time	1	195	4.1	**0.045**	0.020
Attitude about techn	girls	96	2.7	0.5	2.7	0.5	Between groups	1	194	32.7	**0.000**	0.144
	boys	100	3.0	0.5	3.1	0.5	Group * time	1	194	0.2	0.658	0.001
Attitude about ns	girls	93	2.6	0.5	2.7	0.5	Between groups	1	195	6.9	**0.009**	0.034
	boys	104	2.7	0.5	2.9	0.6	Group * time	1	195	0.2	0.663	0.001
Self-concept techn	girls	96	2.6	0.5	2.5	0.5	Between groups	1	196	49.7	**0.000**	0.202
	boys	102	3.1	0.5	3.0	0.6	Group * time	1	196	0.1	0.760	0.000
Self-concept ns	girls	96	2.8	0.5	2.6	0.5	Between groups	1	193	12.1	**0.001**	0.059
	boys	99	3.0	0.5	2.9	0.6	Group * time	1	193	3.4	0.065	0.017
S&T career aspirations	girls	99	1.6	0.8	1.7	0.7	Between groups	1	205	67.8	**0.000**	0.249
	boys	108	2.5	1.0	2.5	1.0	Group * time	1	205	0.2	0.684	0.001

NOTE. techn=technology; ns=natural science; df=degrees of freedom; F=the F-ratio represents the variance between the groups divided by the variance within groups; ηp2=the effect size can be roughly interpreted using Cohen's (1988) benchmarks for partial eta squared: small (ηp2=.01), medium (ηp2=.06) and large (ηp2=.14).

NOTE. Greenhouse-Geisser results are reported to control Type I errors due to possible sphericity.

SCHOOL YEAR (SY): One-way ANOVA

- only between group difference that was significant (bold) was for career aspirations, 3rd year more interested in S&T career, perhaps indicating that year 3 pupils are simply more certain about their career direction (they choose apprenticeship between year 2 and 3)
- no group * time significant interactions

Table 62: Comparison of pupil core S&T outcomes from 2nd versus 3rd year pupils (ANOVA results).

Dependent Variable	Group	N	Pre-visit *M*	Pre-visit *SD*	Post-visit M	Post-visit SD	Test	*df*	*df error*	*F*	p	η_p^2
Interest in techn	year 2	167	2.6	0.6	2.5	0.6	Between groups	1	201	0.7	0.404	0.003
	year 3	36	2.4	0.8	2.4	0.7	Group x time	1	201	0.9	0.344	0.004
Interest in ns	year 2	166	2.4	0.6	2.3	0.6	Between groups	1	199	0.0	0.864	0.000
	year 3	35	2.5	0.7	2.3	0.6	Group x time	1	199	1.7	0.198	0.008
Attitude about techn	year 2	163	2.8	0.5	2.9	0.5	Between groups	1	198	0.0	0.894	0.000
	year 3	37	2.9	0.6	2.9	0.6	Group x time	1	198	2.7	0.105	0.013
Attitude about ns	year 2	164	2.7	0.5	2.8	0.5	Between groups	1	199	1.9	0.168	0.010
	year 3	37	2.6	0.5	2.6	0.6	Group x time	1	199	1.9	0.169	0.009
Self-concept techn	year 2	165	2.9	0.5	2.8	0.6	Between groups	1	200	0.4	0.529	0.002
	year 3	37	2.8	0.6	2.7	0.8	Group x time	1	200	0.5	0.497	0.002
Self-concept ns	year 2	161	2.9	0.5	2.7	0.6	Between groups	1	197	1.3	0.253	0.007
	year 3	38	3.0	0.5	2.8	0.5	Group x time	1	197	0.1	0.751	0.001
S&T career aspirations	year 2	173	2.0	0.9	2.0	0.9	Between groups	1	209	5.1	**0.025**	0.024
	year 3	38	2.4	1.2	2.4	1.1	Group x time	1	209	0.0	0.857	0.000

NOTE. techn=technology; ns=natural science; df=degrees of freedom; F=the F-ratio represents the variance between the groups divided by the variance within groups; ηp2=the effect size can be roughly interpreted using Cohen's (1988) benchmarks for partial eta squared: small (ηp2=.01), medium (ηp2=.06) and large (ηp2=.14).

NOTE. Greenhouse-Geisser results are reported to control Type I errors due to possible sphericity.

SCHOOL TRACK (ST)

One-way ANOVA. No significant between group or group-x-time interactions.

Table 63: Comparison of pupil core S&T outcomes from General versus Vocational Track pupils (ANOVA results).

Dependent Variable	Group	N	Pre-visit *M*	Pre-visit *SD*	Post-visit M	Post-visit SD	Test	*df*	*df error*	*F*	p	η_p^2
Interest in techn	General	41	2.5	0.5	2.5	0.6	Between groups	1	201	0.0	0.979	0.000
	Vocational	162	2.5	0.7	2.5	0.6	Group x time	1	201	0.0	0.854	0.000
Interest in ns	General	42	2.3	0.6	2.2	0.6	Between groups	1	199	2.0	0.154	0.010
	Vocational	156	2.5	0.6	2.3	0.6	Group x time	1	199	0.3	0.602	0.001
Attitude about techn	General	44	2.7	0.6	2.8	0.4	Between groups	1	198	2.5	0.117	0.012
	Vocational	158	2.9	0.5	3.0	0.5	Group x time	1	198	0.1	0.800	0.000
Attitude about ns	General	44	2.6	0.6	2.8	0.5	Between groups	1	199	1.2	0.281	0.006
	Vocational	157	2.7	0.5	2.8	0.6	Group x time	1	199	2.0	0.155	0.010
Self-concept techn	General	42	2.8	0.6	2.7	0.6	Between groups	1	200	0.9	0.332	0.005
	Vocational	160	2.9	0.5	2.8	0.6	Group x time	1	200	1.5	0.229	0.007
Self-concept ns	General	40	2.8	0.5	2.6	0.7	Between groups	1	197	3.9	0.051	0.019
	Vocational	159	3.0	0.5	2.8	0.5	Group x time	1	197	0.1	0.770	0.000
S&T career aspirations	General	45	1.9	1.0	1.9	0.8	Between groups	1	209	2.1	0.145	0.010
	Vocational	166	2.1	1.0	2.1	1.0	Group x time	1	209	0.0	0.990	0.000

NOTE. techn=technology; ns=natural science; df=degrees of freedom; F=the F-ratio represents the variance between the groups divided by the variance within groups; ηp2=the effect size can be roughly interpreted using Cohen's (1988) benchmarks for partial eta squared: small (ηp2=.01), medium (ηp2=.06) and large (ηp2=.14).

NOTE. Greenhouse-Geisser results are reported to control Type I errors due to possible sphericity.

HOME LANGUAGE: One-way ANOVA.

- no significant between-group effects
- one significant difference (bold) between groups regarding how their attitude about technology changed from pre- to post-visit survey.

Table 64: Comparison of pupil core S&T outcomes from pupils with German versus another home language (ANOVA results).

Dependent Variable	Group	N	Pre-visit survey *M*	Pre-visit survey *SD*	Post-visit survey M	Post-visit survey SD	Test	*df*	*df error*	*F*	p	η_p^2
Interest in techn	German	171	2.5	0.6	2.5	0.6	Between groups	1	200	0.5	0.489	0.002
	Other	31	2.6	0.6	2.5	0.6	Group x time	1	200	0.1	0.709	0.001
Interest in ns	German	171	2.4	0.6	2.3	0.6	Between groups	1	198	1.1	0.286	0.006
	Other	29	2.3	0.5	2.2	0.5	Group x time	1	198	0.0	0.901	0.000
Attitude about techn	German	169	2.9	0.5	2.9	0.5	Between groups	1	197	0.0	0.886	0.000
	Other	30	2.8	0.5	2.9	0.4	Group x time	1	197	0.1	0.802	0.000
Attitude about ns	German	172	2.7	0.5	2.8	0.5	Between groups	1	198	0.0	0.950	0.000
	Other	28	2.8	0.5	2.7	0.5	Group x time	1	198	4.1	**0.044**	0.020
Self-concept techn	German	172	2.9	0.6	2.8	0.6	Between groups	1	199	0.3	0.595	0.001
	Other	29	2.8	0.4	2.7	0.5	Group x time	1	199	0.0	0.868	0.000
Self-concept ns	German	169	2.9	0.5	2.8	0.6	Between groups	1	196	1.7	0.196	0.009
	Other	29	2.8	0.4	2.7	0.5	Over time	1	196	1.2	0.266	0.006
S&T career aspirations	German	178	2.1	1.0	2.1	1.0	Between groups	1	208	0.1	0.710	0.001
	Other	32	2.1	1.0	2.0	0.8	Over time	1	208	1.0	0.307	0.005

NOTE. techn=technology; ns=natural science; df=degrees of freedom; F=the F-ratio represents the variance between the groups divided by the variance within groups; ηp2=the effect size can be roughly interpreted using Cohen's (1988) benchmarks for partial eta squared: small (ηp2=.01), medium (ηp2=.06) and large (ηp2=.14).

NOTE. Greenhouse-Geisser results are reported to control Type I errors due to possible sphericity.

TECHNOLOGY AT HOME: Multiple linear regressions.

- Ran standard multiple regressions to see if access to technology at home affects S&T outcomes. HT_IC=internet technologies – television, computer, tablet, mobile phone; HT_Mech = mechanical technologies - bike and car.
- Used pre-visit data about S&T outcomes because I was trying to determine whether access to technology at home made a difference with their pre-visit disposition (not changes).
- No significant results = all p greater than .05, evidence that there are no significant relations between pupils' technology access and their core S&T outcomes.

Table 65: Access to technology at home does not significantly affect core pupil outcomes.

				HTECH_INT			HTECH_MECH		
Dependent Variable	**R**	**R^2**	**p**	**B**	**B SE**	**ß**	**B**	**B SE**	**ß**
Interest in techn	0.079	0.006	0.531	.095	.089	0.08	-0.073	0.107	-0.05
Interest in ns	0.125	0.016	0.212	-0.154	0.088	-0.13	0.037	0.105	0.03
Attitude about techn	0.067	0.005	0.673	0.073	0.077	0.07	-0.022	0.093	-0.02
Attitude about ns	0.098	0.010	0.385	-0.084	0.077	-0.08	-0.045	0.092	-0.04
Self-concept techn	0.043	0.002	0.834	-0.029	0.080	-0.03	0.055	0.096	0.04
Self-concept ns	0.165	0.027	0.062	-0.159	0.070	-0.17	0.113	0.084	0.10
S&T career aspirations	0.093	0.009	0.416	-0.166	0.140	-0.09	0.155	0.168	0.07

EXPERIMENTATION IN THE CLASSROOM: Multiple linear regressions.

A proxy for differences between teachers: EX_GROUP = pupils experiment in classroom in small groups; EX_TEACH= teacher demonstrates experiments for the class.

- Used pre-visit survey values because there were virtually no (one) significant differences over time for DVs and because pupils gave experimenting responses on pre-visit survey.
- One significant result for interest in natural science p=0.040. This suggests that experimentation in the classroom accounts for 18 percent (R=.177) of the variance in pupils' natural science interest. A closer look at the IVs reveals that how often the teacher demonstrates experiments to pupils has a significant effect on their natural science interest (EX_TEACH ß = .17, p=.018), but not how often pupils experiment in groups (EX_TEACH ß = .02, p=.744).
- All other DVs insignificant, that is, all other p´s are greater than .05.

Table 66: Experimentation in the classroom does not significantly affect core pupil outcomes.

				EX_GROUP				EX_TEACH			
Dependent Variable	**R**	**R^2**	**p**	**B**	**B SE**	**ß**	**p**	**B**	**B SE**	**ß**	**p**
Interest in techn	0.111	0.012	.277	-.055	.058	-0.07	.350	0.089	0.06	0.11	.138
Interest in ns	0.177	0.031	**.040**	0.019	0.057	0.02	.744	0.138	0.058	0.17	**.018**
Attitude about techn	0.039	0.002	.855	-0.011	0.051	-0.02	.827	0.028	0.052	0.04	.581
Attitude about ns	0.115	0.013	.257	0.016	0.050	0.02	.749	0.077	0.051	0.11	.135
Self-concept techn	0.080	0.006	.423	0.025	0.052	0.04	.628	0.047	0.053	0.06	.376
Self-concept ns	0.026	0.001	.933	0.017	0.047	0.03	.711	-0.003	0.047	0.00	.957
S&T career aspirations	0.139	0.019	.129	0.116	0.091	0.09	.204	0.114	0.092	0.09	.217

THE COVARIATE, CURIOSITY TRAIT, IS NOT INDEPENDENT FROM PREDICTORS

A covariate is used in a multivariate test to reduce the within-group error variance by allowing the covariate to explain some of this error variance. According to some researchers, for a variable to be a true covariate, it must be independent of the independent variables used as predictors in the investigation (Field, 2013, p. 144). Ideally, the covariate shares its variance with the error, or unexplained variance, from prediction of an IV on a dependent variable (DV). One-way ANOVAs tests, run for each predictor variable as shown in Table 66, can be used to test whether different sample groups differ on the covariate. In this case, technological capability and frequenting technology-related OLSePs vary significantly with the covariate curiosity trait. This supports that idea that pupils who describe themselves as more technologically capable and who more often visit technology-related OSLePs, tend to be more curious by nature.

