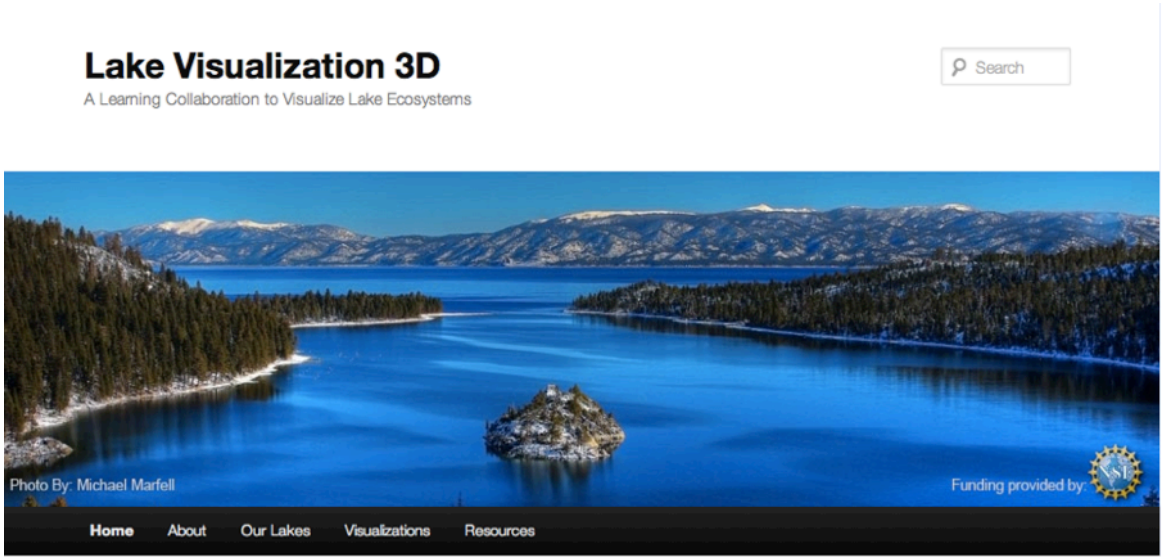
3D Visualization Tools for Enhancing Awareness, Understanding and Stewardship of Freshwater Ecosystems

Summative Evaluation Report



Prepared by:

Steven Yalowitz, Ph.D.
Erin Wilcox, M.A.

Audience Viewpoints Consulting

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Audience Viewpoints Consulting

13148 Rounding Run Circle, Herndon, VA 20171 t: 831-224-3085 www.audienceviewpoints.com

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Executive Summary

Background

The National Science Foundation (NSF) awarded an Informal Science Education (ISE) grant, since renamed Advancing Informal STEM[1] Learning (AISL) to a group of institutions led by two of the University of California, Davis's centers: the Tahoe Environmental Research Center (TERC) and the W.M. Keck Center for Active Visualization in Earth Sciences (KeckCAVES). Additional partner institutions were the ECHO Lake Aquarium and Science Center (ECHO), Lawrence Hall of Science (LHS) at the University of California, Berkeley, and Audience Viewpoints Consulting (AVC). The study was designed to examine how 3D visualizations could most effectively be used to improve the general public's understanding of freshwater lake ecosystems and Earth science processes through the use of immersive three-dimensional (3D) visualizations of lake and watershed processes, supplemented by tabletop science activity stations and a website. Two iconic lakes were the focus of the study: Lake Tahoe in California and Nevada, and Lake Champlain in Vermont and New York, with products readily transferable to other freshwater systems and education venues. The project included the development of 3D visualizations, hands-on activities as well as technology components, including apps for mobile devices.

The purpose of the project was to implement, evaluate, and disseminate knowledge of how 3D visualizations and technologies could be designed and configured to effectively support visitor engagement and learning about physical, biological and geochemical processes and systems related to freshwater ecosystems. An additional part of the project was to evaluate how these technologies could be transferred more broadly to other informal science venues and schools for future career and workforce development in these critical STEM areas. For more information about the project see:
http://www.nsf.gov/awardsearch/showAward?AWD_ID=1114663&HistoricalAwards=false and www.lakeviz.org .

Purpose of the Study and Evaluation Questions

The purpose of this summative evaluation was to measure the extent to which the project and its deliverables were achieving its goals and objectives. In order to evaluate the 3D Viz components, the evaluation approach came up with a series of evaluation questions to guide the study.

Evaluation questions:

1. Who is most likely to engage with the 3-D visualization and the supplementary materials?
2. To what extent does engaging in multiple components affect individual outcomes?
3. How does engaging with the visualizations affected peoples' awareness of, attitudes towards and learning about freshwater ecosystems and the challenges they face?
4. How do the outcomes persist and change over time?

Design and Methods

The study used a quasi-experimental design with both treatment and control groups; control groups were included to provide a comparison to participants who experienced the 3D Viz components. While the control group experienced a regular visit to an institution, the treatment group also experienced the 3D Viz components, allowing for understanding the added value of the 3D Viz components to the experience.

Data were collected at three institutions in the Winter and Spring of 2015: at the Tahoe Environmental Research Center (TERC), the Lawrence Hall of Science (LHS) and the ECHO Lake Aquarium and Science Center. Furthermore, there were two main audiences the study focused on: 1) General Visitors to the institution, and 2) Student field trip groups in late elementary and early middle school. Both groups were included in the data collection at each site. Two methods were employed for the study with the main method being an on-site visitor survey, and a secondary method of online follow-up surveys. A total of 755 on-site surveys were collected, with 313 surveys from General Visitors and 442 surveys from Students; 32 follow-up online surveys were completed. The control and treatment groups were evenly distributed between both the General Visitors and Students at each site, with General Visitors recruited during regular visits to the institution, and Student classes recruited by the institutions ahead of time for participation in the study.

Participation in the 3D visualization components

Only the treatment groups participated in the 3D Viz components, and not every component was included for testing at each site. However, each site included a visualization, the interactive sandbox, and more than one hands-on activity. There was a difference in the amount of time the two treatment groups interacted with the 3D Viz components, resulting from General Visitor groups participating in the components as part of an overall visit and Student groups coming purposefully to engage in the project's components. Student groups tended to engage in the components for an hour or more, while cued General Visitor group participation times tended to vary based on their level of interest and be significantly lower than the Students.

For the General Visitors, five of the six components had more than half of the participants engaging with them. This included almost three quarters participating in the 3D visualization, and almost two thirds at the interactive sandbox or Tahoe board game. Slightly more than half of General Visitors in the treatment group engaged in the making a watershed activity and the seiche wave activity, and just slightly under half used the healthy lakes iPad app. In terms of the Students, about a half of them participated in the 3D visualization. Given that the Student group had a longer, more formal, and facilitated experience, the percentages engaging with the various components were higher than the General Visitor treatment group. For Students there were three components that had close to one hundred percent participation: the Tahoe board game, the make a watershed activity, and the 3D visualization. Other activities were not necessarily part

of the facilitated activities, even when present at an institution, and were more driven by the interest of the students. These included the interactive sandbox (about three quarters of Students engaged) the seiche wave activity (a little less than two thirds), and the healthy lakes iPad app (at just over a half). While there were some differences between and within the two main groups, there was the general pattern of engaging a visualization, the interactive sandbox, then a couple of the hands-on activities.

Main Findings

The findings are separated into six main areas: Experience with freshwater ecosystems, the Visit to the institution, Participation in the 3D visualization components, Knowledge of freshwater ecosystems, Perceiving main messages, and Changes in thinking about freshwater ecosystems.

- *Participants were entertained and impacted by the 3D Viz components, resulting in higher ratings; they were also able to recall aspects of their visit in general and more specifically the 3D visualizations.*
- *In a 2 month follow up survey, more than 50% of visitors report having learned something new from engaging with the 3D Viz project. There were greater cognitive gains right after a visit on measures for the Students, but not for the General Visitors, though the general visitors in the Treatment group were more likely to perceive some of the main messages.*

Experience with freshwater ecosystems

Both General Visitors and Students rated their prior knowledge of freshwater ecosystems medium or between medium and high, suggesting that while they considered themselves to be relatively knowledgeable about the topics they were far from experts. Participants were also asked whether they had a particular connection to freshwater ecosystems, and about two thirds of both General Visitors and Students said they did have some sort of connection. There were slightly higher connection levels for both TERC and ECHO compared to LHS, which is not surprising given that the first two are situated on or very near to large lakes. The most common type of connections were living in close proximity to a freshwater ecosystem, having a hobby like fishing or boating, and vacationing regularly near freshwater ecosystems. About half of those who filled out a follow-up web survey two months after the visit said they had participated in activities since visiting, like taking specific actions related to freshwater ecosystems, participating in a program or even, or reading about/researching specific topics. Some specific actions they had taken include conserving water, scooping dog waste, making landscape changes, limiting uses of fertilizers or participating in a clean up

Visits to the Institution

While the focus was on the project components, the evaluation also looked at the added value of the components to an overall visit. Visits to the institutions were rated highly across the three institutions, even for the control groups. However, certain ratings were significantly higher for the treatment group compared to the control group. For example, General Visitors rated the entertainment experience significantly higher in the treatment group, and Students also rated their overall visit and educational experience significantly higher if they were in the treatment group. In a follow-up web survey two months after the visit, the large majority said they had

thought about the visit or were reminded of it in some way since visiting. The specific ways in which they were reminded included reading news articles or social media posts, viewing a freshwater ecosystem in person, or talking with other family members and friends. Those who provided more detail most frequently mentioned specific exhibit content from the visit. When asked whether they remembered seeing anything about freshwater ecosystems at some point during this visit, the content most often mentioned was pollution, the impact of human development and building, invasive species, and how freshwater ecosystems formed or function. Some visitors (about 1 in 7) did specifically recall the 3D visualizations from the project.

Knowledge of freshwater ecosystems

When participants were asked to name examples of freshwater ecosystems, they most commonly named lakes and rivers, which was true for both the General Visitor and Student groups. The only statistically significant difference between treatment and control groups was recalling creeks as a freshwater ecosystem; a pattern that was true for both General Visitors and Students. There was not a significant difference in the number of freshwater ecosystems recalled, either for General Visitors or Students. When asked to list the problems facing freshwater ecosystems, both General Visitors and Students mentioned pollution and invasive species as the top two. There were no significant differences between treatment and control conditions for the General Visitors, while there were two differences for the Students – the control group was more likely to recall drought or give miscellaneous responses to the problems facing freshwater ecosystems. In comparing the total number of examples provided, there was not a significant difference between control and treatment groups for either the General Visitor or Student groups.

In addition to recalling the above issues, participants were asked to rate their change in knowledge on a number of topics about freshwater ecosystems. The biggest gain for both General Visitors and Students was on an item about how scientists are currently studying freshwater ecosystems. Looking at all of the items, there were not any statistically significant differences in the self-reported knowledge change for General Visitors. However, there were statistically significant differences in comparing the Student control and treatment groups for nine of the items. This included items related to freshwater ecosystems like general knowledge, how they work, the problems faced, how much they affect and are affected by freshwater ecosystems, and what they can do personally to help freshwater ecosystems. The difference between General Visitors and Students may have to do with the fact that the Students were engaged more formally with the 3D Viz components with a facilitator and for a longer time.

Perceiving main messages

There were three main messages around freshwater ecosystems for the project. When looking at agreement ratings with these statements for General Visitors there was a statistically significant difference between control and treatment groups for the idea that humans affect freshwater ecosystems. For the same comparisons with Students, the message that showed a statistically significant difference between control and treatment groups about water connecting all the Earth systems (water, land, air and life). The project found significant differences for two of the three main messages, although there is not enough context to better understand why these two were the ones that resulted in positive outcomes. Another similar item asked whether participants thought that these freshwater ecosystems simply needed to be left alone, but that did not show a

difference between control and treatment groups. Interestingly, most groups seemed pretty split on whether leaving them alone was the solution that was needed to improve their situation.

Thinking about freshwater ecosystems

Participants were asked about their thinking and interest in freshwater ecosystems, to determine if the 3D Viz project made a difference in their perception of freshwater ecosystems on a number of measures. For General Visitors, the treatment group was significantly more likely than the control group to say the visit changed how they thought about freshwater ecosystems. The treatment group also reported that they were more interested in finding out how to protect freshwater ecosystems, compared to the control group. This last piece is not surprising given that the treatment group was significantly more likely to say they learned something new about protecting watersheds during their visit; this difference was particularly strong at ECHO. In terms of what General Visitors learned about protecting freshwater ecosystems, the treatment group was most likely, and significantly more likely than the control group, to talk about pollution as a threat to freshwater ecosystems.

In terms of the Students, they seemed to be focused on the functioning of freshwater ecosystems. The treatment group compared to the control group was more likely to say that the visit helped them better understand how freshwater ecosystems function, and also that it made them more interested in learning how they function. In terms of learning something about how to protect freshwater ecosystems, there was a large difference between Students in the control and treatment groups. The treatment group was more than twice as likely to say they learned something about how to protect freshwater ecosystems during the visit, compared the control group. The largest gain here was at LHS. In terms of what students learned about protecting freshwater ecosystems the treatment group was most likely, and significantly more likely than the control group, to talk about polluting less.

Discussion

There were a number of findings in the summative evaluation that suggest using 3D elements in can be an effective way to engage students and the general public in the science and content about freshwater ecosystems. This was seen across different types of outcomes, including knowledge, attitudes, affective reactions, intentions and also some behaviors. There were a number of results that crossed multiple items or outcomes listed in the findings, and warrant further discussion.

Connections to freshwater ecosystems – The majority of participants, both students and general visitors, had some sort of connection to freshwater ecosystems. While it is not surprising that visitors to ECHO (next to Lake Champlain) or TERC (next to Lake Tahoe) had a lot of connections, the majority of participants at LHS (not that close to any large freshwater ecosystem) also had connections. These came in the form of vacationing or visiting a wider variety of freshwater ecosystems. The fact that this did not result in LHS having lesser outcomes suggests that the project components would be successful at institutions that do not have large freshwater

ecosystems in close proximity. It also suggests that participants in other institutions would not be starting from scratch when it comes to engaging them around freshwater ecosystems. The main implication is that better understanding how to build on these connections is important for the success of engaging the public: there may be some characteristics that allow for common entry points. It also suggests that people could contribute to the discussion, based on their personal connections to the topics. Those who lived closer to large bodies of water, however, did have a stronger connection. While it may be more obvious for how to engage people with specific ecosystems in common, it will take more work figuring out how to build on these connections when the specific ecosystems are not the common denominator in the experience.

Larger knowledge gain for students – In examining the cognitive or knowledge-based outcomes, there was a trend for there to be greater results among the students compared to the general public. There could be a number of explanations for this finding. Since the topics they were covering had to tie in closely to their classroom curriculum, much of the content would either be familiar or be building on something they had already and recently studied. Additionally, and perhaps this is a more likely explanation, the students were part of a formal visit with a longer period of engagement than the general public visitors had with the components. The general visitors often did only one or two of the components, while the students engaged in 3 to 5 of them and for longer periods of time; students in the Treatment group were usually engaging with the 3D Viz components for an hour or more. In knowing that there were greater outcomes for the students, and if time was indeed the driving force in those differences, it begs the question of how it might be possible to engage general public visitors for a longer period of time and with more components.

Students were also more likely to learn basic information about freshwater ecosystems, like how they function and how they can be protected. This is not a surprising finding given that formal school visits are often focused on the curriculum and knowledge gain. While general visitors typically report learning as a main reason for visiting a museum, their experience with certain areas and components may be focused on other motivations such as having a good time, using hands-on or interactive exhibits, socializing, or other results that may or may not include learning about a topic. Students were also much more likely than the general visitors to learn about how to protect ecosystems, another cognitive outcome. While there are many basic differences between school and general visits, there may be some elements of the student approach that can be incorporated into a general visit.

General visitors and affective outcomes – While overall the students showed more positive outcomes than the general visitors for cognitive gain, one exception is that general visitors were more likely to report learning about how humans impact freshwater ecosystems. It may be that adults were more receptive to this kind of information, or that they focused more on human impact stories than the students. Additionally two specific findings showed more of an affective gain for general visitors, compared to students. The difference between the Treatment and Control groups for general visitors, compared to students, was much higher for saying their visit changed how they thought about freshwater ecosystems and for saying their visit increased their interest in finding out how to protect freshwater ecosystems. So while the additional time students spent engaging the 3D Viz components may have tipped the scales for the difference in

cognitive gain, this did not have the same impact on more affective types of outcomes. It would be worthwhile to better understand the relationship between cognitive and affective outcomes, and the extent to which that relationship is similar or different between general visitors and students. It would be beneficial not only for this project but also to find out whether these patterns hold true for similar projects about other science-related topics.

Findings across institutions – The intention for this project has always been to create a suite of projects institutions around the United States, and the world, could employ to engage the public about freshwater ecosystems. There was an understanding that not all components would work or be employed equally at each institution, and this was born in the summative evaluation. For example, on some outcomes like changes in perception there were more significant results for all of the items for two of the sites but none for the third. In another set of outcomes, perception of main messages, there were no significant differences for two institutions but three out of four significant differences for the third. The trend for which institutions had significant results or not was different for these two examples; meaning, the non-significant institution was not the same for both examples. Thus, the differences cannot be explained by which components the institutions employed, or which the groups interacted with in the case of general visitors, suggesting that there are other factors at play. Conducting more studies with these components could allow for greater insight into why there were positive results at some institutions but not for others. It also raises the question of whether or not we should be concerned or indifferent about the experience and outcomes being different across institutions. In a project that aims to provide a menu of options, it is generally understood that the experiences and outcomes will vary to some degree. In a more holistic light, having different outcomes at different institutions allows for a broader impact for the project and a more unique experience for visitors, especially general visitors in a free choice environment.

Augmented Reality Sandbox – One of the technologies employed in the project that was not originally anticipated in the proposal was augmented reality. The Augmented Reality/AR Sandbox was not in the original plans but added during the development, and has been widely touted and imitated within the informal science education field and beyond; it was even included in a Wired magazine article. While the summative evaluation did not focus on the specific impact of this experience, formative testing showed promising results for how it might uniquely engage intergenerational groups around science topics. More specific study of this specific component, and augmented reality in general, would be very useful to the field. Of particular interest is the long-standing question of how engaging visitors in a unique hands-on experience fits with other types of outcomes, including cognitive gain, motivation, attitudes, among others.

INTRODUCTION AND PROJECT BACKGROUND

This section provides an overview of the project itself, the main objectives and impacts the project hoped to achieve, and a description of the main deliverables created to achieve these objectives and impacts.

Overview:

The National Science Foundation (NSF) awarded an Informal Science Education (ISE) grant, since renamed Advancing Informal STEM[1] Learning (AISL) to a group of institutions led by two of the University of California, Davis's centers: the Tahoe Environmental Research Center (TERC) and the W.M. Keck Center for Active Visualization in Earth Sciences (KeckCAVES). Additional partner institutions were the ECHO Lake Aquarium and Science Center (ECHO), Lawrence Hall of Science (LHS) at the University of California, Berkeley, and Audience Viewpoints Consulting (AVC). The study was designed to examine how 3-D visualizations could most effectively be used to improve the general public's understanding of freshwater lake ecosystems and Earth science processes through the use of immersive three-dimensional (3-D) visualizations of lake and watershed processes, supplemented by tabletop science activity stations and a website. Two iconic lakes were the focus of the study: Lake Tahoe in California and Nevada, and Lake Champlain in Vermont and New York, with products readily transferable to other freshwater systems and education venues.

The project was created to implement, evaluate, and disseminate knowledge of how 3-D visualizations and technologies could be designed and configured to effectively support visitor engagement and learning about physical, biological and geochemical processes and systems. An additional part of the project was to evaluate how these technologies could be transferred more broadly to other informal science venues and schools for future career and workforce development in these critical STEM areas. For more information about the project see: http://www.nsf.gov/awardsearch/showAward?AWD_ID=1114663&HistoricalAwards=false and www.lakeviz.org .

Main Objectives:

This project has three overlapping objectives, which collectively guided the design and development of the deliverables. Objective one stresses the importance of building upon the NSF-funded planning grant that led into this project. The research for the project can be found on www.informalscience.org at http://informalscience.org/evaluation/ic-000-000-003-270/_Research_Study_for_Visualization_as_a_Tool_in_Informal_Science_Education_at_Lake_Tahoe_UC_Davis_TERC_ . The second objective involves the team designing and developing a set of deliverables for the project, which were implemented at the three sites: LHS, ECHO and TERC. In terms of the third objective, evaluation was an important part of the project, with front-end, formative and summative (this report) studies conducted throughout the following three stages of the project:

1) To build upon the work started in the NSF Pathways project to continue studying, understanding and gathering more knowledge for how 3-D visualizations can most effectively be used to impact STEM engagement, understanding, attitudes and behaviors around freshwater ecosystems.

2) To help improve general science understanding using freshwater ecosystems and visualizations; to raise awareness of freshwater ecosystems themselves, sustainability, and global human impact; and to transform lack of public interest into concern and raise awareness of societal impact on freshwater ecosystems and the environment.

3) To implement, evaluate, and disseminate knowledge of how 3-D visualizations and technologies can be designed and configured to effectively support visitor engagement and learning about physical, biological and geochemical processes and systems; to evaluate how easily these technologies can be orchestrated, translated, and transferred to additional informal science institutions and venues.

Audience Impacts:

In addition to the main objectives, there were seven specific impacts the project intended to achieve. These specific impacts informed the deliverables to an even greater degree than the main objectives above, and were instrumental in making decisions about the evaluations. While not all of the objectives were measured in the summative evaluation since some of them related to professional audiences and institutions, they helped focus the evaluation questions and methods for the summative evaluation.

- The project will provide new knowledge/practices for implementing 3-D data and visualization technologies in informal science institutions.
- The project will provide new knowledge and practices for presenting content about freshwater ecosystems.
- The project will increase the number of museums/science centers that utilize engaging 3-Dvisualizations for learning.
- The project will document the benefits and practical issues of using a combination of 3-D visualizations and tabletop activities to reach public audiences.
- The project will increase the capacity of informal science institutions to partner with research institutions, by providing a model for obtaining data and rendering it for public audiences.
- The project will increase the number of science centers whose staff understands about how people learn from 3-D visualizations and the benefits/challenges of utilizing 3-D data and 3-D visualization technologies.

- The project will increase the number of science centers presenting Freshwater Ecosystem programs.

As is typical and required for NSF-funded projects of this type, there were a number of indicators created for each of these main impacts. These specific impacts were one of the main ways the evaluation strategies, methods and specific items were constructed. These impacts were also a key for determining the main components or deliverables for the project.

Main Components/Deliverables:

In order to meet the goals and objectives of the project and to achieve the intended impacts, the 3D Viz team created a series of components. Some of these components were to be used across all three of the locations of the project (LHS, ECHO and TERC). Others were created specifically for certain institutions. The idea was to create some deliverables that could be used across a variety of institutions outside of this project, while others were specific to an institution in order to make them more relevant and interesting to specific audiences. For example, there were visualizations at TERC that focused on Lake Tahoe, while the visualizations at LHS and ECHO focused on watersheds near these institutions.

The following were the deliverables created by the 3D Viz project:

3D Visualizations:

 **1. Following a Drop of Water** (@ TERC and @LHS)	Drop of Water 3D visualization includes a narrated version that follows a drop of water landing in the mountains around Lake Tahoe all the way down through creeks, a river, and a wetland until it enters into Lake Tahoe. This 3D view takes the perspective of the drop of water and talks about its path and how it flows into the lake. After the narrated version, the journey continues in a live version where a facilitator can use a joystick to fly around the Lake Tahoe area and even underwater to look at the lakes bottom. The live version typically includes the facilitator going to geographically important places, telling stories about the lake's past and current situation, as well as fielding requests from viewers to visit certain places in and around the lake, including human structures.
 **2. Flood Visualization** (@ECHO only)	Life in the Flood Zone: A 3D Watershed History Tour takes guests on a 3D journey through two of Lake Champlain's largest tributaries. This 25-minute presentation follows the history of dam development and flooding on Vermont's Winooski River and Otter Creek. The visualization layers aerial imagery and GIS data on top of a digital elevation model using UC Davis' KeckCAVES Crusta visualization software. The tour's path is pre-programmed but run and narrated by a live museum educator. It is supported by 2D historic photographs, which are displayed on second screens – monitors adjacent to the main 3D screen.

