INSTITUTE FOR LEARNING INNOVATION

Research Study for NSF ISE planning grant

Visualization as a Tool in Informal Science Education at Lake Tahoe (UC Davis, TERC)

Award Number: 0755578
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March 2010

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Acknowledgements

A special thank you goes to Heather Segale, Education and Outreach Coordinator at TERC, who was a collaborator in every way for the planning, execution and review of this research study. Her enthusiasm, attention to detail, planning and support was very much appreciated.

We would also like to thank the AmeriCorps members at TERC who assisted with recruiting and data collection for this study.

OVERVIEW OF PROJECT

The UC Davis Tahoe Environmental Research Center (UCD-TERC) has conducted multidisciplinary scientific research at Lake Tahoe since 1968. UCD-TERC conducts and supports multidisciplinary research, education, and public outreach on fresh water systems including Lake Tahoe's watersheds and airsheds. Lake systems encompass the physical, biogeochemical and human environments, and the interactions between them. UCD-TERC's research findings have been at the forefront of limnology and ecosystem science, have informed public policy and management of natural resources in the Tahoe Basin, and have been a highly visual and effective part of the organization's education and outreach activities. UCD-TERC's programs are well known and highly regarded in the region, and UCD-TERC continues important scientific exploration of the Lake Tahoe Basin and other inland waters. UCD-TERC is committed to providing objective scientific input to support the restoration and long-term sustainability of the Lake Tahoe Basin.

The UC Davis "Thomas J. Long Foundation Education Center" (TJLFEC) is located in the main atrium area on the first floor of the Tahoe Center for Environmental Sciences building. Exhibits in the Thomas J. Long Foundation Education Center provide visitors with an understanding of the environmental issues of concern at Lake Tahoe and throughout the western United States. Video exhibits contain information about what makes Lake Tahoe so special; the scientific research at the lake and how research is being used in restoration efforts; and the role the public plays in efforts to preserve and protect environmental quality.

The Otellini 3-D Visualization Lab is a state-of-the-art facility and the centerpiece of our efforts to both understand the complexities of Lake Tahoe and to educate and inspire the next generation of scientists and engineers. This public science education lab is a computer simulation and visualization laboratory which utilizes state-of-the-art numerical simulation and visualization resources developed at UC Davis and collaborating institutions. The Visualization Lab 1) assists and advances the work of UC Davis researchers and other collaborators, 2) houses tools for presenting and manipulating very large datasets, and 3) presents scientific data in revolutionary ways to provide students and the public with a better understanding of complex issues. The laboratory is immediately visible from the Great Hall of the Education Center and works in conjunction with the other educational displays located within the education center.

Computer simulation and data visualization offer a method for seeing the unseen. They enrich the process of scientific discovery and foster profound and unexpected insights. In many fields, they revolutionize the way that scientists do science. The goal of visualization is to leverage existing scientific methods by providing new scientific insight through visual methods.

The Otellini Visualization Lab within the UC Davis Education Center houses a 12' by 9' FakeSpace, dual-projection, stereoscopic display system intended for audiences up to 20 people. The Visualization Lab is immediately visible from the Great Hall of the Education Center and works in conjunction with the other educational displays located within the education center. It is driven by a desktop graphics workstation that can display 3D visualizations that are controlled by trained docents using joysticks and similar input devices. The existing 3D visualizations are extensions of visualization research projects performed in the context of the UC Davis W.M. Keck Center for Active Visualization in the Earth Sciences within the Institute for Data Analysis and Visualization (IDAV). These are cutting-edge exploratory applications that, until now, have only used by research scientists. Currently, visitors can come into the fully operational Visualization Lab, don 3D glasses, and receive docent-guided tours of two relevant visualizations based on the following existing datasets:

1. Earth Viewer and Earthquake Dataset from 1940 through 2005: The Earth Viewer shows a global earthquake catalog showing hypocenters of earthquakes of magnitude 5.0 or more from the last 65 years (62,000 events total). Earthquake events are color-coded by magnitude (5.0 - green, 6.0 – turquoise, 7.0 - blue, 8.0 – magenta, and 9.0 - red), with the majority of the events in the lower range. Visitors can easily “see” the tectonic plate boundaries and discover the difference between spreading rift zones and subduction plate boundaries. Zooming into the interior of the earth to view the inner core, outer core, mantel and crust, the visitor views this data as if they were inside the planet looking at the depth, angle and magnitude of the earthquake activity. A simple “animation” of the dataset set to any requested “playback speed” (i.e. one year shown in one second) highlights the frequency of earthquake occurrence around the globe. Visitors comfortable with joystick or mouse user-interface input devices are invited to control the zoom, rotation, and location of views.

2. Lake Tahoe Digital Elevation Model (DEM) and Bathymetry: Explore a 3D model of the Lake Tahoe basin using a multiresolution terrain visualization program. The visualized data is a combination of a 10m-resolution digital elevation map provided by the US Geological Survey, and a 1m-resolution color image provided by the commercial IKONOS earth observation satellite. With 3D glasses on, visitors are taken on a tour of the Lake Tahoe watershed, both around the mountain basin and under the water. Trained docents currently lead a discussion of geologic formation of the lake basin including horst and graben faulting, volcanic activity, active earthquake faults (with visible evidence in underwater sediments), evidence of an underwater landslide which caused a past tsunami, and other unique features of the watershed. Lateral moraines left behind by glaciers, avalanche scars, evidence of erosion and the impacts of development are all visible for discussion and teachable moments of discovery. Visitors comfortable with joystick or mouse user-interface input devices are invited to control the zoom, rotation, location and path of travel.

The Visualization Lab 1) assists and advances the work of UC Davis researchers and other collaborators, 2) houses tools for presenting and manipulating very large datasets, and 3) presents scientific data in revolutionary ways to provide students and the public with a better understanding of complex issues. Computer simulation and data visualization offer a method for seeing the unseen. They enrich the process of scientific discovery and foster profound and unexpected insights. In many fields, they revolutionize the way that scientists do science. The goal of visualization is to leverage existing scientific learning/inquiry methods by providing new scientific insight through visual methods.

Purpose of the Evaluation

The purpose of this evaluation is to see to what extent the Tahoe Environmental Research Center, and more specifically the 3-D Visualization Lab, provides visitors with an understanding of the environmental issues of concern at Lake Tahoe and throughout the western United States.

Central Evaluation Questions:
The central evaluation questions addressed through this project included the following:

1. Who is currently visiting the Center? Are they year-round residents, short-term residents or casual visitors? Where are they coming from, what do they expect and how is their experience?
2. What does the local community know about TERC and what are their perceptions of the center? If they visit, why do they come? If they haven't visited, why not?
3. How effective are the Education Center's exhibits in educating visitors about Lake Tahoe's environmental issues, threats to Lake Tahoe's clarity, and core concepts related to scientific research at Lake Tahoe?
4. What do visitors gain from the new interactive visualization tools? What effect do these new tools have on the science knowledge and attitudes of participants?
5. What indication is there that the 3D visualization improves higher order thinking, communication skills, and understanding of science, technology, engineering, and mathematics (STEM) topics?
6. Does simply viewing the 3D dataset (as in docent-guided tours) provide ample opportunity for learning science concepts, or does the visitor need to interact directly with the data?
7. Does interaction with the 3D visualization technology and subsequent learning stimulate curiosity an interest to learn more?
8. Are the exhibits equally well received by the technology-savvy youth and technology-wary?

Methods

Answering the evaluation questions required multiple methods:

1. Focus group with TERC docents to get their feedback and impressions about how the 3-D Visualization Lab is working (Eval Questions 1, 2, 3, 4)
2. Focus groups with students (Eval Questions 1, 2, 3, 4)
3. 3-D Visualization Lab - Pre- and post-surveys (Eval Questions 3, 4, 6, 7, 8)
4. Focus groups with community members (Eval Questions 1, 2, 3, 4)

Both qualitative and quantitative methods were used to answer the above research questions. This combination of methods covered the broad range of experiences visitors have at the Center, especially in the visualization lab, and helped see the potential for expanding beyond current audiences. All of these methods contributed valuable information necessary for submitting the full grant proposal. To support the development of this study, the literature review conducted for the NSF-ISE proposal Maya Skies will be referenced.

Method	**Sample Size**	**Research questions addressed**
Docent focus group	18	1,2,3,4
6th grade students f.g. (used joystick)	9	1,2,3,4
6th grade students f.g.(didn't use joystick)	13	1,2,3,4
High School/Youth Science Institute f.g.	13	1,2,3,4
College students f.g.	7	1,2,3,4
3-D Visualization testing with students	246	3,4,6,7,8
Tourist f.g.	9	1,2,3,4
Tahoe area homeowners f.g.	11	1,2,3,4
Local environmental agency staff f.g.	12	1,2,3,4
Spanish-speaking residents f.g.	6	1,2,3,4
TOTAL	**344**	

Main Findings

The main findings are organized around answering the research questions from above:

1. Who is currently visiting the Center? Are they year-round residents, short-term residents or casual visitors? Where are they coming from, what do they expect and how is their experience?

   TERC has collected data from visitors since 2008, by way of filling out a survey that is present in the center. Heather Segale, Education and Outreach Coordinator for

TERC, has compiled a summary of the exit surveys from 2008 and 2009. See Appendix B for a complete summary of the findings. Word of mouth was the most common way that visitors had heard of TERC, followed by the brochure. The large majority (75%) of visitors to TERC were visitors to the Tahoe Basin as well, with full time residents making up the smallest percentage of visits. In terms of the visitor experience, the main exhibit experiences of the lab, research vessel exhibit and the 3-D visualization received high marks, ranging from 4.6 t 4.7 on a 5-point scale.

In terms of expectations and their experience, the wide variety of audiences included in this study (i.e., middle, high school and college students, residents, tourists, Spanish-speakers, etc.) the vast majority find the TERC experience to be enjoyable and informative. For those who were visiting TERC for the first time, they found the information about Lake Tahoe to be interesting and were able to cite specific facts and topics that they learned more about. Those who didn't have prior connections to TERC were not sure what to expect, but their expectations appeared to be met or exceeded.

2. What does the local community know about TERC and what are their perceptions of the center? If they visit, why do they come? If they haven't visited, why not?

   There was a perception that most residents were not aware of TERC and what it has to offer, but thought that most residents would find something useful. Many cited a need to better inform the Lake Tahoe community about what TERC has to offer as well as giving them a reason to visit. Some thought that having special events or offerings geared towards the local community, such as festivals and lectures, would be beneficial. Regarding people who have vacation home here, there was a perception that they might not be as interested in TERC, as they have specific activities that they normally do when coming to Lake Tahoe (i.e., gambling, fishing, skiing, etc.).

3. How effective are the Education Center's exhibits in educating visitors about Lake Tahoe's environmental issues, threats to Lake Tahoe's clarity, and core concepts related to scientific research at Lake Tahoe?

   For the 6th grade classes participating in the study, those in the treatment group who saw the 3D visualization were significantly more likely than a control group to agree that the water in Lake Tahoe is getting less clear or dirtier each year (80% versus 57%, respectively). The treatment group was also significantly more likely to report an increase in knowledge in the following areas: what affects how clear the water is, how the lake has stayed clear so long, the research going on at Lake Tahoe and the science of how Lake Tahoe works. The focus group participants were also able to indicate topics that they learned about related to the lake, its clarity, environmental issues and scientific research (see next question).

4. What do visitors gain from the new interactive visualization tools? What effect do these new tools have on the science knowledge and attitudes of participants?

When asked what they learned from the visualizations, the students most commonly mentioned physical and geologic characteristics of the lake, information about earthquakes and faults in Lake Tahoe, and glaciers. In the focus groups, college students said they learned very specific information from the visualization about the lake (e.g., Truckee River, wetlands, the tsunami in the lake, etc.) and about earthquakes (e.g., seismometers relation to nuclear testing, converging and diverging plates).

5. *What indication is there that the 3D visualization improves higher order thinking, communication skills, and understanding of science, technology, engineering, and mathematics (STEM) topics?"*

   As mentioned in the previous question, there are indications from students' self-reports that they are learning about STEM topics. This was also reported from the various adult groups in the focus groups. While the self-reporting is a good indicator, a more rigorous quasi-experimental design is necessary, which was outside the scope of this project. This type of design is suggested for the full development project.