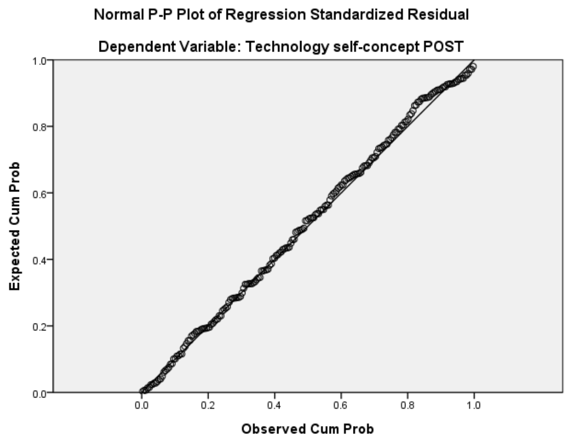
Table 67: Technological capability and frequenting technology-related OLSePs vary significantly with the covariate dispositional curiosity, CURT, evidence that it lacks independence from these predictor variables.

		Curiosity Trait (CurT)			
Predictor	Label	**df**	**df error**	***F***	***p***
technological capability	Tink	16	178	3.00	**<.001**
Frequents tech-OSLePs	V_TECH	21	1	2.47	**.001**
Frequents ns-OSLePs	V_NS	4	1	2.33	.057
Pre-visit knowledge	Know	4	1	2.33	.057

11.7 Appendix: Residual plot from regression test involving curiosity, cognitive load

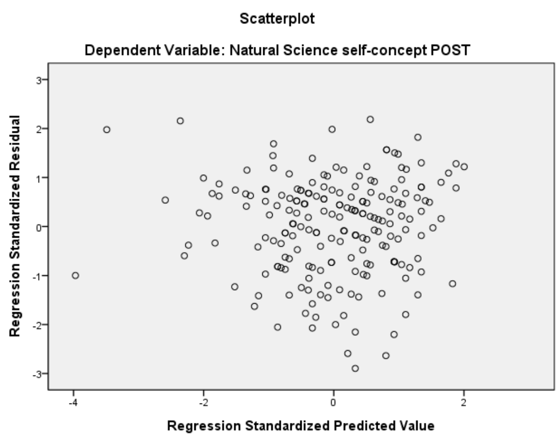
Results: P-P Plot suggest residuals are normally distributed

The two P-P plots for Regressions Standardized Residuals are representative of the P-P plots for all 7 core DVs that were tested with curiosity state. P-P plots compare the cumulative data with a normal distribution, a line that represents expected (normal values). They show us how much the data for residuals (error) deviates from a normal distribution. Here we see that the data deviate little from a normal distribution, suggesting that the regression results are indeed representative of a linear relationship.



Result: scatterplot of model suggests linearity

The scatterplot below of standardized residuals (error) against predicted values shows a random pattern and is representative of scatterplots for all DVs. The points have similar dispersion about the zero line over the predicted value range. Because the scatterplot shows no clear relationship between the residuals and the predicted values, it indicates that the assumptions of linearity and homoscedasticity have been met (Field, 2013, p. 348). Nice explanation here https://www.youtube.com/watch?v=iMdtTCX2Q70 .



11.8 Appendix: Variable frequencies and scale reliability

This section provides basic data, namely frequencies and reliability data, about study variables and survey item scales (group of survey items). The sources for the survey items that were used are listed in the Variable Operationalization Matrix shown in Table 19. The reliability of a scale indicates how free it is from random error. For scales used to measure attitude and changes in attitude over time, an internal consistency measure using Cronbach's alpha is appropriate. The internal consistency of a scale refers to how well the items of the scale 'hang together' and measure the same underlying construct: values greater than .7 are acceptable and .8 are preferable (further discussion in (Field, 2013, p. 709)). Also often reported is the Corrected Item-Total Correlation (r_{it}), which indicates the degree to which each item correlates with the total score, and the Cronbach's Alpha if Item Deleted (a). Values less than .3 indicate that the item is measuring something different from the scale as a whole (Pallant, 2013). The following pages provide these reliability data for each scale used in the surveys: the number of respondents (N), Cronbach's alpha (α), the Corrected Item-Total Correlation (r_{it}) and the Cronbach's alpha if Item Deleted (a). Negatively worded items are shown in italics.

Unless otherwise noted, scalar variables were constructed with a Likert 4-point scale, using the response scale in Table 67.

Table 68: All scalar variables, with the exception of cognitive load (CL), were constructed of a four-point Likert response scale.

German	English
1=Stimmt gar night	1=Not at all true
2=Stimmt wenig	2=Slightly true
3=Stimmt zeimlich	3=Mostly true
4=Stimmt völlig	4=Completely true

Independent Variables

1. Tink

Technological capability

This variable indicates whether the respondent, when interacting with technology, tends to explore and 'tinker' or tends to seek support and direction.

		PU1		PU2		PU3	
	N=	207					
	Cronbach's α =	.73					
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
Tink1	*Lieber schaue ich jemandem zu, der ein kompliziertes technisches Gerät (z.B. Maschinen, Elektrogeräte) bedient, als es selbst zu versuchen.*	.53	.68				
Tink2	*Scheinbar mache ich immer etwas falsch beim Versuch, ein technisches Gerät zu bedienen.*	.44	.71				
Tink3	*Ich lasse lieber andere ein technisches Gerät bedienen, denn ich könnte etwas falsch machen.*	.59	.66				
Tink4	Wenn ich ein neues technisches Gerät sehe, möchte ich sofort mit ihm spielen, um zu sehen, was es alles kann.	.40	.72				
Tink5	Ich probiere lieber sofort, ein technisches Gerät zu bedienen, als beim Lesen der Anleitung viel Zeit zu verlieren.	.37	.73				
Tink6	Es macht Spass, selbst herauszufinden, wie ein technisches Gerät funktioniert, ohne lange eine Anleitung durchzulesen.	.52	.68				

2. V_NS

3. V_TECH

Table 69: Collapsed variables for how often pupils frequented OSLePs: technology OSLePs and natural science OSLePs

Type of OSLeP frequented	Items	Variable Label	N	M	SD	Skew	Kurtosis
Natural science	museum, zoo, aquarium, botanical garden, veggi garden, flower garden, forest	V_NS	192	6.4	.9	-.518	.124
Technology	museum, science center, hobby workshop, tv programs, internet sites	V_Tech	201	6.2	.9	-.437	-.042

Table 70: Frequencies about how often pupils visited various OSLePs.

	museum	science centers	zoos	aquarium	hobby workshop	botanical gardens	vegetable garden	flower gardens	forests	S&T tv shows	S&T websites
once every day	0	0	0	1	2	0	3	6	1	15	1
2-6 times per week	0	0	0	0	5	0	8	6	19	57	2
2-4 times per month	0	0	0	0	11	2	11	7	47	62	11
once per month	4	1	0	1	10	7	23	22	36	29	20
4-11 times per year	16	4	21	3	14	7	24	25	54	20	18
1-3 times per year	71	53	88	44	14	17	22	22	27	10	20
l< once per year	70	89	76	93	31	56	25	37	7	2	28
never	53	65	29	71	120	118	95	87	16	18	113
Total	214	212	214	213	207	207	211	212	207	213	213
missing (no answer)	1	3	1	2	8	8	4	3	8	2	2
Total	215	215	215	215	215	215	215	215	215	215	215

4. CurT

Curiosity trait This variable indicates to what extent a respondent is generally curious as a part of their disposition.	N= Cronbach's α =	PU1		PU2		PU3	
	N=					203	
	Cronbach's α =					.84	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
CurT1	Neues zu lernen fasziniert mich.					.60	.81
CurT2	Ich bin neugierig auf neue Dinge oder Erfahrungen.					.68	.79
CurT3	Ich erfahre gerne etwas über Themen die mir unbekannt sind.					.70	.79
CurT4	Neue Ideen regen meine Phantasie an.					.54	.83
CurT5	Wenn ich etwas Neues erfahre, möchte ich dem gerne nachgehen.					.60	.81
CurT6	Ich gehe Dingen, die ich nicht verstehe, auf den Grund.					.56	.82

5. GrS

Single item interval variable, frequencies described in Table 23.

6. GrM

Single item interval variable, frequencies described in Table 23.

7. ExpB

Interval Scale: 1="stimmt gar nicht" to 4="stimmt völlig"		Visit Pu2	
	N=	211	
	Cronbach's α =	.70	
		r_{it}	a
ExpB1	Ich habe keine Probleme, die mobiLLab-Geräte selbst zu bedienen.	.480	.653
ExpB2	Aufgrund der Vorbereitung habe ich keine Angst, bei der Bedienung der mobiLLab-Geräte Fehler zu machen.	.415	.669
ExpB3	Ich bin in der Lage mit den mobiLLab-Geräten zu „spielen" um zu sehen, was sie alles können.	.428	.666
ExpB4	Ich konnte rasch mit der Bedienung der mobiLLab-Geräte beginnen.	.457	.658
ExpB5	Der zeitliche Ablauf des mobiLLab-Tages ist mir bekannt.	.315	.702
ExpB6	Der mobiLLab-Besuch ist gut organisiert.	.413	.673
ExpB7	Für den mobiLLab-Besuch bin ich gut vorbereitet.	.419	.669

8. OF

The factor analysis did not identify a scale of items for the construct orientated feeling. Instead, the variable was defined through a single item that had a high factor loading from the factor analysis (Varimax=.608, Oblimin=.927; Promax=.957).

ITEM LABEL	ITEM TEXT	*N*	*M*	*SD*	Skew	Kurtosis
OF	Der mobiLLab-Besuch ist gut organisiert.	215	3.6	.5	-.951	-.148

9. <u>CurS</u>

Interval Scale: 1="stimmt gar nicht" to 4="stimmt völlig"		Visit Pu2	
	N=	212	
	Cronbach's α =	.86	
		r_{it}	a
CurS1	Es hat mir Spass gemacht, die mobiLLab-Geräte auszuprobieren.	.597	.847
CurS2	Die Erfahrung mit mobiLLab weckt meine Neugier auf die dort behandelten Themen.	.746	.818
CurS3	Es interessiert mich, wie die Geräte an den verschiedenen Posten funktionieren.	.675	.832
CurS4	Ich möchte mehr über die mobiLLab-Themen erfahren.	.631	.840
CurS5	Die in den mobiLLab-Versuchen behandelten Themen haben mich persönlich angesprochen.	.681	.831
CurS6	Ich möchte die in den mobiLLab behandelten Themen besser verstehen.	.588	.849

10. <u>CL</u>

Interval Scale: 1="sehr niedrig/viel zu lang/ sehr wenig" to 4="sehr hoch/ viel zu kurz/ sehr stark"		Visit Pu2	
	N=	212	
	Cronbach's α =	.70	
		r_{it}	a
CL1	*Die Experimente waren schwierig.*	.440	.663
CL2	*Ich konnte mich gut auf die Experimente konzentrieren, ohne mit den Geräten "kämpfen" zu müssen.*	.512	.638
CL3	Wie hoch war die geistige Belastung bei den Versuchen insgesamt (zuviel Unbekanntes, zuviel auf einmal)?	.428	.666
CL4	Wie empfindest du die Zeit, die für Experimente zur Verfügung stand?	NA	NA
CL5	Wie sehr musstest du dich anstrengen, um die Experimente durchzuführen?	.379	.680
CL6	Wie verunsichert, entmutigt, oder verärgert warst du während der Experimente?	.439	.662
CL7	*Ich konnte rasch mit der Bedienung der mobiLLab-Geräte beginnen.*	.410	.671

11. <u>VidNo</u>

The number of novelty-reducing videos pupils watched is shown in Table 30.

12. Know

Table 71: Score frequencies for knowledge items.

Knowledge item keyword	Variable label	*N*	Missing	0 points		1 point		2 points	
				N	%	*N*	%	*N*	%
transport, PU1	kn_xportSC_t1	209	6	62	29	144	67	3	1
transport, PU2	kn_xportSC_t2	206	9	44	20	117	54	45	21
transport, PU3	kn_xportSC_t3	203	12	27	13	129	60	47	22
visible, PU1	kn_seeSC_t1	214	1	14	7	200	93	0	0
visible, PU2	kn_seeSC_t2	214	1	12	6	189	88	13	6
visible, PU3	kn_seeSC_t3	212	3	14	7	184	86	14	7
wavelength, PU1	kn_sizeSC_t1	213	2	187	87	26	12	NA	NA
wavelength, PU3	kn_sizeSC_t3	209	6	177	82	32	15	NA	NA
spectrum part, PU1	kn_partSC_t1	210	5	155	72	55	26	NA	NA
spectrum part, PU3	kn_partSC_t3	209	6	88	41	121	56	NA	NA
infrared waves	irpost_checkSC_t3	107	108	20	9	87	40	NA	NA
microwaves	mwpost_checkSC_t3	153	62	9	4	144	67	NA	NA
radio waves	radpost_checkSC_t3	157	58	98	46	59	27	NA	NA
ultraviolet waves	uvpost_check_t3	131	84	11	5	120	56	NA	NA
visible light	vispost_check_t3	99	116	32	15	67	31	NA	NA
x-rays	xrfpost_check_t3	123	92	18	8	105	49	NA	NA

Note. NA=not applicable. t1=pre-survey; t2=at-visit survey; t3=post-survey.