Hands-on Activities:

 **1. Seiche Wave Model** (@TERC, @LHS, and @ECHO)	The Seiche Wave Model included a demonstration of how the temperature of water can affect the distribution and movement of water in bodies of water like lakes. It included a tank with a divider that let the facilitator separately pour in two types of water with different temperatures (one cold and one hot). Additional items included thermometers to measure the temperature, colored dyes to make water of different temperatures different colors, and other props used in the demonstration. The main purpose of the activity was to show that lakes stratify with colder waters near the bottom of the lake and warmer waters at the surface of the lake, and how any warming or cooling of water would change the distribution in a body of water. Lakes are dynamic systems and water can mix depending on different temperatures, new water introduced by streams, and
 **2. Make a Watershed Activity** (@LHS only)	This is an adapted version of the "Build Your Basin" activity, which can be found on the "3dh2o" site developed for this project: http://3dh2o.org/build-our-basin-2/ . Participants used everyday materials, including newspaper, a spray bottle with water and pencil shavings to learn how runoff picks up pollutants and how this affects the watershed. The facilitator moved from table to table to talk to the students, offer suggestions and answer any questions. During field trips students spent about 15 minutes or so working on the watershed in small groups.

 **3. Lakes of the World Activity** (@TERC only)	The Lakes of the World Activity involved picking a lake "card" that represented a single lake and had a variety of information about that particular lake (type of lake, where it was located, etc.) created by TERC staff. Students could choose lakes based on the continents and what they were interested in. They were then encouraged to share some information about their lake with the group, and they mostly talked about characteristics of the lake (e.g., it was the biggest lake or the oldest lake). The facilitators then asked the students to line up based on a characteristic of the lake (like size, how it was formed, etc.) and then the group discussed and compared similarities and differences.
 **4. Race to Save Lake Tahoe Game** (@TERC only)	The Race to Save Lake Tahoe game is a board game on the topic of lake stewardship. Ideally, three or more players are needed. The goal of the game is be the first person to make their way around the lake by moving a marker along a path, like the popular children's board game Candy Land. One person plays the role of the score reader and carries the score reader card, with the instruction: "Make sure none of the other players sees this information. Keep it hidden!" Players decide if they are playing in teams or as individuals, and the person who is the youngest goes first. Then they go in order clockwise around the board. The second player draws a card from the desk and reads the question out loud. The player or player team then chooses an answer: A, B, C, etc. The score reader tells them the points earned for the choice taken. Player 2 moves a game piece forward or backwards the given number of spaces. On the next turn, Player 3 draws a card from the deck and tries to answer the question. The score reader tells them the points earned, and moves a token on the board that many points.

Technology and Apps:

 **1. "Shaping Watersheds" Augmented Reality (AR) Sandbox** (@TERC, @LHS, and @ECHO)	The Shaping Watersheds AR Sandbox leverages the open play and exploration paradigm of a sandbox and allows visitors to explore how water interacts with a landscape to form lakes. We took a traditional sandbox one step further and married it with a Microsoft Kinect, which is a 3D camera, and a projector. We created an open, playful sandbox that allows visitors to shape the sand's landscape while the Kinect tracks changes in the sand's elevation The Kinect's data are sent to the computer and an overhead projector displays a virtual topography with corresponding elevation color gradient and contour lines. As the visitor plays by changing the topography, she may place her hand above the landscape and make it virtually rain on the surface. The water flows realistically over the landscape and forms lakes in the basins.
 **2. Healthy/Unhealthy Lakes App** (@TERC, @LHS, and @ECHO)	The "Healthy/Unhealthy Lakes" mobile app is a science deliberation tool for educators, families, and children to assess and discuss factors related to the relative health of lakes. Various lake zones are options presented on an iPad, from the land down to the bottom of the lake, and users are given various images/concepts and photos to determine whether each image shows a Healthy Lake, Unhealthy Lake, or It Depends. The purpose is to begin a dialogue about what makes a lake healthy or unhealthy, how lakes might differ in this respect (from oligotrophic to eutrophic), and to understand how our actions influence habitat zones.

There were also a number of project components that were either still under development at the time of summative testing or there was not enough space or time to test in the summative evaluation, since visitors could only be expected to try out a certain number of activities or deliverables during a visit and many Apps were intended for standalone use outside of the museum setting. This included three visualizations (Lakes of the World Visualization, Let's Go Jump in The Lake, and the Strawberry Creek Watershed Visualization) as well as two additional components ("DIY Lakes" app (available from Apple iTunes) and the "Lake Tahoe Aquatic Food Web Activity").

SUMMATIVE EVALUATION APPROACH AND DESIGN

This study included a number of factors and considerations that determined its ultimate approach and design. One factor was that the project proposed to look at the impact of the deliverables on both general visitors and students; therefore, these were the two main audiences included in the summative evaluation. Another factor was that the deliverables were going to be employed at three institutions: LHS, ECHO and TERC. Lastly, the evaluators decided that in order to effectively measure the impact of the deliverables, it would be important to have both a treatment group who engaged in the deliverables and a control group who did not. This last consideration would allow the evaluators to determine the added value of these experiences to a visit. Therefore, the design is technically a 2 X 3 X 2 design (audience BY location BY participation). Furthermore, since we are using a control group but not randomly assigning people to a control or treatment group, this was a quasi-experimental design. So, to be precise, this summative evaluation study uses a **2 X 3 X 2 quasi-experimental design, with a control group as a comparison**.

The two tables below show the distribution of two of the factors (audience and participation) broken down by the three institutions. While all efforts were made to balance the numbers equally across institution, this was not entirely possible, as explained below. A little more than half (58%) of all participants were students, with more students participating at LHS and ECH0 compared to TERC (see Table 1). The general visitor numbers were the opposite, where there was a higher number of general visitors at TERC compared to LHS and ECHO. See the Methods section below for an explanation of the recruitment of participants and why the numbers were different for the student and general visitor conditions.

Table 1: Students and General Public Visitors by Institution

	LHS		ECHO		TERC		All three	
	#	%	#	%	#	%	#	%
Student	190	66%	174	65%	78	39%	442	58%
General	98	34%	94	35%	121	61%	313	42%
Total	288	100%	268	100%	199	100%	755	100%

In terms of the distribution of control and treatment groups by institution (see Table 2 below), it was evenly split between the control (51%) and treatment (49%) groups. The main difference between the control and treatment group numbers at institutions had to do with the size of the student classes; rather than assign students to the control or treatment groups randomly, which was not possible, a class was assigned to either the control or treatment group. The class sizes were not identical, so there was some variation between the numbers of students in control and treatment groups. Since the general visitor groups were recruited one at a time, it was much easier to ensure that the numbers were either identical or very close.

Table 2: Control and Treatment Groups by Institution

	LHS		ECHO		TERC		All three	
	#	%	#	%	#	%	#	%
Control	142	49%	148	55%	91	46%	381	51%
Treatment	146	51%	120	45%	108	54%	374	49%
Total	288	100%	268	100%	199	100%	755	100%

In order to evaluate the extent to which the project was meeting its objective, the summary evaluation approach came up with a series of evaluation questions that guided the study.

Evaluation questions:

1. Who is most likely to engage with the 3-D visualization and the supplementary materials?
2. To what extent does engaging in multiple components affect individual outcomes?
3. How does engaging with the visualization affect peoples' awareness of, attitudes towards and learning about freshwater ecosystems and the challenges they face?
4. How do the outcomes persist and change over time?

The evaluation questions and indicators were instrumental in coming up with and developing methods that would measure the extent to which the project was meeting its goals and objectives. The next section outlines the methods and recruitment used, and provides further detail about data collection at each site.

METHODS

To answer the evaluation questions above, and in order to gather enough data to make the findings meaningful and more generalizable, surveys were used as the main method (see Appendix A). Since the data were collected across three institutions and there was a desire to compare findings across these sites, it was necessary to maximize the resources available for data collection by employing a method that would allow for a decent number of visitors to participate. For larger samples, surveys are often the method of choice since more than one person can be contributing data at the same time; interviews, for example, happen one at a time so typical summative evaluations can only collect 4 to 6 per hour. Surveys can happen concurrently and the

number of people who say yes and the number of clipboards (or computers/iPads/notebooks) as you can have out there is the only limiting factor. As such, it was possible to collect a lot of surveys from the general public, and the survey format also allowed a lot of data to be collected from the students in a short period of time. For this summative evaluation, the method employed was on-site surveys with a follow-up survey.

Methods:

1. **On-site surveys (n=755) –** The on-site surveys included different approaches to recruit the two different audiences. School groups were recruited ahead of time with the help of each of the three institutions, while the general visitors for two of the institutions (LHS and ECHO) were recruited off the floor from people visiting the institutions. For TERC, which does not have a large regular daily visitation, general visitors were participating in an evening program at the institution. All surveys were collected between February 12 and March 28, 2015. Data were collected February 12 to 15 at LHS, February 18 to 21 at ECHO, and March 24 to 28 at TERC. For the treatment group, it involved recruiting treatment participants during their visit to interact with the project deliverables, and intercepting visitors as they were exiting the museum to fill out the survey for the control group. It was important to have visitors experience the visit/institution itself, with the only difference being that the treatment group participated in one or more of the deliverables while the control group had a "regular" visit.

2. **Follow-up web surveys (n=32) –** In order to gather information how participating in the 3D Viz project might stay with people, adult general visitors were asked to share their email in order to be emailed a link to a follow-up web survey. Students were not eligible to participate in the follow up web survey due to IRB regulations. To encourage participation in the follow up web survey AVC offered an incentive of two $100 gift cards to Amazon.com, the winners of which would be randomly chosen from those who completed the survey. Of the 313 general visitors who participated in the on-site surveys, a total of 115 (or 37%) shared an email address in order to be contacted later (see Table 3). Of this group of 115 individuals, a total of 32 (or 28%) filled out a survey. More than two thirds of those who filled out the follow-up survey were from TERC. There were slightly more respondents from the treatment group compared to the control group (see Table 4).

Table 3: Number of Participants in the Follow Up Web Survey, by Institution

	LHS	ECHO	TERC	All three
General visitor surveys	98	94	121	313
Agree to participate	26	36	53	115
Responded to survey	1	10	21	32
Completion rate (from those who shared emails)	4%	28%	40%	28%
Completion rate (of all general visitors)	1%	11%	17%	10%

Table 4: Number of Participants in the Follow Up Web Survey

	Total Count	Control	Treatment
Agree to participate	115	54	61
Responded to survey	32	13	19

An equal number of women and men (50% each) participated in the study. For 40% of visitors this was their first visit to the museum, while 60% had visited previously. The control and treatment groups were evenly split between individuals who had never been to the museum (either LHS, ECHO or TERC) and those who had visited previously.

Procedures followed for each institution:

Since each site had different strategies for recruiting participants, the details of the data collection process for each site are described in further detail below. It should be noted that the school groups participated in a workshop with museum staff to go through activities and interact with the 3D Viz components. Frequently, the students who were in the control group also participated in the activities, just after they had filled out the survey for the study.

Lawrence Hall of Science

School Groups Summative studies with 5th grade school groups were conducted over two days: Thursday, Feb 12 and Friday, February 13, 2015. One class was from a private school with a focus on public safety, and the other was a suburban public school. Each school brought about 90 students, which were broken into three groups of about 30 students. Day one had two treatment groups and one control group, while day two had one treatment group and two control groups. Students in the control group had time to explore the museum before participating in the workshop; however, some treatment groups did not see any other parts of the museum before beginning the workshop. All groups participated in the complete workshop and had time to explore the rest of the museum exhibits during the visit, regardless of which group they were in.

In terms of the workshop itself, groups were given an introduction to the workshop, including a short discussion and definition of the word "watershed." The group was then split into three smaller groups of 10 to 12 students. Groups rotated between viewing the 3D movie "Following a Drop of Water," which took about 5 minutes, and observing and touching amphibians like frogs, salamanders and toads. The lead facilitator narrated the 3D movie, while other museum staff facilitated the amphibian exploration. Once each smaller group had experienced the 3D movie the groups were recombined to participate in the Make a Watershed activity all together. Students worked in pairs or threes and followed the lead facilitator to create a watershed in a small bin using newspaper and a sheet of plastic; they balled up newspaper to create land features, then covered it with the sheet of plastic so the water could run over the shape of the landscape. Students were then instructed to use water to "make it rain" over their watershed. Students also added "pollution" to their watershed (pencil shavings and powdered ice tea) and sprayed the watershed again with water. The facilitator talked to the groups throughout the process about the content and discussed ideas related to the topics.

General Visitors

Control surveys were collected in the main lobby and throughout LHS over four days: Thursday, February 12 through Sunday, February 15, 2015. Data collectors asked visitors if they were near the end of their visit to ensure they had already seen a number of exhibits in the museum. On days when treatment activities were available data collectors also asked visitors if they had experienced any of the project's activities and were excluded if they had done any of the 3D Viz components.

Treatment surveys were conducted over two days: Saturday, February 14 and Sunday, February 15, 2015.
All treatment activities were set up in the central area of the Science on a Sphere room where the AR Sandbox was also located. Visitors entered the room and were invited to participate in whichever activities they chose - participation in all activities was not mandatory. In addition to intercepting visitors as they entered the room, data collectors also recruited participants for the treatment group from other areas of the LHS to ensure the goal of 50 individuals was reached. Treatment activities included the 3D movie titled "Following a Drop of Water," the interactive sandbox, the "Make a Watershed" activity and the iPad app about healthy and unhealthy lakes.

ECHO

School Groups

Summative studies of school groups at ECHO were conducted over three days: Wednesday, February 18 through Friday, February 20, 2015. All students were in middle school in and around the Burlington, Vermont area, in either 6th or 7th grade. The school group on February 18th included about 80 students and was split into three groups of about 25, with 2 control groups and one treatment group. The school group on February 19th brought about 60 students, which was broken into two groups of about 30 students. The group on February 20th included around 80 students and was split into three groups of about 25 students. Each day included at least one control group and one treatment group. All students were given time to explore the ECHO exhibits during the visit, although due to time constraints the control group on February 18th did not view the 3D visualization. All other students, both treatment and control, watched the 3D visualization at some point during the visit.

Control groups were free to explore the exhibit spaces for about 60 minutes upon arrival to ECHO, although they were instructed not to engage with the treatment components during this time. Control groups were then brought to the theater to complete the survey before viewing the 3D visualization. The control students were then given more time to explore ECHO exhibits, including the Action Lab where the treatment components were located.

Treatment groups viewed the 3D visualization at the beginning of the visit to ECHO, and were then allowed to explore the museum exhibits, including the Action Lab with the treatment components. At the end of the visit the treatment group students returned to the room where they saw the visualization filled out the survey before leaving.

General Visitors

The control surveys were conducted Saturday, February 21, 2015, with visitors intercepted in the main lobby and throughout the ECHO exhibits. Data collectors asked visitors if they were near the end of their visit to ensure they had already seen exhibits in the museum. Since some of the treatment activities are permanently available at ECHO, data collectors also asked if visitors had experienced any of those activities and if they had they were not recruited for the control group.

Treatment surveys were conducted over two days: Thursday February 19 and Friday, February 20, 2015. The treatment hands-on activities were set up in one exhibit space on the second floor called the Action Lab, where the interactive sandbox was located. Other activities included the Healthy/Unhealthy Lakes iPad app and the Seiche Wave model, the latter of which was facilitated by an ECHO staff member or volunteer. Visitors who participated in at least one of these activities were intercepted upon leaving the gallery and asked to complete the survey. If visitors had only explored non-treatment exhibit components of the gallery they were not recruited to participate in the survey. The 3D visualization was shown in the theater area of Lakeside Hall, on the main floor of ECHO. Data collectors and ECHO staff recruited participants for this treatment experience by making an announcement over the public address system or by walking around and asking groups to participate. Visitors were asked to complete the survey immediately following the 3D visualization, in order to maximize the number of completed surveys. Those who saw the visualization were also asked if they had engaged with the other treatment components in the Action Lab during their visit.

TERC

School Groups

Summative studies of school groups were conducted over two days: Tuesday, March 24 and Thursday, March 26, 2015. All students were in 6th grade, and while both classes were from local suburban public schools the class visiting on March 26th was part of an English/Spanish immersion school. Each school brought about 50 students, which were broken into four groups of about 12 students. Each day of student data collection included two control groups and two treatment groups. Unfortunately about half of students March 24th were not able to participate in the survey because they did not complete and return parental consent forms.

All students cycled through four different activities over the course of their visit: a general tour of the TERC education exhibit (conducted by a TERC volunteer docent), a discussion and worksheet about earthquakes (facilitated by an Americorps TERC staff member), 3D visualizations (facilitated by a TERC staff member) and a group of new activities including the Healthy and Unhealthy Lakes iPad app, the Race to Save Lake Tahoe game and a Seiche Wave demonstration (facilitated by and Americorps TERC staff members). Each student participated in each activity; however, there were a few students who could not participate in the 3D Visualizations due to health or visual problems that precluded them from viewing the 3D visualization. These students joined a different group and participated in other activities during that time.

Students in the control group were given a tour of the TERC educational exhibits and participated

in the earthquake discussion and worksheet, then took the survey before seeing the treatment components. Students in the treatment group participated in all activity stations, including the treatment components, during the field trip and completed the survey at the very end of their visit. In this manner, the control group filled out the survey after having a "regular" visit to TERC, while the treatment group had the regular visit as well as the 3d Viz components.

General Visitors

Due to lower walk-in visitation to TERC compared to the other two institutions, it was necessary to use a different approach to include general visitors in the TERC summative sample. Two approaches were used, one of which involved recruiting college students to go through a process similar to the one the student group used for elementary and middle school students (rotating through activities and filling out a survey at different times for the control and treatment groups). A second approach include recruiting local residents on an evening where there was already a speaker scheduled for that evening. This evening lecture/mixer was advertised through many channels, including the Chamber of Commerce. The main event of the evening was a lecture debunking myths about Lake Tahoe presented by Dave Antonucci, a civil & environmental engineer, however it was mentioned in the advertisements that visitors would also be able to test out new exhibits at TERC. The summative evaluation piggy-backed on the event, setting up the 3d Viz components for viewing before and after the presentation, and having participants fill out a control or treatment survey based on whether they engaged with the exhibits. Processes for the two groups, control and treatment, are described below.

Control surveys were conducted over three days: Tuesday, March 24, through Thursday, March 26, 2015. Control surveys included the following groups:

- College student control participants: TERC staff recruited two environmental science classes from the Sierra Nevada College. It should be noted that the TERC building is located on the campus of Sierra Nevada College, and students have classes in the TERC building. Surprisingly, only one student out of the three classes had ever taken a tour of the TERC exhibits before this testing. Each group had roughly 12 students. Students were given a tour of the TERC education exhibits (conducted by a TERC volunteer docent or staff member), then asked to complete the survey. After taking the survey, students were shown two 3D visualizations that were still in production, and one finalized 3D visualization.

- "Evening Lecture/Mixer" control participants: Some visitors were also recruited as part of the TERC Mixer Event on Tuesday, March 24th. Visitors were asked upon entry to the event if they would be willing to test out new exhibits and give feedback. If visitors did not want to participate in new activities, or they arrived too late to participate in new activities, they were asked to complete a control survey. There is a possibility that visitors who completed a control survey during this event did in fact participate in a treatment activity; however, due to the nature and schedule of the event it was very difficult to separate and regulate visitor activity. These visitors were given a control survey and were asked to complete the survey following the lecture. When they handed the survey in, they were again asked whether they had participated in any of the activities, just to be sure.

TERC docent tour control participants: A few additional general visitors to TERC completed the control survey on Tuesday and Wednesday, March 24th and 25th as part of their regular tour. Though TERC does not receive many walk-in visitors compared to other museums, there were a few visitor groups who took the docent lead tour of the TERC education exhibits and were asked to complete a control survey at the end of the tour.

Treatment surveys were conducted on Tuesday, March 24th. Treatment surveys included the following groups:

- College student treatment participants: TERC staff recruited one environmental science class from the Sierra Nevada College to participate as a treatment group. None of the students in this class had ever taken a tour or participated in TERC programs before this visit. Students were given a demonstration and discussion about Lake Tahoe, lake mixing, lake stratification and Seiche Waves. The class was then invited to play the Race to Save Lake Tahoe game and use the Healthy and Unhealthy Lakes iPad app. The students were then asked to complete the survey.

- "Evening Lecture/Mixer" treatment participants: Visitors were recruited as part of the TERC Mixer Event on Tuesday, March 24th completed the majority of treatment surveys. All treatment activities were set up in the main lobby of the TERC building Treatment activities included the 3D movie "Following a Drop of Water," the interactive sandbox, the Healthy and Unhealthy Lakes iPad app, the Seiche Wave activity and the Race to Save Lake Tahoe board game. Visitors were intercepted as they entered the building and asked if they would be willing to test out new exhibits and give feedback. If they agreed they were given a treatment survey, and asked to fill it out after they were done participating in the activities. Visitors were encouraged to try out as many activities as they wished, then complete the survey following the lecture.

Characteristics of the Sample

General public visitors were typically recruited on the museum floor at LHS and ECHO, usually as they were exiting the museum (for the control group) or as they finished experiencing the 3D Visualization components (for the treatment group). At TERC, as mentioned above, they were recruited as part of an evening program conducted at the museum. These recruitment approaches determined who was included in the study. The breakdown of demographics of the general public visitors can be seen in Table 5.

In terms of students, the field trips were organized by each institution before data collection in order to meet the sample size determined by the study. While students were given an overview and prepared for their field trip to the institution on that day, they were not given details about the purpose of the study or the fact that there were control and treatment groups. All students who participated provided a consent form signed by a parent or guardian; however, data collectors informed them that participation was voluntary. The breakdown of demographics of the students can be seen in **Table 6**.