6. Does simply viewing the 3D dataset (as in docent-guided tours) provide ample opportunity for learning science concepts, or does the visitor need to interact directly with the data?

   It seems like there is neither a need nor a desire on the part of visitors to interact directly with the data by using the joystick to "fly" around the lake rather than watch someone else do it. While we anticipated that there might be an issue with some students getting to use the controller while others didn't, this did not seem to cause a problem. Furthermore, the fact that the majority of students stated that they learned about many specific science concepts when only a few got to use the controller suggests that watching someone else is a worthwhile learning experience.

7. Does interaction with the 3D visualization technology and subsequent learning stimulate curiosity an interest to learn more?

   Those in the treatment group, who saw the 3D visualizations in addition to receiving a tour, reported an increase in interest in science in general (48%), using science to study Lake Tahoe (54%) and learning what they could do to protect Lake Tahoe (46%). While their self-reported increases were higher than the control group who only had a tour and no 3D visualizations (40%, 47% and 32%, respectively), these differences were not statistically significant.

8. Are the exhibits equally well received by the technology-savvy youth and technology-wary?

To what extent we could observe through the focus groups and the student surveys, the exhibits were received equally well between both youth and adults. The youth liked the technology and did not bring up any issues related to the technology. Also, adults enjoyed the experience and thought the technology effective in communicating geologic and environmental content. In fact, the 6th graders rated the 3D visualization experience highly: 66% rated it as "Great" and another 27% rated is as "Good." When asked what they liked about the visualization, a full 60% of the students specifically mentioned the technology. Given the visual sophistication of the movies, television and video games these 6th graders are engaging in, before conducting this study there was some question as to whether the technology would not be seen as very impressive. This was not found to be the case.

Implications for the 3D Visualization

The purpose of the planning grant was to gather information that will assist with the further development and design of the 3D Visualizations. Based on the research study, the following recommendations are made for improving the visitor experience and meeting the goals of the 3D Visualization:

1. Add additional layers to the Lake Tahoe visualization. Nearly all groups, unprompted, suggested adding man-made features, such as roads, towns and other identifiable components. They also mentioned adding landmarks and water to the lake.
2. Add animation. Many groups suggested adding animation of various concepts discussed, like the formation of glaciers, the formation of McKinney Bay and how human building and pollution affects the lake.
3. Study current expectations about 3D. With the recent release of many 3D movies, including Avatar, there may have been a shift in the general public's expectations about 3D environments. This will allow for designing an experience that will meet or exceed visitors' expectations.
4. Additional implications will be determined as the team discusses the project further and works on the full Development proposal to be submitted to NSF in November 2010.

LITERATURE REVIEW

PURPOSE:

To support the goals of the evaluation, the literature review aims to provide a summary of current thinking on the topic of 3D/virtual/immersive learning environments and science [and STEM] education.

APPROACH:

The review focused on the following term searches:

- 3D visualization, virtual reality
- Immersive [learning] environments
- Science education / science learning

SUMMARY OF LITERATURE:

1. **DEFINITIONS/EXPLANATIONS** (*What is a 3D/virtual/immersive learning environment?)*

1.1 Definitions of key terms (e.g., immersive, presence, realism, game, etc.)

As is typical for emerging fields, the literature on virtual environments and 3D visualizations incorporates an array of new terminology that is not always clearly or consistently defined. What follows is a summary of key terms and the range of definitions that emerged in the literature review, organized into three broad areas: Virtual environments; Immersion; and Play and games.

Virtual environments

The literature refers to virtual spaces using numerous terms, including virtual environments, virtual reality, more specific applications such as virtual experiments (Fiore et al., 2009), and specific characteristics associated with virtual environments.

Virtual reality (VR) is defined as an interactive, computer-based, multimedia environment in which the user becomes a participant in the computer-generated world (Shin, 2003) and "can be interactively experienced through sensory stimuli," including visual and auditory and, less frequently, touch, smell, and taste (Fiore et al., 2009). Experiencing a VR requires that the user is able to navigate or interact with the virtual world, and that the interaction must be in real-time (immediate) and consistent within the VR system (Fiore et al., 2009; Shin, 2003). In VR, users can experiment and explore by manipulating variables that cannot be manipulated in the real world (Gazit, Yair, & Chen, 2005).

A **virtual learning environment (VLE)** is seen as one that supports the learning of abstract concepts, and increases "the human capacity for certain types of learning by allowing users to cross the boundary between third and first person experience" (Jackson & Winn, 1999).

More specific applications of the term "virtual" include **virtual experiments**, "an experiment set in a controlled lab-like environment that generates synthetic field

cues using virtual reality technology," which can offer both internal (lab-based) and external (field-based) validity (Fiore et al., 2009).

The literature also defines numerous characteristics associated with virtual reality environments, including presence, realism, and expectation. The concept of **presence** refers to a condition in which the VE becomes more "real" or salient for the user than the real environment, the phenomenon of the VE being experienced by the user as a real place, or when the user's sensory inputs are dominated by those being generated by the VR (Nunez, 2004; Whitelock et al., 2000; Fiore et al., 2009). It is a sense of "being there."

Realism is defined by one author as the result of a process of inference, which draws on prior knowledge about the world in addition to information provided by sensory stimuli (Nunez, 2004). So rather than being an objective reality, realism is subjectively inferred from the framework of the user. In light of this view, Nunez argues that it makes more sense to speak of **expectation** than realism. He notes that "we will perceive of something as realistic if it is in line with our expectations of what one will find in that particular setting" (Nunez, 2004).

Immersion, immersive environments

Not all virtual environments are immersive. **Immersion** is defined as "the degree to which a system delivers information about the virtual world (to all the senses)" and tracks the user so that there is a high degree of consistency between virtual and real-world interactions (Nunez, 2004). An **immersive environment** refers to one that "dominates the affected senses," with the primary sense often being visual (Fiore et al., 2009). One paper defines specific **immersive displays**, which include small-scale, single-user displays; medium-scale displays designed for small groups of collaborative users, and large-scale displays designed for group immersion experiences, such as IMAX (Lantz, 2007).

Play, gaming

While not the focus of this literature review, some references to play and gaming naturally emerged. The concept of **transformational play** involves the user projecting into the role of a character, being in the context of a problem (rather than just seeing a concept or context), and apply concepts in order to transform the context (Barab et al., 2009)

Game is defined as a rule-based formal system with valuable and quantifiable outcomes, in which the player exerts influence over the outcome, and consequences are negotiable (Champion, 2005).

1.2 What are the expected benefits/hypotheses/theories? How do these environments fit into learning models?

While rigorous, generalizable research on the impacts of virtual/immersive environments and 3D visualizations on learning is limited (see Lessons Learned), there are numerous theories and hypotheses about the benefits of virtual environments. This literature focuses on two key areas: 1) how learning in virtual

environments relates to, complements, or builds on traditional learning approaches; and 2) potential benefits and value of learning in virtual environments.

Learning models, approaches, and frameworks

As VLEs become increasingly used in formal and informal learning settings, there is a need for new learning models to reflect new ways of organizing learning (de Freitas & Neumann, 2009). Much of the literature builds on learning theory from traditional contexts and expands these models into the virtual world, or proposes that VEs can better support certain types of learning and engagement than can traditional approaches. Two approaches/theories addressed in the literature are: 1) inquiry-based, participatory; and 2) constructivism.

In the sciences specifically, learning theory supports that science is best taught by having learners engage in **scientific inquiry** and actively participating in scientific processes (Ketelhut et al., 2008; Barab & Dede, 2007). Ketelhut argues that multi-user virtual environments (MUVE) can be beneficial in creating authentic science experiences in the classroom and engaging learners in the processes of scientists, which can be challenging when using traditional approaches; and Barab and Dede propose that games and immersive environments focus on *doing* (not receiving) science and that new technologies can facilitate the inquiry process. One useful pedagogical framework for inquiry-based learning in virtual environments is called the "Triple GU," which stands for "technology-rich, inquiry-based, participatory learning environments for grounded understanding." Triple GU environments use VR to establish "participatory environments that immerse students within a context that challenges, grounds, and extends their understandings" (Barab et al., 2000). They propose that virtual reality environments support student empowerment over learning, independence, and self-motivation.

Constructivist and **social constructivist** learning models also seem to play a strong role in current thinking about learning in virtual environments. The Exploratory Learning Model (ELM) is based on **constructivist experiential learning** (Kolb, 1984), but extends into 3D immersive environments (deFreitas & Neumann, 2009). Based on e-learning models, three descriptor categories emerged (associative – immediate feedback, contextual transfer; cognitive, build upon experience, reflection, abstraction, experimentation; and situative, which supports communities of practice), which researchers argue need to be brought together to support game-based and other immersive learning. Jackson and Winn (1999) assert that the constructivist model of learning assumes a learner-centered approach that is consistent with new technologies. VR and 3D technologies are also thought to be consistent with **social constructivist frameworks** by involving students in collaborative problem solving, and supporting them in reflecting on their own understanding and constructing shared knowledge (Keating et al., 2002).

Benefits, value of VLEs

Virtual/immersive environments are seen as promoting effective science learning because they can:

- Provide 3D representations of objects and complex systems that can better or more accurately convey complex scientific concepts, and help learners visualize abstract concepts, particularly those that involve multiple time and length scales (Angelov, Smieja, & Styczynski, 2007; Dean et al., 2000; Gazit, Yair, & Chen, 2005 Keating et al., 2002)
- Promote learning that is open-ended, exploratory, non-linear, multi-modal, and personalized, and provide greater learner control and autonomy (Dean et al., 2000; de Freitas & Neumann, 2009);
- Promote exploration, inquiry , and the construction of knowledge, because learners can easily view objects from different points of view, and can experiment by manipulating variables that can't be manipulated in the real world (Gazit, Yair, Chen, 2005)
- Provide greater interactivity and the ability to create a sense of immersion (Dean et al., 2000).
- Support increased engagement because it is participatory and allows for multiple routes for learning (de Freitas & Neumann, 2009; Barab & Dede, 2007; Lim, Nonis, Hedberg, 2006)
- Help learners develop a contextual understanding of science, rather than decontextualized facts, concepts and principles (Barab & Dede)
- Promote learning that is procedural or process oriented (e.g. learning how to solve a task) rather than prescriptive knowledge (e.g. right and wrong) (Champion, 2005).

2. SCOPE/USAGE *(How are these environments being used?)*

Audience

The literature review suggests that the majority of virtual environments in the STEM field are being used in **formal education** or **classroom settings**. Of the VR applications included in this review, about 80% (n=28) were being used in a formal education context, with 9 at the university/college level, 7 in middle school, 6 in high school, 3 in elementary,2 for general education or all ages, and 1 for adult education. Other audiences being reached to a lesser extent include **professionals** (n=4), such as teachers, environmental scientists, and firefighters; and the general public in **informal settings** (n=3), such as in a science museum or planetarium.

Content/discipline

The review also suggests that the majority of VR environments in STEM are focused on the **sciences**. In this review, 80% (n=24) of the VR applications focused on science. Of those, 6 focused on astronomy or space science, 5 on general science, 4 on environmental science, 2 each on earth science, watershed/ocean science, and chemistry, and 1 focused on biology (human immunology).

Only 3 of the applications were being used to teach **math** concepts, 2 for **technology** or computer programming, and 1 for **engineering**. This may in part be due to the review's focus on science over technology, engineering, and math.

3. LESSONS LEARNED (*What degree of success has using these 3D visualizations had? What are the continuing challenges or problems with 3D visualizations that need to be overcome?*

Lessons learned (both successes and challenges) are drawn from research and evaluation studies related to using VR and 3D visualization as educational tools in STEM environments. Overall, little of the research conducted to date involves rigorous, experimental or quasi-experimental design. Many of the studies were naturalistic, anecdotal, or included very small sample sizes; and few could be considered generalizable to other applications, contexts, or populations. The following key points, then, should be used as guidance for thinking about the benefits and potential pitfalls of VR technology rather than as generalizable findings.

Successes

The literature suggests that virtual learning environments and 3D visualization can be used to support or enhance the following areas: 1) learning of science concepts; 2) building science skills, scientific inquiry; 3) interest, engagement and motivation; 4) empowerment and confidence; and 5) collaboration and peer learning. In many cases, it is believed that virtual technologies work best when coupled with other learning modalities (lecture, discussion), to provide enough scaffolding to minimize misconceptions that may occur with VR technology alone (Angelov, Smieja, & Styczynski, 2007; Dean et al., 2000; Gazit, Yair, & Chen, 2005; Jackson & Winn, 1999; Sumners, Reiff, & Weber, 2008).