13. R/A

Related to everyday life

This variable indicates to what extent the respondent felt the mobiLLab experience related to their everyday life.

		PU1		PU2		PU3	
	N=					207	
	Cronbach's α =					.88	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
LIFE1	Was wir an den mobiLLab-Posten erfahren haben, ist im Alltag nützlich.					.64	.86
LIFE2	Die Inhalte der mobiLLab-Posten sind für Dinge interessant, mit denen ich ausserhalb der Schule zu tun habe.					.61	.87
LIFE3	Die Aufgaben, die wir in den mobiLLab-Posten bearbeitet haben, sind im Alltag hilfreich.					.73	.86
LIFE4	Bei den mobiLLab-Posten geht es um Dinge, die mit dem täglichen Leben zu tun haben.					.69	.85
LIFE5	Die Themen der mobiLLab-Posten sind nützlich für das tägliche Leben.					.77	.84
LIFE6	Die Aufgaben, die wir in den mobiLLab-Posten bearbeitet haben, sind auf den Alltag bezogen.					.64	.86

Dependent variables

14. Tint

Interest in technology Indicates to what extent the respondent feels generally interested in technology as part of their disposition.		PU1		PU2		PU3	
	N=	210				208	
	Cronbach's α =	.80				.84	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
TI1	Technik macht mir Spass.	.68	.75			.71	.80
TI2	*Bei Technik-Sendungen im Fernsehen schalte ich immer um oder aus.*	.56	.77			.59	.82
TI3	Technik gehört für mich persönlich zu den wichtigen Dingen.	.47	.79			.68	.80
TI4	*Ich unterhalte mich in meiner Freizeit nur ungern über technische Themen.*	.54	.78			.53	.83
TI5	Ich finde es wichtig, mich mit technischen Fragestellungen zu beschäftigen.	.52	.78			.52	.83
TI6	*Artikel über Technik finde ich völlig uninteressant.*	.39	.80			.47	.84
TI7	*In meiner Freizeit habe ich Besseres zu tun, als über technologische Sachen nachzudenken.*	.61	.76			.66	.81

15. Sint

Interest in natural science Indicates to what extent the respondent feels generally interested in natural science as part of their disposition.		PU1		PU2		PU3	
	N=	205				209	
	Cronbach's α =	.82				.82	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
NSI1	Naturwissenschaften machen mir Spass.	.59	.80			.59	.79
NSI2	*Bei naturwissenschaftlichen Sendungen im Fernsehen schalte ich immer um oder aus.*	.59	.80			.60	.79
NSI3	Naturwissenschaften gehören für mich persönlich zu den wichtigen Dingen.	.48	.82			.53	.80
NSI4	*Ich unterhalte mich in meiner Freizeit nur ungern über naturwissenschaftliche Themen.*	.53	.81			.57	.79
NSI5	Ich finde es wichtig, mich mit naturwissenschaftlichen Fragestellungen zu beschäftigen.	.59	.80			.60	.79
NSI6	*Naturwissenschaftliche Artikel finde ich völlig uninteressant.*	.52	.81			.48	.81
NSI7	*In meiner Freizeit habe ich besseres zu tun, als über naturwissenschaftliche Phänomene nachzudenken.*	.70	.78			.57	.79

16. Tatt

Attitude about technology This variable indicates to what extent the respondent has a positive attitude about technology.		PU1		PU2		PU3	
	N=	207				207	
	Cronbach's α =	.69				.71	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
TAT1	Technischer Fortschritt ist wichtig für eine Verbesserung der menschlichen Lebensbedingungen.	.56	.60			.53	.64
TAT2	Technische Fortschritte sind wichtig für die Wirtschaft.	.48	.63			.56	.64
TAT3	Technik ist nützlich für die Gesellschaft.	.48	.63			.48	.67
TAT4	Ich finde, dass Technik hilft, die Dinge um mich herum zu verstehen.	.37	.68			.37	.71
TAT5	Technische Fortschritte bringen oft Vorteile für die Gesellschaft mit sich.	.39	.68			.44	.68

17. Satt

Attitude about natural science This variable indicates to what extent the respondent has a positive attitude about natural science.		PU1		PU2		PU3	
	N=	206				210	
	Cronbach's α =	.72				.79	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
NSAT1	Fortschritte in Naturwissenschaft sind wichtig für eine Verbesserung der menschlichen Lebensbedingungen.	.47	.70			.57	.75
NSAT2	Fortschritte in Naturwissenschaft sind wichtig für die Wirtschaft.	.59	.65			.55	.76
NSAT3	Naturwissenschaften sind nützlich für die Gesellschaft.	.57	.66			.64	.73
NSAT4	Ich finde, dass Naturwissenschaften helfen, die Dinge um mich herum zu verstehen.	.36	.74			.49	.79
NSAT5	Naturwissenschaftliche Fortschritte bringen oft Vorteile für die Gesellschaft mit sich.	.50	.69			.61	.74

18. Tsc

Self-concept with respect to technology Indicates to what extent the respondent identifies themselves as someone who is good at working with technology.		PU1		PU2		PU3	
	N=	207				210	
	Cronbach's α =	.83				.86	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
TSC1	*Mich würde Technik mehr interessieren, wenn nicht alles so kompliziert wäre.*	.25	.85			.33	.87
TSC2	*Obwohl ich mir Mühe gebe, fällt mir der Umgang mit Technik schwer.*	.70	.80			.71	.83
TSC3	Das Verstehen technischer Erklärungen fällt mir leicht.	.60	.81			.68	.83
TSC4	*Kein Mensch kann alles. Für Technik habe ich einfach keine Begabung.*	.72	.79			.73	.83
TSC5	*Bei manchen komplizierten technischen Themen weiss ich von vornherein: "Das verstehe ich nie."*	.57	.81			.62	.84

TSC6	Anhand anschaulicher Experimente verstehe ich auch komplizierte technische Erklärungen.	.55	.81			.58	.85
TSC7	*Technik liegt mir nicht besonders.*	.65	.80			.68	.83
SC8	*Für das Durchführen von Experimenten habe ich kein Händchen.*	.44	.83			.52	.85

19. Ssc

Self-concept with respect to natural science Indicates to what extent the respondent identifies themselves as someone who is good at working with natural science.		PU1		PU2		PU3	
	N=	209				205	
	Cronbach's α =	.79				.85	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
NSSC1	*Mich würden Naturwissenschaften bestimmt interessieren, wenn nicht alles so kompliziert wäre.*	.36	.78			.39	.85
NSSC2	*Obwohl ich mir Mühe gebe, fallen mir Naturwissenschaften schwer.*	.64	.74			.67	.82
NSSC3	Das Lernen von naturwissenschaftlichen Theorien fällt mir leicht.	.50	.76			.55	.83
NSSC4	*Kein Mensch kann alles. Für Naturwissenschaften habe ich einfach keine Begabung.*	.61	.74			.78	.81
NSSC5	*Bei manchen Sachen in den Naturwissenschaften weiss ich von vornherein: "Das verstehe ich nie."*	.47	.77			.59	.83
NSSC6	Anhand anschaulicher Experimente verstehe ich auch komplizierte naturwissenschaftliche Theorien.	.35	.78			.56	.83
SCNS7	*Naturwissenschaften liegen mir nicht besonders.*	.58	.75			.65	.82
SC8	*Für das Durchführen von Experimenten habe ich kein Händchen.*	.44	.77			.51	.84

20. CA

Single item interval.

ITEM LABEL	ITEM TEXT	*N*	*M*	*SD*	Skew	Kurtosis
CAREER	Ich möchte in meinem zukünftigen Beruf mit Naturwissenschaften und Technik zu tun haben.	214	2.1	1.0	.526	-.758

21. PSat

Program satisfaction Indicates to what extent the respondent enjoyed the mobiLLab experience.		PU1		PU2		PU3	
	N=					211	
	Cronbach's α =					.64	
ITEM LABEL	ITEM TEXT	r_{it}	a	r_{it}	a	r_{it}	a
SAT1	Ich habe mich beim mobiLLab-Tag mehr angestrengt als sonst in "Natur und Technik".					.23	.81
SAT2	Ich würde gerne an einem weiteren mobiLLab-Tag teilnehmen.					.55	.38
SAT3	Der mobiLLab-Tag hat mir gefallen.					.61	.32

Control Variables

22. Gen

Single item nominal. See Table 16.

23. SY

Single item nominal. See Table 16.

24. ST

Single item nominal. See Table 16 for frequencies.

25. HT_IC

26. HT_Mech

Table 72: Collapsed variables for technology at home: internet-related technology and mechanical technology.

Type of technology at home	Items	Variable Label	N	M	SD	Skew	Kurtosis
Internet Technology	Mobile phones, tvs, computers/ notebooks, iPads/ tablets	HT_IC	210	2.0	.5	-151	-.325
Mechanical technology	Bikes, cars	HT_Mech	210	2.3	.4	-.213	.143

Table 73: Frequencies showing how much technology pupils have at home.

Wie viele der folgenden Geräte gibt es bei dir zuhause?

HTECH	*N*	*M*	*SD*	3 or more	Skewness		Kurtosis	
# smartphones, mobile phones	214	2.86	.439	192 (89%)	-3.681	.166	14.719	.331
# tvs	214	1.72	.795	39 (18%)	.141	.166	-.764	.331
# computers or notebooks	212	2.33	.743	104 (48%)	-.607	.167	-.959	.333
# iPads or tablets	212	1.22	.960	27 (12%)	.417	.167	-.735	.333
# bikes	211	2.88	.403	192 (89%)	-3.577	.167	12.452	.333
# cars	213	1.72	.742	34 (16%)	.285	.167	-.781	.332

27. HL

Indicates language spoken at home most of the time (N=214).

ITEM LABEL	ITEM TEXT	Home language	Frequency	Percent
HL	Welche Sprache sprichst du normalerweise zuhause?	1.00 German (including dialects)	182	84.7
		2.00 Other national language (French, Italian, Ràtoromanisch)	3	1.4
		3.00 Not an official language of Switzerland	29	13.5

28. EXP_G

29. EXP_T

ITEM LABEL	ITEM TEXT	*N*	*M*	*SD*	Skew	Kurtosis
EXP_G	Wie oft werden in „Natur und Technik" Schüler-experimente in Kleingruppen von dir gemein-sam mit deinen Mitschülerinnen/Mitschülern durchgeführt?	215	2.6	0.8	.166	-.234
EXP_T	Wie oft werden in „Natur und Technik" Experi-mente von deinem Lehrer/deiner Lehrerin vorgeführt?	215	2.8	0.7	.166	.045

11.9 Appendix: Observation Instrument (pilot study only)

Schulname______________________ Einsatz (Datum)________________ (Vormittag oder Nachmittag?)
Lehrperson ___________________________ Beobachter (Ihr Name) __________________________________

BEOBACHTUNGSINSTRUMENT {matches Te2}

Ist der Postenablauf irgendwo angeschlagen? ☐ Ja ☐ Nein

Schätzen Sie wie viele Schüler…	0%	25%	50%	75%	100%
… die Journalblätter ausfüllen.	☐	☐	☐	☐	☐
… etwas mitgebracht haben, um es beim mobiLLab Posten zu testen.	☐	☐	☐	☐	☐

Was für ein Verhalten stellen die Schülerinnen und Schüler dar?	0%	25%	50%	75%	100%
Erforschend Tätig	☐	☐	☐	☐	☐
Ziel-gerichtet	☐	☐	☐	☐	☐
Mit anderen über mobiLLab Aufgabe austauschen	☐	☐	☐	☐	☐
Mit anderen über etwas Ausser mobiLLab austauschen	☐	☐	☐	☐	☐
Sich in der Mittelpunkt stellen (nicht bezüglich mit mobilLab)	☐	☐	☐	☐	☐
Zurückziehend und/oder abgelenkt, z.B. mit ihr Handy	☐	☐	☐	☐	☐

Wie verbringt die Lehrperson ihre Zeit?	0%	25%	50%	75%	100%
ist abwesend	☐	☐	☐	☐	☐
macht ihre eigenen Aufgaben	☐	☐	☐	☐	☐
schaut die Schülerinnen und Schüler zu	☐	☐	☐	☐	☐
handelt Diziplin	☐	☐	☐	☐	☐
unterstutzt Bedarfe des mobiLLab Teams	☐	☐	☐	☐	☐
macht mit beim mobiLLab experimentalische Posten	☐	☐	☐	☐	☐
Sonstiges ___________________________________	☐	☐	☐	☐	☐

Wie würdest du die Stimmung der Schulgruppe beschreiben? *Kreuzen alle zutreffenden Antworten an.*

☐ begeistert	☐ neugierig	☐ fleissig
☐ konzentriert	☐ enthusiastisch	☐ gelangweilt
☐ abgelenkt	☐ undiszipliniert	☐ motiviert
☐ wild	☐ laut	☐ interessiert
		☐ Sonstiges: _____________

Weitere Kommentare betreffend die Vorbereitung der Schülerinnen und Schüler auf den mobiLLab-Besuch:
____
____
____

11.10 Appendix: Main Study Pupil Surveys

mobiLLab

PH SG

Erste mobiLLab-Befragung für Schülerinnen und Schüler

Liebe Schülerin, lieber Schüler

Mit diesem Fragebogen möchte das mobiLLab-Team deine Haltung und Erfahrung zu Natur und Technik erfassen. Deine Antworten sind für uns wichtig, damit wir mobiLLab optimieren können. Bitte lies jede Frage sorgfältig durch und antworte so genau wie möglich oder suche eine Antwort, die am besten auf dich zutrifft.