Students watching the 3D Flythrough at ECHO

Table 5: Demographics for General Public Visitors

Characteristic	Total	LHS (n=98)	ECHO (n=95)	TERC (n=122)
Group Type	**n=315**	**n=98**	**n=95**	**n=122**
Control	47%	49%	53%	41%
Treatment	53%	51%	47%	59%
Gender	***n=304***	***n=93***	***n=92***	***n=119***
Male	50%	46%	44%	58%
Female	50%	54%	56%	42%
Age Category	***n=295***	***n=90***	***n=89***	***n=116***
6 to 12	1%	4%	0%	0%
13 to 17	2%	2%	2%	1%
18 to 24	18%	7%	9%	33%
25 to 34	16%	18%	24%	8%
35 to 44	25%	42%	34%	4%
45 to 54	15%	19%	19%	8%
55 to 64	13%	3%	8%	24%
65 and older	12%	4%	4%	22%
Adult Group Composition	**n=288**	**n=91**	**n=90**	**n=107**
0 adults in group	18%	22%	18%	16%
1 other adult in group	41%	44%	48%	33%
2 other adults in group	19%	23%	23%	12%
3 or more other adults in group	22%	11%	11%	39%
Family Group Composition	**n=275**	**n=89**	**n=89**	**n=97**
Adults WITH NO Children 12 or younger	41%	10%	12%	95%
Adults WITH Children 12 or younger	59%	90%	88%	5%
Age of adults in group	**n=341**	***n=107***	**n=106**	**n=128**
18-24	18%	7%	13%	32%
25-34	14%	18%	19%	5%
35-44	23%	33%	35%	4%
45-54	15%	25%	13%	7%
55-64	14%	3%	13%	25%
65 and over	17%	15%	6%	27%
Age of children in group	**n=298**	**n=157**	**n=136**	**n=5**
0-5	34%	30%	38%	40%
6-12	58%	60%	57%	20%
13-17	8%	10%	5%	40%
Previous Visitation	***n=304***	***n=93***	***n=92***	***n=119***
First time visitor	39%	41%	45%	32%
Have visited before	61%	59%	55%	68%
Location	**n=281**	**n=83**	**n=84**	**n=114**
Local	73%	89%	56%	74%
Tourist	27%	11%	44%	26%

Table 6: Demographics for Students

Characteristic	Total (n=440)	LHS (n=190)	ECHO (n=173)	TERC (n=77)
Group Type	**n=440**	**n=190**	**n=173**	**n=77**
Control	53%	50%	57%	47%
Treatment	47%	50%	43%	53%
Gender	***n=432***	***n=189***	***n=167***	***n=76***
Male	50%	48%	48%	57%
Female	50%	52%	52%	43%
Age Category	***n=434***	***n=188***	***n=170***	***n=76***
6 to 12	83%	100%	57%	99%
13 to 17	17%	0%	43%	1%
Student status	***n=440***	***n=190***	***n=173***	***n=77***
Full time student	100%	100%	100%	100%
Grade Level	**n=436**	***n=189***	**n=171**	**n=76**
3rd-5th grade	43%	100%	0%	0%
6th-8th grade	57%	0%	100%	100%
Previous Visitation	***n=417***	***n=182***	***n=162***	***n=73***
First time visitor	41%	80%	7%	18%
Have visited before	59%	20%	93%	82%

Students using the Augmented Reality Sandbox at ECHO

FINDINGS: *Summative Evaluation*

The findings section is separated into six main areas: Experience with freshwater ecosystems, the Visit to the institution, Participation in the 3D visualization components, Knowledge of freshwater ecosystems, Perceiving main messages, and Changes in thinking about freshwater ecosystems. These generally correspond to the main outcome categories the project was focused on, looking at how people experience the visit and the project components, then the degree to which this impacts their knowledge of and thinking about freshwater ecosystems. In these sections the large majority of the findings are generated from the on-site surveys at the three institutions. Given the moderate sample size for the follow-up web survey, these findings are included in the report to provide additional context to the on-site findings. The smaller sample size means that they are not going to be representative of all of those who participated in the study, and should be interpreted as such.

In the tables below, statistically significant differences are noted with an asterisk (*) and mentioned or interpreted in the narrative sections above the tables. If there is not an asterisk then there was not a statistically significant difference.

Experience with Freshwater Ecosystems

On Site Survey

In an effort to account for visitors' prior knowledge and how that might affect the study, visitors were asked to rate their familiarity with freshwater ecosystems. In general, there was little difference between control and treatment groups overall, and little difference between institutions (see Table 7 and Table 8). Both general public visitors and students on average rated their familiarity with freshwater ecosystems between 4.5 and 5.5 out of 7, suggesting that while knowledgeable about freshwater ecosystems they did not consider themselves extremely knowledgeable. In fact, the only significant difference between the control and treatment group in the four comparisons (Total, LHS, ECHO, and TERC) was between the control and treatment groups for the students. In this case the control group had a higher mean perceived knowledge about freshwater ecosystems than the treatment group.

Participants were also asked whether they had a particular connection, either professionally or personally, to freshwater ecosystems (see Table 9 and Table 10). Overall, about one third of all General Visitors and Students said they had some sort of connection to freshwater ecosystems. There were slightly higher levels for both TERC and ECHO compared to LHS, which is not surprising given that the first two are situated on or very near to large lakes. Visitors were asked more specifically about the type of connections they have to freshwater ecosystems, to see if there differences between the control that treatment group that would need to be accounted for in the study (seen Table 11 and Table 12). For general visitors there was only a statistically significant difference between the control and treatment group in the "other" category, with regard to their connections to freshwater ecosystems. Similarly, students also had a statistically significant difference in their experience with the "other" category. In general, there were no

differences between the control and treatment group that would have an effect outside of the 3D visualization activities in the study.

Both general public visitors and students most often had connections to freshwater ecosystems through their homes and neighborhoods and their hobbies. Almost half of general public visitors (45% control, 46% treatment) and slightly fewer students (42% control, 37% treatment) reported "I live very close to a freshwater ecosystem," while some general public visitors (36% control, 40% treatment) and students (29% control, 30% treatment) said they had a hobby related to freshwater ecosystems. Fewer respondents said they vacation regularly near freshwater ecosystems (general visitor control 28%, treatment 26%; student control 22%, treatment 25%), and that they have family members (general visitor control 8%, treatment 8%; student control 9%, treatment 6%) or they themselves had a job related to freshwater ecosystems (general visitor control 12%, treatment 16%; student control 1%, treatment 4%). Some visitors also answered "Other" and gave responses that did not fit into any of these categories. For example,

Science teacher, biologist

Yearly participant in coastal cleanup

My drinking water

Table 7: General Visitor Familiarity with Freshwater Ecosystems, Control and Treatment

	Total (n=302)		LHS (n= 92)		ECHO (n= 92)		TERC (n= 118)	
	Con	Treat	Con	Treat	Con	Treat	Con	Treat
Familiarity with freshwater ecosystems	4.9	5.0	4.5	4.8	5.1	4.9	5.2	5.1

Note: Scale was from 1 (not at all familiar) to 7 (very familiar)

Table 8: Student Familiarity with Freshwater Ecosystems, Control and Treatment

	Total (n=433)*		LHS (n=188)		ECHO (n=169)		TERC (n=76)	
	Con	Treat	Con	Treat	Con	Treat	Con	Treat
Familiarity with freshwater ecosystems	5.4	5.1	5.7	5.3	5.0	4.7	5.4	5.3

Note: Scale was from 1 (not at all familiar) to 7 (very familiar)

Table 9: General Visitor Connection to Freshwater Ecosystems, Control and Treatment

	Total (n=301)		LHS (n=91)		ECHO (n=92)		TERC (n=118)	
	Con	Treat	Con	Treat	Con	Treat	Con	Treat
Have a connection	64%	69%	53%	50%	67%	72%	70%	79%

Table 10: Student Connection to Freshwater Ecosystems, Control and Treatment

	Total (n=433)		LHS (n=187)		ECHO (n=171)		TERC (n=75)	
	Con	Treat	Con	Treat	Con	Treat	Con	Treat
Have a connection	64%	59%	62%	56%	62%	63%	71%	62%

Table 11: General Visitor Connections to Freshwater Ecosystems

	Total (n=309)		**LHS (n=98)**		**ECHO (n=92)**		**TERC (n=119)**	
	Con	Treat	Con	Treat	Con	Treat	Con	Treat
I live very close to freshwater ecosystem	45%	46%	25%	26%	45%	58%	67%	53%
A hobby (e.g., fishing, boating, etc.)	36%	40%	25%	30%	39%	46%	44%	44%
I vacation regularly near freshwater ecosystem(s)	28%	26%	27%	20%	26%	35%	29%	24%
My job	12%	16%	4%	14%	6%	7%	25%	22%
Someone in my immediate family's work	8%	8%	10%	8%	2%	7%	12%	10%
Other	5%*	11%*	4%	6%	8%	14%	2%*	13%*

Note: Visitors could provide more than one response to this item so the column percentages total more than 100%

Table 12: Student Connections to Freshwater Ecosystems

	Total (n=435)		LHS (n=189)		ECHO (n=171)		TERC (n=75)	
	Con	Treat	Con	Treat	Con	Treat	Con	Treat
I live very close to freshwater ecosystem	42%	37%	40%	34%	39%	36%	54%	50%
A hobby (e.g., fishin boating, etc.)	29%	30%	24%	22%	35%	42%	27%	26%
I vacation regularly near freshwater ecosystem(s)	22%	25%	19%	29%	27%	25%	19%	9%
Someone in my immediate family's work	9%	6%	8%	5%	7%	5%	15%	9%
My job	1%	4%	0%	2%	3%	7%	0%	3%
Other	9%*	3%*	8%*	2%*	9%	5%	7%	3%

Note: Visitors could provide more than one response to this item so the column percentages total more than 100%

Follow Up Web Survey (2 months after the visit)

Since visiting, some web survey respondents had participated in activities or learned new information regarding freshwater ecosystems (see Table 13). More respondents said they had learned something new or participated in an activity related to freshwater ecosystems (18 respondents) than those who said they had not learned something new (11 respondents). While there were a few more individuals in the treatment group who said they did not learn something new or participate in an activity, in general the differences between the control and treatment groups were not very large.

Table 13: Some Visitors Participate in Activities or Encounter New Information

	Total Count (n=29)	Control (n=11)	Treatment (n=18)
Participated in or learned something new	18	9	9
Have not participated in or learned something new	11	2	9

Of the visitors who said they participated in activities or encountered new information after their visit, 7 out of 18 respondents took specific **actions** related to freshwater ecosystems.

We took a hike in Tahoe and found beaver dams

Paddle boarding and wetland observations for science classes

Purchased my own apparatus to demonstrate lake layering in my classroom

Some visitors (6 out of 18) **participated in a program or an event** related to freshwater ecosystems.

Tahoe water suppliers association events, earth day, snapshot day

Weed identification programs

I taught a class at the Tahoe Regional Planning Agency

And some visitors (5 out f 18) **read more about or researched** topics related to freshwater ecosystems.

Searched online for various manure systems- i.e. subsoil distribution to minimize runoff

News articles and information about California's drought.

I've read Heather's materials about nitrogen fixation and denitrogenation. The materials are extremely informative.

Respondents were given a list of activities and asked which ones they had participated in since visiting; many of them had participated in activities connected to the preservation of freshwater ecosystems (see Table 14). Respondents most often cited conserving water as an activity they practice related to freshwater ecosystems (9 control, 16 treatment). About half of the respondents (7 control, 9 treatment) said they scooped dog waste to protect freshwater ecosystems. Other visitors mentioned making landscaping changes, limiting their use of fertilizers and participating in nature clean ups.

Table 14: Activities Visitors Participate in Connected to Freshwater Ecosystems

	Total Count (n=31)	Control (n=12)	Treatment (n=19)
Conserved water	25	9	16
Scooped dog waste	16	7	9
Made landscape changes	14	6	8
Limited use of fertilizers	13	5	8
Participated in a clean up	13	6	7
Looked up information	12	6	6
Supported an organization	11	5	6
Reconsidered disposal	8	3	5
Joined citizen science group	6	3	3
Watershed improvement	6	2	4
Washed or inspected boat	5	2	3

Other	5	1	4

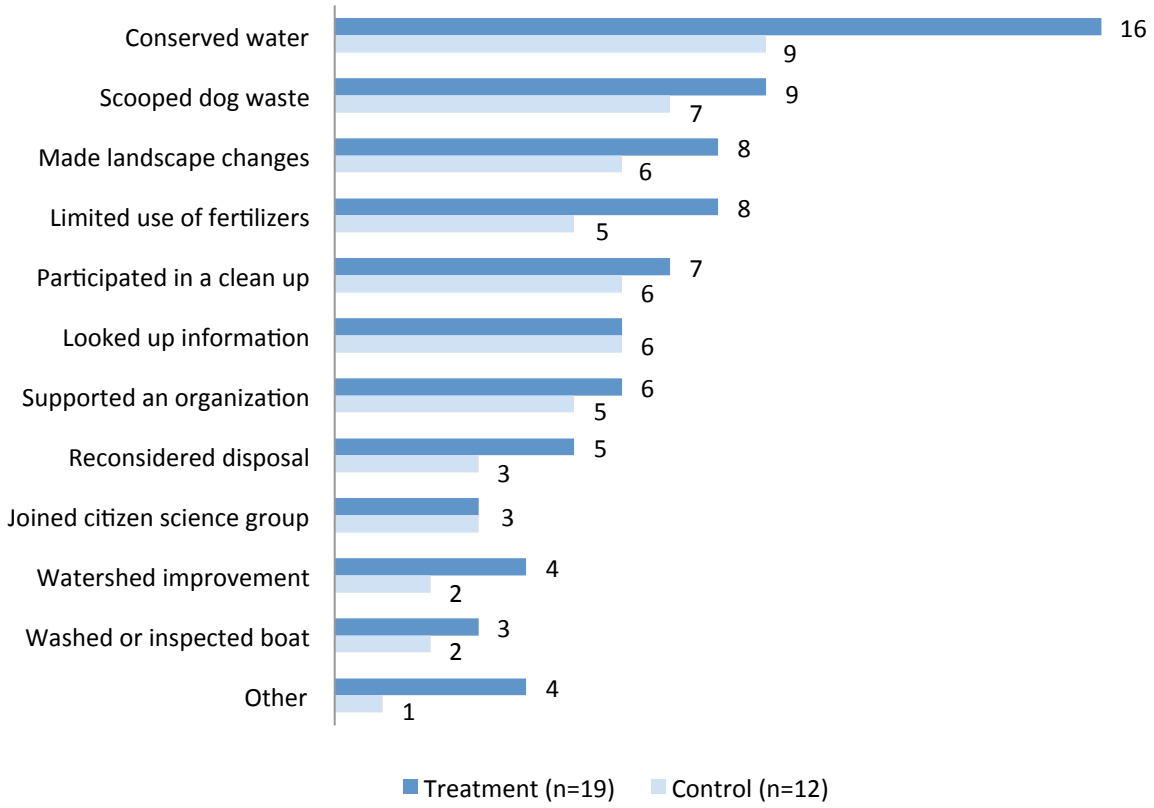
Respondents were asked if their visit to the institution influenced any of their listed actions. Of the total respondents, 11 out of 31 individuals **said their actions were influenced by the visit**.

> *They all were*
>
> *Manure runoff interest was sparked by visit*
>
> *Supporting local watershed improvements!*
>
> *Several classroom activities I have used were inspired by visiting TERC*
>
> *The visit just made me more concerned, and helped me understand that actions have consequences, even if those actions*

Only one respondent said **their actions were not influenced by their visit**.

> *I have lived at Tahoe for over 40 years so I always try to keep the forest and beaches clean by picking up after myself*

Figure 1: Activities Visitors Participate in Connected to Freshwater Ecosystems (n=31)



Visit to the Institution

On Site Survey

The first three questions of the 3D Visualizations summative evaluation survey were designed to gather feedback about the overall visit to the institution at the end of the visit, in order to determine if participating in the 3D Viz components resulted in a more positive overall experience (see Table 15). While it would be ideal to collect all of the on-site survey data at the absolute end of a person's visit, this was not possible due to the amount of surveys needed, the desire not to have the evaluation greatly disrupt the quality and flow of a visitor's experience, and time constraints of the data collection. Some visitors were asked to complete the survey before they had finished their entire visit to the museum - for example, visitors who interacted with the treatment elements were often given the survey immediately after their 3D Viz experience to ensure their data were captured. The evaluators felt that trying to approach people for the treatment group as they were leaving would result in not being able to identify enough people who had engaged with the 3d Viz components, and that there might be confusion about whether they had actually engaged in the components. Visitors were instructed to fill out the survey in response to whatever they had experienced in their visit up until that moment.

All visitors had high ratings of the overall visit, the educational experience and the entertainment experience at the Lawrence Hall of Science, ECHO Lake Aquarium and Science Center and the Tahoe Environmental Research Center. All of the mean scores of the control and treatment groups, for both general visitors and student populations, were above 7 on a 1 to 10 scale, and all but one of the mean scores was above 8 on a 1-10 scale (the mean rating of the educational experience for students in the control group was 7.6).

There was a statistically significant difference between the control and treatment groups in the overall visitor experience and the educational experience. Visitors in all of the treatment groups (general visitors and students combined) rated their overall experience higher (8.8) than the control groups combined (8.6), and the treatment groups rated their educational experience higher (8.7) than individuals in the control groups (8.1).

General visitors, those in both the treatment and control groups, rated the overall experience and the educational experience of the visit as almost a 9 out of 10 (See Table 16). There was a statistically significant difference in the entertainment experience between the treatment and control groups: the treatment group rated their entertainment experience higher (8.8) than the control group (8.4). There was a positive effect for visitors who participated in the treatment activities - the individuals who participated in 3D visualization activities on average rated their entertainment experience higher than those general visitors who did not participate in the treatment activities.

Students also gave high scores for their general ratings of the visit in both the control and treatment groups (see Table 17). There was a statistically significant difference between the control and treatment group for the mean of the overall visit score (control 8.4, treatment 8.8)

and the educational experience score (control 7.6, treatment 8.6). There was a positive effect for students who participated in the treatment activities - their overall rating of the visit and educational experience was significantly higher than those students who did not participate in the treatment activities. There was not a statistically significant difference between in the groups for the mean score of the entertainment experience category; the average scores for entertainment experience for control (8.9) and treatment groups (8.8) were almost the same.

Table 15: General Ratings, Control Versus Treatment, All Visitors

	Control (n=380)		Treatment (n=373)		
Item	**Mean**	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Overall Visit	8.6	1.6	8.8	1.3	**Yes**
Educational Experience	8.1	2.0	8.7	1.4	**Yes**
Entertainment Experience	8.7	1.6	8.8	1.5	No

Note: Scale was from 1 (poor) to 10 (excellent)

Institutional comparison of treatment groups: In comparing the three sites with the treatment group only, one of the three ratings was a statistically significant difference. Educational experience was rated higher at TERC (8.9) and LHS (8.8), compared to ECHO (8.4).

Table 16: General Ratings, Control Versus Treatment, General Visitors Only

	Control (n=147)		Treatment (n=166)		
Item	**Mean**	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Overall Visit	8.9	1.3	8.8	1.2	No
Educational Experience	8.8	1.4	8.8	1.3	No
Entertainment Experience	8.4	1.5	8.8	1.3	**Yes**

Note: Scale was from 1 (poor) to 10 (excellent)

Institutional comparison of treatment groups: In comparing the three ratings given by the treatment groups for general visitors only, none of the three ratings were a statistically significant difference. All three main ratings were consistent across the three institutions.

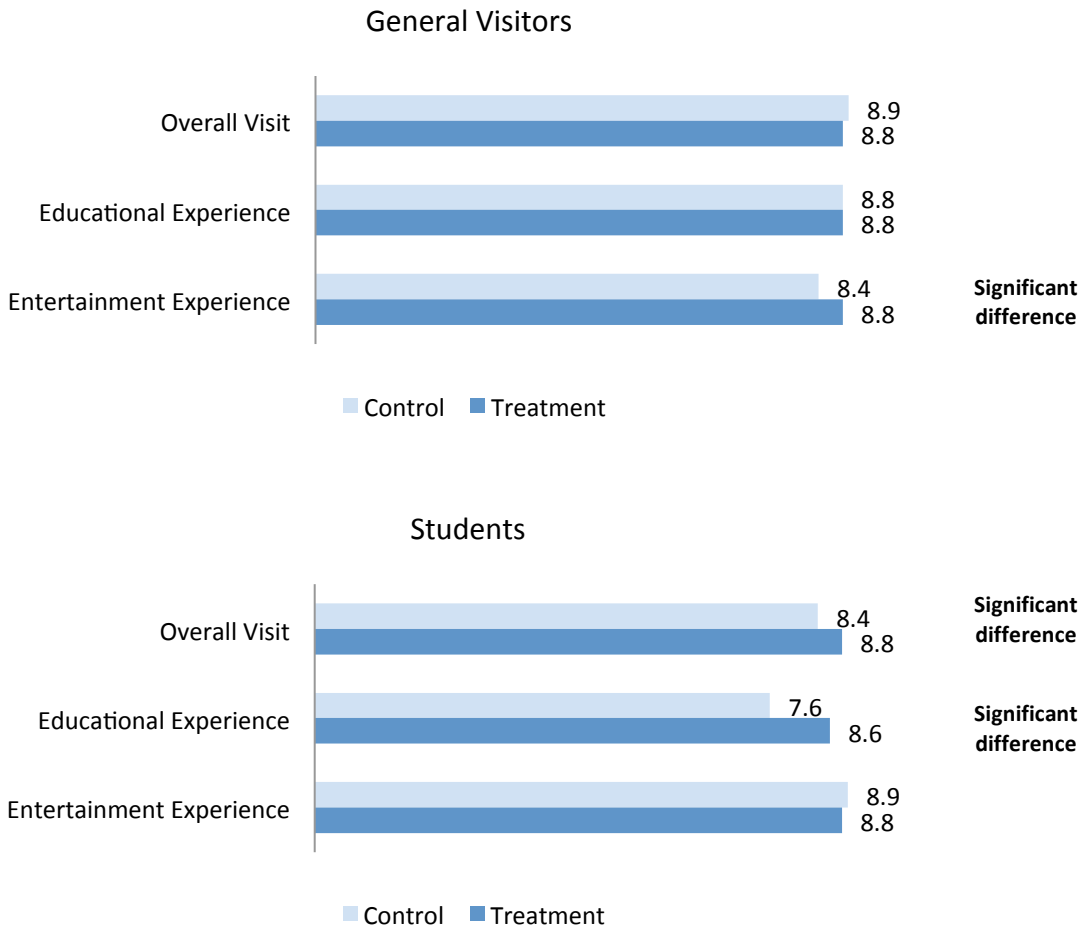
Table 17: General Ratings, Control Versus Treatment, Students Only

	Control (n=233)		Treatment (n=207)		
Item	**Mean**	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Overall Visit	8.4	1.7	8.8	1.4	**Yes**
Educational Experience	7.6	2.2	8.6	1.5	**Yes**
Entertainment Experience	8.9	1.7	8.8	1.6	No

Note: Scale was from 1 (poor) to 10 (excellent)

Institutional comparison of treatment groups: In comparing the main ratings with the treatment groups only, one of the three ratings was a statistically significant difference. Educational experience was rated higher at LHS (8.9) and TERC (8.8), compared to ECHO (8.1).

Figure 2: General Ratings, Control Versus Treatment



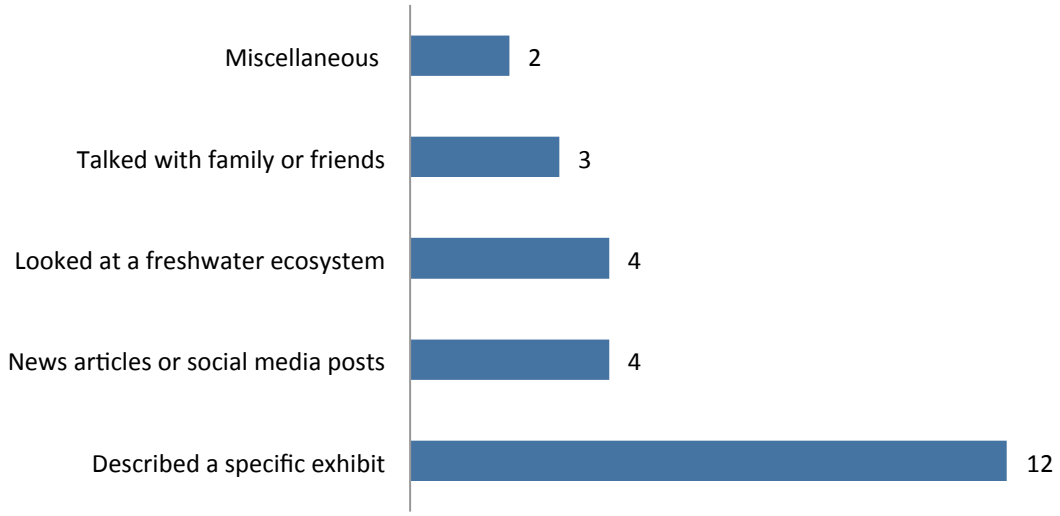
Follow Up Web Survey (2 months after the visit)

The majority of respondents to the follow up web survey said that at some point since leaving they were reminded of their visit during their daily lives (see Table 18). However, there was not a large difference in the proportion of those in the treatment group and those in the control group who were reminded of their visit in their daily life. Visitors were most often reminded of their visit when talking with family members or friends, reading the news, or actually looking at a freshwater ecosystem.

Table 18: Visitors Were Reminded of Their Visit

	Total Count (n=32)	Control (n=13)	Treatment (n=19)
Thought about visit	26	11	15
Did not think about visit	6	2	4

Figure 3: How Visitors Were Reminded of Their Visit (n=32)



Rather than answering about what reminded them, some visitors (12 out of 26) **described the specific exhibit content** they remember from their visit.