- **Learning of science concepts**

Much of the emerging research on the impacts of VR and 3D visualizations on STEM learning asserts that these environments can improve cognition around science concepts. Some studies have shown that 3D representations provide learners with **more accurate graphic information** about complex science concepts than can 2D representations (Angelov, Smieja, & Styczynski, 2007; Barab et al., 2000; Barnea & Dori, 1999; Keating et al., 2002; Murphy, 2004; Yeung, 2004). For example, one study showed that undergraduate students learned concepts like erosion and water quality most effectively with the most immersive intervention (Barab et al., 2009). Another study showed that middle school and high school students in earth science could more easily grasp basic concepts such as elevation when using a 3D anaglyph map, versus a 2D topographical map (Murphy, 2004).

The research also posits that VR environments allow users to explore an object or phenomenon from **multiple perspectives**, which improves learning (Gazit, Yair, & Chen, 2005; Harrell et al., 2008; Keating et al., 2002; Shin, 2003; Wang, Chang & Li, 2007). For example, Keating et al. (2002) conducted a very small-scope study that showed undergraduate astronomy students' ability to better visualize abstract scientific concepts such as the sun-moon-Earth relationships. A larger study reported that VR increased middle school students' understanding of the seismic wave, earth's crust balance, radiation balance, and the ocean environment (Shin, 2003).

Other studies supported the idea that VR or immersive environments did increase students' knowledge of science concepts, but did not address the factors contributing to increase in knowledge (Ketelhut et al., 2008; Lim, Nonis, & Hedberg, 2006; Sumners, Reiff, & Weber, 2008). 3D visualizations are seen as particularly effective for concepts that are intrinsically 3-dimensional (Kreylos et al., 2006; Sumners, Reiff & Weber), such as those in earth and space sciences. One study showed that VR environments helped close the gap between low-efficacy and high-efficacy students (Ketelhut et al., 2008).

- **Interest, engagement, motivation**

There is some evidence that the use of VR and 3D in STEM learning environments lead to increased interest, engagement, and motivation (Barab et al., 2009; Elliot & Bruckman, 2002; Harrell et. al, 2008; Korakakis et al., 2009; Lim, Nonis, & Hedberg, 2006; Shin, 2003; Wang, Chang & Li, 2007; Whitelock et al., 2000). One study that tested different levels of 3D visualizations (static, animated, and interactive) with middle school chemistry students showed that 3D increased student engagement and interest overall, regardless of type (Korakakis et al., 2009). In a study of middle school students learning earth science, Shin (2003) showed that the immersive environment increased motivation and interest in the majority of students (82%). One study suggested that audio feedback increased presence and engagement (Whitelock et al., 2000), and another showed longer stay times for VR applications (Wang, Chang, & Li, 2007), though it was unclear whether this was engagement in content or time spent figuring out the technology itself. Similarly, in a small case study (n=8), elementary students using a MUVE (multi-user virtual environment) experienced an increased sense of "flow," which is characterized by "intense concentration and excitement" (Lim, Nonis, & Hedberg, 2006), however the engagement was focused more on the technology and less on learning activities and content.

- **Empowerment and confidence**

A couple of studies suggested that VLEs impacted affective learning, such as building confidence, a sense of empowerment, and a even a new "*e-merging"* identity as a learner (Harrell et al., 2008; Lim, Nonis, & Hedberg, 2006). However, these studies involved small sample sizes and did not clearly explicate what was meant by these terms or how the virtual environment contributed to empowerment or building self-confidence. There is some sense that providing a learner-oriented experience provides increased **control** over the learning process, and thus could contribute to higher levels of self-empowerment and confidence in learning.

- **Collaboration, peer learning**

Some of the literature suggests that virtual environments are particularly effective in encouraging collaboration and peer learning (Barab et al., 2009; Harrell et. al, 2008; Jackson & Winn, 1999). In a study conducted with at-risk high school students, researchers found that "whereas in the real world the students

preferred to work independently, in the virtual world they shared objects, scripts, and skills they had developed" (Harrell et al., 2008). A preliminary study of 110 middle school students showed that peer collaboration plays a significant role in student engagement with VLE; and that there is a potential for VR to provide valuable collaborative learning experiences in conjunction with traditional methods (Jackson & Winn, 1999). In a quasi-experimental study with undergraduate students using a game-based application designed to teach water quality concepts, researchers found that the most effective learning occurred when students worked in pairs (Barab et al., 2009).

Challenges

The literature suggests numerous challenges to effectively utilizing virtual environments in STEM learning. The following areas should be considered when developing and implementing VR applications: 1) usability and functionality; 2) cognitive overload; 3) novelty factor; 4) potential misconceptions; and 5) transfer between virtual and real worlds. The literature also suggests that some of these challenges can be mitigated by employing multiple modes of learning and/or coupling virtual learning with more traditional approaches (lecture, discussion, etc.) to scaffold the virtual experience.

- **Usability**

  Several studies point to usability and functionality as potential barriers to learning and engagement in VR environments (Barab et al., 2000; Elliot & Bruckman, 2002). This suggests a strong need for formative testing in order to minimize usability issues. For example, undergraduate astronomy students using the Virtual Solar System became frustrated at times with the lack of usability and intuitiveness of the application and spent a lot of time focused on learning the software tool itself. Because of this, students wondered whether goal was to learn technology or astronomy (Barab et al., 2000). Another study with middle and high school students using anaglyph/3D maps found that students had some issues with the comfort of the glasses and difficulty focusing, which distracted from the learning process (Murphy, 2004).

- **Cognitive overload**

  In a quasi-experimental study that compared three types of 3D visualizations (static, animated, and interactive), researchers found that students using the animated and interactive applications experienced the most cognitive overload, while those applications did increase student interest in the content more than the static illustrations did. Static illustrations give students time to control the learning process and decreased the cognitive load, though were seen as less attractive than the interactive and animated versions (Korakakis et al., 2009).

- **Novelty factor**

As is well-documented in other literature on new technology, VR environments can pose issues with the "novelty factor," in which users become more focused on exploring or figuring out the technology itself while ignoring the content or learning activities embedded in the technology. For example, one study of gaming in virtual environments suggested that users "tend to look for interaction and personalization while disregarding the actual content, and they conflate fact, conjecture, and fiction" (Champion, 2005). Another study found that elementary students using a MUVE lost focus on their task and spent time on "aimless exploration" (Lim, Nonis, & Hedberg, 2006).

- **Misconceptions**

One small-scale study (n-=10) addressed misconceptions that emerged for high school students using the Virtual Solar System tool (Gazit, Yair, & Chen, 2005). While all of the participants developed a scientific understanding of the causes of the day-night phenomena, alternate misconceptions of the earth-moon-sun system emerged because of: 1) cognitive difficulty in coordinating visual information from different perspectives; 2) misinterpreting features of the Virtual Solar System; 3) ignoring the 3D nature of the Moon and incorrect perceptions of Moon and Earth's relative size; and 4) an inability to move away from the Earth's frame of reference. The researchers concluded that VR experiences such as the VSS require "suitable scaffolding and guided reflection" to minimize misconceptions.

- **Transfer**

The literature suggests that learners may experience some difficulty in "transferring" concepts or tasks from the virtual to the physical context (Angelov, Smieja, & Styczynski, 2007; deFreitas & Neumann, 2009). One study found that only one-third of university engineering students participating in the study felt they could repeat a task in real life that they had practiced in 3D application (Angelov, Smieja, & Styczynski, 2007), suggesting that a combination of 3D and traditional hands-on learning may be most effective.

4. GAPS

→ *What don't we know? Any areas related to TERC not yet researched?*
→ *What opportunities are there for TERC to contribute to the literature?*
→ What implications are there for TERC and their development and use of 3D visualization?

4.1. What don't we know?

Based on an overview of the current literature on VR and 3D environments in STEM learning, the following are broad areas that suggest the need for further research:

- **Lack of rigorous, generalizable data -** Overall, there have not been enough rigorous, generalizable studies conducted to definitively support claims about the benefits and challenges of VLEs.

- **Comparing VR to traditional learning** – Given the lack of experimental, treatment/control studies that compare traditional learning to VR technologies, it is difficult to compare the benefits of each learning environment and how they might best be used together to support the most effective science learning. While studies suggest that VR is best used in conjunction with traditional methods, scaffolding, etc., the field would benefit from more rigorous and definitive research in this area.
- **Best practices** – While the current literature provides an initial sense of how VLEs can benefit learners and learning in STEM, there is less research that links specific practices or components to these outcomes.
- **Focus on 4D** – One study suggests the need to focus more on 4D GIS for the Web, particularly for geo-sciences such as weather: "Dynamic engineering of real-time datasets into visualization output based on time requests would allow the flexibility a Web audience desires" (Campbell et al. (2002).

4.2. What opportunities are there for TERC to contribute to the literature?

Given that there is a need for more generalizable, rigorous studies, TERC has an opportunity to add to the literature of how VR and 3D environments can provide valuable experiences in informal learning environments like museums. The current study used a quasi-experimental approach that was able to show the effectiveness of the 3D environment in STEM-related outcomes. However, the current study relied mostly on self-report data from the students. A more extensive study of actual learning using the same approach would be very beneficial.

4.3. What implications are there for TERC and their development and use of 3D visualization?

Answering this question will take more discussion with the team, and how the current study and literature review inform the next steps for the project, specifically the submission of a proposal for the next round of NSF ISE.

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DOCENT FOCUS GROUP
OCTOBER, 2008

FOCUS GROUP #1: Docent Focus Group

Overview: On October 9, 2008 a 3 ½ hour focus group was held at the Tahoe Environmental Research Center (TERC) with a total of 18 docents and AmeriCorps members. The primary purposes of the focus group was to get feedback from the docents about 1) how the visualization lab works, 2) their perception of what visitors think about it, and 3) what could be improved as it gets updated.

The following is a compilation of notes taken by Steve Yalowitz and Heather Segale during the focus group. Some docents and AmeriCorps members who could not attend emailed their responses; these have been incorporated into the notes from the focus group.

Overall findings: The docents find the overall experience of the Viz Lab to be interesting and enjoyable, except when there are technology glitches. There was a sense that the docents vary the experience based on the audience, and respond to and pose questions to make it a more interactive experience. During the focus group, some docents referred to the "5 key points" for the Viz Lab, but when asked what these key points were they came up with many more than five and covered many different topics. Perhaps the key messages of the experience should be reinforced so everyone is communicating the same basic ideas every presentation. There is a strong feeling that it should not be a "canned" presentation, but the docents were open to the idea of being consistent in their messaging.

Docents perceived the strengths of the Viz Lab being its flexibility, the graphics, its basic presentation, and the unique view of the lake you can't get anywhere else. Additionally, docents feel that it's a valuable experience for people to learn about how the lake was formed, how humans are affecting the lake, and what is being done to monitor and help change that. However, it was perceived as much more challenging to communicate to people what they can do as individuals. Some docents also talked about how important it is it communicate a sense of place and to make a personal connection in the Viz Lab. It was seen as a successful Viz Lab experience if visitors were asking questions, staying longer than planned, lingering after the presentation, suggesting that others visit, and especially when they ask what they can do to save Lake Tahoe.

There was some discussion about "uninterested" visitors and ways to deal with them, with some of the techniques for doing so not being very visitor-focused (i.e., the docent deciding to cut the tour short). While these seem to be the exception rather than the rule, it might be useful to think of these visitors as unengaged rather than labeling them as uninterested. Tourists were specifically mentioned as an audience that's less familiar with the lake and sometimes difficult to engage; understanding their experience would

be helpful in making the Viz Lab more relevant for them. While younger kids (under 7) are not a target audience, there was discussion about what could be offered, in another room perhaps, to allow them and their caregivers a more positive experience.