Während und nach dem mobiLLab-Besuch werden weitere Fragebogen verteilt, die nach deinen Erfahrungen mit mobiLLab fragen. Alle Fragebogen bleiben anonym, aber sie müssen für die Auswertung eindeutig einander zugeordnet werden können. Damit dies möglich ist, erhält jede befragte Person einen Erkennungscode. Fülle bitte zunächst aus:

Der zweite und dritte Buchstabe des Vornamens deiner Mutter. (z.B. wenn deine Mutter „Gabi“ heisst: 2. *A* 3. *B*)	Der zweite und dritte Buchstabe des Vornamens deines Vaters. (z.B. wenn dein Vater „Urs“ heisst: 2. *R* 3. *S*)	Die letzten zwei Ziffern der Postleitzahl des Wohnorts (z.B. 9126: 3. *2* 4. *6*)
2._____ 3. _____	2. _____ 3. _____	3._____ 4. _____

Du brauchst ungefähr 20 Minuten, um diesen Fragebogen auszufüllen.

Vielen Dank für deine Mithilfe!

Das mobiLLab-Team

Fragen zu deiner Person

1 **Ich bin:**

- ❒ männlich
- ❒ weiblich

2 **Ich bin Schülerin / Schüler in:**

- ❒ OS Burgerau R2b
- ❒ OS Burgerau S2b
- ❒ OS Burgerau S2c
- ❒ Schule Mosnang Sek 3A
- ❒ Schule Mosnang Sek 3B
- ❒ OZ Degenau R2a
- ❒ OZ Degenau S2c
- ❒ OZ Degenau S2b
- ❒ OZ Bad Ragaz EBV
- ❒ OZ Bad Ragaz EBN
- ❒ OZ Bad Ragaz 3sb
- ❒ OZ Bad Ragaz 3sa
- ❒ OMR Heerbrugg 2rb
- ❒ OMR Heerbrugg 2rc
- ❒ OMR Heerbrugg 2sd
- ❒ OMR Heerbrugg 2sb
- ❒ OMR Heerbrugg 2ra
- ❒ OMR Heerbrugg 2sa
- ❒ OMR Heerbrugg 2se
- ❒ OZ Walenstadt 2sb
- ❒ OZ Walenstadt 2sa
- ❒ OZ Schaan 3ab
- ❒ Andere Schule ________________________

3 **Wie viele der folgenden Geräte gibt es bei dir zuhause?**

Bitte in jeder Zeile nur ein Kästchen ankreuzen

	kein(en)	ein(en)	zwei	drei oder mehr
Smartphone, Handy	☐	☐	☐	☐
Fernseher	☐	☐	☐	☐
Computer oder Notebook	☐	☐	☐	☐
iPad oder Tablet	☐	☐	☐	☐
Fahrrad	☐	☐	☐	☐
Auto	☐	☐	☐	☐

4 **Welche Sprache sprichst du normalerweise zuhause? *(Bitte nur ein Kästchen ankreuzen)***

- ❒ Schweizerdeutsch
- ❒ Liechtensteiner Dialekt
- ❒ Hochdeutsch
- ❒ Französisch
- ❒ Italienisch
- ❒ Rätoromanisch
- ❒ Spanisch
- ❒ Portugiesisch
- ❒ Türkisch
- ❒ Südslawisch (Bosnisch, Kroatisch, Mazedonisch, Serbisch, Slowenisch)
- ❒ Albanisch
- ❒ Englisch
- ❒ Andere Sprache ________________________

Fragen zu Schulfächern und Unterricht

5 **Welche Note hattest du im Fach „Natur und Technik“ im letzten Zeugnis?**

1	2	3	3,5	4	4,5	5	5,5	6	Ich hatte im letzten Zeugnis kein benotetes Fach „Natur und Technik“.
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6 **Welche Note hattest du im Fach „Mathematik“ im letzten Zeugnis?**

1	2	3	3,5	4	4,5	5	5,5	6	Ich hatte im letzten Zeugnis kein benotetes Fach „Mathematik“.
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

7 **Wiederholst du das vorgängige Schuljahr (2013-2014)?**

- ❒ ja
- ❒ nein

		Sehr selten	selten	oft	Sehr oft
8	Wie oft werden in „Natur und Technik“ *Schüler-experimente* in Kleingruppen von *dir gemein-sam mit deinen Mitschülerinnen/Mitschülern* durchgeführt?	☐	☐	☐	☐
9	Wie oft werden in „Natur und Technik“ Experi-mente *von deinem Lehrer/deiner Lehrerin vorgeführt?*	☐	☐	☐	☐

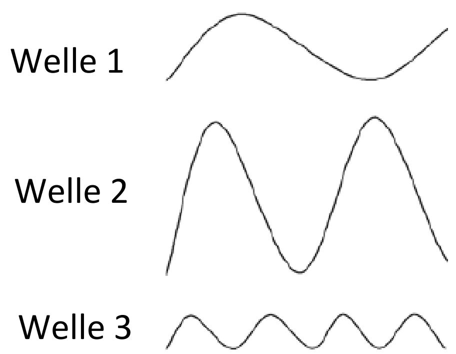
Wissensfragen zum Thema elektromagnetische Strahlung

In den folgenden Fragen geht es um die Strahlung, die beim Radio, Handy, dem Mikrowellenherd und mehreren Versuchen von mobiLLab benutzt wird und die elektromagnetische Strahlung genannt wird. Diese Fragen sind kein Test und keine Leistungskontrolle. Wir möchten nur wissen, was du schon gelernt hast, und Deine Antworten helfen uns, mobiLLab zu verbessern.

10 Strahlung, zum Beispiel Radiowellen, Mikrowellen oder das Licht einer Glühbirne, transportiert ______________________ .
- ❒ Stoff
- ❒ Energie
- ❒ Post
- ❒ Licht
- ❒ Keine von den genannten Lösungen
- ❒ Das weiss ich nicht

11 Alle Arten von Strahlung sind sichtbar.
- ❒ Ja
- ❒ Nein
- ❒ Einige sind sic
- ❒ Das weiss ich

12 Welche Welle hat
- ❒ Welle 1
- ❒ Welle 2
- ❒ Welle 3
- ❒ Alle haben die
- ❒ Das weiss ich



13 Der Bereich des elektromagnetischen Spektrums, den wir mit unseren Augen wahrnehmen können, ist
- ❒ ein ganz winziger Teil
- ❒ weniger als ein Zehntel
- ❒ mehr als die Hälfte
- ❒ fast alles
- ❒ Ich weiß nicht, was das elektromagnetische Spektrum ist
- ❒ Ich weiß , was das elektromagnetische Spektrum ist, kann aber die Frage nicht beantworten

Fragen zu deinen Stärken und Erfahrung mit den Themen „Natur“ und „Technik“

Gib bitte mit einem Kreuz an, inwieweit folgende Aussagen für dich zutreffen:

		stimmt gar nicht	stimmt wenig	stimmt ziemlich	stimmt völlig
14	Mich würde Technik mehr interessieren, wenn nicht alles so kompliziert wäre.	☐	☐	☐	☐
15	Naturwissenschaften liegen mir nicht besonders.	☐	☐	☐	☐
16	Obwohl ich mir bestimmt Mühe gebe, fällt mir der Umgang mit Technik schwer.	☐	☐	☐	☐
17	Anhand anschaulicher Experimente verstehe ich auch komplizierte naturwissenschaftliche Zusammenhänge.	☐	☐	☐	☐
18	Das Verstehen technischer Erklärungen fällt mir leicht.	☐	☐	☐	☐
19	Bei manchen Themen in den Naturwissenschaften weiss ich von vornherein: "Das verstehe ich nie".	☐	☐	☐	☐
20	Kein Mensch kann alles. Für Technik habe ich einfach keine Begabung.	☐	☐	☐	☐
21	Bei manchen komplizierten technischen Themen weiss ich von vornherein: "Das verstehe ich nie".	☐	☐	☐	☐
22	Das Verstehen der naturwissenschaftliche Theorien fällt mir leicht.	☐	☐	☐	☐
23	Anhand anschaulicher Experimente verstehe ich auch komplizierte technische Zusammenhänge.	☐	☐	☐	☐
24	Obwohl ich mir bestimmt Mühe gebe, fallen mir Naturwissenschaften schwer.	☐	☐	☐	☐
25	Technik liegt mir nicht besonders.	☐	☐	☐	☐
26	Mich würden Naturwissenschaften bestimmt interessieren, wenn nicht alles so kompliziert wäre.	☐	☐	☐	☐
27	Für das Durchführen von Experimenten habe ich kein Händchen.	☐	☐	☐	☐
28	Kein Mensch kann alles. Für Naturwissenschaften habe ich einfach keine Begabung.	☐	☐	☐	☐
29	Ich möchte in meinem zukünftigen Beruf mit Naturwissenschaften und Technik zu tun haben.	☐	☐	☐	☐

Fragen zu deinen ausserschulischen Erfahrungen

Lernen kannst du nicht nur in der Schule. Eine wichtige Rolle spielen auch sogenannte „ausserschulische Lernorte“. Wir möchten gerne mehr über die ausserschulischen Lernorte erfahren, die du kennst.

30 **Wie viel Zeit in den letzten zwei Jahren hast du ungefähr an folgenden ausserschulischen Lernorten und oder bei folgenden Aktivitäten verbracht?**

Ausserschulische Lernorte	Jeden Tag	2-6 Mal pro Woche	2-4 Mal im Monat	1 Mal im Monat	4-11 Mal pro Jahr	1-3 Mal pro Jahr	Seltener als 1 Mal pro Jahr	nie
Museum	☐	☐	☐	☐	☐	☐	☐	☐
Zoo	☐	☐	☐	☐	☐	☐	☐	☐
Aquarium (z. B. Sealife)	☐	☐	☐	☐	☐	☐	☐	☐
Science Center (z. B. Technorama)	☐	☐	☐	☐	☐	☐	☐	☐
Freizeitwerkstatt	☐	☐	☐	☐	☐	☐	☐	☐
Botanischer Garten	☐	☐	☐	☐	☐	☐	☐	☐
Gemüsegarten	☐	☐	☐	☐	☐	☐	☐	☐
Blumengarten	☐	☐	☐	☐	☐	☐	☐	☐
Wald	☐	☐	☐	☐	☐	☐	☐	☐
Technik- oder Wissenschaftliche TV-Sendungen (z.B. Galileo)	☐	☐	☐	☐	☐	☐	☐	☐
Technik- oder Wissenschaftsseiten auf dem Internet (z.B. www.geolino.de)	☐	☐	☐	☐	☐	☐	☐	☐
Sonstiges ____________________	☐	☐	☐	☐	☐	☐	☐	☐
Sonstiges ____________________	☐	☐	☐	☐	☐	☐	☐	☐

31 **Hast du ein Abonnement für eine Technik- oder Wissenschafts-Zeitschrift (z.B. Geolino)?**

❒ Ja
❒ nein

Hast du zusätzliche Kommentare zu deinen Aktivitäten bei ausserschulischen Lernorten? ____

Fragen über dein Interesse an Technik (Computer, Elektrogeräte)