> *The shifting of the lake water underneath the ice like in the exhibit by the shipwreck*
>
> *The simulation of weather and water with the topography and sand*
>
> *Mostly about rain and snowmelt and its impact on lake water clarity*

Of the visitors who said they were reminded of their visit during their daily life, 4 out of 26 were reminded when they saw or **read news articles or social media posts**.

> *Social media story on environmental impact on water*
>
> *Also, with the prevalence of California's drought issue, I'm reminded of my visit and learning about different freshwater ecosystems and the ways in which they're important for our planet.*

Of the visitors who said they were reminded of their visit during their daily life, 4 out of 26 were reminded when they **looked at a freshwater ecosystem**.

> *I remember the presentation every time I look at Lake Tahoe*
>
> *Seeing the lake so low. Seeing being careless with trash especially cigarette butts. They leave their trash along Hwy 28 on the east shore.*
>
> *Lake water clarity. We have been watching and keeping an eye on the dredging at the various marinas.*

Of the visitors who said they were reminded of their visit during their daily life, 3 out of 26 were reminded when they were **talking with family members or friends**.

> *My daughter is studying Marine Biology and has referred to our visit several times*
>
> *Recently, my daughter and I were in Boston and she requested a return visit to ECHO. We were walking by the Charles River at the time. The other time was when we were discussing vernal pools and I wondered about the possibility of an exhibit specific to that phenomena.*
>
> *When I see my friends who work there, discussing invasive species with kids*

And 2 visitors gave responses that did not fit into any of these categories.

> *I see it on the hill as I drive to work*
>
> *When I visited, Tim Kosier, one of the docents provided me with information about the Shaping Watersheds exhibit. I have been investigating opportunities for installing a similar exhibit at the science center that I manage (Water Resources Education Center) in Vancouver.*

Almost all respondents to the follow up web survey (28 out of 29 respondents) remembered seeing or hearing information about freshwater ecosystems during their visit (see Table 19). Only

one respondent to the web survey, who was part of the control group, did not remember content about freshwater ecosystems. Most respondents were able to describe specific exhibits or activities from their visit that related to freshwater ecosystems.

Table 19: Visitors Remembering Seeing Content about Freshwater Ecosystems in the Visit

	Total Count (n=29)	Control (n=11)	Treatment (n=18)
Remembered content	28	10	18
Do not remember content	1	1	0

Visitors most often (7 out of 28 respondents) remembered content about **pollution**.

> *How runoff, fresh water from snowmelt and pollutants from human intervention affect water clarity and marine life*
>
> *Impact of buffer zones surrounding feeder streams- importance of wetlands as filtering system- farming is major factor in several regional areas*
>
> *Lake Tahoe is clean but it has over the past 50 years become a degree less clear due to various pollutants. Oil is a huge problem, non-native species, bacteria... Also the Tahoe keys is a major pollutant*

Of the visitors who said they remembered seeing or hearing about freshwater ecosystems, 7 out of 28 respondents talked about **human development and building**.

> *How our homes and lifestyles affect watersheds*
>
> *The effects of Lake /shore development.*
>
> *They are in danger because of human interference.*

Of the visitors who said they remembered seeing or hearing about freshwater ecosystems, 7 out of 28 respondents remembered learning about **invasive species**.

> *They are being affected by invasive species. Some have even been completely destroyed such as in the Tahoe Keys*
>
> *They are fragile and change permanently when we alter them ... like with Mysis shrimp.*
>
> *Invasive species upset the balance.*

Some visitors (5 out of 28 respondents) remembered learning about **how freshwater ecosystems were formed or how freshwater ecosystems function**.

> *About how lakes form when glaciers retreat*
>
> *Wetlands help filter.*
>
> *The fact that the water in the lake circulates up from the bottom to the top on a regular basis.*

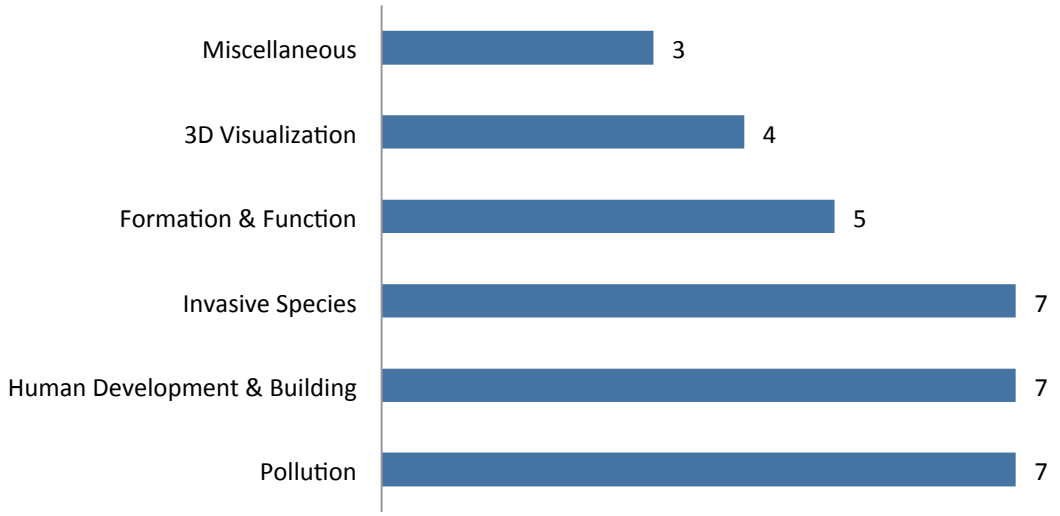
A few visitors (4 out of 28 respondents) specifically remembered the **3D Visualizations**.

> *I remember the fly-over presentation. It was pretty high tech and very informative!*
>
> *The shaping Watersheds exhibit, the wonderful 3-D movie, the lab and limnology, exhibits, hands on exhibit/experiments and the new board game*
>
> *The video of the lake and showing all of the lakes, rivers, and wetlands that feed into the lake and how they also can change the lake in positive and negative ways.*

And 3 out of 28 individuals gave responses that did not fit into any of these categories.

> *There are lots of them, different ones*
>
> *Rivers and wetlands. Upper Truckee River, etc.*
>
> *That there is a lot going on.*

Figure 4: What Visitors Remembering Seeing Content about Freshwater Ecosystems in Visit (n=29)



Participation in 3D Visualization Components

In order to test the effects of the 3D visualizations components on visitors, two separate groups were recruited to take part in the study: a control group visited each institution and experienced the current exhibits and programs available (but not the 3d Viz components), and a treatment group visited each institution and experienced the current exhibits with the additional experience of the special visualization activities and programs developed by the Lake Visualization team. This method was used to see if there was a difference in the experiences of the individuals in the control group and the treatment group, and to determine the added value of the 3d Viz components on top of the regular or typical experience. Without a control group it would be very difficult to determine whether it was the 3d Viz components or the visit itself that resulted in specific outcomes.

To provide the best possible scenario for detecting difference across the control and treatment groups, an effort was made the recruit similar numbers for the four main categories of respondents in the study: general visitor control, general visitor treatment, student control, and student treatment. The range of treatment components available for students and general visitors, visitation patterns, and different size classes in the school groups led to some differences among these four groups across institutions.

While the general visitor treatment groups, as far as the evaluators know, did not ever circle back and participate in the 3d Viz components. Many of the students' teachers wanted all of the students to have the same experience, so many of the control group classes did experience the 3d Viz components, just after they had already filled out the survey as part of the control group. Due to the experimental design of the study and the fact the control group participants did not experience any of the project components, a comparison between control and treatment groups in their participation in visualizations cannot be completed because only the treatment group participated in the visualizations.

There were a number of 3d Viz components available for the institutions, broken down into three types of component:

Visualizations:
- Following a Drop of Water (TERC, LHS)
- Flood Visualization (ECHO)

Apps/Technology:
- Interactive Sandbox (TERC, LHS, ECHO)
- Healthy/Unhealthy Lakes App (TERC, LHS, ECHO)

Hands-on Activities:
- Seiche Waves (TERC, ECHO)
- Make a Watershed (LHS)
- Race to Save Lake Tahoe Game (TERC)

All of the 3D Viz components included in the study are listed in the tables below (see Table 20 and Table 21); each institution chose which of them to include in the 3D Viz experience, and no

institution offered all of them. The two tables below show which components were offered for both the student treatment groups (see Table 21) and general public treatment groups (see Table 20) to experience. This difference also had to do with the general focus and program capabilities of each institution; for example, the Race to Save Lake Tahoe Game was only available at the Tahoe Environmental Research Center because the team at TERC developed the game specifically for that particular institution. If a component was not offered at an institution, it is indicated with a "N/A" or "Not Applicable." For general public visitors the Make a Watershed activity was only available at the Lawrence Hall of Science. The Seiche Wave activity was available for visitors to experience at the Lawrence Hall of Science but was added after the survey instrument was finalized. Some visitors did participate in this activity but were unable to measure how many. And the Race to Save Lake Tahoe Game was only available at the Tahoe Environmental Research Center. The details about the set up and execution of the treatment activities are located in the Methods section of this report.

As a result of the more structured nature of the school field trip and limited time for each group to visit, not all students were able to experience all of the treatment components in the time allotted for their visit. Students visiting the Lawrence Hall of Science only experienced the 3D Movie and the Make a Watershed Activity. Similar to the adult treatment group, the Make a Watershed Activity was only available for students at the Lawrence Hall of Science, and the Race to Save Lake Tahoe Game was only available for students at the Tahoe Environmental Research Center.

Table 20: General Visitor Participation in 3D Visualization Components, Treatment Group Only

	Total (n=167) or total across sites		LHS (n=50)		ECHO (n=45)		TERC (n=72)	
Component	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**
3D Visualization	118	71%	27	54%	32	71%	59	82%
Interactive Sandbox	109	65%	38	76%	27	60%	44	61%
Race to Save Lake Tahoe Game (TERC only)	47	65%	-	-	-	-	47	65%
Make a Watershed (LHS only)	30	60%	30	60%	-	-	-	-
Seiche Waves Activity (ECHO, TERC)	65	56%	-	-	15	33%	50	69%
Healthy Lakes iPad App	77	46%	22	44%	7	16%	48	67%

Note: Visitors could provide more than one response to this item so the column percentages total more than 100%.
Note: a dash indicates the component was not tested at the site during the study.

Table 21: Student Participation in 3D Visualization Components, Treatment Group Only

	Total (n=206) or total across sites		LHS (n=96)		ECHO (n=74)		TERC (n=36)	
Component	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**
Tahoe Board Game	36	100%	-	-	-	-	36	100%
Make a Watershed	95	99%	95	99%	-	-	-	-
3D Visualization	200	97%	96	100%	68	92%	36	100%
Interactive Sandbox (ECHO, TERC)	79	72%	-	-	62	84%	17	47%
Seiche Waves Activity	71	65%	-	-	35	47%	36	100%
Healthy Lakes iPad App	58	53%	-	-	22	30%	36	100%

Note: Visitors could provide more than one response to this item so the column percentages total more than 100%

Note: a dash indicates the component was not tested at the site during the study.

Students using the Healthy and Unhealthy Lakes iPad app at TERC

Knowledge of Freshwater Ecosystems

One of the main messages of the 3D Viz project was "*Freshwater ecosystems like lakes, rivers and wetlands are diverse,*" and part of that main message was being able to recognize the distinction between what is and what is not a freshwater ecosystem. Visitors and students were asked to name some examples of freshwater ecosystems (see **Table 22** and **Table 23**). This was an open-ended question, so visitors were given space to write as many or as few examples as they could think of. Many of the visitors named more than one example, and only a few could not think of an example and others suggested things that were not freshwater ecosystems.

A majority of adult general visitors (64% control, 63% treatment) named Lakes, and over half of general visitors (56% control, 53% treatment) named Rivers as an example of a freshwater ecosystem. General visitors also often cited Wetlands/Marshes, Streams, Ponds, and Swamps/Bogs as examples of freshwater ecosystems. The only statistically significant difference in frequency between the control and treatment groups was the number of visitors who mentioned Creeks as a freshwater ecosystem; 12% of the treatment group, and only 5% of the control group mentioned Creeks. Only a small percentage of visitors could not name an example of a freshwater ecosystem (3% control, 3% treatment). Looking at the average number of examples given, there was no statistically significant difference between the general visitor control and treatment groups.

Table 22: General Visitor Examples of Ecosystems

	Control (n=148)	Treatment (n=167)	Statistically Significant?
Lake	64%	63%	No
River	56%	53%	No
Wetland/Marsh	34%	31%	No
Stream	31%	27%	No
Pond	30%	23%	No
Swamp/Bog	22%	16%	No
Creek	5%	12%	**Yes**
I don't know	3%	3%	No
Miscellaneous	21%	25%	No
Average number of examples	2.9	2.7	No

Note: Visitors could provide more than one response to this item so the column percentages total more than 100%

In looking at the examples in specific categories, the most common example from adult general visitors of a freshwater ecosystem (control 64%, treatment 63%) was **lakes**. Some visitors wrote generally about lakes, while others gave specific examples like the Great Lakes or Lake Tahoe.

More than half of general visitors (56% control, 53% treatment) said **rivers** were an example of a freshwater ecosystem. Similar to lakes, some visitors simply wrote the word "rivers," while others were more specific and wrote things like Mississippi River or Truckee River.

Almost one third of general visitors (34% control, 31% treatment) wrote **marshes or wetlands** as an example of freshwater ecosystems. These two words were grouped together because they describe a similar ecosystem; however, it should be noted that some visitors wrote both of these words as examples of freshwater ecosystems.

Over one quarter of general visitors (31% control, 27% treatment) suggested **streams** as an example of freshwater ecosystems.

Some visitors (30% control, 23% treatment) mentioned **ponds** as an example of freshwater ecosystems.

Some visitors (22% control, 16% treatment) mentioned **swamps or bogs** as examples of freshwater ecosystems. Similar to marshes and wetlands, these words were grouped together because they describe basically the same ecosystem, however some visitors wrote both swamp and bog on their survey.

Creek was the only example that had statistical significance between the control (5%) and treatment (12%) groups. It's possible that the 3D visualization components mentioned creeks, which could have made the treatment group more aware of creeks as an example of a freshwater ecosystem.

Only a small percentage of general visitors (3% control, 3% treatment) did not name any examples of freshwater ecosystems. These visitors usually wrote, "I don't know" in this space, so something similar. Visitors who left this section blank are not included in this group.

There were also visitors (21% control, 25% treatment) who wrote other examples that did not fit into any of these categories. These examples varied widely. Examples include **watersheds, vernal pools, reservoirs, deltas, glaciers, springs and tributaries.**

Similar to the general visitors, the majority of students (71% control, 70% treatment) named Lakes, and over half of students (59% control, 62% treatment) named Rivers as an example of a freshwater ecosystem (see Table 23). A smaller percentage of students mentioned Wetlands and Marshes, Streams, Ponds, Swamps and Bogs as examples of freshwater ecosystems. Again, the only statistically significant difference between the control and treatment groups was the number of students who mentioned Creeks as a freshwater ecosystem; 9% of the treatment group, and only 3% of the control group, wrote about Creeks. A slightly larger percentage of students could not name an example of a freshwater ecosystem (6% control, 6% treatment) compared to general visitors. There was not a statistically significant difference between the number of examples given by the student control group and the number of examples given by the student treatment group.

Table 23: Student Examples of Ecosystems

	Control (n=233)	Treatment (n=207)	Statistically Significant?
Lake	71%	70%	No
River	59%	62%	No
Stream	23%	20%	No
Pond	21%	22%	No
Wetland/Marsh	18%	15%	No
I don't know	6%	6%	No
Creek	3%	9%	**Yes**
Swamp/Bog	3%	3%	No
Miscellaneous	26%	22%	No
Average number of examples	2.4	2.3	No

Note: Students could provide more than one response to this item so the column percentages total more than 100%

The example most often given by students of a freshwater ecosystem (control 71%, treatment 70%) was **lakes**. Some students wrote generally about lakes, while others gave specific examples like the Lake Champlain or Lake Tahoe.

More than half of students (59% control, 62% treatment) said **rivers** were an example of a freshwater ecosystem. Similar to lakes, some students simply wrote rivers, while others were more specific and wrote things like Mississippi River or Truckee River.

One fifth of students (23% control, 20% treatment) suggested **streams** as an example of freshwater ecosystems.

Some students (21% control, 22% treatment) mentioned **ponds** as an example of freshwater ecosystems.

Some students (18% control, 15% treatment) wrote **marshes or wetlands** as an example of freshwater ecosystems. These two words were grouped together because they describe a similar ecosystem.

Only a small percentage of students (6% control, 6% treatment) did not name any examples of freshwater ecosystems. These visitors usually wrote, "I don't know" in this space, or something similar. Visitors who left this section blank are not included in the "I don't know" group.

Creek was the only example that had a statistically significant difference between the control (3%) and treatment (9%) groups. It is possible that the 3D visualization components focused on creeks, which made the treatment group more aware of creeks as an example of a freshwater ecosystem.

A small percentage of students (3% control, 3% treatment) mentioned **swamps or bogs** as

examples of freshwater ecosystems. Similar to marshes and wetlands, these words were grouped together because they describe basically the same ecosystem.

There were also students (26% control, 22% treatment) who wrote other examples that did not fit into any of these categories. These examples varied widely. Examples include **watersheds, vernal pools, reservoirs, deltas, glaciers, springs and tributaries,** all of which could be classified as freshwater ecosystems.

Visitors and students were also asked to list as many problems or challenges facing freshwater ecosystems as they could. This was an open-ended response, so individuals could list as many or as few examples as they wanted (see Table 24 and Table 25). Both general visitors (70% control, 71% treatment) and students (74% control, 76% treatment) most often cited pollution as an example of a problem facing freshwater ecosystems, which is typically the number one answer when people are ask about the problems facing the environment. Very few visitors (1% control, 0% treatment) or students (1% control, 0.5% treatment) wrote that they could not come up with any problems. However, it should be noted that individuals who left this answer blank are not included in this number. There were no statistically significant differences between the examples listed by the control and treatment groups for general visitors, but there were statistically significant differences for the students who mentioned drought and miscellaneous examples.

Table 24: General Visitor Examples of Challenges to Ecosystems

	Control (n=148)	Treatment (n=167)	Statistically Significant?
Pollution	70%	71%	No
Invasive Species	35%	28%	No
Human Development	31%	33%	No
Drought	23%	22%	No
Climate Change	15%	15%	No
Erosion	8%	8%	No
Overfishing	7%	4%	No
I don't know	1%	Less than 1%	No
Miscellaneous	38%	31%	No
Average number of examples	2.9	2.6	No

Note: Visitors could provide more than one response to this item so the column percentages total more than 100%

Most general visitors (70% control, 71% treatment) said that **pollution** was a problem facing freshwater ecosystems.

Pollution- dumping of household goods

Poisoned aquifers from hydraulic fracking

Polluted run off from farms and cities

Over one quarter of visitors (35% control, 28% treatment) mentioned **invasive species** as an example of problems for freshwater ecosystems.

Invasive species of plants and animals

Fish introduced into lake

Invasive weeds

Many general visitors (31% control, 33% treatment) wrote about **human development** as a challenge facing freshwater ecosystems.

Dams

Clear cutting

Overpopulation of people, commercializing these areas and lack of preservation

Some visitors (23% control, 22% treatment) said that **drought** was an issue facing freshwater ecosystems.

West has water scarcity. Ogallala has no water!

We need rain in the lakes because we have a drought

No rain and low snowpack levels in the Sierras. Drought and low rainwater levels

Some visitors (15% control, 15% treatment) mentioned **climate change** as an example of a problem for freshwater ecosystems.

Climate change (this year especially with lack of snowfall and rain)

Global Warming

Extreme seasonal changes

A smaller percentage of visitors (8% control, 8% treatment) wrote about **erosion** as a current problem for freshwater ecosystems.

Erosion

Erosion due to building close to the shore

A few visitors (7% control, 4% treatment) cited **overfishing** as an example of a challenge for freshwater ecosystems.

Overfishing

Excessive fishing

Only a small number of visitors (1% control, less than 1% treatment) said they **didn't know any problems or challenges** facing freshwater ecosystems.

I don't know

And some visitors (38% control, 31% treatment) gave examples that didn't fit into any of these categories.

Lack of natural mixing because of high temperature

Eutrophication

Endangered species within these systems

Recreation

Acid rain

Table 25: Student Examples of Challenges to Ecosystems

	Control (n=233)	Treatment (n=207)	Statistically Significant?
Pollution	74%	76%	No
Invasive Species	15%	14%	No
Drought	15%	5%	**Yes**
Human Development	7%	9%	No
Climate Change	5%	5%	No
Overfishing	6%	4%	No
Erosion	1%	1%	No
I don't know	1%	Less than 1%	No
Miscellaneous	32%	21%	**Yes**
Average number of examples	2.0	2.1	No

Note: Students could provide more than one response to this item so the column percentages total more than 100%

Most students (74% control, 76% treatment) said that **pollution** was the biggest problem facing freshwater ecosystems.

Pollution, gas, oil, plastics

People are littering in lakes

Pollution: oil spills, trash, fertilizers, food. Sea creatures choke on trash. Sea creatures get stuck with trash

Many students (15% control, 14% treatment) mentioned **invasive species** as an example of problems for freshwater ecosystems.

Foreign animals

Non-native fish

Some problems are the shrimp are eating fish food

Some students (15% control, 5% treatment) said that **drought** was an issue facing freshwater ecosystems.

There is not enough water in them because California is in a drought

Lakes are drying

Lack of precipitation

Some students (7% control, 9% treatment) wrote about **human development** as a challenge facing freshwater ecosystems.

Loss of habitat

Some cities cut down trees or plants to build roads.

Extending towns

A smaller percentage of students (5% control, 5% treatment) mentioned **climate change** as an example of a problem for freshwater ecosystems.

Global warming

A few students (6% control, 4% treatment) cited **overfishing** as an example of a challenge for freshwater ecosystems.

Overfishing

A few students (1% control, 1% treatment) wrote about **erosion** as a current problem for freshwater ecosystems.

Erosion

Only a small number of students (1% control, less than 1% treatment) said they **didn't know any problems or challenges** facing freshwater ecosystems.

I don't know

And some students (32% control, 21% treatment) gave examples that didn't fit into any of these categories.

Floods

Another is people are not thinking about the water-life

People are wasting water

Algae blooms caused by famer's runoff

In order to gauge whether visitors had learned about specific topics during their visit, and to see whether the change in knowledge was different between the control and treatment groups, visitors were asked to rate their knowledge on a variety of freshwater-related topics, using a scale from 1 to 7. They rated their knowledge for two time periods: one rating for their knowledge before the visit, and another knowledge rating for after the visit (see these tables on the following pages:

Table 26: General Visitor Change in Perception During , **Table 27**, **Table 28**, **Table 29**, **Table 30**, **Table 31**, **Table 32** and **Table 33**). The specific topics were derived from the Lake 3D Visualization Project Content Map in order to align with the original goals of the project, as the questions in the survey were designed to test the goals of the project in a summative evaluation.

It should be noted that visitors were asked to rate their knowledge before their visit and after their visit at the same time, what is referred to as a retrospective pre-post approach to measuring change. While there were no statistically significant differences in the average change in perception on these items between the control and treatment groups for general visitors, there were positive gains in every category (see **Table 26: General Visitor Change in Perception During** , **Table 27**, **Table 28** and **Table 29**). That is, general visitors in both the control and treatment groups on reported knowing slightly more about each category after their visit to the institution compared to their knowledge before the visit.

In comparison, there was a statistically significant difference in the average change in perception in every category between the control and treatment groups for student visitors (see Table 30, Table 31, Table 32, Table 33). Both the student treatment and control groups reported knowing more about every category after their visit compared to before their visit, with the treatment group having a larger change in perception than the control group. The average difference in perception for the student treatment group was more than 1 point for every category.