Docents had many suggestions for how to improve the DEM visualization, falling into five general areas:

- Orientation – help visitors relate to where they are by including the shoreline, labeling cities or other points of interest, or asking them where they live or are staying and go to those areas first. There was a lot of discussion about the waterline and making it more obvious.
- Impact of Humans – there was a general request for including more information, especially as it related to the effects of humans on the lake. They thought it would be useful to include some way of showing how pollution, development and runoff are affecting the lake.
- Interaction – docents thought they should all be engaging groups by asking visitors questions at the beginning and during the presentation, customizing the experience based on who people are or possibly even figuring out a way for visitors to “fly” on their own
- Technology – sometimes the technology or the joystick doesn’t work, and some docents are concerned that they are making visitors nauseous
- Visualization – there is sometimes confusion based on the vertical exaggeration or the data anomalies. Also, there was an idea about adding things to the lake itself to help visualize what is there (e.g., sunken boats, fish, plankton, algae, etc.)

Overall, the docents find the Viz Lab to be a valuable and very popular part of the tour that they enjoy doing very much. Since the Viz Lab is docent-driven it is important and useful to have their perspective on how it is functioning and how it might be improved.

STUDENT FOCUS GROUPS
MARCH, 2009

Student Focus Groups Findings Summary

From March 4 to March 6, 2009 four focus groups were held at the Tahoe Environmental Research Center (TERC) with four groups of students:

- middle school (who didn't use the joystick)
- middle school (some of whom used the joystick)
- high school
- college – Sierra Nevada college

The primary purpose of the focus groups was to get feedback from students about 1) how the visualization lab works, 2) what they were learning from the visualization, and 3) suggestions for how it can be improved.

Overall findings:
The student groups found the visualizations to be interesting and enjoyable. They liked 3D graphics, the immersive nature of the experience and the information interesting. Some common themes and patterns emerged, and mostly these had to do with either a) adding new layers of information, b) slightly modifying current features, or c) including new design elements. Students are engaged, interested and learning from the current versions of the visualizations, and would likely see even greater levels of engagement with some of these changes.

TERC experience and staff: Each of the student groups thought of TERC as a unique place, very different from their school environments, and provided experiences and opportunities they couldn't get anywhere else, such as going in-depth into a specific topic. Students regularly described TERC staff and docents as very excited, enthusiastic and knowledgeable. This combination resulted in an enjoyable experience and one where they felt they were learning more than they might in a different environment.

Lake Tahoe Visualization: Students gave the visualization good ratings and enjoyed the experience. They liked that it was about a local/familiar place, the 3D effect, the ability to "fly" around and into the lake, and that it was immersive making you feel like you were really there. They also learned new information, specifically mentioning the glacial features, the makeup of the lake and surrounding areas, and geologic events like the tsunami and the underwater landslide which formed McKinney Bay. They also had a number of suggestions that were common across the four groups: adding or enhancing the color especially for the water, making the shoreline more distinct, adding embedded animations for geologic events, including identifying or descriptive labels for both geologic and man-made features, as well as adding things like fish, people and cars to make it even more realistic.. Both of the 6th grade student groups came up with the idea of your "plane" turning into a submarine when you went underwater.

Earthquake Visualization: Groups rated the visualization highly, and liked the 3D quality, could zoom in on certain areas and that could see the faults. Some individuals mentioned that they never knew there were so many earthquakes, and the idea of the data becoming more available as a result of monitoring nuclear testing was fascinating to some. There were suggestions for improving the use of the dots, including making the yellow and green more distinct, somehow making it easier to see the high-magnitude earthquakes, and including a magnitude legend to refer back to. Determining where the laser was pointing (front vs. back) also seemed to be minor issue, since some students had a hard time figuring out which it was referring to.

Audience Member Using Joystick: There was a general consensus that it would be a good idea to let someone in the audience use the joystick, but it was nearly unanimous that there need to be specific conditions. Groups thought that there should either be a specific goal like going to visit a particular part or feature of the lake. They also thought that this should be a very small portion of the overall presentation, maybe 2 to 5 minutes total. The students believed that without these conditions it would not be very enjoyable or useful for those not controlling the joystick.

FOCUS GROUP #2: 6th Grade Students (Used joystick)

Method and sample: This group of 6th graders from North Tahoe Middle School included 9 students (4 boys and 5 girls), took a tour of TERC, viewed the visualizations and afterwards participated in a short focus group. Due to time limitations there was only 20 minutes of discussion, so the conversation focused exclusively on the Lake Tahoe visualization. In addition, this was the only group where the students were able to use the joystick themselves. Three different students in this group used the joystick to fly around the lake.

Learning: The group mentioned that they learned about earthquakes, such as there were so many earthquakes and they went so deep below the surface. About Lake Tahoe, they said that they didn't realize there was so much sediment and boulders on the bottom, as well as that the water level was so low for a while and there were fully formed trees underwater.

Lake Tahoe Visualization: They liked the 3D effect, and definitely thought it felt like you were really flying around the lake. Some suggestions included having you fly a plane that turns into a submarine when you go into the water adding more color, having cars driving by and making the shoreline more distinct. They also suggested having animations like the west shore (now McKinney Bay) falling into the lake with the landslide, tsunami, glacier movements and Mount Rose exploding.

Audience Members Using Joystick: Those who controlled the joystick said it was really fun, and that it was challenging at first but got easier as you did it. Some of them said their experiences with video games and flight simulators helped a lot. Those who didn't

control the joystick said it was still fun to watch someone from the audience do it and that it was worth doing. They also said that you might not learn quite as much as watching the docent, and that maybe the docent should tell them where to go and what to do.

FOCUS GROUP #3: 6th Grade Students (Did not use joystick)

Method and sample: This group of 6th graders from North Tahoe Middle School included 13 students (6 boys and 7 girls), took a tour of TERC, viewed the visualizations and afterwards participated in a focus group which lasted about 45 minutes. Different from the previous group, these students did not have the opportunity to use the joystick during the visualization activity.

TERC experience and staff: The students enjoyed a variety of experiences, and specifically mentioned the two visualizations, the lab and the boat. They also mentioned learning about specific topics like plankton, scientists' research, Lake Tahoe and the watershed. In describing what TERC does, they talked about environmental research, what scientists are doing and studies of the lake and earthquakes.

Learning: When asked what they learned during their visit, they talked a lot about the 3D visualization of Lake Tahoe, covering topics such as how deep the lake was, how earthquakes formed bays, the drop by the California/Nevada border, lateral moraines and glaciers. The students also mentioned elements from the boat, like the scientists' use of tools to measure the clarity of the lake and invasive species, use of Secchi disks, and the decrease in lake clarity over time. The lab was also a source of learning, including learning about plankton and invasive species.

Lake Tahoe Visualization: The students thought the visualization was about learning about the physical makeup of Lake Tahoe and its surroundings, showing how it was formed, the effects of glaciers, and geologic features such as rocks at the bottom of the lake and the mountains. They came up with many suggestions for improving the visualization, including adding colors for the various physical features, having one version with water that gets bluer as you go deeper, being able to fly under that water (maybe in a submarine), and having wraparound screens on the side to make the 3D effect more effective. The students liked the idea of including animations, and suggested a variety of animations; these included geologic features as well as human-impact features (see full list below). They thought the animations would help them learn because they would capture your attention, get you more interested in learning and possibly even influence them to change behaviors.

Earthquake Visualization: Students said that they learned things from the visualization including that there were so many earthquakes, not all earthquakes occur along faults and that the measurement of earthquakes increased in 1963 as a result of the Cold War (watching for atomic testing around the world). Suggestions for improving the visualization focused on adding information such as a legend for the magnitude of earthquakes, emphasizing the larger magnitude quakes, and showing the outer and

inner cores in different colors. They also talked about some of the visual challenges, such as not knowing whether the laser pointer was on the front or back of the globe, and that the menu on the side had a red line that with the 3D effect “hurt their eyes” when they were sitting too close.

Audience Members Using Joystick: Asked specifically about having someone from the audience fly around Lake Tahoe, they thought it was a good idea but only at after the main part of the program occurred. Similar to other groups, the students thought the person in charge of the program should guide the person rather than half a “free fly” where they went wherever they wanted.

FOCUS GROUP#4: Youth Science Institute Program

Method and sample: This group of students from various high schools in the Lake Tahoe area included 13 students (7 boys and 6 girls), viewed the visualizations and afterwards participated in a focus group which lasted about 30 minutes. This group was unique in that it consisted of students participating in a TERC program that gets local high school students more involved in science.

TERC experience and staff: They regarded TERC as an interesting and fun place to visit, that they liked better than school. Participants had many positive comments about TERC staff that centered on their positive attitudes, enthusiasm, dedication and knowledge. They said that this enthusiasm, especially tone of voice and excitement, made it a more fun and enjoyable experience. Another aspect they saw as unique to TERC was the level of depth they could get into, going into a topic in much more detail than they did at school. Examples they gave were learning about the lake and going out on the boat to do the Secchi disk. They also talked about the opportunity they had at Science Expo, especially how they liked interacting with the kids.

Lake Tahoe Visualization: When asked to rate this particular visualization, most gave 7’s, 8’s or 9’s. Positive comments included being able to change the exaggeration, seeing through the water, going along the bottom of the lake, how simple it was (i.e., not too many data points), and being able to see what was out there. Suggestions for improving it were making it more colorful, adding features like water in the lake, labeling things (e.g., cities, shore line or other reference points), adding people and/or fish, making other features more distinct, and animating past geological occurrences (e.g., small earthquakes, when parts of land dropped, glaciers, forming of Emerald Bay). Quite a bit of time was spent discussing adding colors, including semi-transparent colors for the water with it getting darker as you went deeper, as well as colors for the land, beaches, mountains, etc. A few participants did mention getting dizzy or feeling slightly sick when watching the visualization.

Earthquake Visualization: The majority of participants rated it a 9, and no one rated it lower than an 8. Positive comments related to it being eye-catching, how the earthquakes lined up with the plates, and the perception of depth and being able to turn

it. The color of the dots seemed to be a minor issue, with the green and yellow dots looking alike, and that it was difficult to see the high-magnitude earthquakes (they got buried in the other ones). One suggestion was to make the different colors also different sizes to distinguish them from each other. Another comment was that with the laser pointer it was not easy to know where it was pointing – discriminating between the front and back was difficult. They also thought it was sometimes difficult to determine where the continents were. One person suggested including reference points for cities, another suggested being able to zoom in on different parts of the planet.

Audience Members Using Joystick: The group was unanimous thinking it was a good idea to have members in the audience control the joystick, but only with certain conditions. They thought the large majority of the time should be the docent-led experience, with only about 5 minutes for audience members to control the movement. Additionally, they felt strongly that the person should have some direction as to where to go and what to do. They did not think it would be good to give someone free rein over what they were doing; they thought this would not be a positive experience for the whole group.

FOCUS GROUP #5: College Students

Method and sample: This group of 7 college students and 2 AmeriCorps members included 5 males and 4 females. They viewed the visualizations and afterwards participated in a focus group which lasted about 30 minutes. This group consisted mostly of Sierra Nevada college students; TERC is located on the campus of Sierra Nevada College.

Learning: For the Lake Tahoe visualization, they mentioned a variety of topics, including aspects of the Truckee River, wetlands, small lakes next to Lake Tahoe, there was a tsunami and there was rock debris at the bottom of the lake. For the earthquake visualization, they never realized that the seismometers were added to detect nuclear blasts, there were so many earthquakes around the Himalayans (this student was from there), and the difference in earthquake frequency between converging and diverging plates.

Lake Tahoe Visualization: The students rated the visualization with 6's, 7's or 8's. They liked the visualization and thought the idea of using visualizations was an effective tool, but also saw some room for improvement. Their suggestions included making the visualization more colorful (there were quite a few comments about this), adding some labels of both geographic and human-based features such as roads, ski resorts, or buildings. Students also suggested adding specific layers of information like roads, streams, vegetation, historical information, elevations of mountains and depth of the lake. In terms of having someone operate the joystick, they were not as enthusiastic about the idea as other groups, but did say that will some specific guidelines it could be a good idea. They thought at most it should be 3 to 5 minutes of the whole presentation.

Earthquake Visualization: Their ratings for this visualization were 7's, 8's and 9's. They liked the 3D quality, seeing where the earthquakes were, and that when you zoomed in you could see the series of earthquakes near Thailand (magnitude 9 quake in 2004??). They had multiple suggestions for improving the visualization, including having a legend for the magnitudes, pointing out specific historical earthquakes, being able to see only the red dots, and not having the globe be transparent.