Gib bitte mit einem Kreuz an, inwieweit folgende Aussagen für dich zutreffen:

		stimmt gar nicht	stimmt wenig	stimmt ziemlich	stimmt völlig
32	Lieber schaue ich jemandem zu, der ein kompliziertes technisches Gerät (z.B. Maschinen, Elektrogeräte) bedient, als es selbst zu versuchen.	☐	☐	☐	☐
33	Technische Fortschritte bringen oft soziale Vorteile mit sich.	☐	☐	☐	☐
34	In meiner Freizeit habe ich Besseres zu tun, als über technologische Sachen nachzudenken.	☐	☐	☐	☐
35	Scheinbar mache ich immer etwas falsch beim Versuch, ein technisches Gerät zu bedienen.	☐	☐	☐	☐
36	Ich finde, dass Technik hilft, die Dinge um mich herum zu verstehen.	☐	☐	☐	☐
37	Nachrichten (Zeitung, Fernsehen, Internet) über Technik finde ich völlig uninteressant.	☐	☐	☐	☐
38	Ich lasse lieber andere ein technisches Gerät bedienen, denn ich könnte etwas falsch machen.	☐	☐	☐	☐
39	Technik ist nützlich für die Gesellschaft.	☐	☐	☐	☐
40	Ich finde es wichtig, mich mit technischen Fragestellungen zu beschäftigen.	☐	☐	☐	☐
41	Wenn ich ein neues technisches Gerät sehe, möchte ich sofort mit ihm spielen, um zu sehen, was es alles kann.	☐	☐	☐	☐
42	Technische Fortschritte helfen oft, dass es der Wirtschaft besser geht.	☐	☐	☐	☐
43	Ich probiere lieber sofort, ein technisches Gerät zu bedienen, als beim Lesen der Anleitung Zeit zu verlieren.	☐	☐	☐	☐
44	Ich unterhalte mich in meiner Freizeit nur ungern über technische Themen.	☐	☐	☐	☐
45	Es macht Spass, selbst herauszufinden, wie ein technisches Gerät funktioniert, ohne eine Anleitung durchzulesen.	☐	☐	☐	☐
46	Technik macht mir Spass.	☐	☐	☐	☐
47	Meine Mitschülerinnen und Mitschüler interessieren sich im Allgemeinen für Technik.	☐	☐	☐	☐
48	Bei Technik-Sendungen im Fernsehen schalte ich immer aus oder um.	☐	☐	☐	☐
49	Technischer Fortschritt verbessert oft die Lebensbedingungen der Menschen.	☐	☐	☐	☐
50	Technik gehört für mich persönlich zu den wichtigen Dingen.	☐	☐	☐	☐

Fragen über dein Interesse an Naturwissenschaften

Gib bitte mit einem Kreuz an, inwieweit folgende Aussagen für dich zutreffen:

		stimmt gar nicht	stimmt wenig	stimmt ziemlich	stimmt völlig
51	Naturwissenschaften machen mir Spass.	☐	☐	☐	☐
52	Meine Mitschülerinnen und Mitschüler interessieren sich im Allgemeinen für Naturwissenschaften.	☐	☐	☐	☐
53	Bei naturwissenschaftlichen Sendungen im Fernsehen schalte ich immer aus oder um.	☐	☐	☐	☐
54	Naturwissenschaftliche Fortschritte bringen oft soziale Vorteile mit sich.	☐	☐	☐	☐
55	Naturwissenschaften gehören für mich persönlich zu den wichtigen Dingen.	☐	☐	☐	☐
56	Ich finde, dass Naturwissenschaften helfen, die Dinge um mich herum zu verstehen.	☐	☐	☐	☐
57	Ich unterhalte mich in meiner Freizeit nur ungern über naturwissenschaftliche Themen.	☐	☐	☐	☐
58	Naturwissenschaften sind nützlich für die Gesellschaft.	☐	☐	☐	☐
59	Ich finde es wichtig, mich mit naturwissenschaftlichen Fragestellungen zu beschäftigen.	☐	☐	☐	☐
60	Fortschritte in Naturwissenschaft helfen oft, dass es der Wirtschaft besser geht.	☐	☐	☐	☐
61	Naturwissenschaftliche Nachrichten (Zeitung, Fernsehen, Internet) finde ich völlig uninteressant.	☐	☐	☐	☐
62	Fortschritte in Naturwissenschaft verbessern oft die Lebensbedingungen der Menschen.	☐	☐	☐	☐
63	In meiner Freizeit habe ich besseres zu tun, als über naturwissenschaftliche Phänomene nachzudenken.	☐	☐	☐	☐

Du hast es geschafft! Danke für deine wertvolle Mitarbeit!

Bitte lege den Fragebogen in den Briefumschlag, verschliesse ihn und gib ihn dann deiner Lehrperson.

mobiLLab

PH SG

mobiLLab-Befragung für Schülerinnen und Schüler
Fragen zu deinen Erfahrungen während des mobiLLab-Tages

Mit diesem Fragebogen möchte das mobiLLab-Team deine Haltung und Erfahrung zu mobiLLab erfassen. Deine Antworten sind für uns wichtig, damit wir mobiLLab optimieren können.

Der zweite und dritte Buchstabe des Vornamens deiner Mutter. (z.B. wenn deine Mutter „Gabi“ heisst: 2. *A* 3. *B*)	Der zweite und dritte Buchstabe des Vornamens deines Vaters. (z.B. wenn dein Vater „Urs“ heisst: 2. *R* 3. *S*)	Die letzten zwei Ziffern der Postleitzahl des Wohnorts. (z.B. 9126: 3. *2* 4. *6*)
2.______ 3. ______	2. ______ 3. ______	3.______ 4. ______

		Stimmt gar nicht	stimmt wenig	stimmt ziemlic h	stimmt völlig
1	Ich habe keine Probleme, die mobiLLab-Geräte selbst zu bedienen.	☐	☐	☐	☐
2	Der zeitliche Ablauf des mobiLLab-Tages ist mir bekannt.	☐	☐	☐	☐
3	Aufgrund der Vorbereitung habe ich keine Angst, bei der Bedienung der mobiLLab-Geräte Fehler zu machen.	☐	☐	☐	☐
4	Der mobiLLab-Besuch ist gut organisiert.	☐	☐	☐	☐
5	Ich bin in der Lage mit den mobiLLab-Geräten zu „spielen“ um zu sehen, was sie alles können.	☐	☐	☐	☐
6	Für den mobiLLab-Besuch bin ich gut vorbereitet.	☐	☐	☐	☐
7	Ich konnte rasch mit der Bedienung der mobiLLab-Geräte beginnen.	☐	☐	☐	☐
8	Die Erfahrung mit mobiLLab weckt meine Neugier auf die dort behandelten Themen.	☐	☐	☐	☐
9	Es hat mir Spass gemacht, die mobiLLab-Geräte auszuprobieren.	☐	☐	☐	☐
10	Es interessiert mich, wie die Geräte an den verschiedenen Posten funktionieren.	☐	☐	☐	☐
11	Wir haben genügend Informationen, um die Experimente durchführen zu können.	☐	☐	☐	☐
12	Die Experimente waren schwierig.	☐	☐	☐	☐
13	Ich möchte mehr über die mobiLLab-Themen erfahren.	☐	☐	☐	☐

		Stimmt gar nicht	stimmt wenig	stimmt ziemlic h	stimmt völlig
14	Ich konnte mich gut auf die Experimente konzentrieren, ohne mit den Geräten “kämpfen” zu müssen.	☐	☐	☐	☐
15	Die in den mobiLLab-Versuchen behandelten Themen haben mich persönlich angesprochen.	☐	☐	☐	☐
16	Ich möchte die in den mobiLLab behandelten Themen besser verstehen.	☐	☐	☐	☐

17 Wie hoch war die geistige Belastung bei den Versuchen insgesamt (zuviel Unbekanntes, zuviel auf einmal)?

sehr niedrig ☐ ☐ ☐ ☐ sehr hoch

18 Wie empfindest du die Zeit, die für Experimente zur Verfügung stand?

viel zu lang ☐ ☐ ☐ ☐ viel zu kurz

19 Wie sehr musstest du dich anstrengen, um die Experimente durchzuführen?

sehr wenig ☐ ☐ ☐ ☐ sehr stark

20 Wie verunsichert, entmutigt, oder verärgert warst du während der Experimente?

sehr wenig ☐ ☐ ☐ ☐ sehr stark

21 Strahlung, zum Beispiel Radiowellen, Mikrowellen oder das Licht einer Glühbirne, transportiert:
- ❒ Stoff
- ❒ Energie
- ❒ Post
- ❒ Licht
- ❒ Keine von den genannten Lösungen
- ❒ Das weiss ich nicht

22 Alle Arten von Strahlung sind sichtbar.
- ❒ Ja
- ❒ Nein
- ❒ Einige sind sichtbar und einige nicht
- ❒ Das weiss ich nicht

Danke für deine wertvolle Mitarbeit!

Bitte gib den Fragebogen dem mobiLLab-Mitarbeiter.

Dritte mobiLLab-Befragung für Schülerinnen und Schüler

Liebe Schülerin, lieber Schüler

Mit diesem Fragebogen möchte das mobiLLab-Team deine Haltung und Erfahrung zu Natur und Technik und deine Erfahrung im Umgang mit mobiLLab erfassen. Deine Antworten sind für uns wichtig, damit wir das mobiLLab-Programm weiter optimieren können. Bitte lies jede Frage sorgfältig durch und antworte so genau wie möglich oder wähle diejenige Antwort, die am besten auf dich zutrifft.

Alle Fragebogen bleiben anonym, doch müssen sie für die Auswertung einander eindeutig zugeordnet werden können. Daher erhält jede befragte Person einen Erkennungscode. Bitte trage die gefragten Buchstaben und Ziffern in die untenstehende Tabelle ein:

Der zweite und dritte Buchstabe des Vornamens deiner Mutter. (z.B. wenn deine Mutter „Gabi“ heisst: 2. *A* 3. *B*)	Der zweite und dritte Buchstabe des Vornamens deines Vaters. (z.B. wenn dein Vater „Urs“ heisst: 2. *R* 3. *S*)	Die letzten zwei Ziffern der Postleitzahl des Wohnorts (z.B. 9126: 3. *2* 4. *6*)
2._____ 3. _____	2. _____ 3. _____	3._____ 4. _____

Du brauchst ungefähr 20 Minuten, um diesen Fragebogen auszufüllen.

Vielen Dank für deine Mithilfe!

Das mobiLLab-Team

Fragen zu deinen Stärken und Erfahrung mit den Themen „Natur“ und „Technik“

Gib bitte mit einem Kreuz an, inwieweit folgende Aussagen für dich zutreffen:

		stimmt gar nicht	stimmt wenig	stimmt ziemlich	stimmt völlig
1	Mich würde Technik mehr interessieren, wenn nicht alles so kompliziert wäre.	☐	☐	☐	☐
2	Naturwissenschaften liegen mir nicht besonders.	☐	☐	☐	☐
3	Neues zu lernen fasziniert mich.	☐	☐	☐	☐
4	Obwohl ich mir bestimmt Mühe gebe, fällt mir der Umgang mit Technik schwer.	☐	☐	☐	☐
5	Anhand anschaulicher Experimente verstehe ich auch komplizierte naturwissenschaftliche Zusammenhänge.	☐	☐	☐	☐
6	Ich bin neugierig auf neue Dinge oder Erfahrungen.	☐	☐	☐	☐
7	Das Verstehen technischer Erklärungen fällt mir leicht.	☐	☐	☐	☐
8	Bei manchen Themen in den Naturwissenschaften weiss ich von vornherein: "Das verstehe ich nie".	☐	☐	☐	☐
9	Kein Mensch kann alles. Für Technik habe ich einfach keine Begabung.	☐	☐	☐	☐
10	Bei manchen komplizierten technischen Themen weiss ich von vornherein: "Das verstehe ich nie".	☐	☐	☐	☐
11	Das Verstehen der naturwissenschaftlichen Theorien fällt mir leicht.	☐	☐	☐	☐
12	Ich erfahre gerne etwas über Themen die mir unbekannt sind.	☐	☐	☐	☐
13	Anhand anschaulicher Experimente verstehe ich auch komplizierte technische Zusammenhänge.	☐	☐	☐	☐
14	Obwohl ich mir bestimmt Mühe gebe, fallen mir Naturwissenschaften schwer.	☐	☐	☐	☐
15	Neue Ideen regen meine Phantasie an.	☐	☐	☐	☐
16	Technik liegt mir nicht besonders.	☐	☐	☐	☐
17	Mich würden Naturwissenschaften bestimmt interessieren, wenn nicht alles so kompliziert wäre.	☐	☐	☐	☐
18	Wenn ich etwas Neues erfahre, möchte ich dem gerne nachgehen.	☐	☐	☐	☐
19	Für das Durchführen von Experimenten habe ich kein Händchen.	☐	☐	☐	☐
20	Kein Mensch kann alles. Für Naturwissenschaften habe ich einfach keine Begabung.	☐	☐	☐	☐

		stimmt gar nicht	stimmt wenig	stimmt ziemlich	stimmt völlig
21	Ich gehe Dingen, die ich nicht verstehe, auf den Grund.	☐	☐	☐	☐
22	Ich möchte in meinem zukünftigen Beruf mit Naturwissenschaft und Technik zu tun haben.	☐	☐	☐	☐

Fragen zu deinem Interesse an Technik (Computer, Elektrogeräte)