Interestingly, the biggest gain in knowledge for both the adult general visitors and the students came in the category "How scientists are currently studying lakes, rivers and wetlands" (a general visitor treatment group change of 1.2, a student treatment group change 1.7). Both students and general visitors rated their knowledge of this topic the lowest of any other category before their visit, and this is true not only for the treatment group but also for the control group. It seems that the 3D Visualization activities were successful in addressing the scientific study of freshwater ecosystems.

Some of the smallest gains came from the categories "The impact humans have on lakes, rivers and wetlands" (a general visitor treatment group change of 0.8, a student treatment group change of 1.2) and "My own impact on lakes, rivers and wetlands" (a general visitor treatment group change of 0.7, a student treatment group change of 1.1). It is possible that given their general familiarity with freshwater ecosystems, the students and adults were already familiar with the human impact on them, or that the 3D Viz components did not address these topics as thoroughly as others.

Students playing the Race to Save Lake Tahoe game at TERC

Table 26: General Visitor Change in Perception During Visit, All Visitors

	Control (n=148)			Treatment (n=167)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	4.3	5.3	1.0	4.5	5.6	1.1	No
The role of my local lakes, rivers and wetlands in the environment	4.4	5.2	0.8	4.6	5.6	0.9	No
The science of how lakes, rivers and wetlands work	4.3	5.2	1.0	5.1	5.5	1.0	No
Problems facing lakes, rivers and wetlands	4.6	5.5	0.9	4.9	5.8	0.9	No
How scientists are currently studying lakes, rivers and wetlands	3.8	4.9	1.2	3.9	5.1	1.2	No
The impact humans have on lakes, rivers and wetlands	4.9	5.6	0.7	5.1	5.9	0.8	No
My own impact on lakes, rivers and wetlands	4.5	5.2	0.7	4.9	5.7	0.7	No
How much lakes, rivers and wetlands affect me personally	4.6	5.3	0.7	4.7	5.6	0.8	No
What I can personally do to help lakes, rivers and wetlands	4.3	5.1	0.8	4.7	5.6	0.9	No

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Figure 5: General Visitor Change in Perception During Visit, All Visitors

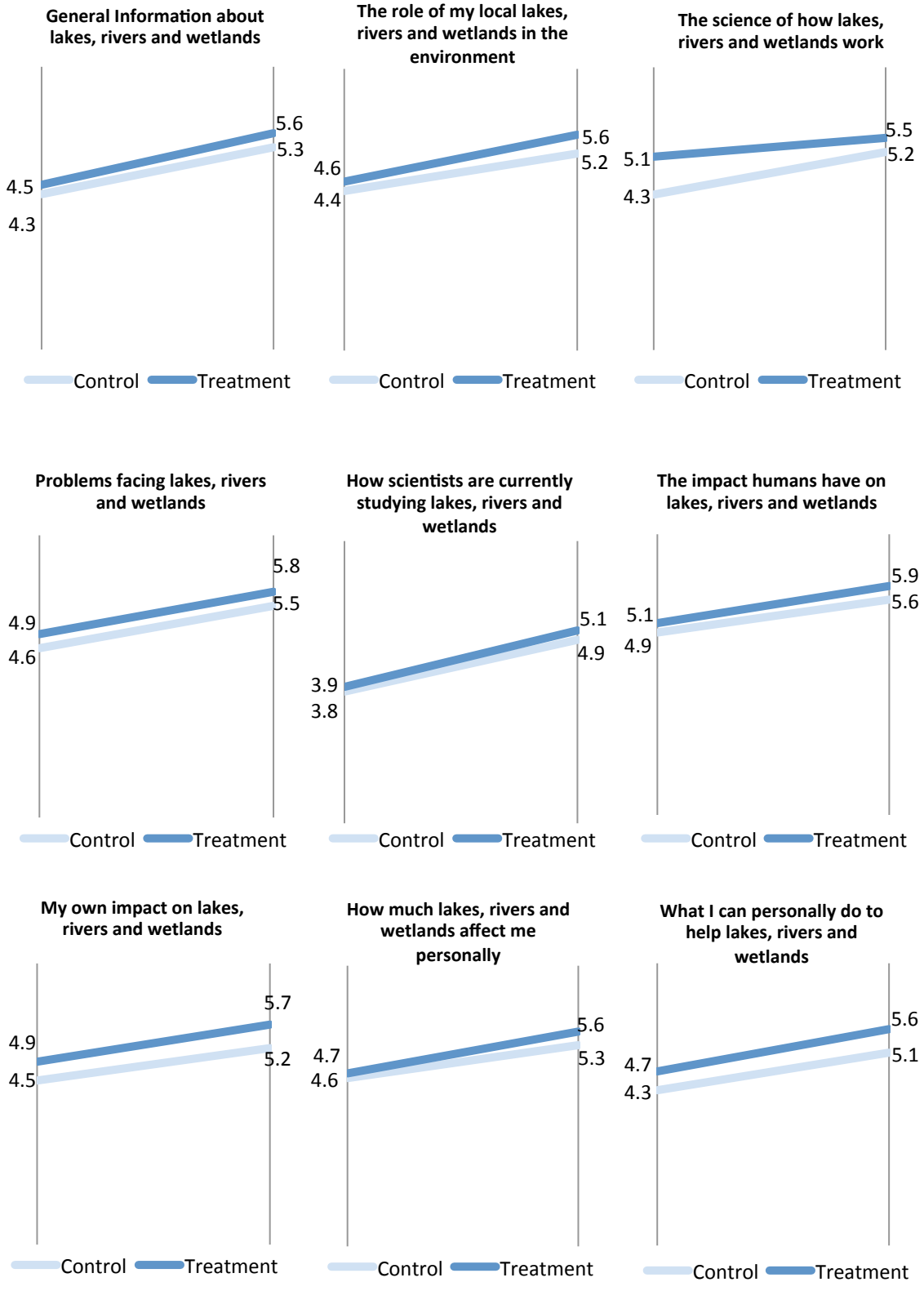


Table 27: General Visitor Change in Perception During Visit (LHS only)

	Control (n=148)			Treatment (n=167)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	3.9	4.7	0.8	4.4	5.3	0.9	No
The role of my local lakes, rivers and wetlands in the environment	3.9	4.5	0.6	4.3	5.2	0.8	No
The science of how lakes, rivers and wetlands work	3.9	4.5	0.6	4.3	5.0	0.8	No
Problems facing lakes, rivers and wetlands	4.2	4.8	0.7	4.8	5.4	0.7	No
How scientists are currently studying lakes, rivers and wetlands	3.4	4.2	0.8	3.5	4.5	1.0	No
The impact humans have on lakes, rivers and wetlands	4.4	5.1	0.6	4.9	5.7	0.7	No
My own impact on lakes, rivers and wetlands	4.1	4.8	0.6	4.6	5.3	0.7	No
How much lakes, rivers and wetlands affect me personally	4.3	5.0	0.6	4.5	5.2	0.7	No
What I can personally do to help lakes, rivers and wetlands	4.0	4.6	0.6	4.5	5.2	0.6	No

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Table 28: General Visitor Change in Perception During Visit (ECHO only)

	Control (n=148)			Treatment (n=167)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	4.5	5.4	1.0	4.6	5.6	1.0	No
The role of my local lakes, rivers and wetlands in the environment	4.6	5.3	0.7	4.6	5.6	1.0	No
The science of how lakes, rivers and wetlands work	4.3	5.4	1.1	4.6	5.6	1.0	No
Problems facing lakes, rivers and wetlands	4.9	5.6	0.7	5.0	6.0	1.0	No
How scientists are currently studying lakes, rivers and wetlands	3.9	4.8	0.9	3.9	5.2	1.3	No
The impact humans have on lakes, rivers and wetlands	5.1	5.7	0.6	5.2	6.1	0.9	No
My own impact on lakes, rivers and wetlands	4.5	5.2	0.7	4.9	5.8	0.8	No
How much lakes, rivers and wetlands affect me personally	4.5	5.2	0.7	4.6	5.6	0.9	No
What I can personally do to help lakes, rivers and wetlands	4.4	5.3	0.8	4.5	5.6	1.1	No

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Table 29: General Visitor Change in Perception During Visit (TERC only)

	Control (n=148)			Treatment (n=167)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	4.5	5.7	1.1	4.6	5.8	1.1	No
The role of my local lakes, rivers and wetlands in the environment	4.6	5.7	1.2	4.9	5.9	1.0	No
The science of how lakes, rivers and wetlands work	4.6	5.8	1.2	4.6	5.7	1.1	No
Problems facing lakes, rivers and wetlands	4.6	5.7	1.3	5.0	5.9	0.9	No
How scientists are currently studying lakes, rivers and wetlands	4.0	5.7	1.7	4.2	5.6	1.4	No
The impact humans have on lakes, rivers and wetlands	5.2	6.1	0.9	5.2	6.0	0.7	No
My own impact on lakes, rivers and wetlands	4.9	5.6	0.7	5.2	5.8	0.6	No
How much lakes, rivers and wetlands affect me personally	4.7	5.5	0.8	5.0	5.9	0.9	No
What I can personally do to help lakes, rivers and wetlands	4.6	5.3	0.8	5.0	6.0	1.0	No

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Table 30: Student Change in Perception During Visit, All Students

	Control (n=233)			Treatment (n=207)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	4.7	5.3	0.7	4.6	6.1	1.5	**Yes**
The role of my local lakes, rivers and wetlands in the environment	4.5	5.2	0.7	4.3	5.8	1.4	**Yes**
The science of how lakes, rivers and wetlands work	4.3	5.1	0.8	4.5	5.9	1.4	**Yes**
Problems facing lakes, rivers and wetlands	5.0	5.5	0.5	5.1	6.2	1.1	**Yes**
How scientists are currently studying lakes, rivers and wetlands	3.6	4.4	0.8	3.5	5.2	1.7	**Yes**
The impact humans have on lakes, rivers and wetlands	5.1	5.6	0.5	5.0	6.1	1.2	**Yes**
My own impact on lakes, rivers and wetlands	4.7	5.2	0.6	4.6	5.7	1.1	**Yes**
How much lakes, rivers and wetlands affect me personally	4.5	5.2	0.6	4.2	5.6	1.3	**Yes**
What I can personally do to help lakes, rivers and wetlands	5.1	5.6	0.5	4.9	6.1	1.2	**Yes**

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Figure 6: Student Change in Perception During Visit, All Students

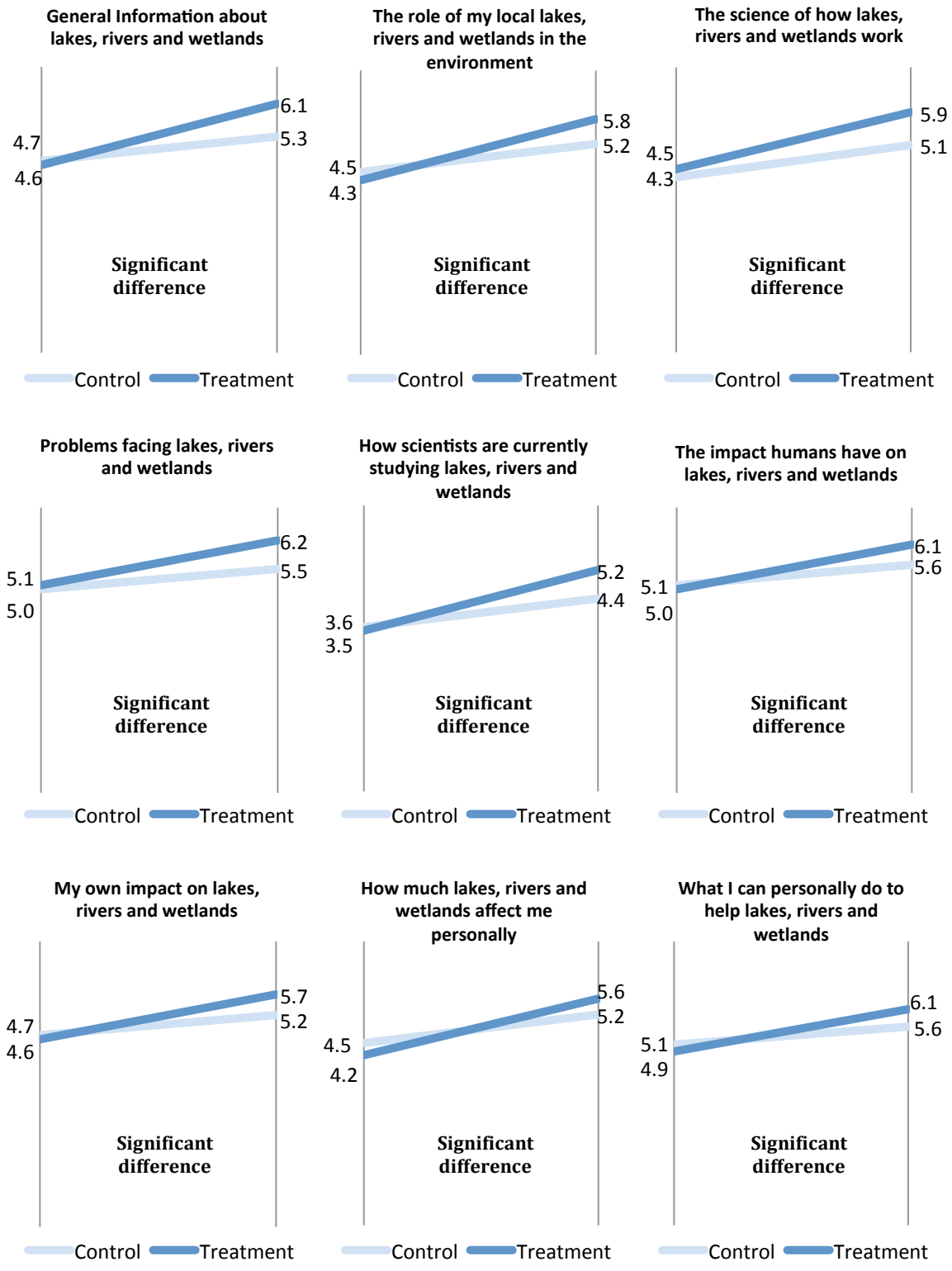


Table 31: Student Change in Perception During Visit (LHS only)

	Control (n=148)			Treatment (n=167)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	5.0	5.5	0.5	5.0	6.5	1.5	**Yes**
The role of my local lakes, rivers and wetlands in the environment	4.9	5.4	0.4	4.7	6.2	1.5	**Yes**
The science of how lakes, rivers and wetlands work	4.6	5.2	0.5	4.7	6.2	1.5	**Yes**
Problems facing lakes, rivers and wetlands	5.4	5.6	0.1	5.9	6.6	0.7	**Yes**
How scientists are currently studying lakes, rivers and wetlands	3.9	4.4	0.4	3.4	5.4	1.9	**Yes**
The impact humans have on lakes, rivers and wetlands	5.3	5.6	0.4	5.5	6.5	1.0	**Yes**
My own impact on lakes, rivers and wetlands	5.0	5.4	0.4	5.0	6.2	1.2	**Yes**
How much lakes, rivers and wetlands affect me personally	4.9	5.4	0.4	4.7	6.1	1.4	**Yes**
What I can personally do to help lakes, rivers and wetlands	5.7	6.0	0.2	5.5	6.5	1.0	**Yes**

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Table 32: Student Change in Perception During Visit (ECHO only)

	Control (n=148)			Treatment (n=167)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	4.5	4.9	0.4	4.3	5.6	1.3	**Yes**
The role of my local lakes, rivers and wetlands in the environment	4.3	4.8	0.5	4.1	5.1	1.0	**Yes**
The science of how lakes, rivers and wetlands work	4.2	4.7	0.5	4.3	5.4	1.1	**Yes**
Problems facing lakes, rivers and wetlands	4.9	5.1	0.2	4.3	5.4	1.1	**Yes**
How scientists are currently studying lakes, rivers and wetlands	3.3	3.8	0.5	3.4	4.6	1.2	**Yes**
The impact humans have on lakes, rivers and wetlands	5.2	5.2	0.0	4.4	5.5	1.1	**Yes**
My own impact on lakes, rivers and wetlands	4.7	4.9	0.2	4.4	5.0	0.6	**Yes**
How much lakes, rivers and wetlands affect me personally	4.6	4.8	0.2	3.8	4.8	1.0	**Yes**
What I can personally do to help lakes, rivers and wetlands	4.7	5.0	0.3	4.4	5.4	1.1	**Yes**

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Table 33: Student Change in Perception During Visit (TERC only)

	Control (n=148)			Treatment (n=167)			Statistically Significant Difference?
	Pre Mean	Post Mean	Mean Difference	Pre Mean	Post Mean	Mean Difference	
General Information about lakes, rivers and wetlands	4.4	6.1	1.7	4.5	6.1	1.6	No
The role of my local lakes, rivers and wetlands in the environment	3.8	5.8	2.0	3.8	5.9	2.1	No
The science of how lakes, rivers and wetlands work	3.9	6.0	2.1	4.5	6.2	1.8	No
Problems facing lakes, rivers and wetlands	4.1	6.3	2.2	4.7	6.6	1.9	No
How scientists are currently studying lakes, rivers and wetlands	3.5	5.9	2.4	4.1	6.2	2.1	No
The impact humans have on lakes, rivers and wetlands	4.6	6.4	1.8	4.7	6.4	1.7	No
My own impact on lakes, rivers and wetlands	4.0	5.7	1.6	4.0	6.0	2.0	No
How much lakes, rivers and wetlands affect me personally	3.5	5.6	2.1	3.9	5.9	2.0	No
What I can personally do to help lakes, rivers and wetlands	4.3	6.0	1.7	4.6	6.5	1.9	No

Note: Scale was from 1 (nothing) to 7 (a lot). The statistically significant difference is testing whether the mean difference score for the Control group was different from the mean difference score for the Treatment group.

Perceiving Main Messages

The project had three main messages or big ideas around freshwater ecosystems, listed below. It is important to note that these messages were used by the project team to guide the development of the deliverables, rather than being communicated directly to the public. As such, they were not specifically included in the exhibit components.

1. Water connects all Earth systems: water, land, air and life.
2. Freshwater ecosystems like lakes, rivers and wetlands are diverse.
3. Humans affect freshwater ecosystems.

A fourth idea was added to be included when testing these messages.

4. If we left freshwater ecosystems alone they would recover just fine.

In order to determine whether participating in the project objectives contributed to a further or deepening understanding of these messages, both control and treatment participants were asked the extent to which they agreed with the four statements above. For General Visitors, there was a statistically significant difference in agreeing that *"Humans affect freshwater ecosystems,"* suggesting that there was an increased awareness of the human impact on freshwater ecosystems for those engaging in the project compared to a control group who did not (see Table 34).

A set of comparisons was done between treatment and control groups, looking only at a single institution. There were no statistically significant differences when looking at just LHS or at ECHO (see Table 35 and Table 36). There were significant differences for three of the four statements at TERC, although in each of these cases the control group had a higher level of agreement about the main messages than the treatment group (see Table 37).

Table 34: Understanding of Main Messages for Control and Treatment Groups, General Visitors

	Control (n=146)		Treatment (n=164)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	6.6	0.8	6.4	1.1	No
Freshwater ecosystems like lakes, rivers and wetlands are diverse	6.6	0.8	6.3	1.1	No
Humans affect freshwater ecosystems	6.6	0.7	6.4	1.0	**Yes**
If we left freshwater ecosystems alone they would recover just fine	4.0	1.7	4.2	1.7	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 7: Understanding of Main Messages for Control and Treatment Groups, General Visitors

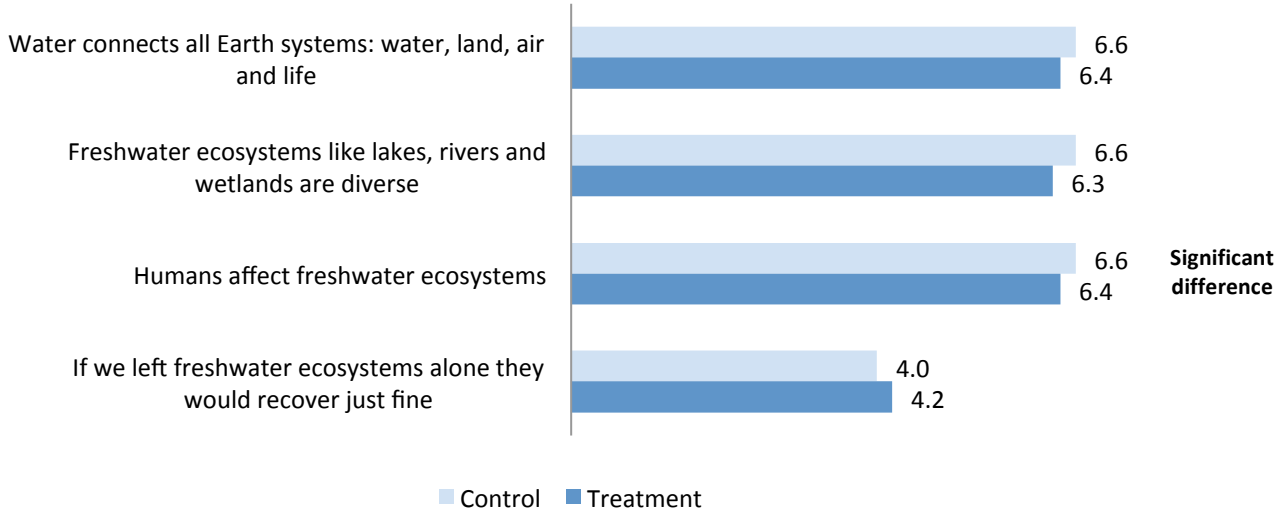


Table 35: Understanding of Main Messages for Control and Treatment Groups, General Visitors (LHS only)

	Control (n=45)		Treatment (n=50)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	6.5	1.0	6.7	0.6	No
Freshwater ecosystems like lakes, rivers and wetlands are diverse	6.5	1.1	6.5	0.8	No
Humans affect freshwater ecosystems	6.7	0.7	6.6	0.7	No
If we left freshwater ecosystems alone they would recover just fine	3.8	1.8	3.8	2.0	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 8: Understanding of Main Messages for Control and Treatment Groups, General Visitors (LHS only)

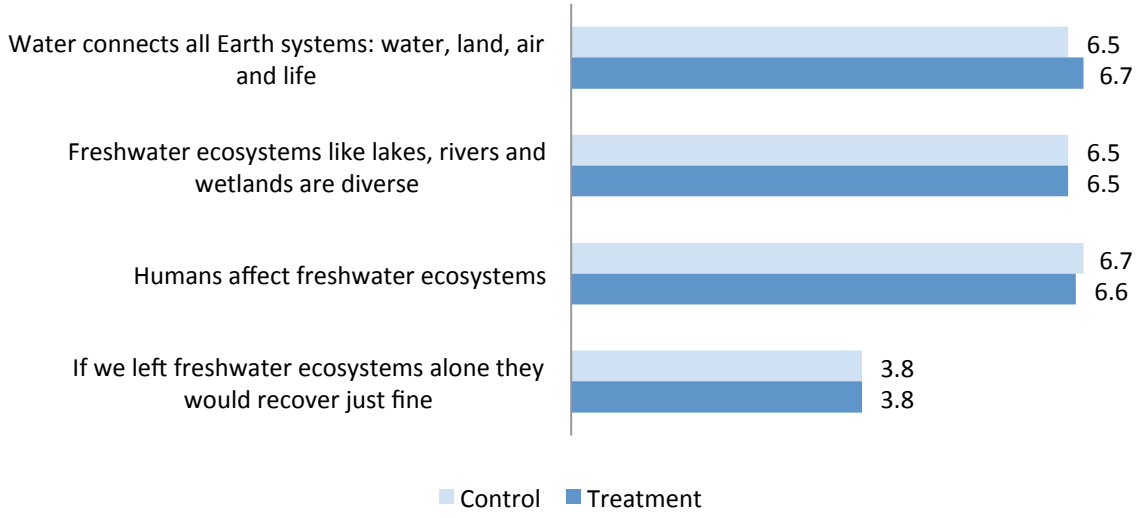


Table 36: Understanding of Main Messages for Control and Treatment Groups, General Visitors (ECHO only)