Engaging Sierra Nevada students: Only two students had been to TERC previously, and most of them were not aware of what was available to do there. The students had many suggestions for how to communicate with them, including using the school web site and paper, sandwich boards, mass emails, announcements in class and having guest lecturers come to class. Other ideas included making connections with SNC more formal, by talking to specific teachers or incorporating a visit to TERC in student tours and orientation. They thought college students would find TERC interesting, if they had heard about it. The monthly lectures were also seen as an attractive option, but the time might be hard to make sometimes.

3-D VISUALIZATION TESTING WITH STUDENTS (April, 2009)

SUMMARY

Purpose of the Study

The purpose of this study was to find out how the 3-D Visualization Lab exhibits are working: 1) are the exhibits effective or not?, and 2) how can they be improved? To answer these questions students filled out a pre- and post-retrospective survey about their experiences with the visualization lab. In order to more specifically isolate the impact of the experiences, control groups were employed.

Methods and Sample

A total of 8 6th grade student groups from local elementary schools participated in the study: 4 were control groups who didn't see the 3-D visualizations and 4 were treatment groups who did both the Lake Tahoe and Earthquake visualizations. A total of 246 students completed the survey: 121 students in the control group and 125 students in the treatment group. Data collection occurred on March 26 and 31 and April 6 and 7, 2009. On each of these dates one treatment and one control group was conducted, with classes from the same school. Furthermore, to be consistent four docents delivered the tours, with each docent doing one control and one treatment tour.

Main Findings:

The following research questions for the overall study relate particularly to the student survey portion of the study.

1. How effective are the Education Center's exhibits in educating visitors about Lake Tahoe's environmental issues, threats to Lake Tahoe's clarity, and core concepts related to scientific research at Lake Tahoe?
2. What do visitors gain from the new interactive visualization tools? What effect do these new tools have on the science knowledge and attitudes of participants?
3. Does simply viewing the 3D dataset (as in docent-guided tours) provide ample opportunity for learning science concepts, or does the visitor need to interact directly with the data?
4. Does interaction with the 3D visualization technology and subsequent learning stimulate curiosity an interest to learn more?

1. *How effective are the Education Center's exhibits in educating visitors about Lake Tahoe's environmental issues, threats to Lake Tahoe's clarity, and core concepts related to scientific research at Lake Tahoe?*

   The center's exhibits were rated highly, and for 9 of 13 specific areas more than half of the students reported an increase in their knowledge about these areas. Almost two-thirds reported an increase in understanding what affects the clarity of the water and how the lake has stayed clear so long, while one-third reported an increase in understanding what they could do to help Lake Tahoe.

2. *What do visitors gain from the new interactive visualization tools? What effect do these new tools have on the science knowledge and attitudes of participants?*

   Students who saw the visualizations, compared to a control group who did not, were significantly more likely to say they increased their knowledge about the following topics: size of the lake, what affects how clear the water is, how the lake stayed clear so long, how it was formed, what a watershed is and how it functions, what a fault is, the research going on at Lake Tahoe, and how the science of Lake Tahoe works.

3. *Does simply viewing the 3D dataset (as in docent-guided tours) provide ample opportunity for learning science concepts, or does the visitor need to interact directly with the data?*

   While this was not tested systematically by comparing groups who did and did not "drive" the visualizations, it can be determined that there is not as much of a desire by the students to drive as was originally thought. Focus groups with students showed that they were fine with other students driving, and while desirable they didn't need to do the driving themselves. In fact, they thought there should be specific instructions or tasks so that anyone flying would add something to the visualization experience. While some students suggested letting them fly in response to different questions, it was not anywhere near a majority.

4. *Does interaction with the 3D visualization technology and subsequent learning stimulate curiosity an interest to learn more?*

   Students were asked about their increase regarding interest in the following topics: science in general, using science to study Lake Tahoe, and learning what you can do to protect Lake Tahoe. When comparing those who had seen the visualizations to a control group who had not, none of the differences for increased interest were statistically significant. However, there was a non-significant trend for the treatment groups having a higher proportion who reported an increase.

I. OVERALL VISIT

In general the students were very satisfied with their visit, as more than two-thirds gave it a rating of Excellent (a 9 or 10 on a 10-point scale). When those who rated the visit lower than 10 were asked what would improve the visit, the most common responses were to have more activities (22%), make it more fun (13%), have more dealing with animals (8%), adding water to the Lake Tahoe visualization (7%) and having more information (7%).

Q1. Please rate how satisfied you are with your <u>entire visit</u> to the Tahoe Environmental Research Center (TERC) today, using the following scale:

1 2 3 4 5 6 7 8 9 10
(very dissatisfied) (very satisfied)

Table 1. Rating of overall visit

Rating	Frequency	Percent
9 to 10	163	68%
7 to 8	55	23%
4 to 6	20	8%
1 to 3	2	<1%
Total responses	**230**	**100%**

Q1a. If you rated it 9 or lower, What would make it a 10?

Table 2. What would improve the visit

Response	Frequency	Percent
More activities	23	22%
Make it more fun	14	13%
More animals, more with animals	9	8%
Add water to the 3D part	7	7%
More information	7	7%
More games	5	5%
More hands-on, interactives	5	5%
Less talking, more doing	4	4%
Seats	3	3%
Make it more interesting	3	3%
More time	3	3%
Nothing, fine as is	2	2%
TV's, videos to work better	2	2%
More, in general	2	2%
Tour guide	2	2%
Comment about visualization	2	2%
Shorter	2	2%
More exciting	2	2%

Don't know	2	2%
Miscellaneous	21	20%
Total respondents	**106**	

Q2. Now we want to ask you some questions about how much you knew about some topics before you visited, and how much you know now.

When asked about their knowledge of various topics related to Lake Tahoe, most students self-reported a knowledge gain from visiting TERC in almost all of the areas. Largest gains were related to the size of the lake, how it has stayed clear for so long and how it was formed.

The treatment group who had both had a tour and seen the 3D visualizations was compared to the control group who had received a tour but had not yet seen the 3D visualization. There were statistically significant differences between the two groups' self-reported knowledge gain in 9 of the 13 areas. This strongly suggests that viewing the 3D visualizations is, on its own, having a positive impact in many of the topics covered during a TERC visit. Seeing the 3D visualizations is significantly adding to the students' visits.

Table 3. Self-reported knowledge of various Lake Tahoe topics

Topic	**How much you knew before the visit (in %)**				**How much you know right now (in %)**			
	Nothing	**A little**	**Some**	**A lot**	**Nothing**	**A little**	**Some**	**A lot**
Size of Lake Tahoe	10	32	45	14	3	4	39	55
Shape of Lake Tahoe	14	25	29	31	5	10	29	55
What affects how clear the water is	21	37	24	18	4	10	35	50
How the lake has stayed clear so long	42	32	17	10	10	19	37	34
How Lake Tahoe was formed	22	30	28	20	2	11	31	56
What a watershed is	46	31	16	6	14	26	30	29
How a watershed functions	58	24	14	4	22	27	29	22
What a "fault" is	22	19	31	28	7	16	26	52
Boundaries between tectonic plates (Plate Tectonics)	16	19	24	41	5	10	24	61
How glaciers change the landscape	17	25	37	21	4	13	27	57
What you can do to help Lake Tahoe	4	19	27	50	4	7	22	67
Research going on at Lake Tahoe	22	35	31	12	8	12	35	45
The science of how Lake Tahoe works	22	36	30	12	6	15	39	41

Table 4. Self-reported knowledge change in topic areas, all students

Topic	Decreased	No Change	Increased
Size of Lake Tahoe	4%	29%	67%
Shape of Lake Tahoe	6%	46%	49%
What affects how clear the water is	3%	33%	64%
How the lake has stayed clear so long	5%	28%	67%
How Lake Tahoe was formed	5%	32%	63%
What a watershed is	2%	35%	62%
How a watershed functions	3%	37%	61%
What a "fault" is	6%	45%	48%
Boundaries between tectonic plates (Plate Tectonics)	6%	52%	42%
How glaciers change the landscape	6%	36%	58%
What you can do to help Lake Tahoe	8%	59%	33%
Research going on at Lake Tahoe	7%	31%	62%
The science of how Lake Tahoe works	4%	34%	62%

Table 5. Self-report knowledge gain in topics, Control group and Treatment group

Topic	Control Group, % Who Increased	Treatment Group % Who Increased
Size of Lake Tahoe *	**59%**	**74%**
Shape of Lake Tahoe	42%	55%
What affects how clear the water is *	**55%**	**73%**
How the lake has stayed clear so long *	**54%**	**79%**
How Lake Tahoe was formed *	**55%**	**70%**
What a watershed is *	**45%**	**79%**
How a watershed functions *	**42%**	**79%**
What a "fault" is *	**39%**	**58%**
Boundaries between tectonic plates (Plate Tectonics)	35%	49%
How glaciers change the landscape	56%	59%
What you can do to help Lake Tahoe	26%	40%
Research going on at Lake Tahoe *	**50%**	**74%**
The science of how Lake Tahoe works *	**53%**	**70%**

* Indicates a statistically significant difference, at $p<.05$.

Q3. Some people say that the water in Lake Tahoe is getting less clear or dirtier each year. Do you think that's true?

More than two-thirds of all students believed that the water in Lake Tahoe is getting dirtier each year. Those who saw the 3D visualizations, including one about Lake Tahoe, were significantly more likely to believe this to be true (80%) compared to the control group (57%). In fact, the control group was more than twice as likely to say they didn't know (36%) compared to the treatment group (15%). When asked why the lake was getting dirtier each year, the most common responses were because of pollution in general (28%), runoff (15%) or people putting trash in the lake (14%).

Table 6. Belief that Lake Tahoe is getting less clear

Response	Control	Treatment	All Students
Yes	57%	80%	69%
No	7%	5%	6%
Don't know	36%	15%	25%
Total responses	**100%**	**100%**	**100%**

NOTE: There is a statistically significant difference between the control and treatment groups.

Q3a. Why do you think it might be getting less clear or dirtier?

Table 7. Why Lake Tahoe is getting less clear

Response	Frequency	Percent
Pollution (non-specific)	58	28%
Runoff	31	15%
Putting trash in lake	29	14%
Erosion, soil, dirt	20	9%
Littering (non-specific)	17	8%
Algae	10	5%
Boats	9	4%
Cars, motorcycles	8	4%
It's not dirtier, looks clean	7	3%
Other human impact	7	3%
Non-native species	6	3%
Not taking care of the lake	6	3%
Destruction of wetlands	5	2%
It's just getting dirtier	5	2%
Mysis / zooplankton / algae	5	2%
More people	4	2%
Casinos	3	1%
Not recycling	2	1%
Don't know	13	6%
Miscellaneous	13	6%
Total respondents	**212**	

Q4. Please let us know about your interest in the following topics, both before visiting today and now that you have visited.

When asked about their perceived change in interest related to the visit, a little less than half (44%) of the students said the visit increased their interest in science. Meanwhile, half of them said the visit increased their interest in using science to study Lake Tahoe (50%). Meanwhile, a little more than one-third (39%) said it increased their interest in learning what they can do to protect Lake Tahoe. While there was a trend for those in the treatment group who saw the 3D Visualizations reporting higher changes in interest for all three, these differences were not statistically significant. One consideration is that these items were very general in nature, and perhaps using more specific items related to the messages in the visualizations would have resulted in different results.

Table 8. Self-reported interest in science and Lake Tahoe topics

Topic	Your interest before the visit (in %)				Your interest right now (in %)			
	No interest	A little	Some	A lot	No interest lot	A little	Some	A
Science in general	9	35	32	24	5	15	42	39
Using science to study Lake Tahoe	15	34	36	16	8	13	41	40
Learning what you can do to protect Lake Tahoe	7	20	29	44	1	9	25	65

Table 9. Self-reported change in interest in science and Lake Tahoe topics, all students

Topic	Decreased	No Change	Increased
Science in general	7%	50%	44%
Using science to study Lake Tahoe	6%	44%	50%
Learning what you can do to protect Lake Tahoe	4%	57%	39%

Table 10. Self-reported change in interest in science and Lake Tahoe topics, control group and treatment group

Topic	Control Group, % Who Increased	Treatment Group % Who Increased
Science in general	40%	48%
Using science to study Lake Tahoe	47%	54%
Learning what you can do to protect Lake Tahoe	32%	46%

NOTE: None of the differences between the control and treatment groups were statistically significant differences.