Gib bitte mit einem Kreuz an, inwieweit folgende Aussagen für dich zutreffen:

		stimmt gar nicht	stimmt wenig	stimmt ziemlich	stimmt völlig
23	Technische Fortschritte bringen oft soziale Vorteile mit sich.	☐	☐	☐	☐
24	In meiner Freizeit habe ich Besseres zu tun, als über technologische Sachen nachzudenken.	☐	☐	☐	☐
25	Ich finde, dass Technik hilft, die Dinge um mich herum zu verstehen.	☐	☐	☐	☐
26	Nachrichten (Zeitung, Fernsehen, Internet) über Technik finde ich völlig uninteressant.	☐	☐	☐	☐
27	Technik ist nützlich für die Gesellschaft.	☐	☐	☐	☐
28	Ich finde es wichtig, mich mit technischen Fragestellungen zu beschäftigen.	☐	☐	☐	☐
29	Technische Fortschritte helfen oft, dass es der Wirtschaft besser geht.	☐	☐	☐	☐
30	Ich unterhalte mich in meiner Freizeit nur ungern über technische Themen.	☐	☐	☐	☐
31	Technik macht mir Spass.	☐	☐	☐	☐
32	Bei Technik-Sendungen im Fernsehen schalte ich immer aus oder um.	☐	☐	☐	☐
33	Technischer Fortschritt verbessert oft die Lebensbedingungen der Menschen.	☐	☐	☐	☐
34	Technik gehört für mich persönlich zu den wichtigen Dingen.	☐	☐	☐	☐

Fragen über dein Interesse an Naturwissenschaften

Gib bitte mit einem Kreuz an, inwieweit folgende Aussagen für dich zutreffen:

		stimmt gar nicht	stimmt wenig	stimmt ziemlich	stimmt völlig
35	Naturwissenschaften machen mir Spass.	☐	☐	☐	☐
36	Bei naturwissenschaftlichen Sendungen im Fernsehen schalte ich immer aus oder um.	☐	☐	☐	☐
37	Naturwissenschaftliche Fortschritte bringen oft soziale Vorteile mit sich.	☐	☐	☐	☐
38	Naturwissenschaften gehören für mich persönlich zu den wichtigen Dingen.	☐	☐	☐	☐
39	Ich finde, dass Naturwissenschaften helfen, die Dinge um mich herum zu verstehen.	☐	☐	☐	☐
40	Ich unterhalte mich in meiner Freizeit nur ungern über naturwissenschaftliche Themen.	☐	☐	☐	☐
41	Naturwissenschaften sind nützlich für die Gesellschaft.	☐	☐	☐	☐
42	Ich finde es wichtig, mich mit naturwissenschaftlichen Fragestellungen zu beschäftigen.	☐	☐	☐	☐
43	Fortschritte in Naturwissenschaft helfen oft, dass es der Wirtschaft besser geht.	☐	☐	☐	☐
44	Naturwissenschaftliche Nachrichten (Zeitung, Fernsehen, Internet) finde ich völlig uninteressant.	☐	☐	☐	☐
45	Fortschritte in Naturwissenschaft verbessern oft die Lebensbedingungen der Menschen.	☐	☐	☐	☐
46	In meiner Freizeit habe ich besseres zu tun, als über naturwissenschaftliche Phänomene nachzudenken.	☐	☐	☐	☐

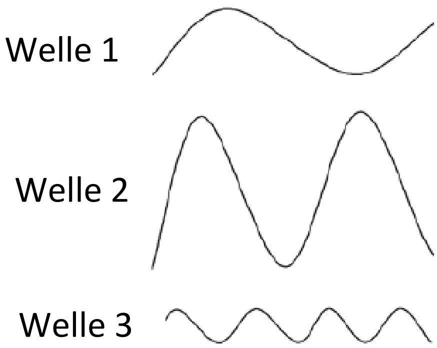
Wissensfragen zum Thema elektromagnetische Strahlung

In den folgenden Fragen geht es um die Strahlung, die beim Radio, beim Handy, dem Mikrowellenherd und mehreren Versuchen von mobiLLab benutzt wird, und die elektromagnetische Strahlung genannt wird. Diese Fragen sind kein Test und keine Leistungskontrolle. Wir möchten nur wissen, was du schon gelernt hast. Deine Antworten helfen uns, mobiLLab zu verbessern.

47 Strahlung, zum Beispiel Radiowellen, Mikrowellen oder das Licht einer Glühbirne, transportiert:
- ❒ Stoff
- ❒ Energie
- ❒ Post
- ❒ Licht
- ❒ Keine von den genannten Lösungen
- ❒ Das weiss ich nicht

48 Alle Arten von Strahlung sind sichtbar.
- ❒ Ja
- ❒ Nein
- ❒ Einige sind sichtbar und einige nicht
- ❒ Das weiss ich nicht

49 Welche Welle hat die grösste Wellenlänge?
- ❒ Welle 1
- ❒ Welle 2
- ❒ Welle 3
- ❒ Alle haben die gleiche Wellenlänge
- ❒ Das weiss ich nicht



50 Der Teil des elektromagnetisches Spektrums, den wir mit unseren Augen wahrnehmen können, ist
- ❒ ein ganz winziger Teil
- ❒ weniger als ein Zehntel
- ❒ mehr als die Hälfte
- ❒ fast alles
- ❒ Das weiss ich nicht

51 Ich habe beim mobiLLab-Einsatz folgende Experimente (Arbeitsplätze) bearbeitet:

- ❒ Wärmebildkamera
- ❒ Ionenchromatographie IC
- ❒ Highspeed-Kamera
- ❒ Abgasmessung
- ❒ Mikrowellensynthese
- ❒ IR-Spektroskopie
- ❒ Lebensmittelanalyse
- ❒ Röntgenfluoreszenz
- ❒ Farbe und Spektren
- ❒ Atmung /Spirometer
- ❒ Haushaltmikrowelle
- ❒ UV-Strahlung

Gib für die folgenden Strahlungsarten an, bei welchem der von dir bearbeiteten Posten sie hauptsächlich verwendet wurden.

		Schreibe den Namen des oder der Posten auf, bei dem hauptsächlich diese Strahlungsart verwendet wurde (mehrere Antworten möglich) :	in keinem der Posten	Das weiss ich nicht
52	Infrarot-Strahlung		☐	☐
53	UV-Strahlung		☐	☐
54	Sichtbares Licht		☐	☐
55	Mikrowellen		☐	☐
56	Radiowellen		☐	☐
57	Röntgenstrahlung		☐	☐

Fragen zur deiner Erfahrung mit mobiLLab

Ich habe folgende „Gewusst-Wie“ Video(s) gesehen: *Wenn du das Video gesehen hast*, wie würdest du es beschreiben?

58	❒ Wärmebildkamera	nicht verständlich	☐	☐	☐	☐	verständlich
		nicht nützlich	☐	☐	☐	☐	nützlich (für den mobiLLab-Tag)
59	❒ Highspeed-Kamera	nicht verständlich	☐	☐	☐	☐	verständlich
		nicht nützlich	☐	☐	☐	☐	nützlich (für den mobiLLab-Tag)
60	❒ Lebensmittelanalyse	nicht verständlich	☐	☐	☐	☐	verständlich
		nicht nützlich	☐	☐	☐	☐	nützlich (für den mobiLLab-Tag)
61	❒ UV-Strahlung	nicht verständlich	☐	☐	☐	☐	verständlich
		nicht nützlich	☐	☐	☐	☐	nützlich (für den mobiLLab-Tag)
62	❒ IR-Spektroskopie	nicht verständlich	☐	☐	☐	☐	verständlich
		nicht nützlich	☐	☐	☐	☐	nützlich (für den mobiLLab-Tag)
63	❒ Röntgenfluoreszenz (XRF)	nicht verständlich	☐	☐	☐	☐	verständlich
		nicht nützlich	☐	☐	☐	☐	nützlich (für den mobiLLab-Tag)

Sonstiges zu den Videos:

____

		stimmt gar nicht	Stimmt wenig	stimmt ziemlich	stimmt völlig
64	Ich habe mich beim mobiLLab-Tag mehr angestrengt als sonst in “Natur und Technik”.	☐	☐	☐	☐
65	Was wir an den mobiLLab-Posten erfahren haben, ist im Alltag nützlich.	☐	☐	☐	☐
66	Die Inhalte der mobiLLab-Posten sind für Dinge interessant, mit denen ich ausserhalb der Schule zu tun habe.	☐	☐	☐	☐
67	Die Aufgaben, die wir in den mobiLLab-Posten bearbeitet haben, sind im Alltag hilfreich.	☐	☐	☐	☐
68	Ich würde gerne an einem weiteren mobiLLab-Tag teilnehmen.	☐	☐	☐	☐
69	Bei den mobiLLab-Posten geht es um Dinge, die mit dem täglichen Leben zu tun haben.	☐	☐	☐	☐
70	Der mobiLLab-Tag hat mir gefallen.	☐	☐	☐	☐
71	Die Themen der mobiLLab-Posten sind nützlich für das tägliche Leben.	☐	☐	☐	☐
72	Die Aufgaben, die wir in den mobiLLab-Posten bearbeitet haben, sind auf den Alltag bezogen.	☐	☐	☐	☐

73 Gib dem mobiLLab eine Note: 6 5,5 5 4,5 4 3,5 3 2 1

74 Gibt es etwas Besonderes, was du uns gerne zum mobiLLab-Tag sagen willst? (Was dir besonders gut oder schlecht gefallen hat usw.)

75 Gibt es etwas Besonderes, das du beim mobiLLab-Tag gelernt hast?

Du hast es geschafft! Danke für deine wertvolle Mitarbeit!

Bitte lege den Fragebogen in den Briefumschlag, verschliesse ihn und gib ihn dann deiner Lehrperson ab.

12 References

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science Knowledge and Attitudes Across Cultures: A Meta-Analysis. *Public Understanding of Science, 17*(1), 35-54.
Anderson, D. (1999). *The Development of Science Concepts Emergent from Science Museums and Post-Visit Activity Experiences: Students' Construction of Knowledge.* (Doctor of Philosophy), Queensland University of Technology.
Anderson, D., & Ellenbogen, K. (2012). Learning Science in Informal Contexts – Epistemological Perspectives and Paradigms. In B. Fraser, K. Tobin, C. McRobbie (Ed.), *Second International Handbook of Science Education* (pp. 1179-1187). New York: Springer.
Anderson, D., & Lucas, K. (1997). The Effectiveness of Orienting Students to the Physical Features of a Science Museum Prior to Visitation. *Research in Science Education, 27*(4), 485-495.
Aubusson, P., Griffin, J., & Kearney, M. (2012). Learning Beyond the Classroom: Implications for School Science. In B. Fraser, K. Tobin, C. McRobbie (Ed.), *Second International Handbook for Science Education* (pp. 1123-1134). New York: Springer.
Baldi, E., & Bucherelli, C. (2005). The inverted 'u-shaped' dose-effect relationships in learning and memory: modulation of arousal and consolidation. *Nonlinearity in Biology, Toxicology, and Medicine, 3*(1), 9-21.
Barmby, P., Kind, P. M., Jones, K., & Bush, N. (2005). Evaluation of Lab in a Lorry (Vol. Final Report): CEM Center and School of Education, Durham University.
Baron, R., & Kenny, D. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Jounal of Personality and Social Psychology, 51*(6), 1173-1182.
Bauer, M., Petkova, K., & Boyadjieva, P. (2000). Public Knowledge of Attitudes to Science: Alternative Measures That May End the 'Science War'. *Science, Technology, & Human Values, 25*(1).
Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. PDF is available at: http://www.nap.edu/catalog/12190.html: National Academies Press.
Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, B 57*, 289-300.
Bennett, J., Lubben, F., Hogarth, S. (2006). Bringing Science to Life: A Synthesis of the Research Evidence on the Effects of Context-Based and STS Approaches to Science Teaching. *Wiley Interscience*.
Berlyne, D. E. (1951). Novelty and Curiosity as Determinants of Exploratory Behavior. *The British Journal of Psychology, 41*, 68-80.
Berlyne, D. E. (1954). A Theory of Human Curiosity. *The British Journal of Psychology, 45*, 180-191.
Berlyne, D. E. (1960). *Conflict, Arousal and Curiosity*. New York: McGraw-Hill.
Berlyne, D. E. (1963). Motivational Problems Raised by Exploratory Behavior. In S. Koch (Ed.), *Psychology: A Study of Science*. New York: McGraw-Hill.
Boekaerts, M. (2007). Understanding Students' Affective Processes in the Classroom. In P. Schutz, R. Pekrun (Ed.), *Emotion in Education* (pp. 37-56): Elsevier Academic Press.
Boekaerts, M., & Corno, L. (2005a). Self-Regulation in the Classroom: A Perspective on Assessment and Intervention. *Applied Psychology, 54*(2), 199-231.

Boekaerts, M., & Corno, L. (2005b). Self-Regulation in the Classroom: A Perspetive on Assessment and Intervention. *Applied Psychology: An International Review, 54*(2), 199-231.

Boekaerts, M., Koning, E., & Vedder, P. (2006). Goal-Directed Behavior and Contextual Factors in the Classroom: An Innovative Approach to the Study of Multiple Goals. *Educational Psychologist, 41*(1), 33-51.