	Control (n=49)		Treatment (n=45)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	6.6	0.8	6.5	1.0	No
Freshwater ecosystems like lakes, rivers and wetlands are diverse	6.6	0.8	6.4	0.9	No
Humans affect freshwater ecosystems	6.6	0.8	6.5	1.0	No
If we left freshwater ecosystems alone they would recover just fine	3.7	1.5	4.2	1.6	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 9: Understanding of Main Messages for Control and Treatment Groups, General Visitors (ECHO only)

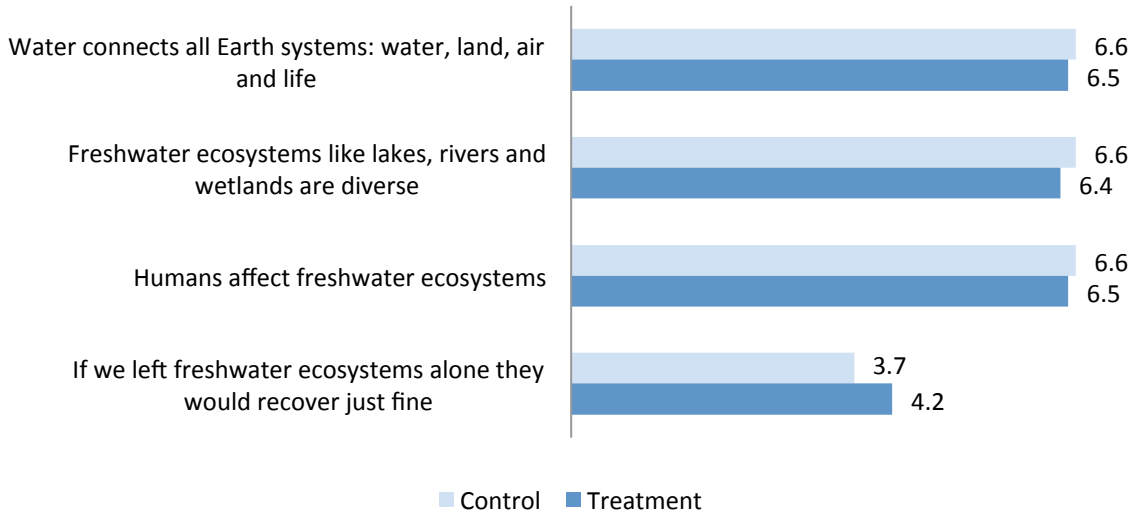
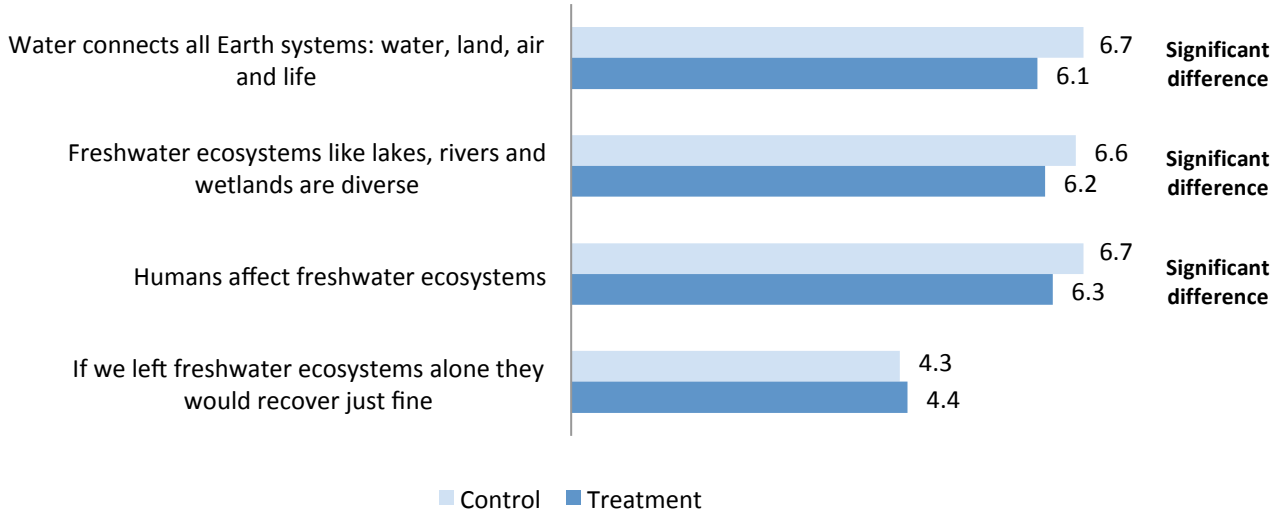


Table 37: Understanding of Main Messages for Control and Treatment Groups, General Visitors (TERC only)

	Control (n=50)		Treatment (n=71)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	6.7	0.6	6.1	1.4	**Yes**
Freshwater ecosystems like lakes, rivers and wetlands are diverse	6.6	0.7	6.2	1.3	**Yes**
Humans affect freshwater ecosystems	6.7	0.7	6.3	1.2	**Yes**
If we left freshwater ecosystems alone they would recover just fine	4.3	1.7	4.4	1.7	No

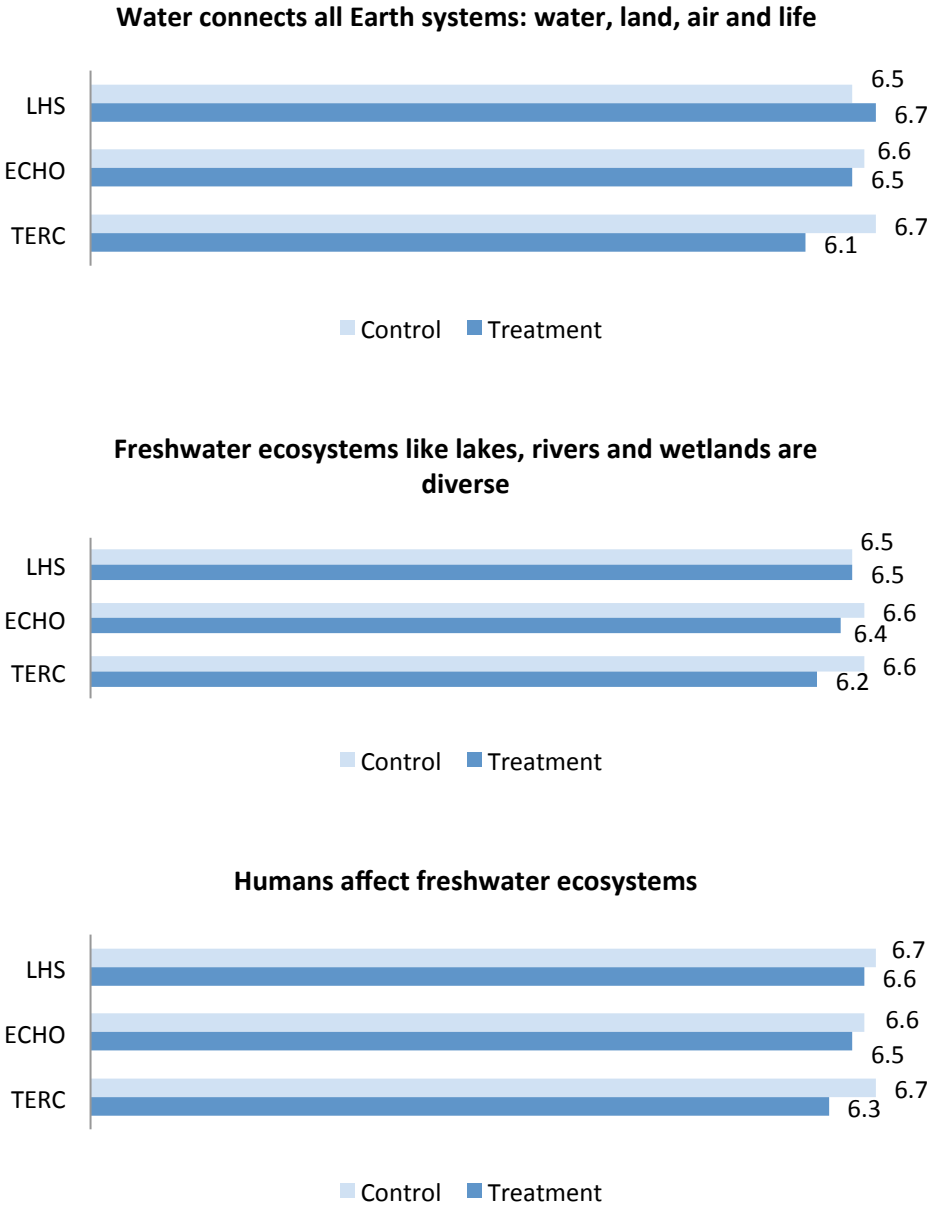
Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

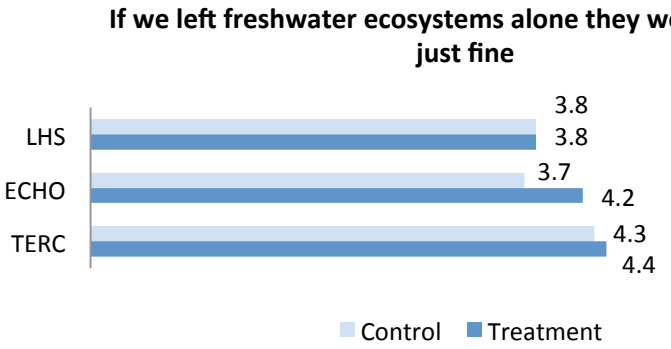
Figure 10: Understanding of Main Messages for Control and Treatment Groups, General Visitors (TERC only)



Students watching the Follow a Drop of Water 3D Visualization at TERC

Figure 11: Comparison of Responses to Main Messages from Institutions, General Visitors





For the Students, the main message that was a statistically significant difference was that *"Water connects all Earth systems: water, land, air and life"* (see Table 38). Students who participated in the 3D Viz activities were more likely to see the Earth systems connected by water.

When comparing treatment and control groups to each other on the main messages for each individual institution, none of the differences were statistically significant (see Table 39, Table 40 and Table 41).

Table 38: Understanding of Main Messages for Control and Treatment Groups, Students

	Control (n=227)		Treatment (n=198)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	5.5	1.6	5.8	1.4	**Yes**
Freshwater ecosystems like lakes, rivers and wetlands are diverse	5.5	1.4	5.5	1.4	No
Humans affect freshwater ecosystems	6.1	1.3	6.1	1.2	No
If we left freshwater ecosystems alone they would recover just fine	4.2	2.0	4.4	2.0	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 12: Understanding of Main Messages for Control and Treatment Groups, Students

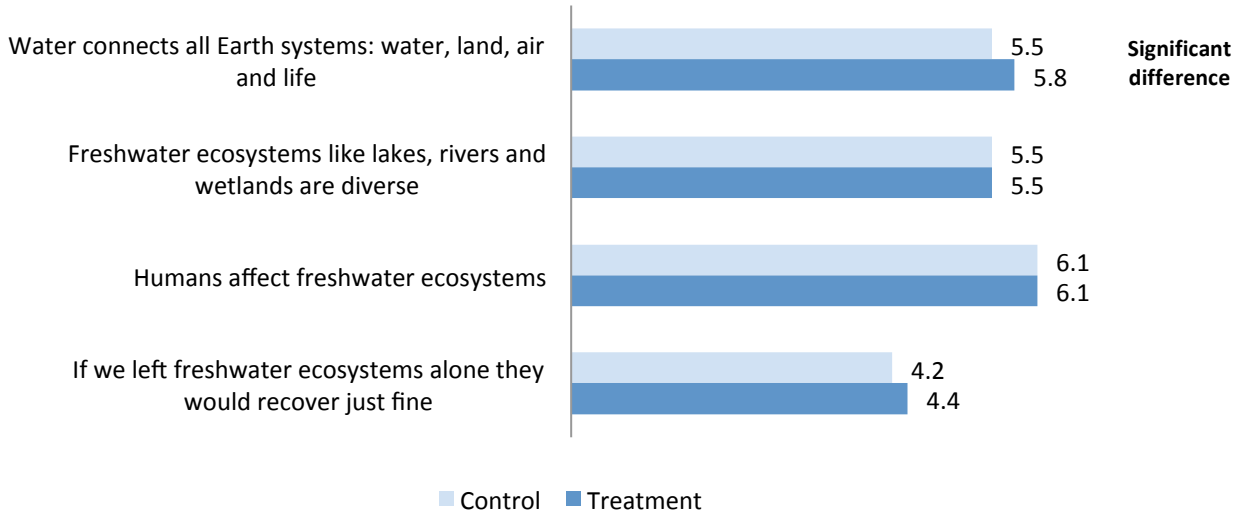


Table 39: Understanding of Main Messages for Control and Treatment Groups, Students (LHS only)

	Control (n=88)		Treatment (n=90)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	5.7	1.5	6.1	1.3	No
Freshwater ecosystems like lakes, rivers and wetlands are diverse	5.2	1.5	5.6	1.3	No
Humans affect freshwater ecosystems	6.1	1.3	6.4	1.0	No
If we left freshwater ecosystems alone they would recover just fine	4.5	2.0	4.9	2.1	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 13: Understanding of Main Messages for Control and Treatment Groups, Students (LHS only)

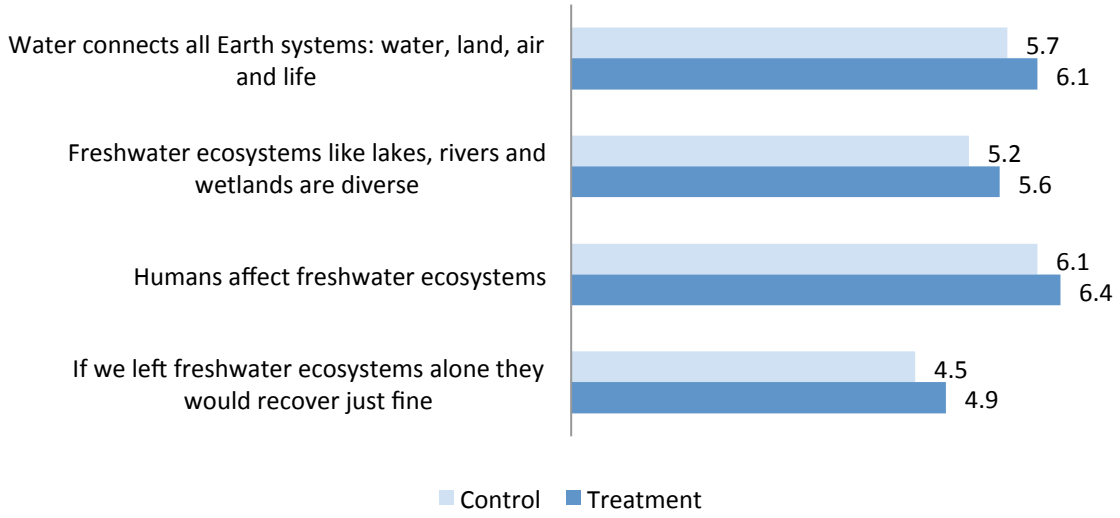


Table 40: Understanding of Main Messages for Control and Treatment Groups, Students (ECHO only)

	Control (n=97)		Treatment (n=72)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	5.4	1.6	5.5	1.5	No
Freshwater ecosystems like lakes, rivers and wetlands are diverse	5.7	1.4	5.4	1.6	No
Humans affect freshwater ecosystems	6.1	1.3	5.8	1.4	No
If we left freshwater ecosystems alone they would recover just fine	3.7	1.9	3.8	1.7	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 14: Understanding of Main Messages for Control and Treatment Groups, Students (ECHO only)

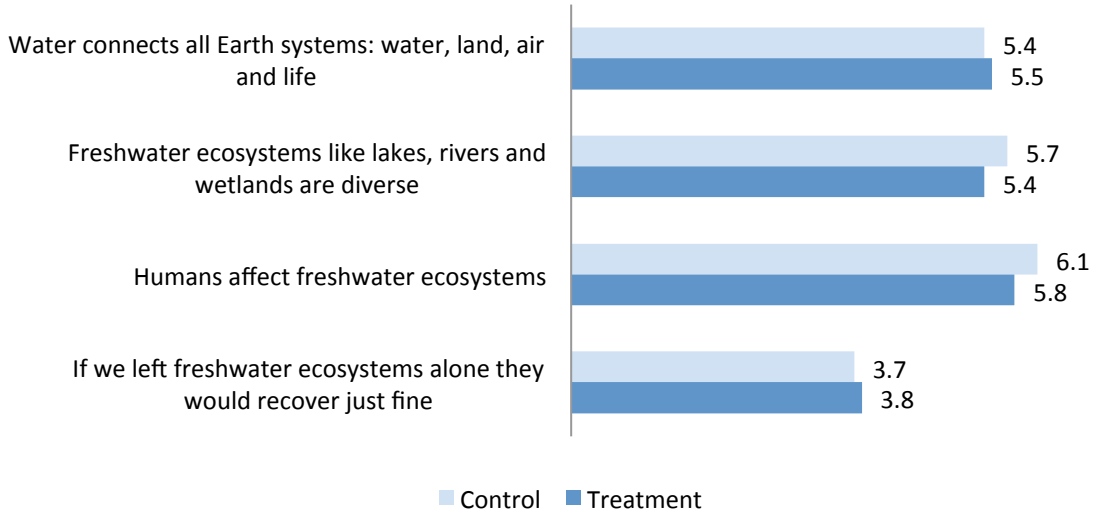


Table 41: Understanding of Main Messages for Control and Treatment Groups, Students (TERC only)

	Control (n=40)		Treatment (n=36)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Water connects all Earth systems: water, land, air and life	5.3	1.8	5.5	1.2	No
Freshwater ecosystems like lakes, rivers and wetlands are diverse	5.6	1.2	5.4	1.0	No
Humans affect freshwater ecosystems	6.1	1.3	6.0	1.2	No
If we left freshwater ecosystems alone they would recover just fine	4.5	1.8	4.1	2.0	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 15: Understanding of Main Messages for Control and Treatment Groups, Students (TERC only)

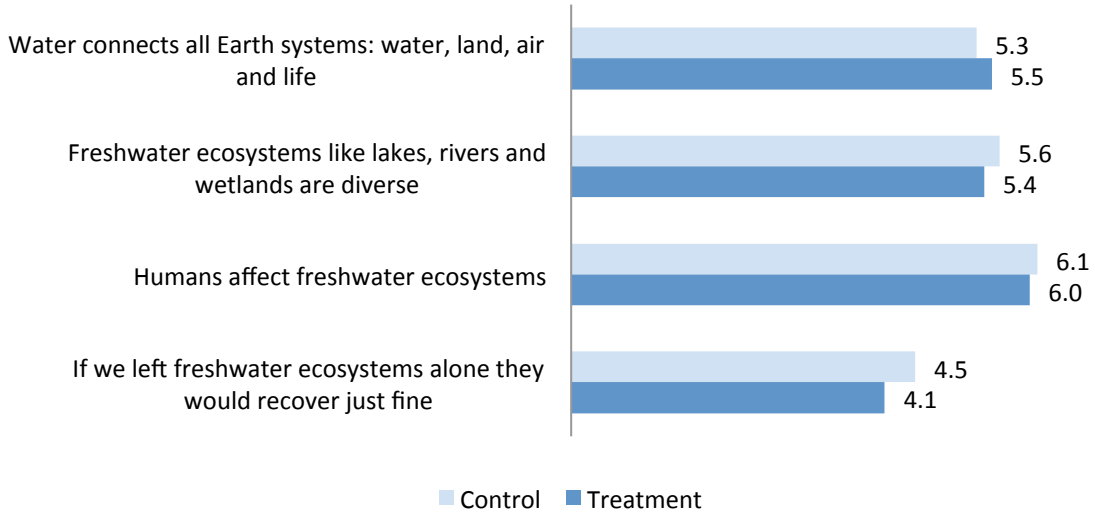
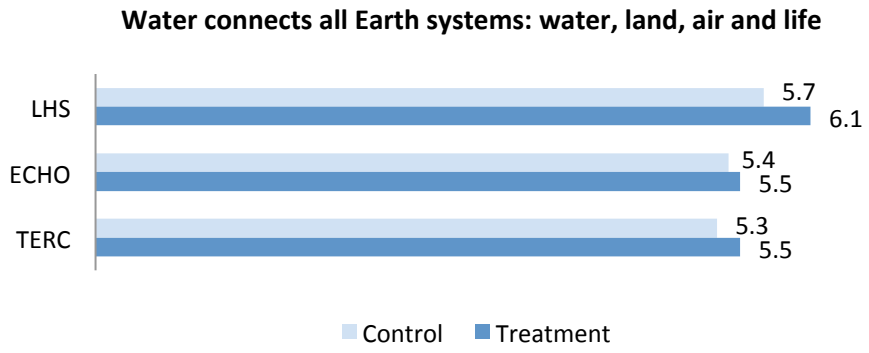
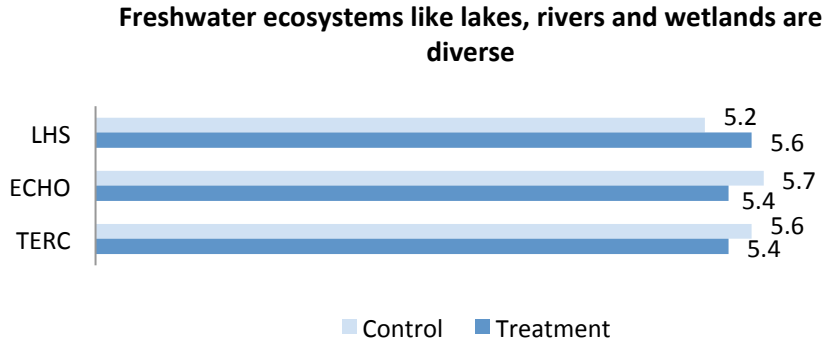
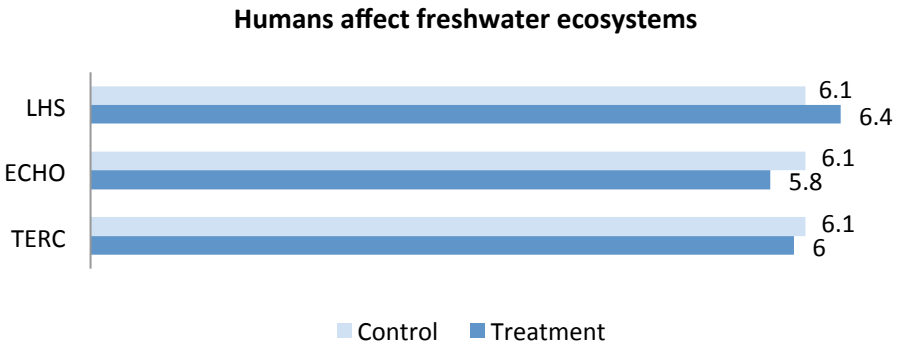
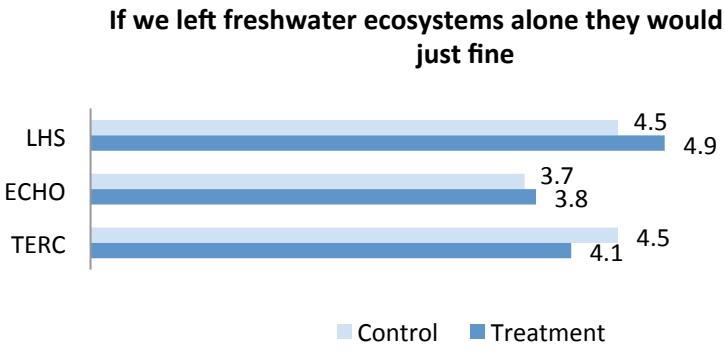


Figure 16: Understanding of Main Messages for Control and Treatment Groups, Students









Changes in Thinking About Freshwater Ecosystems

In order to determine how engaging in the 3D Viz components may have affected how participants were thinking about and interested in freshwater ecosystems, they were asked to rate their agreement with a number of statements (see Table 42 and Table 46):

1. Changed how I think about lakes, rivers and wetlands.
2. Helped me better understand how lakes, rivers and wetlands function.
3. Made me more interested in learning how lakes, rivers and wetlands work.
4. Made me more interested in finding out how to protect lakes, rivers and wetlands.