Q5. Please let us know about your concern for the following topics, both before visiting today and now that you have visited.

When asked about their perceived concern about protecting the environment before and after visiting, the majority of students (57%) said they had no change, while more than one-third (39%) said there was an increase in their concern. Again, while there was no statistically significant difference in those in the treatment versus control groups, the treatment group had a slightly higher percent who said there was an increase. In considering the non-significant result, it is important to note that the visualization does not include anything that specifically shows the impact humans have had on Lake Tahoe. In future versions perhaps it would be possible to include more animations showing human impact could be added. It would also have been useful to use an item that asked about concern related to protecting Lake Tahoe.

Table 11. Self-reported concern about the environment

Topic	Your concern <u>before</u> the visit (in %)				Your concern <u>right now</u> (in %)			
	No interest	A little	Some	A lot	No interest	A little	Some	A lot
Your concern about protecting the environment	7	20	29	44	1	9	25	65

Table 12. Self-reported change in concern about the environment, all students

Topic	Decreased	No Change	Increased
Your concern about protecting the environment	4%	57%	39%

Table 13. Self-reported change in concern about the environment, Control group and Treatment group

Topic	Control Group, % Who Increased	Treatment Group % Who Increased
Your concern about protecting the environment	32%	46%

NOTE: This was not a statistically significant increase.

Q6. Whose job do you think it is to protect Lake Tahoe and make sure it stays clean?

When asked whose job it is to protect Lake Tahoe, students most likely identified groups that included themselves, saying everyone (40%), us (23%) as well as everyone who lives at Tahoe 920%). Almost off of their responses fit into these three categories.

Table 14. Who students think should be protecting Lake Tahoe

Response	Frequency	Percent
The Public / Organizations	**211**	**94%**
Everyone	89	40%
Us	51	23%
Everyone who lives at Tahoe	45	20%
Scientists	9	4%
Me	7	3%
Everyone who visits Tahoe	6	3%
TRPA	4	2%
Government	**11**	**5%**
The Governor	4	2%
The government	4	2%
The President	3	1%
General	**27**	**12%**
Don't know	7	3%
Miscellaneous	20	9%
Total respondents	**224**	

Q7. From the topics below about Lake Tahoe, please tell us which would you be interested in hearing more about? Tell us your top three choices:

Students were given a choice of seven different topics related to Lake Tahoe and asked to pick the three they would be most interested in hearing more about. The purpose of this question was to find out which topics to include in an updated version of the Lake Tahoe visualization. The two most often chosen were related to what lives in the lake (59% chose it as one of their top three) and the forest health in the Lake Tahoe Basin (58% chosen as one of their top three). In examining the list, it is possible that the geology topic rated lower than the others since there is already a wealth of information in the visualization about this topic. Further testing would show whether in fact this could be the case.

Table 15. Interest in specific Lake Tahoe-related topics

Choice (n = 221)	First choice (%)	Second Choice (%)	Third Choice (%)	1st, 2nd, or 3rd Choice (%)
Biology of Lake Tahoe (what lives in the lake)	35%	12%	12%	59%
Forest health in the Lake Tahoe Basin (trees, animals, fire)	20%	22%	16%	58%
History of the lake (Washoe tribe, Pioneer families, post 1960's development)	12%	19%	18%	49%
Climate change impacts at Lake Tahoe (weather, temperature, invasive species)	10%	11%	13%	34%
Physics of Lake Tahoe (changes in temperature, water level, mixing)	5%	11%	17%	33%
Development affecting the lake (roads, buildings, people)	7%	11%	14%	32%
Geology of Lake Tahoe (rocks, earthquakes, glaciers)	8%	11%	7%	26%
Other	3%	3%	4%	10%
Total responses	**100%**	**100%**	**100%**	**100%**

II. EARTHQUAKE VISUALIZATION

When asked to rate the earthquake visualizations, the majority of students rated it as great (55%) while another 33% rated it as good.

Q8. How about the 3-D Visualization where you saw where the Earthquakes happened. Would you say that 3-D Visualization was…

Table 16. Rating of Earthquake Visualization

Rating	Frequency	Percent
Great	68	55%
Good	41	33%
Okay	10	8%
Bad	4	3%
Total responses	**123**	**100%**

Q8a. What did you like about it?

When asked what they liked about it, more than four-fifths (86%) said the effects, especially the 3D effects (33%) and showing the earthquakes (19%). One out of ten (11%) specifically mentioned the information.

Table 17. What students liked about Earthquake Visualization

Response	Frequency	Percent
Effects	**89**	**86%**
3D	34	33%
Showing the earthquakes	20	19%
Looked real	8	8%
Other effect	6	5%
How stuff popped out at you	6	6%
Seemed like you could touch it	5	5%
See inside the Earth	4	4%
Special effects	3	3%
How the Earth got really big	2	2%
Seeing things up close	1	1%
Information	**11**	**11%**
Interesting	5	5%
Information itself	2	2%
Easier to learn	2	2%
How earthquakes form	1	1%
Showed the past	1	1%
General	**15**	**14%**
Miscellaneous	8	8%

Everything	7	7%
Total respondents	**104**	

NOTE: Students could give more than one response, so categories total more than 100%
Q8b. What would make it better?

When asked what would make it better, more than one-tenth of students (13%) specifically mentioned adding color to the visualizations. Other responses had to do with making it bigger, being able to be closer and making it more immersive.

Table 18. Suggestions for improving Earthquake Visualization

Response	Frequency	Percent
Add color	13	13%
Make it bigger	4	4%
Go closer, touch it	4	4%
More 3D, immersive	4	4%
Better seats	3	3%
More to see	3	3%
Less confusing (visually)	3	3%
Comments about dots	3	3%
Water and mountains	3	3%
Let us do it	2	2%
Different pictures	2	2%
More graphics	2	2%
See through water	2	2%
Have it not hurt your eyes	2	2%
Make it longer	2	2%
Names of cities	1	1%
More interactive	1	1%
Label more things	1	1%
Fine the way it is	1	1%
Don’t know	28	28%
Miscellaneous	16	16%
Total respondents	**101**	

Q9. Please complete the following sentence about the Earthquake Visualization: "I never knew that…"

Asked what they learned in the visualization, more than half (56%) mentioned that fact that so many earthquakes had occurred. Another one in ten (9%) mentioned the Indonesian earthquake and the tsunami that occurred after it. Meanwhile, 7% mentioned volcanoes and 4% mentioned the Earth.

Table 19. Learning from Earthquake Visualization

Response	Frequency	Percent
Earthquakes	**74**	**74%**
So many earthquakes	56	56%
Indonesian earthquake	9	9%
Three faults in Lake Tahoe	4	4%
Lake Tahoe earthquake	2	2%
Earthquakes in the sea	2	2%
Earthquake at Lake Tahoe	1	1%
Volcanoes	**7**	**7%**
Volcanoes	4	4%
Seismographs	3	3%
Earth	**4**	**4%**
Earth's core	2	2%
Earth's crust	2	2%
General	**17**	**17%**
I'd really like this	2	2%
Would learn this	2	2%
Miscellaneous	10	10%
Total respondents	**99**	

III. LAKE TAHOE VISUALIZATION

When asked to rate the Lake Tahoe visualization, nearly two-thirds (66%) rated it as great. Another one-quarter (27%) rated it as good.

Q10. There was also the 3-D Visualization where you flew around Lake Tahoe and went underwater. Would you say that 3-D visualization was…

Table 20. Rating of Lake Tahoe Visualization

Rating	Frequency	Percent
Great	81	66%
Good	33	27%
Okay	7	6%
Bad	2	2%
Total responses	**123**	**100%**

Q10a. What did you like about it?

When asked what they like about the majority mentioned the effects (60%) and almost another one-quarter (23%) referred to the physical features depicted in the visualization. A little more than one-tenth (11%) specifically said that they liked everything.

Table 21. What students liked about Lake Tahoe visualization

Response	Frequency	Percent
Effects	**69**	**60%**
Go underwater	12	10%
Go through mountains, Earth	11	10%
The flying	10	9%
Three dimensional	9	8%
Special effects	8	7%
Looked real	6	5%
No water	5	4%
Physical features	**26**	**23%**
Specific feature	9	8%
Mountains	8	7%
Specific features under water	5	4%
The details	4	4%
General	**36**	**31%**
Everything	13	11%
General positive statement	10	9%
See our school	3	3%
The information	2	2%
Don’t know	2	2%

Miscellaneous	6	5%
Total respondents	**115**	

NOTE: Students could give more than one response, so categories total more than 100%

Q10b. What would make it better?

In terms of what would make the visualization better, the top three responses were to add water (23%), add color (21%) and many students said it was fine the way it is (20%).

Table 22. Suggestion for improving Lake Tahoe Visualization

Response	Frequency	Percent
Add water	26	23%
Add color	23	21%
Fine the way it is	22	20%
More description, information	6	5%
Better detail when you zoom	4	4%
Adding a specific feature (variety)	3	3%
More graphics	3	3%
Make it longer	3	3%
Better pictures, graphics	2	2%
More interaction	2	2%
Add vegetation, trees	2	2%
Don't know	3	3%
Miscellaneous	19	17%
Total respondents	**111**	

Q11. Please complete the following sentence about the Lake Tahoe Visualization: "I never knew that…"

In terms of what they learned from the visualization, they were most likely to learn a characteristic of Lake Tahoe (43%), particularly how deep or big it is (13%). They also said they learned about the earthquakes and faults of Lake Tahoe (21%) and about the role glaciers played in forming the lake (18%).

Table 23. Learning from Lake Tahoe Visualization

Response	Frequency	Percent
Lake Tahoe Characteristic	**44**	**42%**
Tahoe so deep, big	14	13%
Bottom of lake feature	8	8%
Landslide in Lake Tahoe	5	5%
A drop off in the lake	5	5%
Volcanoes / volcanic activity	4	4%

Clarity of lake		4		4%
Other Lake Tahoe characteristic		4		4%
Earthquakes / Faults	**22**		**21%**	
Three faults in Lake Tahoe		9		9%
Earthquakes in Lake Tahoe		7		7%
Earthquakes cause lake tsunamis		6		6%
Glaciers	**19**		**18%**	
Glaciers formed ridges / moraines		10		10%
Glaciers made Lake Tahoe		5		5%
So many glaciers		4		4%
General	**24**		**23%**	
General positive comment		5		5%
Don't know		1		1%
Miscellaneous		18		17%
Total respondents	**106**			

NOTE: Students could give more than one response, so categories total more than 100%

Q12. Did seeing the Lake Tahoe 3-D Visualization change how you think about the lake?

More than three-fifths (61%) of the students said the visualization changed how they thought about the lake. When asked how, they were most likely (56%) to mention learning about the lake (e.g., how deep it is, how it looks). Meanwhile almost one-fifth (17%) talked about conservation or the human impact on the lake.

Table 24. Whether the visualization changed perception of Lake Tahoe

Response	Frequency	Percent
Yes	74	61%
No	48	39%
Total responses	**122**	**100%**

Q12a. If Yes, how?

Table 25. How Lake Tahoe visualization changed their perception

Response	Frequency	Percent
Learning about the Lake	**33**	**56%**
Things about lake, in general	8	14%
How deep it is	8	14%
How the lake looked	7	12%
Geologic feature	4	7%
How big it is	3	5%
Think about it in a different way	3	5%
Conservation	**10**	**17%**
We're affecting the lake	4	7%
Will change my behaviors	3	5%
Cars and fuel	1	2%
Improve the lake, clarity	1	2%
Must change what we do	1	2%
General	**14**	**24%**
General positive comment	2	3%
Don't know	3	5%
Miscellaneous	9	15%
Total	**59**	

Q13. What would you say about seeing the 3-D Visualization about Lake Tahoe. Do you think it…

In reference to whether the visualization impacted how they care about the lake, more than three-quarters (76%) said it made them care more about the lake, while another one-fifth (20%) said it didn't change how they felt about the lake.

Table 26. How Lake Tahoe visualization changed caring about Lake Tahoe

Response	Frequency	Percent
made you care more about what happens to Lake Tahoe.	93	76%
made you care less about what happens to Lake Tahoe.	5	4%
didn't change how you feel about Lake Tahoe.	24	20%
Total responses	**122**	**100%**

Q14. There are some things we can add to the 3-D Visualization of the Lake. Which of the following would best help you understand what affects the lake?