Boekaerts, M., & Minnaert, A. (1999). Self-regulation with respect to informal learning. *International Journal of Educational Research, 31*, 533-544.

Börlin, J. (2011). *Das Experiment als Lerngelegenheit: Von interkulturellen Vergleich des Physikunterrichts zu Merkmalen seiner Qualität.* (PhD), Universität Basel, Disseration.

Bradley, J. C., Waliczek, T. M., & Zajicek, J. M. (1999). Relationship Between Environmental Knowledge and Environmental Attitude of High School Students. *Journal of Environmental Education, 30*(3), 17-21.

Brandt, A., Möller, J., & Kohse-Höinghaus, K. (2008). Was bewirken außerschulische Experimentierlabors? Ein Kontrollgruppenexperiment mit Follow up- Erhebung zu Effekten auf Selbstkonzept und Interesse (What's the Effect of Science Laboratories? A Control Group Experiment with Follow-up Data on Self-Concept and Interest). *Zeitschrift für Pädagogische Psychologie, 22*(1), 5-12.

Brownell, S. E., Kloser, M. J., Fukami, T., & Shavelson, S. (2013). Context Matters: Volunteer Bias, Small Sample Size, and the Value of Comparison Groups in the Assessment of Research-Based Undergraduate Introductory Biology Lab Courses. *Journal of Microbiology Biology Education, 14*(2), 176–182.

Buccheri, G., Abt Gürbera, N., & Brühwilera, C. (2011). The Impact of Gender on Interest in Science Topics and the Choice of Scientific and Technical Vocations. *International Journal of Science Education, 33*(1), 159–178.

Buccheri, G., Brühwiler, C., Erzinger, A., & Hochweber, J. (2014). PISA 2012: Porträt des Kantons St. Gallen. Bern: Institute Professionsforschung und Kompetenz-entwicklung, Pädagogische Hochschule St. Gallen (PHSG).

Bundesamt für Statistic. (2008). Schulprogramme, Für die Schweiz und Liechtenstein, Stand 2002 (pp. 42): Bundesamt für Statistic.

Bybee, R., & McCrae, B. (2011). Scientific Literacy and Student Attitudes: Perspectives from PISA 2006 science. *International Journal of Science Education, 33*(1), 7-26.

Castranova, J. A. (2002). Discovery Learning for the 21st Century: What is it and how does it compare to traditional learning in effectiveness in the 21st Century? *Action research exchange, 1*(1).

Cohen, J. W. (Ed.). (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Coletta, V. P., & Phillips, J. A. (2005). Interpreting FCI scores: Normalized gain, preinstruction scores, and scientific reasoning ability. *American Association of Physics Teachers, 73*(12), 1172-1182.

Collier-Reed, B. I. (2006). *Pupils' experiences of Technology: Exploring dimensions of technological literacy.* (Doctor of Philosophy), University of Cape Town, Unpublished PhD.

Cors, R. (2013). MobiLLab Program Background Investigation: Directions for Program Improvement and Evaluation Research (Verschaffen eines Überblicks des mobiLLabs) (http://phsg.contentdm.oclc.org/cdm/ref/collection/p15782coll3/id/94, Trans.) (pp. 32). St. Gallen, Switzerland: University of Teacher Education (Pädagogische Hochschule St. Gallen).

Cors, R., Courter, S., & Eagan, P. (2003). *An International Case for Sharpening the Focus on Facilitation Skills in Undergraduate Engineering Curricula.* Paper presented at the American Society for Engineering Education Annual Conference Proceedings, Nashville, Tennessee.

Cors, R., Matsubae, K., Street, A. . (2013). Chapter 8: How MFA, transdisciplinarity, complex adaptive systems thinking, and education reform are keys to better managing P: P is for Parity. In K. Wyant, J. Corman, J. Elser (Ed.), *Phosphorus, Food, and Our Future* (pp. 167-184). New York City, New York, USA: Oxford University Press.

Cors, R., Müller, A., & Robin, N. (2015a). Advancing Informal MINT Learning: Preparation and Novelty at a Mobile Laboratory. *New Perspectives in Science Education*, 53-58.

Cors, R., Müller, A., & Robin, N. (2015b). Novelty at a mobile laboratory: pilot study results. *GDCP (Gesellschaft für Didaktik der Chemie und Physik)*, 223-225.

Cors, R., & Robin, N. (2016). Evaluating informal science education: Identifying and measuring meaningful indicators of program effectiveness for a mobile laboratory program. *Journal of Finnish Universities of Applied Sciences* (Special Issue: EAPRIL 2016), Available online: https://uasjournal.fi/in-english/strategies-for-evaluating-informal-science-education-identifying-and-measuring-meaningful-indicators-of-program-effectiveness-for-a-mobile-laboratory-program/.

Cotton, D. R. E., & Cotton, P. (2009). Field biology experiences of undergraduate students: the impact of novelty space. *Journal of Biology Education, 43*(4), 169-174.

Cresswell, J. W. (2009). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. Thousand Oaks, California: Sage Publications, Inc.

de Jong, T. (2009). Cognitive Load Theory, Educational Research, and Instructional Design: Some Food for Thought. *Instructional Science, 38*, 105-134.

Deci, E., & Ryan, R. (2000a). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology, 25*, 54-67.

Deci, E., & Ryan, R. (2000b). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *American Psychologist, 55*(1), 68-78.

Deci, E., Valleran, R. J., Pelletier, L. G., & Ryan, R. (1991). Motivation and Education: The Self-Determination Perspective. *Educational Psychologist, 26*(3&4), 325-346.

Denissen, J., Zarrett, N., & Eccles, J. (2007). I Like to Do It, I'm Able, and I Know I Am: Longitudinal Couplings Between Domain-Specific Achievement, Self-Concept, and Interest *Child Development, 78*(2), 430-447.

Dewey, J. (1913). *Interest and Effort in Education*. Cambridge, Massachusetts: The Riverside Press.

Dierking, L., Falk, J., Rennie, L., Anderson, D., & Ellenbogen, K. (2003). Policy Statement of the "Informal Science Education" Ad Hoc Committee. *Journal of Research in Science Teaching, 40*(2), 108-111.

Ding, L., & Beichner, R. (2009). Approaches to data analysis of multiple-choice questions. *Physics Education Research, Physical Review Special Topics*(5), 1-17.

Dohn, N. B. (2010). Situational Interest of High School Students Who Visit an Aquarium. In L. Dierking, J. Falk (Ed.), *Science Learning in Everyday Life*: Wiley Periodicals, Inc.

Dorie, B. L., Dankenbring, C. A., Denick, D. L., Ferguson, D., Huff, J., Phillips, C., . . . Cardella, M. E. (2012). *File: A Taxonomy of Formal and Informal Learning Environments*. Paper presented at the American Society for Engineering Education, Valparaiso University, Valparaiso, Indiana.

Dowell, K. (2010). 2009-2010 Evaluation of the MdBioLab Program (Vol. September): Prepared for MdBio Foundation, Rockville, MD.

Dowell, K. (2011). 2010-2011 Evaluation of the MdBioLab Program. In EvalSolutions (Ed.), (pp. 33): Prepared for: MdBio Foundation, Rockville, Maryland.

Dresel, M., & Lämmle, L. (2011). Motivation. In T. Goetz (Ed.), *Emotion, Motivation, und selbsreguliertes Lernen*. Schöning/UTB: Paderborn.

Edelman, S. (1997). Curiosity and Exploration. California State University, Northridge Retrieved from http://www.csun.edu/~vcpsy00h/students/explore.htm.

Eichenberger, I. (2010, December 8). Swiss students get an encouraging report, *Swissinfo*.

Eid, M., Gollwitzer, M., & Schmitt, M. (2011). *Statistik und Forschungsmethoden* (Vol. 2). Weinheim: Beltz.

Engel, K. (2004). *Schülerlabors: authentische, aktivierende Lernumgebungen als Möglichkeit, Interesse an Naturwissenschaften und Technik zu wecken.* (Disseration), Christian-Albrechts-Universität, Kiel, Germany.

Eschach, H. (2007). Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology, 16*(2), 171-190.

Evans, G., & Durant, J. (1995). The relationship between knowledge and attitudes in the public understanding of science in Britain. *Public Understanding of Science, 4*(1), 57-74.

Falk, J. H., & Balling, J. D. (1982). The Field Trip Milieu: Learning and Behavior as a Function of Contextual Events. *Journal of Educational Research, 76*(1), 22-28.

Falk, J. H., & Dierking, L. (2012). Lifelong Science Learning for Adults: The Role of Free-Choice Experiences. In B. Fraser, K. Tobin, C. McRobbie (Ed.), *Second International Handbook for Science Education* (pp. 1063-1095). New York: Springer.

Falk, J. H., & Dierking, L. (Eds.). (2000). *Learning from Museums*. Lanham, Maryland: AltaMira Press.

Falk, J. H., & Dierking, L. (Eds.). (2011). *The Museum Experience*. Walnut Creek, CA: Left Coast Press.

Falk, J. H., Martin, W. M., & Balling, J. D. (1978). The Novel Field-Trip Phenomenon: Adjustment to Novel Settings Interferes with Task Learning. *Journal of Research in Science Teaching, 15*(2), 127-134.

Falk, J. H., Randol, S., & Dierking, L. (2012a). Understanding the informal science education landscape: An exploratory report. *Public Understanding of Science, 21*(7), 865-874.

Falk, J. H., Randol, S., & Dierking, L. D. (2012b). Understanding the Informal Science Education Landscape: An Exploratory Study. *Public Understanding of Science, 21*(7), 865 – 874.

Falk, J. H., & Storksdieck, M. (2005). Using the Contextual Model of Learning to Understand Visitor Learning from a Science Center Exhibition. *Science Education, 89*(5), 744-778.

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics*. London: SAGE publications.

Förster, J., Marguc, J., & Gillebart, M. (2010). Novelty Categorization Theory. *Social and Personality Psychology Compass, 4*(9), 736-755.

Franzblau, C., Romney, C. A., Faux, R., & DeRosa, D. (2011, October 12-15). *Mobile Laboratory Programs as Vehicles to Promote STEM Education in K-12 and Beyond.* Paper presented at the 41st ASEE/ IEEE Frontiers in Education Conference, Rapid City, SD.

Garmire, E. M., & Pearson, G. (2006). Tech tally: Approaches to assessing technological literacy. Washington, DC: National Academies Press.

Gassmann, F. (2012). Das Schülerlabor iLab des Paul Scherrer Instituts (pp. 2). Switzerland: Paul Scherrer Institute.

Glowinski, I. (2007). *Schülerlabore im Themenbereich Molekularbiologie als Interesse Fördernde Lernumgebungen.* (Disseration), Christian-Albrechts-Universität, Kiel, Germany.

Glowinski, I., & Bayrhuber, H. (2011). Student labs on a university campus as a type of out-of-school learning environment: Assessing the potential to promote students' interest in science. *International Journal of Environmental & Science Education, 6*(4), 371-392.

Güdel, K. (2014). *Technikaffinität von Mädchen und Jungen der Sekundarstufe I: Untersuchung von Technikinteresse, Selbstwirksamkeitserwartung, Geschlechterrollen und Berufswünsche.* (Disseration: Doctrat és sciences, Mention didactique des sciences), University of Geneva. (4688)

Guderian, P. (2007). *Wirksamkeitsanalyse außerschulischer Lernorte - der Einfluss mehrmaliger Besuche eines Schülerlabors auf die Entwicklung des Interesses an Physik.* (Disseration), Mathematisch-Naturwissenschaftliche Fakultät I. Retrieved from http://edoc.hu-berlin.de/docviews/abstract.php?id=27927

urn:nbn:de:kobv:11-10077545

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Association of Physics Teachers, 66*(1), 64-74.

Hart, S., & Staveland, L. (1988). Development of the NASA-TLX (Task Load Index). In P. A. H. N. Meshkati (Ed.), Human Mental Workload (pp. 239-250). Amsterdam: North Holland Press.

Heitzmann, A., & Güdel, K. (2014, March 27-28). *Increasing Students' Affinity to Technology: The Teaching Model EXRETU – Explicit, Reflective Technology Education.* Paper presented at the PATT-28 PATT-28 Conference, Orlando, Florida, USA.

Hidi, S., & Renniger, K. A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist, 41*(2), 111-127.

Hofstein, A., & Rosenfeld, S. (1996). Bridging the Gap Between Formal and Informal Science Learning. *Studies in Science Education, 28*, 87-112.

Högström, P., Ottander, C., & Benckert, S. (2010). Lab Work and Learning in Secondary School Chemistry: The Importance of Teacher and Student Interaction. *Research in Science Education, 40*, 505-523.

Huber, B. (2014). Swiss Barometer of Young Talent in STEM subjects (MINT-Nachwuchsbarometer Schweiz): Swiss Academy of Engineering Sciences.

Impey, O., & MacGregor, A. (2001). *The Origins of Museums*. Poughkeepsie, NY: House of Stratus.