For general visitors, two of the four statements had a statistically significant difference between the control and treatment groups. Those who engaged in the 3D Viz components (treatment group) were more likely to say that the visit changed how they thought about lakes, rivers and wetlands, in addition to making them more interested in finding out how to protect these freshwater ecosystems (see Table 42).

There were also some differences when looking just at data from specific institutions. For LHS, the treatment group for general visitors said participation made them more interested in how certain freshwater ecosystems worked than the control group (see **Table 43**). This was also a statistically significant difference for treatment participants saying it made them more interested in findings out how to protect these freshwater ecosystems. For ECHO, there was only one statistically significant difference between control and treatment groups: treatment participants were more likely to say that participation changed how they think about lakes, rivers and

wetlands (see **Table 44**). There were not any statistically significant differences on these four items between general visitor treatment and control conditions for TERC participants (see **Table 45**).

Table 42: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors

	Control (n=140)		Treatment (n=165)		
	Mean	SD	Mean	SD	Statistically Significant Difference?
Changed how I think about lakes, rivers and wetlands	4.0	1.6	4.4	1.5	**Yes**
Helped me better understand how lakes, rivers and wetlands function	4.9	1.6	5.1	1.4	No
Made me more interested in learning how lakes, rivers and wetlands work	5.1	1.6	5.4	1.4	No
Made me more interested in finding out how to protect lakes, rivers and wetlands	5.2	1.6	5.6	1.3	**Yes**

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 17: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors

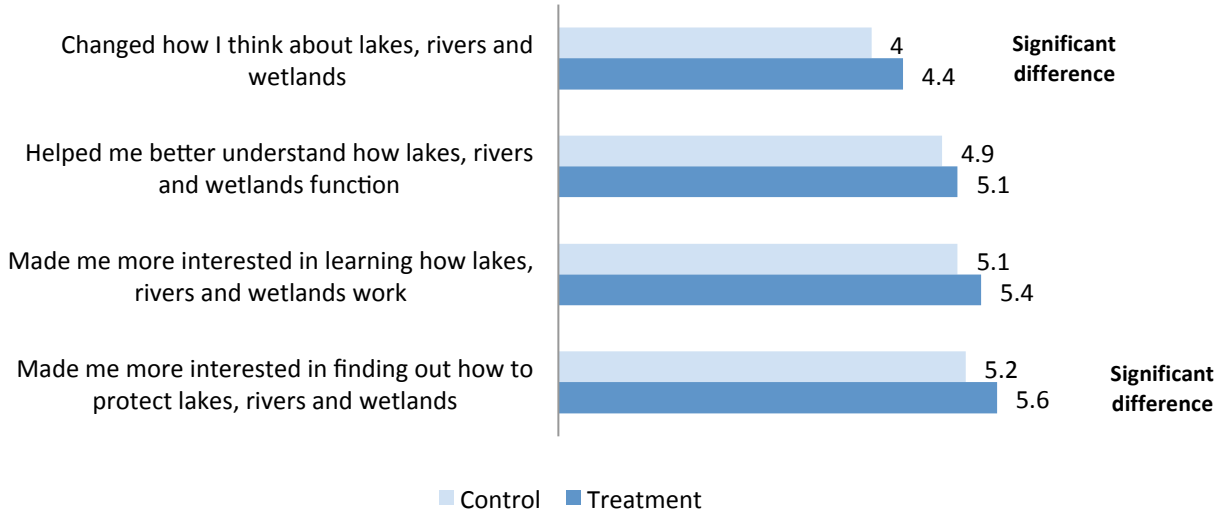


Table 43: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors (LHS only)

	Control (n=41)		Treatment (n=50)		
	Mean	SD	Mean	SD	Statistically Significant Difference?
Changed how I think about lakes, rivers and wetlands	3.8	1.8	4.3	1.6	No
Helped me better understand how lakes, rivers and wetlands function	4.2	2.0	4.8	1.5	No
Made me more interested in learning how lakes, rivers and wetlands work	4.3	1.9	5.2	1.3	**Yes**
Made me more interested in finding out how to protect lakes, rivers and wetlands	4.4	2.0	5.3	1.3	**Yes**

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 18: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors (LHS only)

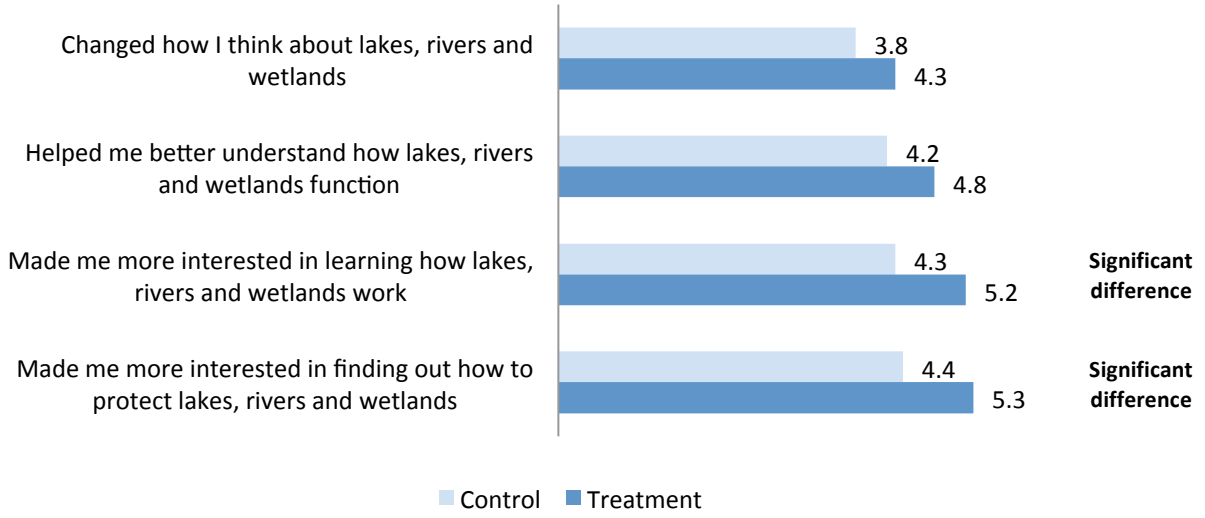


Table 44: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors (ECHO only)

	Control (n=48)		Treatment (n=45)		
	Mean	**SD**	**Mean**	**SD**	**Statistically Significant Difference?**
Changed how I think about lakes, rivers and wetlands	3.8	1.4	4.5	1.5	**Yes**
Helped me better understand how lakes, rivers and wetlands function	4.7	1.4	5.3	1.3	No
Made me more interested in learning how lakes, rivers and wetlands work	5.0	1.3	5.3	1.4	No
Made me more interested in finding out how to protect lakes, rivers and wetlands	5.1	1.2	5.4	1.5	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 19: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors (ECHO only)

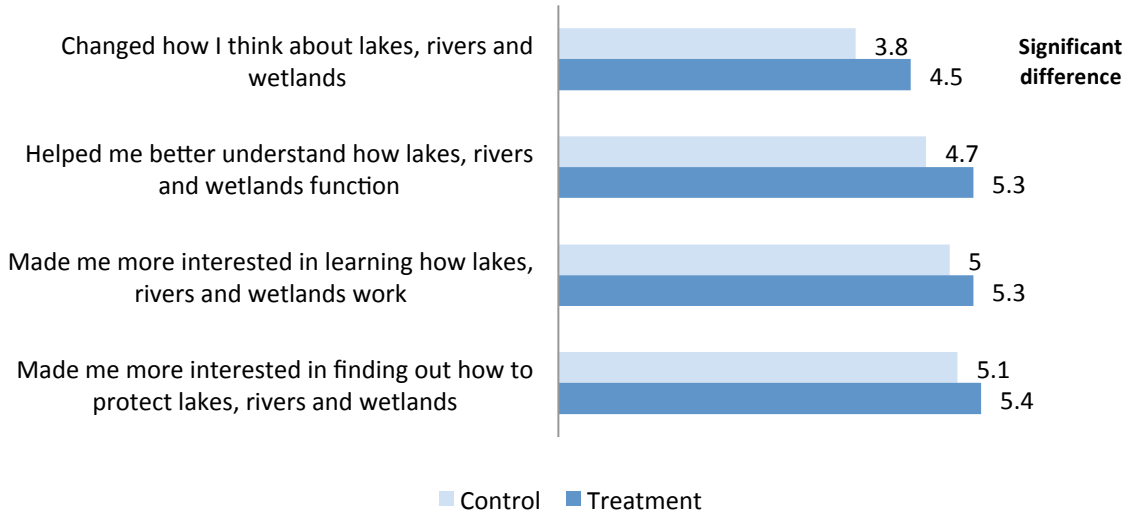
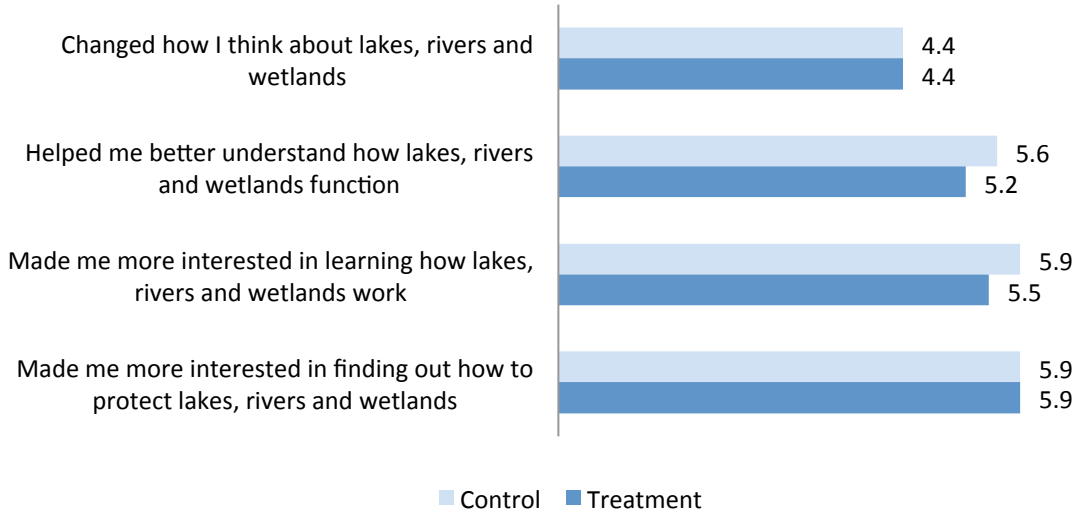


Table 45: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors (TERC only)

	Control (n=49)		Treatment (n=70)		
	Mean	SD	Mean	SD	Statistically Significant Difference?
Changed how I think about lakes, rivers and wetlands	4.4	1.6	4.4	1.5	No
Helped me better understand how lakes, rivers and wetlands function	5.6	1.1	5.2	1.5	No
Made me more interested in learning how lakes, rivers and wetlands work	5.9	1.0	5.5	1.5	No
Made me more interested in finding out how to protect lakes, rivers and wetlands	5.9	1.3	5.9	1.2	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 20: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, General Visitors (TERC only)



When the same comparisons were made for control and treatment groups of Students, the other two statements yielded statistically significant differences (see Table 46). This meant that Students who engaged in the 3D Viz components were more likely than control group Students to say the visit helped them better understand how lakes, rivers and wetlands function, and also to say it made them more interested in learning how lakes rivers and wetlands work. This converse relationship between the General Visitors and Students was interesting, in that the General Visitors seemed to be more likely to show a difference in the more attitudinal/conservation-related items, while the Students were more likely to show a difference in the more cognitive/learning items.

In comparing student control and treatment groups at each institution, there were some statistically significant differences. The LHS students showed a statistically significant difference where treatment groups were significant higher on all four of the items (see **Table 47**.) The largest increases were on the item about changing how they think about lakes, rivers and wetlands, and the item about helping them better understand how lakes, rivers and wetlands function. At ECHO, there were again statistically significant differences on all four of the items. Interestingly, it was the same two items that showed the largest increases for ECHO as for LHS (see **Table 48**). However, none of the four items showed statistically significant differences for the TERC students (see **Table 49**).

Table 46: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students

	Control (n=227)		Treatment (n=198)		
	Mean	SD	Mean	SD	Statistically Significant Difference?
Changed how I think about lakes, rivers and wetlands	4.1	1.9	5.3	1.6	**Yes**
Helped me better understand how lakes, rivers and wetlands function	4.2	1.9	5.6	1.4	**Yes**
Made me more interested in learning how lakes, rivers and wetlands work	4.3	1.9	5.3	1.6	**Yes**
Made me more interested in finding out how to protect lakes, rivers and wetlands	4.5	2.0	5.5	1.6	**Yes**

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 21: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students

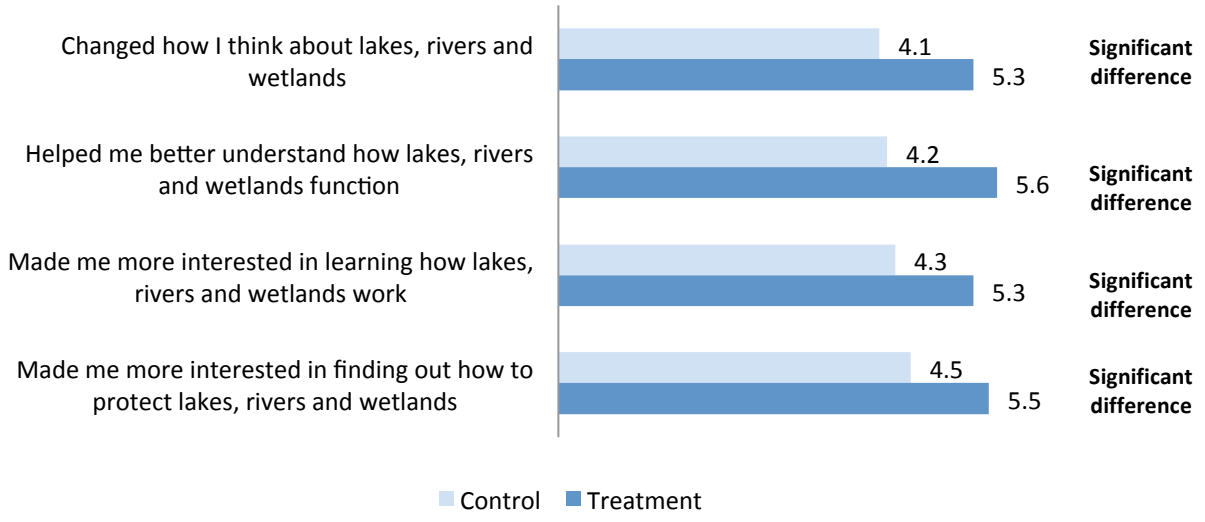


Table 47: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students (LHS only)

	Control (n=88)		Treatment (n=90)		
	Mean	SD	Mean	SD	Statistically Significant Difference?
Changed how I think about lakes, rivers and wetlands	4.2	2.0	5.8	1.4	**Yes**
Helped me better understand how lakes, rivers and wetlands function	4.3	1.9	6.1	1.2	**Yes**
Made me more interested in learning how lakes, rivers and wetlands work	4.3	1.8	5.7	1.6	**Yes**
Made me more interested in finding out how to protect lakes, rivers and wetlands	4.7	2.0	6.0	1.4	**Yes**

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 22: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students (LHS only)

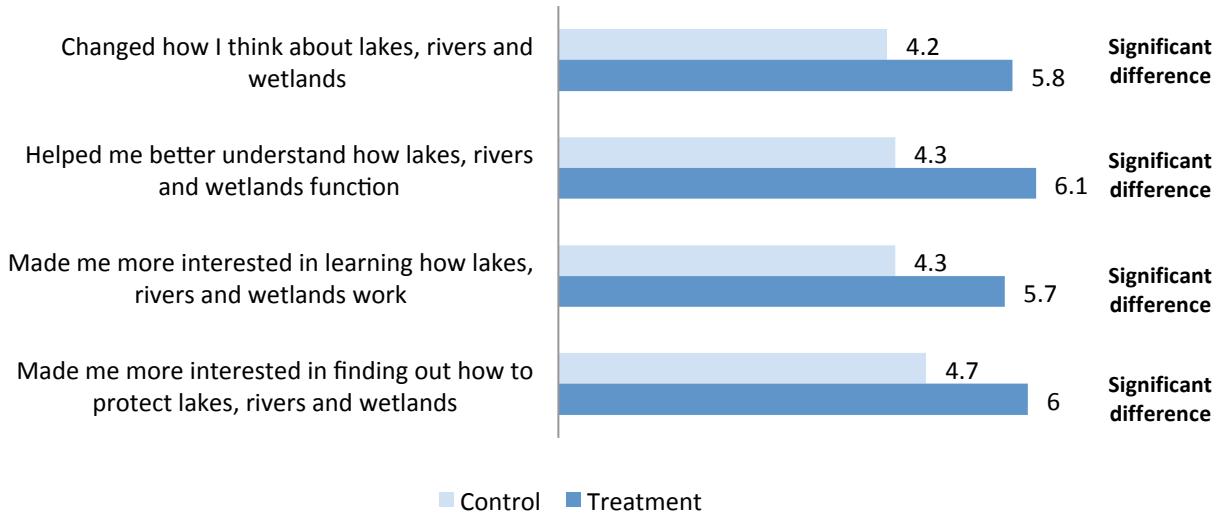


Table 48: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students (ECHO only)

	Control (n=97)		Treatment (n=73)		
	Mean	SD	Mean	SD	Statistically Significant Difference?
Changed how I think about lakes, rivers and wetlands	3.4	1.7	4.5	1.6	**Yes**
Helped me better understand how lakes, rivers and wetlands function	3.6	1.8	5.0	1.6	**Yes**
Made me more interested in learning how lakes, rivers and wetlands work	3.7	2.0	4.8	1.7	**Yes**
Made me more interested in finding out how to protect lakes, rivers and wetlands	3.9	2.0	4.7	1.7	**Yes**

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 23: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students (ECHO only)

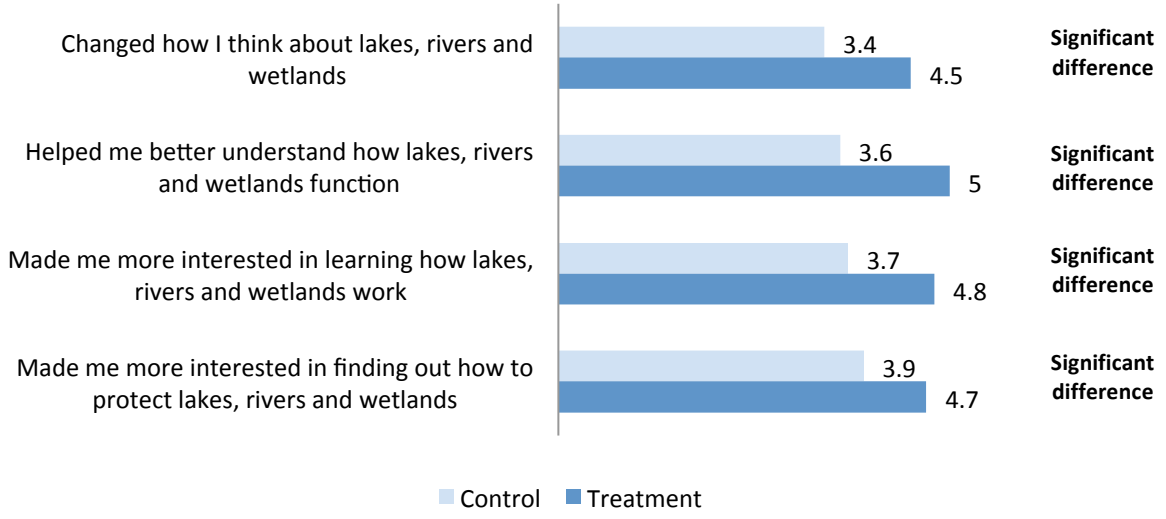
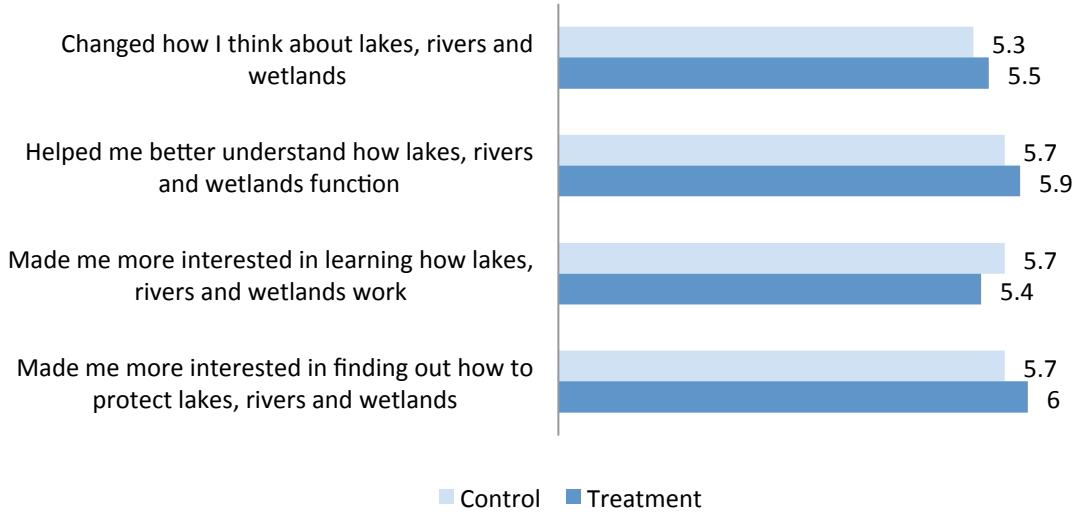


Table 49: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students (TERC only)

	Control (n=41)		Treatment (n=35)		
	Mean	SD	Mean	SD	Statistically Significant Difference?
Changed how I think about lakes, rivers and wetlands	5.3	1.4	5.5	1.1	No
Helped me better understand how lakes, rivers and wetlands function	5.7	1.3	5.9	1.2	No
Made me more interested in learning how lakes, rivers and wetlands work	5.7	1.2	5.4	1.2	No
Made me more interested in finding out how to protect lakes, rivers and wetlands	5.7	1.3	6.0	1.1	No

Note: Scale was from 1 (strongly disagree) to 7 (strongly agree)

Figure 24: Thinking About and Interest in Freshwater Ecosystems for Control and Treatment Groups, Students (TERC only)



In a follow up to the last item in the previous table, participants were asked if they learned something new about protecting watersheds during their visit). Almost 3 out of 5 General Visitors in the treatment group (58%) said they did learn something new, compared to almost 2 out of 5 General Visitors in the control group (38%); this was a statistically significant difference (see Table 50). When looking at the difference between control and treatment general visitors at each institution, only ECHO showed a statistically significant difference, with 19% of the control group and 44% of the treatment group saying they learned something new (see Table 51). Note that the sample sizes were relatively small, so the difference had to be quite large for it to be statistically significant.