Students were shown a list of six options that could be added to the visualization and asked to pick their top two choices. Two-thirds (67%) picked adding animations that could be embedded in the visualization as one of their top two choices, and another 44% picked enhancing the colors on the map. Another 30% said they would like to have water added to the lake.

Table 27. Preference for adding components to Lake Tahoe visualization

Choice (check top two choices)	Frequency	Percent
Animations (pollution, lake currents, amount and location of fish, etc.)	79	67%
Enhancing the colors on the map (shades of blue for water depth, etc.)	52	44%
Water in the lake (see where the shoreline is)	35	30%
Labels of places (cities, roads, streams, points of interest, etc.)	28	24%
More map information (north arrow, legend, location of roads, boundaries, etc.)	15	13%
Other	2	2%
Total respondents	**118**	

NOTE: Students could choose two, so columns add to more than 100%

Q15. In terms of what you actually did, was the Lake Tahoe 3-D Visualization more like…

Asked about the level of interactivity for the visualization, almost half of the students (45%) said it felt more like watching a movie (passive viewing) than any of the other options. Less than one in five (17%) said it felt like playing a video game (active viewing).

Table 28. Perception of level of activity in viewing the visualization

Response	Frequency	Percent
Watching a movie in the theater (passive viewing)	53	45%
Choosing which video segments to watch (passive viewing with choices)	17	14%
Watching someone play a video game and giving some directions (semi-active viewing)	28	24%
Playing a video game yourself (active viewing)	20	17%
Total responses	**118**	**100%**

Q16. Do you think it should be even more interactive?

When asked whether it should be interactive, the students were split: while 54% said yes, 46% did not feel like it needed to be more interactive. Given that many adults view children as always wanting more interactivity, despite how interactive something already is, this is somewhat of a surprising finding. When those who said it could be more interactive were asked how this could be done, the most common responses were to let them “drive” it (25%), make it more colorful (13%), make it more like a PSP (a Playstation game system), or have more images and pictures (7%).

Table 29. Whether Lake Tahoe visualization should be more interactive

Response	Frequency	Percent
Yes	64	54%
No	55	46%
Total responses	**119**	**100%**

16a. If Yes, how could we make it more interactive?

Table 30. How Lake Tahoe Visualization could be more interactive

Response	Frequency	Percent
Let us drive it	15	25%
More colorful	8	13%
Make it like a PSP (Play Station)	5	8%
More images, pictures	4	7%
Add water in the lake	3	5%

More information, explanation	2	3%
Make it better (non-specific)	2	3%
Add fish, animals	2	3%
Don’t know	5	8%
Miscellaneous	13	22%
Total responses	**60**	**100%**

IV. CHARACTERISTICS OF THE STUDENTS

All of the students were in 6th grade, and were evenly split between boys (51%) and girls (49%). When asked what kind of student they were, most thought they were either about the same (43%) or better than (45%) other students. The large majority of students (85%) had lived in Tahoe 5 or more years. As far as outdoor activities, more than two-thirds (69%) said their families did so a lot (42%) or some (27%). Considering activities on or near the lake, almost two-thirds (65%) did so a lot (36%) or some (29%). They were not very likely to talk about science at home, with about half (54%) said they did so either not much (32%) or never (22%). When asked about frequency of speaking English at home, only 58% said they did so all the time, and 12% said either a little bit of the time or never.

Q17. Are you a…

Table 31. Gender of students

Response	Frequency	Percent
Boy	123	51%
Girl	119	49%
Total responses	**242**	**100%**

Q18. Compared to other students in your class, how are your grades?

Table 32. Perceived level of student ability

Response	Frequency	Percent
Better than others students	106	45%
Not as good as other students	29	12%
About the same as other students	102	43%
Total responses	**237**	**100%**

Q19. Which grade are you in?

All students were in 6th grade.

Q20. How long have you lived in the Lake Tahoe area?

Table 33. Length of time living in Lake Tahoe

Response	Frequency	Percent
Less than 1 year	11	5%
1 to 2 years	10	4%

3 to 4 years	16	7%
5 or more years	205	85%
Total responses	**242**	**100%**

Q21. How often do you do outdoors activities like going hiking with your family?

Table 34. Frequency of outdoor activities

Response	Frequency	Percent
A lot	100	42%
Some	64	27%
A little	34	14%
Not much	29	12%
Never	14	6%
Total responses	**241**	**100%**

Q22. How often do you do activities on or right next to Lake Tahoe with your family?

Table 35. Frequency of activities at Lake Tahoe

Response	Frequency	Percent
A lot	88	36%
Some	69	29%
A little	47	19%
Not much	26	11%
Never	11	5%
Total responses	**241**	**100%**

Q23. At home, how often do you talk about science with your family?

Table 36. Frequency of science conversations at home

Response	Frequency	Percent
A lot	21	9%
Some	40	17%
A little	49	20%
Not much	76	32%
Never	54	22%
Total responses	**241**	**100%**

Q24. At home, how often do you speak English?
Table 37. Frequency of speaking English at home

Response	Frequency	Percent
All the time	141	58%
Most of the time	43	18%
Some of the time	28	12%
A little bit of the time	20	8%
Not at all	10	4%
Total responses	**242**	**100%**

COMMUNITY FOCUS GROUPS
AUGUST, 2009

Community Focus Group Findings Summary

From August 27 to 28, 2009 four focus groups were held at the Tahoe Environmental Research Center (TERC) with different audiences:

- Tourists
- Tahoe area homeowners
- those who work for local environmental agencies
- Spanish-speaking residents

A total of 38 people participated in the four focus groups. Except for the tourist group participants, most had some kind of previous connection to TERC.

Since the center is trying to reach out to and build audiences among these four groups, much of the focus group was spent discussing their awareness, use of and impressions of TERC. The primary purpose of the focus groups was to get feedback from groups about 1) their perceptions of TERC, 2) how TERC can better engage their particular group, and 3) feedback about the visualization lab.

Overall findings:
The community groups found TERC and the visualizations to be interesting and enjoyable, and most of the suggestions had to do with adding layers of information or functions to the visualizations. TERC was seen as relevant to residents and tourists alike, and those who worked for environmental agencies perceived there being a lot of relevance of TERC for their organizations. Suggestions for reaching specific communities included having special events or exhibits that were relative to those audiences.

Reaction to TERC visit: Reactions to the visit were overwhelmingly positive, although there were quite a few suggestions people came up with. These suggestions tended to focus on two areas: 1) improving the visualization and 2) adding specific content. Suggestions for improving the visualization mostly focused on adding elements: color, roads, orientation, and more technology including animation. Various ideas were proposed for adding specific content; see the various sections for specific suggestions, as there were no specific identifiable patterns across the groups.

Relevance of TERC: TERC was perceived as having relevance not only to those who are from the Tahoe area, but also for tourists. Most of the tourists could relate the environmental issues faced by Lake Tahoe to similar issues in their own areas. Residents talked about TERC as a place where they could come to learn about the local issues currently affecting the lake and its health. Those who worked for local environmental agencies were able to come up with ideas for collaboration between TERC and their agency, and included not only ways that TERC can provide information

to them but that TERC could also serve as a meeting place and as a way their agencies could better reach the general public.

Reaching Specific Audience Segments: Each group had specific suggestions for attracting audiences that TERC is not currently reaching as well as they would like. The suggestions included ideas for both how to reach the audiences (e.g., direct mail, through specific groups) and also for what kinds of activities or experiences would be compelling (e.g., special events, types of exhibits, media, etc.). In each of the focus groups, it was suggested that the best way to reach the groups would be through its own members, either by having specific individuals serve as ambassadors for TERC or by working with community groups.

Reaction to 3-D Visualization: Reactions to the visualizations were very positive, with participants enjoying the topic and the technology. There were many suggestions for improving the Lake Tahoe Digital Elevation Model, most of which had to do with adding layers of information: roads, landmarks and other man-made components. Adding an orientation feature was also desirable.

FOCUS GROUP #6: Tourists

Method and sample: The tourist group was the only one that was recruited that day. TERC staff went to local tourist areas like the beach, hotels and stores to recruit for the focus group. A total of nine tourists participated, coming from a variety of areas in California (Orange County, Los Angeles) as well as from other states (Florida, North Carolina, Delaware). Of the group two were married couples from the same area. One of the participants was a resident who came with a tourist who was visiting him. Participants were given the standard guided tour of TERC, which included experiencing both 3D Visualizations: Digital Elevation Model and Earthquakes. Participants were offered a gift card as an incentive. Participants were offered a gift card as an incentive.

Prior Experience with TERC: None of the participants had previously been to TERC, including the one resident.

Relevance of TERC: Since tourists were from outside the area, they were asked how TERC was relevant to them. It is important to note that all of the participants lived in states that border oceans and the majority lived near major waterways, rivers or the ocean. These participants related what is going on at Tahoe to their own areas, with a couple of people mentioning pollution and environmental problems in their area such as invasive species. A 5th and 6th grade teachers and related TERC to when they use a microscope to teach class, one participant talked about seeing a program about underwater geology on television and another mentioned they had always heard about the blue water of Lake Tahoe.

TERC and Tourists: When asked why tourists don't visit, they unanimously said that they don't know about it. When asked which types of tourists would be interested in

TERC, they talked about two distinctive groups of tourists: 1) those who are coming to do one specific activity like skiing, gambling, hiking or fishing, and 2) those coming as general tourists to the area looking for a variety of activities. The participants thought that the former group would neither have the time nor be interested in TERC, while the latter group would be the ones to target for a visit.

Suggestions for Tour: Suggestions for the tour were varied, and included the following: have something to appeal to teenagers and college students, more technological effects, explaining the relationship of the earthquake visualization, enhance recognizable areas like the Hyatt pier, and have actual pictures of the things you're seeing.

Suggestions for 3-D Visualization: Suggestions for improving the Digital Elevation Model of Lake Tahoe included adding color (especially to the lake), putting in a compass to provide orientation, including roads and landmarks, and including an overlay model that can be either on or off of the model. Their suggestions were in line with other groups who had seen the visualization.

FOCUS GROUP #7: Tahoe Area Homeowners

Method and sample: A total of eleven homeowners participated in the focus group. Almost all of the homeowners, however, have some connection to TERC, so they likely do not represent the average homeowner in terms of their awareness of and impressions of TERC. The majority were also at least aware or very aware of the environmental issues surrounding Lake Tahoe (this may or may not be different from other Tahoe homeowners). Participants were offered a gift card as an incentive.

Prior Experience with TERC: Most of the homeowners had a previous connection to TERC, with three of them being volunteers at TERC and one person being involved early in the establishment of TERC. The other members either were working in or had worked in environmental issues related to TERC. For example, one person was a member of the Nevada Tahoe Conservation District, another was an environmental geologist, and another had a background in environmental resource planning.

Relevance of TERC When asked what was relevant to them, participants talked about the Center being a place for the community to learn about and discuss issues relevant to Lake Tahoe. They talked about local issues such as deforestation, usable space and BMP's, as well as mentioning specific parts of the tour: the laboratory, Daphnia, and repetition of specific messages.

Suggestions: Homeowners had some specific suggestions for improving TERC. These included having more flat screen t.v.'s, examples of how the data are used by scientists, focusing on Tahoe as an ecosystem, finding ways to look at the current information in more depth, and looking at unintentional consequences of humans on the lake.

Increasing Awareness: Homeowners discussed the lack of awareness among locals as the largest barrier to visiting. Suggestions for increasing awareness include reaching out to particular groups like service clubs, residents, and homeowners. Specific ways suggested included providing free tickets and direct mail.

Increasing Visits: When asked why more homeowners haven't visited, participants mentioned a general lack of awareness for TERC and the building, people may not think of it as a kid-friendly place, they might expect it to be more of a university building (i.e., not so engaging), or that it might be better to ask them to visit particular times like Fall and Spring.

Reaction to 3-D Visualization: When asked for suggestions for comments on the Digital Elevation Model of Lake Tahoe, participants had suggestions for improving the visualization. These included examples showing particular features (e.g., buried forests, Emerald Bay, their houses), focusing in on particular areas, ways to locate more easily where you are, driving the visualization on their own, making the lake blue, and including animations in the following areas: formation of the lake, invasive species like Mysis shrimp, and showing how sediment comes into the lake and following its path.