Itzek-Greulich, H., Flunger, B., Vollmer, C., Nagengast, B., Rehm, M., & Tratwein, U. (2015). Effects of a science center outreach lab on school students' achievement -Are student lab visits needed when they teach what students can learn at school? *Learning and Instruction, 38*, 43-52.

Iyengar, S. R. S., Madhavan, C. E. V., Zweig, K. A., & Natarajan, A. (2012). Understanding Human Navigation Using Network Analysis. *Topi{CS} - {T}opics in {C}ognitive {S}cience, 4*(1).

Jarvis, T., & Pell, A. (2005). Factors Influencing Elementary School Children's Attitudes toward Science before, during, and after a Visit to the UK National Space Centre. *Journal of Research in Science Teaching, 42*(1), 53-83.

Jones, C., & Shao, B. (2011). The Net Generation and Digital Natives: Implications for Higher Education (Vol. MK7 6AA). The Open University, Walton Hall, Milton Keynes: A literature review commissioned by the Higher Education Academy.

Kirschner, P., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist, 41*(2), 75–86.

Krapp, A. (1999). Interest, Motivation and Learning: An Eduational-Psychological Perspective. *European Journal of Psychology of Education, XIV*(1), 23-40.

Krapp, A. (2005). Basic Needs and the Development of Interest and Intrinsic Motivational Orientations. *Learning and Instruction, 15*, 381-395.

Krapp, A., Hidi, S., & Renninger, K. (1992). Interest, Learning and Development. In K. A. Renninger, S. Hidi, A. Krapp (Ed.), *The role of interest in learning and development* (pp. 3-25). Hillsdale, NJ: Erlbaum.

Kubota, C. A., & Olstad, R. G. (1991). Effects of Novelty-Reducing Preparation on Exploratory Behavior and Cognitive Learning in a Science Museum Setting. *Journal of Research in Science Teaching, 28*(3), 225–234.

Kuhn, J. (2010). *Authentische Aufgaben im theoretischen Rahmen von Instruktions- und Lehr-Lern-Forschung: Effektivität und Optimierung von Ankermedien für eine neue Aufgabenkultur im Physikunterricht* (Habilitationsschrift ed.). Wiesbaden: Vieweg &Teubner.

Kuhn, J., Müller, A., & Schneider, C. (2008). Das Landauer Programm zur Lehrerbildung in den Naturwissenschaften (LeNa): Standardbezongene Evaluation und Interventionen für eine verbesserte Abstimmung auf dem Prüfstand *Empirische Pädagogik:Zeitschrift zu Theorie und Praxis erziehungswissenschaftlicher Forschung* (Vol. 22, pp. 305-327). Landau: Verlag Empirische Pädagogik.

Lancaster, B. P. (1999, January 21-23). *Defining and Interpreting Suppressor Effects: Advantages and Limitations.* Paper presented at the Annual Meeting of the Southwest Education Research Association, San Antonio, TX.

Lee, T.-H., & Crompton, J. (1992). Measuring Novelty Seeking in Tourism. *Annals of Tourism Research, 19*, 732-751.

LernortLabor. (2015). *Schülerlabor-Atlas 2015: Schülerlabore im deutschsprachigen Raum*. Germany: Klett MINT GmbH.

Litman, J. A., & Spielberger, C. D. (2003). Measuring Epistemic Curiosity and its Diversive and Specific Components. *Journal of Personality Assessment, 80*(1), 75-86.

Long, J. F., & Woolfolk, A.H. (2006). Interested Instructors: A composite portrait of individual differences and effectiveness. *Teaching and Teacher Education, 22*, 303-314.

Luckay, M., & Collier-Reed, B. (2011a, 10-12 August). *Admitting Engineering Students with the Best Chance of Success- Technological Literacy and the Technological Profile Inventory (TPI).* Paper presented at the 1st Biennial Conference of the South African Society for Engineering, Sellenbosch.

Luckay, M., & Collier-Reed, B. (2011b). *The Development and Validation of an Instrument - the Techological Profile Inventory - to Determine Students' Levels of Technological Literacy in South Africa* Paper presented at the ICERI, Madrid, Spain.

Luckay, M., & Collier-Reed, B. (2012). *Technological Profile Inventory (TPI): Determining First Year University Students' Levels of Technological Literacy.* Paper presented at the Paper presented at the South African Association of Research in Mathematics, Science and Technology Education, Lilongwe, Malawi.

Mayers, A. (Ed.). (2013). *Introduction to Statistics and SPSS in Psychology*: Pearson.

McGinnis, J. R., Hestness, E., Riedinger, K., Katz, P., Marbach-Ad, G., & Dai, A. (2012). Informal Science Education in Formal Science Teacher Preparation. In B. Fraser, K. Tobin, C. McRobbie (Ed.), *Second International Handbook of Science Education* (pp. 1097-1108). New York: Springer.

McManus, P. M. (1992). Topics in Museums and Science Education. *Studies in Science Education, 20*, 157-182.

Meier, A. (2015). *Motivation, Emotion und kognitive Prozesse beim Lernen in der Lernwerkstatt: Ergebnisse einer quantitativen Fragebogenstudie und einer qualitativen Videostudie mit Grundschulkindern*. Berlin: Logos GmbH.

MINT-Meter. (2012, May 23). Neuer Höchststand der MINT-Fachkräftelücke.

Naylor, J. D. (2007). A state-trait curiosity inventory. *Australian Psychologist, 16*(2), 172-183.

Nederhof, A. J. (1985). Methods of coping with social desirability bias: A review". European Journal of Social Psychology. *European Journal of Social Psychology, 15*(3), 263–280.

OECD. (2006). Test PISA 2006 *Schweiz und Liechtenstein; Deutsch*: OECD Programme for International Student Assessment:.

OECD. (2007). PISA Codebook.

OECD. (2009). PISA Data Analysis Manual *SPSS® SECOND EDITION*.

Oppenheimer, F. (1968). Rationale For A Science Museum. *The Museum Journal, 1*(3), 206-209.

Orion, N. (1989). Development of a High-School Geology Course Based on Field Trips. *Journal of Geological Education, 37*, 13-17.

Orion, N. (1993). A Model for the Development and Implementation of Field Trips as an Integral Part of the Science Curriculum. *School Science and Mathematics, 93*(6), 325-331.

Orion, N., & Hofstein, A. (1991a). *Factors which influence learning ability during a scientific field trip in a natural environment.* Paper presented at the Proceedings of the annual convention of the National Association for research in Science Teaching, Fontana, IL.

Orion, N., & Hofstein, A. (1991b). The Measurement of Students' Attitudes Towards Scientific Field Trips. *Science Education, 75*(5), 513-523.

Orion, N., & Hofstein, A. (1994). Factors that Influence Learning during a Scientific Field Trip in a Natural Environment. *Journal of Research in Science Teaching, 31*(10), 1097-1119.

Orion, N., Hofstein, A., Tamir, P., & Giddings, G. (1997a). Development and Validation of an Instrument for Assessing the Learning Environment of Outdoor Science Activities. *Science Education, 81*, 161-171.

Orion, N., Hofstein, A., Tamir, P., & Giddings, G. (1997b). Development and Validation of an Instrument for Assessment the Learning Environment of Outdoor Science Activities. *Science Education, 81*, 161-171.

Paas, F., van Gog, T., & Sweller, J. (2010). Cognitive Load Theory: New Conceptualizations, Specifications, and Integrated Research Perspectives. *Educational Psychology Review, 22*, 115-121.

Pallant, J. (2013). *SPSS Survival Manual: A step by step guide to data analysis using SPSS*. New York: Open Universities Press.

Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods* (3rd Edition ed.). Thousand Oaks, California: Sage Publications.

Pawek, C. (2009). *Schülerlabore als interessefördernde ausserschulische Lernumgebuhngen für Schülerinnen und Schüler aus der Mittel- und Oberstufe.* (Dissertation), Christian-Albrechts-Universität, Kiel, Germany.

Pearson, G., & Young, A. T. (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC: National Academy Press.

Pearson, P. (1970). Relationships between global and specified measures of novelty seeking. *Jounal of Consulting and Clinical Psychology, 24*, 199-204.

Piaget, J. (1952). Chapter 3: When Thinking Begins *The Origins of Intelligence in Children*. New York: International University Press.

PISA. (2014). PISA 2012: Vertiefende Analysen. Bern und Neuchatel: Konsortium PISA.ch.

Potvin, P., & Abdelkrim, H. (2014). Interest, Motivation and Attitude Towards Science and Technology at K-12 Levels: a Systematic Review of 12 Years of Educational Research. *Studies in Science Education, 50*(1), 85–129.

Prenzel, M., & Duit, R. (2000). *Increasing the efficiency of science and mathematics instruction Report of a national quality development problem.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (NARST), New Orleans.

PresenceSwitzerland. (2012). Foreign workers. swissworld.org: Federal Department of Foreign Affairs, Switzerland.

Priemer, B., & Pawek, C. (2014). *Out-of-school STEM learning in Germany: Can we catch and hold students' interest?* Paper presented at the NARST (National Association for Research in Science Teaching) Annual International Conference Pittsburg.

Rennie, L. J. (1994). Measuring Affective Outcomes from a Visit to a Science Education Centre. *Research in Science Education, 24*, 261-269.

Rennie, L. J. (2007). Learning Science Outside of School. In S. K. Abell, N.G. Lederman (Ed.), *Handbook of Research on Science Education* (pp. 125-167). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Renninger, K. A. (2009). Interest and Identity Development in Instruction: An Inductive Model. *Educational Psychologist, 44(2), 105–118, 44*(2), 105-118.

Renninger, K. A., & Hidi, S. (2015). *The Power of Interest and Motivation and Engagement*. New York: Routledge.

Roberts, D. (2007). Science Literacy/ Scientific Literacy. In S. K. Abell, N.G. Ledermann (Ed.), *Handbook of Research on Science Education* (pp. 729-781). Mahwah, NJ: Lawrence Erlbaum.

Roeckelein, J. (Ed.) (2006) Dictionary of Psychological Theories. Amsterdam: Elsevier.

Ryan, R., & Deci, E. (2000). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *American Psychologist, 55*(1), 68-78.

Sandifer, C. (2003). Technological Novelty and Open-Endedness: Two Characteristics of Interactive Exhibits That Contribute to the Holding of Visitor Attention in a Science Museum. *Journal of Research in Science Teaching, 40*(2), 121–137.

Sauerborn, P., & Brühne, T. (2009). *Didaktik des ausserschulischen Lernens*. Germany: Schneider Verlag Hohengehren.

Schmitt, F. F., & Lahroodi, R. (2008). The Epistemic Value of Curiosity. *Educational Theory, 58*(2), 125-147.

Scholz, R. W. (2011). *Environmental Literacy in Science and Society: From Knowledge to Decisions*. New York: Cambridge University Press.

Sjøberg, S., & Schreiner, C. (2010). The ROSE project: An overview and key findings (pp. 31): University of Oslo.

Sliva, Y. (2013). *In search for Instructional Techniques to Maximize the Use of German Cognitive Resources: A Case of Teaching Complex Tasks in Physics.* (Doctor of Philosophy), Old Dominion University. (UMI: 3580483)

SPSS. (1998). More reliable test assessment using statistics *Using SPSS for item analysis*. USA.

Stevens, J. (2002). *Applied multivariate statistics for the social sciences.* Hillsdale, NJ: Lawrence Erlbaum.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using Multivariate Statistics* (Vol. Sixth Edition). New Jersey: Pearson Education, Inc.

Taylor-Powell, E., Jones, L., & Henert, E. (2003). Enhancing Program Performance with Logic Models. Retrieved January 7, 2013, from the University of Wisconsin-Extension web site: http://www.uwex.edu/ces/lmcourse/.

Thomas, D. R. (2006). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation, 27*(2), 237-246.

Tran, N. A. (2011). The Relationship between Students' Connections to Out-of-School Experiences and Factors Associated with Science Learning. *International Journal of Science Education, 33*(12), 1625-1651.

Vogel-Misicka, S. (2012, October 7). Switzerland faces a lack of IT professionals. *swissinfo.ch*.

von Stumm, S., Hell, B., & Chamorro-Premuzic, T. (2011). The Hungry Mind: Intellectual Curiosity Is the Third Pillar of Academic Performance. *Perspectives on Psychological Science, 6*(6), 574-588.

Werquin, P. (2010). Recognition of Non-Formal and Informal Learning: Country Practices: Organization for Economic Co-operation and Development.

WHO. (2008). Part 4: 5.Conducting the Survey, Data Entry, Data Analysis and Reporting and Disseminating Results *WHO STEPS Surveillance Manual* (Vol. Last Updated: 13 June 2008): World Health Organization.

Willig, C. (2013). *Introducing Qualitative Research in Psychology* (Third Edition ed.). Berkshire, England: Open Universtiy Press.

Wilson, D. B. (2015). Practical Meta-Analysis Effect Size Calculator Retrieved last accessed 1. April, 2105, George Mason University, from http://www.campbellcollaboration.org/escalc/html/EffectSizeCalculator-SMD-main.php