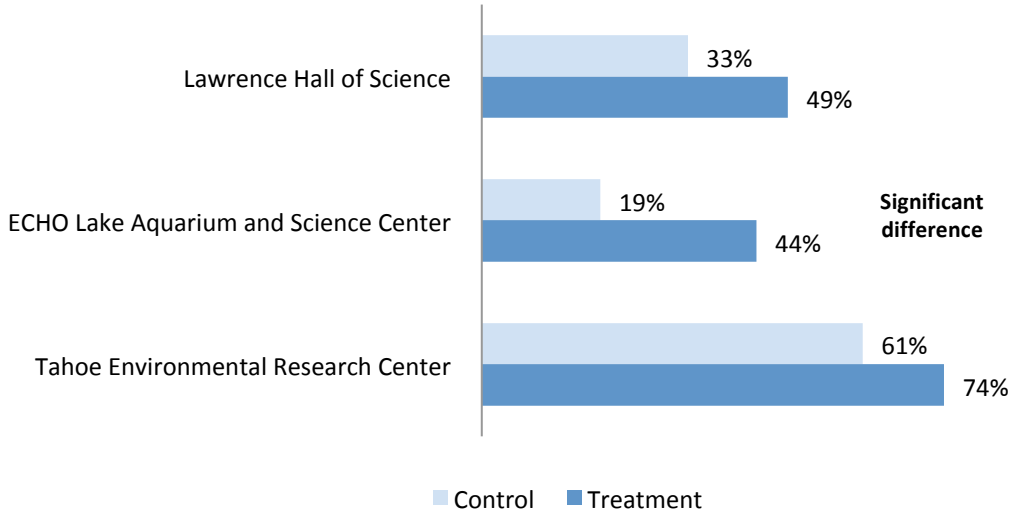
Table 50: Learned Something New About Protecting Freshwater Ecosystems, General Visitors

	Control (n=126)	Treatment (n=153)	Statistically Significant Difference?
Learned Something New	38%	58%	**Yes**
Did Not Learn Something New	62%	42%	
Total	100%	100%	

Table 51: Learned Something New About Protecting Freshwater Ecosystems, General Visitors by Institution

	Control	Treatment	Statistically Significant Difference?
Lawrence Hall of Science (n=86)	33%	49%	No
ECHO Lake Aquarium and Science Center (n=84)	19%	44%	**Yes**
Tahoe Environmental Research Center (n=109)	61%	74%	No

Figure 25: Learned Something New About Protecting Freshwater Ecosystems, General Visitors by Institution



When looking at the Student control and treatment groups, there was an even larger difference. Even though the same percentage (58%) of students in the treatment group said they learned something new about how to protect watersheds, only a little more than a quarter (27%) of students in the control group agreed with this; this was also a statistically significant difference (see Table 52). When looking at the difference between control and treatment students at each institution, only LHS showed a statistically significant difference, with 12% of the control group and 72% of the treatment group saying they learned something new (see Table 53). Given that LHS does not have a lot of content about watersheds in its general collections, this large discrepancy is not unexpected. Note that the sample sizes were relatively small, so the difference had to be quite large for it to be statistically significant.

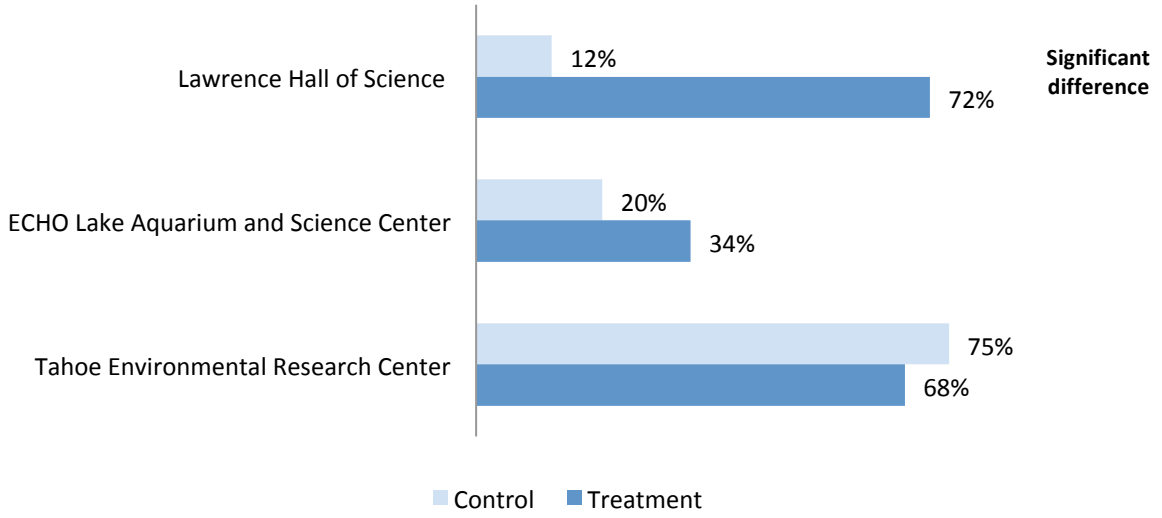
Table 52: Learned Something New About Protecting Freshwater Ecosystems, Students

Students	Control (n=227)	Treatment (n=199)	Statistically Significant Difference?
Learned Something New	27%	58%	**Yes**
Did Not Learn Something New	73%	42%	
Total	100%	100%	

Table 53: Learned Something New About Protecting Freshwater Ecosystems, Students by Institution

	Control	Treatment	Statistically Significant Difference?
Lawrence Hall of Science (n=86)	12%	72%	**Yes**
ECHO Lake Aquarium and Science Center (n=84)	20%	34%	No
Tahoe Environmental Research Center (n=109)	75%	68%	No

Figure 26: Learned Something New About Protecting Freshwater Ecosystems, Students by Institution



General visitors and students were asked to be more specific about what they learned about protecting freshwater ecosystems during their visit (see Table 54 and Table 55). This was an open-ended question, so individuals could give as many examples as they wanted. Both general visitors and students most often cited learning about how to pollute less, and this response was statistically significant between the control and treatment groups for both adults (9% control, 18% treatment) and students (11% control, 36% treatment). Pollution is a topic covered in multiple 3D visualization components (Healthy and Unhealthy Lakes iPad app, Make a Watershed Activity, Following a Drop of Water 3D Movie, Race Around Lake Tahoe Board Game) and is a common theme in general conservation messages, so it is unsurprising that this was the most commonly mentioned topic. Smaller percentages of participants gave other responses including conserving more water, being more aware of their actions, and reducing or prohibiting the introduction invasive species.

Table 54: What General Visitors Learned about Protecting Freshwater Ecosystems

	Control (n=48)	Treatment (n=89)	Statistically Significant?
Pollute less	9%	18%	**Yes**
Invasive species	10%	7%	No
Respect	3%	5%	No
Conserve	3%	4%	No
Be an advocate	2%	2%	No
Miscellaneous	9%	13%	No

Note: Visitors could provide more than one response to this item

General visitors most often said (9% control, 18% treatment) they learned about **minimizing pollution** as a way to protect freshwater ecosystems. This was the only response that had a statistically significant difference between the control and treatment groups. The treatment group had twice as many respondents who mentioned minimizing pollution, compared to the control group.

> *Limit Pollution*
>
> *Pollute less*
>
> *When on lake don't use gas vehicles. Don't drop any garbage. Ride our bikes and walk more.*

Some visitors (10% control, 7% treatment) learned about protecting freshwater ecosystems from **invasive species**.

> *Rinse boats before entering/exiting different lake/water sources*
>
> *Removal of zebra mussels*
>
> *I'm not sure specifically for my part- but in hearing what people can and do, wow, makes sense. Don't introduce anything to the lake. Now I really understand what the "Save Lake Tahoe" coalition means after living here 35+ years. I understand more.*

A small percentage of visitors (3% control, 5% treatment) said they would be **more respectful and thoughtful** about her environment.

> *Awareness increased*
>
> *Be respectful when in nature*
>
> *Being aware of waste, being aware of our environment*

A small percentage of general visitors (3% control, 4% treatment) wrote about **conserving water** as a way of protecting freshwater ecosystems.

> *Using less water while brushing teeth, and using recycled water for watering grass helps save water.*
>
> *Conserve water, don't use harmful chemicals*

A few visitors (2% control, 2% treatment) said they would be **advocates for freshwater ecosystems** in order to protect them in the future.

> *Continue to encourage my daughter to clean more*
>
> *Global impact, human and why wetlands are so important. Why dams are so important for all to coexist.*
>
> *Support TERC and other environmental organization*

And some visitors (9% control, 13% treatment) gave responses that did not fit into any of these categories.

> *BMPs*
>
> *Filtering river water*
>
> *How the Lake was formed*
>
> *Lake wise landscaping*

Table 55: What Students Learned about Protecting Freshwater Ecosystems

	Control (n=61)	Treatment (n=115)	Statistically Significant?
Pollute less	11%	36%	**Yes**
Invasive species	6%	2%	Yes
Conserve	1%	1%	No
Be an advocate	1%	1%	No
Respect	Less than 1%	Less than 1%	No
Miscellaneous	5%	9%	No

Note: Students could provide more than one response to this item

Students most often said (11% control, 36% treatment) they learned about **minimizing pollution** as a way to protect freshwater ecosystems. This was the only response that had a statistically significant difference between the control and treatment groups. The treatment group had more

than three times as many respondents who mentioned minimizing pollution, compared to the control group.

Recycle, don't litter

To not pollute and be careful what I put in the drain

I learned a little about the pollution

Some students (6% control, 2% treatment) learned about protecting freshwater ecosystems from **invasive species**.

Like not to introduce many non-native things to the lake

Not to dump your non-native fish in the lake

A small percentage of students (1% control, 1% treatment) wrote about **conserving water** as a way of protecting freshwater ecosystems.

I learned that Earth's water is being wasted

Manage how much water you use

A few students (1% control, 1% treatment) said they would be **advocates for freshwater ecosystems** in order to protect them in the future.

Stop littering, pick up trash, help the world

A small percentage of students (less than 1% control, less than 1% treatment) said they would be **more respectful and thoughtful** about her environment.

How I affect lakes and rivers

And some students (5% control, 9% treatment) gave responses that did not fit into any of these categories.

I learned a lot how the cycle of how water travels

History

I learned about where the ice melt is changing the water

Appendix A: General Visitor Treatment Survey instrument (TERC)

We would like to get some feedback about your experiences here today. The survey is anonymous so please answer as honestly as possible. Thank you for helping us out today!

YOUR VISIT TODAY

1) How would you rate your <u>overall</u> experience for the entire visit so far today?

1	2	3	4	5	6	7	8	9	10
Poor									Excellent

2) How would you rate your entire visit so far as an <u>educational</u> experience?

1	2	3	4	5	6	7	8	9	10
Not at all Educational									Extremely Educational

3) How would you rate your entire visit so far as an <u>entertainment</u> experience?

1	2	3	4	5	6	7	8	9	10
Not at all Entertaining									Extremely Entertaining

4) We're curious about how familiar people are with "freshwater ecosystems" and what they are. Please list as many examples of freshwater ecosystems as you can.

_____

5) Which of the following activities did you participate in or engage with today? Check as many as apply

LHS
- ☐ 3D movie, Following a drop of water
- ☐ Interactive sandbox
- ☐ iPad app about healthy and unhealthy lakes
- ☐ Make a Watershed Activity

ECHO
- ☐ 3D movie, Flythrough
- ☐ Interactive sandbox
- ☐ iPad app about healthy and unhealthy lakes
- ☐ Seiche waves activity

TERC
- ☐ 3D movie, Following a drop of water
- ☐ Interactive sandbox
- ☐ iPad app about healthy and unhealthy lakes
- ☐ Seiche waves activity
- ☐ Board game about Lake Tahoe

FRESHWATER ECOSYSTEMS

The next sections ask questions about freshwater ecosystems. For these questions, we are defining freshwater ecosystems as *"any freshwater aquatic system, including the most common examples of lakes, rivers and wetlands."*

6) Please list as many of the current problems or challenges facing lakes, rivers and wetlands as you can.

_____

_____

7) Please indicate how much you knew about the following topics both <u>before</u> and <u>after</u> you visited. Rate each topic on the scale below, from 1 (nothing) to 7 (a lot).

	How much you knew <u>before visiting today</u>	**How much you know <u>right now</u>**
Topic	**Nothing A lot**	**Nothing A lot**
General information about lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
The role of my local lakes, rivers and wetlands in the environment	1 2 3 4 5 6 7	1 2 3 4 5 6 7
The science of how lakes, rivers and wetlands work (how they form, how they function, etc.)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Problems facing lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
How scientists are currently studying lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
The impact humans have on lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
My own impact on lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
How much lakes, rivers and wetlands affect me personally	1 2 3 4 5 6 7	1 2 3 4 5 6 7
What I can personally do to help lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7

8) How much do you agree with the following statements?

8a. Water connects all Earth systems: water, land, air and life.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

8b. Freshwater ecosystems like lakes, rivers and wetlands are diverse (in their size, shape, and biological and physical conditions) and are formed by a variety of geologic and geomorphic processes.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

8c. Humans affect freshwater ecosystems like lakes, rivers and wetlands in many ways: locally and globally, short-term and long-term, negatively and positively.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

8d. If we left freshwater ecosystems like lakes, rivers and wetlands alone, they would recover just fine.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

9) How much do you agree with the following statements? My visit today…

9a. Changed how I think about lakes, rivers and wetlands.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

9b. Helped me better understand how lakes, rivers and wetlands function.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

9c. Made me more interested in learning how lakes, rivers and wetlands work.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

9d. Made me more interested in finding out how to protect lakes, rivers and wetlands.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

10) During your visit today, did you learn about anything specific about how you might help protect lakes, rivers and wetlands? □ Yes □ No

10a. If Yes, list the specific actions you learned about. Please list as many as you can.

_____

EXPERIENCE WITH FRESHWATER ECOSYSTEMS

11) How familiar are you with freshwater ecosystems in your area, like lakes, rivers and wetlands?

1 2 3 4 5 6 7
Not at all familiar Very familiar

12) Do you have any connections, either professionally or personally, to lakes, rivers and wetlands?

□ **Yes** □ **No**

12a. If Yes, what kinds of connections.

- ☐ My job
- ☐ A hobby (e.g., fishing, boating, etc.)
- ☐ I live very close to freshwater ecosystem(s)
- ☐ I vacation regularly near one(s)
- ☐ Someone in my immediate family's work
- ☐ Other: _____

ABOUT YOU

13) Is this your first visit to the Tahoe Environmental Research Center (TERC)? □ **Yes** □ **No**

14) What is your gender? □ **Male** □ **Female**

15) Which city and state do you live in (or city and country if from outside United States)?

_____

16) How old are you? _____

17) How many other adults 18 years or older in your group today? _____

17a. What are the ages of these adults: ____ ____ ____ ____ ____ ____ ____ ____

18) How many children under 18 years of age are in your group today? _____

18a. What are the ages of these children: ____ ____ ____ ____ ____ ____ ____ ___

19) **We will be contacting a select group of people in a few weeks to follow up about your visit. Would you be willing to be contacted? If yes, please write your email below- it will only be used to contact you about this visit, and not for any other purpose. This will be a one-time short survey that will only take 5 to 10 minutes. Thank you in advance! (please write legibly)**

_____

Thank you very much for your time and feedback, it is much appreciated!

Appendix B: Student Control Survey instrument (LHS)

We would like to get some feedback about your experiences here today. The survey is anonymous so please answer as honestly as possible. Thank you for helping us out today!

YOUR VISIT TODAY

1) How would you rate your <u>overall</u> experience for the entire visit so far today?

1 2 3 4 5 6 7 8 9 10
Poor Excellent

2) How would you rate your entire visit so far as an <u>educational</u> experience?

1 2 3 4 5 6 7 8 9 10
Not at all Educational Extremely Educational

3) How would you rate your entire visit so far as an <u>entertainment</u> experience?

1 2 3 4 5 6 7 8 9 10
Not at all Entertaining Extremely Entertaining

4) We're curious about how familiar people are with "freshwater ecosystems" and what they are. Please list as many examples of freshwater ecosystems as you can.

_____

FRESHWATER ECOSYSTEMS

The next sections ask questions about freshwater ecosystems. For these questions, we are defining freshwater ecosystems as *"any freshwater aquatic system, including the most common examples of lakes, rivers and wetlands."*

5) Please list as many of the current problems or challenges facing lakes, rivers and wetlands as you can.

_____

_____

6) Please indicate how much you knew about the following topics both <u>before</u> and <u>after</u> you visited. Rate each topic on the scale below, from 1 (nothing) to 7 (a lot).

	How much you knew <u>before visiting</u> today	**How much you know <u>right now</u>**
Topic	**Nothing** 1 2 3 4 5 6 7 **A lot**	**Nothing** 1 2 3 4 5 6 7 **A lot**
General information about lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
The role of my local lakes, rivers and wetlands in the environment	1 2 3 4 5 6 7	1 2 3 4 5 6 7
The science of how lakes, rivers and wetlands work (how they form, how they function, etc.)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Problems facing lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
How scientists are currently studying lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
The impact humans have on lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
My own impact on lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7
How much lakes, rivers and wetlands affect me personally	1 2 3 4 5 6 7	1 2 3 4 5 6 7
What I can personally do to help lakes, rivers and wetlands	1 2 3 4 5 6 7	1 2 3 4 5 6 7

7) How much do you agree with the following statements?

7a. Water connects all Earth systems: water, land, air and life.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

7b. Freshwater ecosystems like lakes, rivers and wetlands are diverse (in their size, shape, and biological and physical conditions) and are formed by a variety of geologic and geomorphic processes.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

7c. Humans affect freshwater ecosystems like lakes, rivers and wetlands in many ways: locally and globally, short-term and long-term, negatively and positively .

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

7d. If we left freshwater ecosystems like lakes, rivers and wetlands alone, they would recover just fine.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

8) How much do you agree with the following statements? My visit today…

8a. Changed how I think about lakes, rivers and wetlands.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

8b. Helped me better understand how lakes, rivers and wetlands function.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

8c. Made me more interested in learning how lakes, rivers and wetlands work.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

8d. Made me more interested in finding out how to protect lakes, rivers and wetlands.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

9) During your visit today, did you learn about anything specific about how you might help protect lakes, rivers and wetlands? □ Yes □ No

9a. If Yes, list the specific actions you learned about. Please list as many as you can.

_____

EXPERIENCE WITH FRESHWATER ECOSYSTEMS

10) How familiar are you with freshwater ecosystems in your area, like lakes, rivers and wetlands?

1	2	3	4	5	6	7
Not at all familiar						Very familiar

11) Do you have any particular connections, either professionally or personally, to lakes, rivers and wetlands?
□ Yes □ No

11a. If Yes, what kinds of connections.

- ☐ My job
- ☐ A hobby (e.g., fishing, boating, etc.)
- ☐ I live very close to freshwater ecosystem(s)
- ☐ I vacation regularly near one(s)
- ☐ Someone in my immediate family's work
- ☐ Other: _____

ABOUT YOU

12) Are you currently a full time student? □ Yes □ No

12a. If Yes, in which grade/level?

- ☐ K - 2nd
- ☐ 3rd -5th
- ☐ 6th – 8th
- ☐ 9th – 12th
- ☐ College/University

13) Is this your first visit to the Lawrence Hall of Science? □ Yes □ No

14) What is your gender? □ Male □ Female

15) Which city and state do you live in (or city and country if from outside United States)?

_____

16) How old are you? _____

Thank you very much for your time and feedback, it is much appreciated!

Appendix C: Follow Up Web Survey instrument

INTRODUCTION

*A couple of months ago you visited the [**insert institution name**] and were kind enough to not only give us some feedback, but you also shared your email and were willing to be contacted a bit later.*

As we may have mentioned, this feedback is part of the evaluation of a National Science Foundation project looking at how to engage the public about freshwater ecosystems, and knowing how you are feeling and thinking about your visit right now would be extremely helpful in figuring out what kinds of experiences are more meaningful.

This survey will take less than five minutes to complete. All responses are confidential, so we welcome your honesty and thoughtfulness. Your experiences and perspectives are very important to us – and we look forward to hearing from you. Click the "Next Page" button below to provide your important feedback.

By completing this survey, you can choose to enter into a drawing to win one of two $100 Amazon.com gift cards. To enter the drawing, complete the survey and provide your contact information at the end. Two people will be randomly drawn from those who have completed the survey and provided contact information. Winners will be contacted by July 15th, 2015.

*To get started, click on "**Next Page**."*

1. Have there been any times in your day-to-day life since visiting that you have specifically been reminded of your visit to [institution name]?

- ☐ Yes
- ☐ No

1a. If YES, what have you been specifically reminded about since visiting?

2. Do you remember seeing or hearing anything about freshwater ecosystems during the visit, like lakes, rivers and wetlands?

- ☐ Yes
- ☐ No

2a. If YES, what specifically do you remember about freshwater ecosystems from the visit (like lakes, rivers, wetlands, etc.)?

3. Since visiting, have you participated in any activities or encountered information about freshwater ecosystems?

- ☐ Yes
- ☐ No

3a. If YES, What specific activities have you participated in? Or what specific information have you encountered?

4. Since visiting which of the following things, if any, have you done to help protect freshwater ecosystems? [Check all that apply]

- ☐ Participated in a clean-up (trash pick up)
- ☐ Looked up information about protecting freshwater ecosystems
- ☐ Supported a local organization that protects freshwater ecosystems
- ☐ Made landscaping changes to my yard/property
- ☐ Limited my use of fertilizers on plants and lawns
- ☐ Scooped dog waste
- ☐ Conserved water
- ☐ Joined a citizen science project related to freshwater
- ☐ Washed or inspected a boat to reduce risk of invasive species spread
- ☐ Thought twice about pouring something down a stormdrain
- ☐ Supported local watershed improvements
- ☐ Other (please describe below)
- ☐ None of the above

4a. If you selected "Other" above, please describe here.
4b. If any of the options you checked **were influenced by your visit a couple of months ago**, please describe.

5. *Please tell us to what extent you agree with the following statements.*

	Strongly Disagree 1	2	3	4	5	6	**Strongly Agree** 7
(a) **Water connects all Earth systems: water, land, air and life.**	○	○	○	○	○	○	○
(b) **Freshwater ecosystems like lakes, rivers and wetlands are diverse (in their size, shape, and biological and physical conditions) and are formed by a variety of geologic and geomorphic processes.**	○	○	○	○	○	○	○
(c) **Humans affect freshwater ecosystems like lakes, rivers and wetlands in many ways: locally and globally, short-term and long-term, negatively and positively.**	○	○	○	○	○	○	○
(d) **If we left freshwater ecosystems like lakes, rivers and wetlands alone, they would recover just fine.**	○	○	○	○	○	○	○

6. *Thinking back to the visit to [institution] a couple of months ago, to what extent do you agree with the following statements related to your visit.*

The visit that day….	**Strongly Disagree** 1	2	3	4	5	6	**Strongly agree** 7
(a) **Changed how I think about lakes, rivers and wetlands.**	○	○	○	○	○	○	○
(b) **Helped me better understand how lakes, rivers and wetlands function.**	○	○	○	○	○	○	○
(e) **Helped me learn something specific about how I might help protect lakes, rivers and wetlands.**	○	○	○	○	○	○	○
(c) **Made me more interested in learning how lakes, rivers and wetlands work.**	○	○	○	○	○	○	○
(d) **Made me more interested in finding out how to protect lakes, rivers and wetlands.**	○	○	○	○	○	○	○

As a thank you for the thoughtful feedback we will be holding a drawing for two $100 Amazon.com gift cards. Two names will be randomly drawn from a list of those who completed the survey and provided an email address to contact them.
As mentioned above, the drawing will be held from completed surveys and if you win the drawing you will be contacted by July 15th, 2015.

7. Are you interested in entering our drawing to win one of two $100 Amazon.com gift cards? Your email address will not be used for any other reason than to contact you if you win the drawing.

- ☐ Yes
- ☐ No

8. Please provide us with your contact information so we may enter you in our drawing. We will only use this information to contact you about the drawing and will not share it for any other purpose.

Name: _____
Email address: _____
Re-type Email Address: _____

Thank you again very much for your time and participation.
To submit your responses, please click the "**Submit Survey**" below.
To review your answers, click "Previous Page."