FOCUS GROUP #8: Local Environmental Agency Staff

Method and sample: For this focus group, TERC recruited twelve people who worked in local environmental- or Tahoe-related agencies with whom they already had a connection or relationship. These included representatives from the California Tahoe Conservancy, Tahoe Resource Conservation District, Nevada Tahoe Conservation District, (3) Forest Service (2), USGS Nevada Water Science Center, California State Parks, the Tahoe Visitor Center, North Lake Tahoe Chamber of Commerce and Nevada Division of Environmental Protection. Participants were offered a gift card as an incentive.

Opportunities for Collaboration: Participants were asked to what extent the purpose of TERC overlapped with their own agency's mission, and what opportunities there might be to collaborate. Some suggestions included TERC providing printed materials these organizations could distribute or use, such as laminated cards. Some suggested providing content for already existing publications such as Sky Journal or a weekly publication on the history of the lake. Others saw TERC as a place where groups could meet, either to communicate science content to the public or to exchange information with other groups. A couple of groups already take advantage of TERC's presence by having their staff take the tour to learn more about Lake Tahoe and be better able to talk about the lake.

Suggestions for New Topics: Participants were asked which additional topics or content TERC should consider adding. Not surprisingly, since these groups were environmental in nature, multiple suggestions focused on conservation: what people can do to protect and keep Tahoe blue, information about personal responsibility (e.g., gardening) and

water conservation. Other topics suggested included helping people make a connection between Tahoe and their local watersheds, developing material collaboratively, focusing on positive messages (e.g., forest restoration, boat inspections), including a main message that is present throughout TERC and including girls-in-science curricula or programs.

Increasing Visits: When asked what TERC could do to increase visitation among Lake Tahoe area residents, they had many suggestions. Some of the suggestions were logistical, like having better signage and parking. Others suggested adding more traditional types of experiences, such as an outdoor garden, lecture series or live animals. Multiple people suggested using technology, through audio or downloadable tours, having a more engaging web site or some kind of a live feed to the lake. A booth at various festivals was also suggested. Participants mentioned that they thought second homeowners were a particularly challenging group to reach, especially because they come to the lake and have a standard group of activities they engage in (i.e., golfing, gambling, etc.). It was suggested that there be a secondary activity like a festival to engage them.

Other suggestions: Additional suggestions including having more engaging experiences as the visit was rather museum-like, having a self-guided tour for local drop-ins, using technology that allows for more frequent updating, and having a local class adopt an aquarium.

FOCUS GROUP #9: Spanish-speaking Residents

Method and sample: Spanish-speaking staff members ((Sierra Nevada College? TERC?)) were recruited by TERC staff. A total of six people participated; four only spoke Spanish, one spoke predominantly Spanish and a third spoke Spanish and English equally. Participants were offered a gift card as an incentive.

Reaction to TERC visit: Participants were asked if anything during the visit surprised them, and they mentioned the Secchi disk, the algae on rocks, that it needed to be removed by boat, and the invasive species.

Reaching the Hispanic/Latino Community: When asked how to reach the Spanish-speaking community in Lake Tahoe, respondents suggested using direct mail, newspapers like Bonanza, or through casinos, churches or invitations to people who work at TERC already. Specific suggestions included through Human Resources and the Tahoe Women's Center.

Spanish Language Day: One specific idea that was presented to the group regarded having a day titled "Spanish Language Day/Un Dia de Hablahispana" where there is much more offered in Spanish, in September or October. They were asked which activities should be included. They thought snacks would be nice, also interactive

activities like drawing or making things, something about water and how to keep it clean, as well as something about invasive species and where they come from.

When asked which day of the week this day should occur on, they suggested a Thursday or Friday afternoon starting at 5:00. Asked how to find Spanish-speaking volunteers, they suggested high school and college students.

Reaction to 3-D Visualization: Respondents liked the Lake Tahoe Digital Elevation Model and rated it highly. They said that they would like to see the lake without water, show Highway 28 and other sites and talk more about Mount Rose. One commented that they don't know the lake very well and it was difficult for them to know where they were during the visualization.

Appendix A
Thomas J Long Foundation Education Center Visitor Exit Survey Data Write Up by Heather Segale, TERC Education and Outreach Coordinator

Introduction

Since the opening of the Thomas J Long Foundation Education Center in October 2006, over 26,000 individuals have visited the center. Starting in late 2007, we began collecting various demographic information as well as feedback from our visitors about the effectiveness of the exhibits in our Visitor Exit Survey. However, since the survey is completely voluntary, only a small percent of visitors have actually completed the Visitor Exit Survey, only 458 surveys accounting for 2% of our visitors. Our volunteer docents have been trained and instructed to ask all visitors to complete the one-page survey at the end of their visit, most visitors declined. Data from 2008 (n=276) and 2009 (n=166) will be discussed in detail while data from 2007 (n=16) will be included only in the overall visitor response percentage given its sample size.

How Did Visitors Hear About the TJLF Education Center

The primary way visitors heard about the TJLF Education Center is through word of mouth which brought in 34% of overall visitors. The percent of visitors who heard about the education center through word of mouth increased 34.2% in 2008 to 40.2% in 2009. The brochure was the second most effective way of bringing visitors in accounting for roughly 27% in 2008/2009 and 24% overall. The newspaper also proved to be effective, bringing in 21.8% of visitors in 2008 but dropped slightly to 16.4% in 2009. Overall, 20% of visitors heard about us from the newspaper. 18% of overall visitors were referred by a local visitor's center. Across both 2008 and 2009, 19.7% of visitors were referred by a local visitor's center, accounting for 18% overall. The least effective marketing technique appears to be the TERC website only bringing in 3.1% in 2008 and 6.6% in 2009 and 4% overall.

Age of Visitors to the TJLF Education Center

Visitors 50+ in age, represent the majority age group who visit TJLF Education Center accounting for 51% of overall visitors. In 2008, visitors 50+ in age represented 49.2% of visitors, while in 2009, it increased to 54.9%. Visitors age 26-50 made up our second largest age group accounting for 33.6% of visits in 2008, 24.1% in 2009 and 30% overall. The 18-25 age group was the third largest group to visit the center. We saw an increase from 5.3% in 2008 to 11.1% in 2009, and they accounted for 8% of overall visits. The youngest age groups, under 12 and 13-17, accounted for the least amount of visits according to our Visitor Exit Survey. The Under 12 age group accounted for 6.9% of visits in 2008 and 4.9% in 2009 while the 13-17 age group represented only 5% in 2008 and 4.9% in 2009. Overall, the Under 12 and 13-17 age groups each represented 6% of overall visitors.

Resident Status of Visitors

Overwhelmingly, visitors to the TJLF Education Center are visitors to the Tahoe Basin as well. In 2008, visitors accounted for 76.9% of site visits, 76.3% in 2009 and 75% overall. Part-time residents in the Tahoe Basin accounted for 14.5% of visits in 2008,

15.6% in 2009 and 16% overall. Full-time residents make up the smallest percentage of site visits. They represent only 8.6% of visits in 2008, 7.1% in 2009 and 9% overall.

Homeowners within the Tahoe Basin
Most visitors to the TJLF Education Center do not own homes within the Tahoe Basin. In 2008, 83.7% of visitors did not own a home within the Tahoe Basin while the numbers drop slightly to 83.1% in 2009. Overall, homeowners within the Tahoe Basin represent only 18% of visits while those who do not own homes within the Tahoe Basin account for 82% of visits.

Were any of the exhibits confusing?
Overall, 2% of visitors have found some exhibit confusing however, we have continued to improve our exhibits with 2.5% of visitors finding an exhibit confusing in 2008 dropping to 1.2% in 2009.

Exhibit Ratings
Visitors of the TJLF Education Center continue to give high ratings in effectiveness of the exhibits. On a scale of 1 to 5, 1 being not at all effective and 5 being very effective, visitors rated exhibits with a score of 4.66 or higher. In 2008, the R/V John Le Conte Research Vessel exhibit averaged a rating of 4.73 and 4.66 in 2009 with an overall average rating of 4.59. The virtual lab exhibit increased average effectiveness from 4.68 in 2008 to 4.71 in 2009 with an overall average rating of 4.55. The 3-D visualization also received high marks of 4.79 in 2008 and 4.68 in 2009 with an overall average rating of 4.66. Visitors who took the Green Building Tour had an average rating of 4.73 in 2008 and 4.74 in 2009 with an overall average rating of 4.58.

Effectiveness of the TJLF Education Center
The overall effectiveness of the center to educate visitors about Lake Tahoe, its formation, environmental threats and current research projects has increased over the past two years as well. In 2008, visitors rated overall effectiveness of the TJLF Education Center as 4.51 out of 5. This rating increased to 4.53 in 2009.

What did you enjoy most about the TJLF Education Center?
2009 excerpts of comments
“That is was free!”
“The research vessel – hands on and I could quickly grasp the big picture”
“Organization of the tour material and visual aids”
“3D room was great!”

2008 excerpts of comments
“The guide really enjoyed his work and it showed!”
“Both my six year olds and I enjoyed it all! Great combination of video and hands on”
“The combination of video with tangible items. The lab was cool!”
“The personal attention and explanations”
“It was all great! I especially enjoyed the simulation walk on the lake bottom”

“All three parts that we experienced were terrific! Lots of information at each station. My son who is 7 remained interested throughout.”

What did you enjoy the least? excerpts of comments
“Breakfast at the motel”
“Sitting in long meetings”
“When you had to put the black glasses on”
“I didn’t feel so well in the viz lab”
“Dizzying!”

Appendix B
Docent Focus Group Notes: October, 2008

The following are a compilation of notes taken by Steve Yalowitz and Heather Segale during the focus group. Some docents and AmeriCorps members who could not attend emailed their responses; these have been incorporated into the notes from the focus group.

During introductions we asked about the docents' general thoughts and impressions about the Viz Lab.

The general consensus was that the Viz Lab is very good; people find it interesting and enjoyable, and also entertaining. There were a couple of comments about it being entertaining and wondering if the entertainment value took away from the educational part, but there was no consensus on this.

- Good, but it could be better
- Not a very good opinion of it, will share why later
- Thought Viz Lab was great
- Enjoy it, different audiences like it the same, but some don't know about TERC
- Sometimes the technology doesn't work, but people love it, it's a good follow up to the other exhibits
- Nice to have a formal program like this
- Lot of fun, may not be as on message as other exhibits, maybe it's not so good at the end of the tour (are people tired?)
- Entertainment value is great, and visitors come away learning something
- Wonderful, entertaining and interesting
- Good way to repeat messages, resonates with people
- No problem with Viz Lab, speaks across generations
- What can we add to the visualization model? There are other models that we might use
- Have more hands-on type things, allow audience participation, particularly in the Viz Lab
- Maybe not so central to what I would be teaching people
- Popular, people don't want to miss it
- Kids and adults love it, with kids you can experiment a little bit. Like to give people different views, get color more involved, help identify some locations and features, learn as much from other docents, different people, what can we do to make it more interactive? Tough for people who drop in during the tour and

haven't gotten the first part. Involvement with the kids would be good. Some people come back, to bring others

- The Viz Lab is, almost across the board, the most popular exhibit.

What are the 5 key points to the Viz Lab?

During the focus group, people repeatedly mentioned the "5 key points" for the DEM. To clarify, we asked them what they thought the key points were for the DEM, and there was not a consensus on exactly what the key points were. Topics that did come up related to formation of the lake, watersheds, how pollution has and continues to affect the lake, and specific places that are opportunities to show these concepts. While there wasn't agreement on what they were, there was a desire for having an agreed-upon 5 key points.

  - How the lake was formed – geology (faulting, volcanoes and glaciers)
  - Concept of a watershed basin
  - Uniqueness of the lake because of the watershed (very clear/pure, size of watershed, nutrient-poor granitic soils, wetlands, we've added many things to the watershed) * Maybe easier to see at the wall map on the side
  - Water in the lake that is so pure. The type of water that is in the lake (doesn't need to be purified). Loss of certification if that changes, and the consequences of that. Truckee River is largest of watersheds feeding the lake, possibility of restoring that area
  - Wetlands (loss of wetlands from Tahoe Keys, not many areas around the lake available for wetlands)
  - Science that goes into preserving the lake
  - Lake has had problems in the past and recovered. Loss of clarity can be recovered. Some people question whether the changes are manmade and can be undone, but when recovered before there were no people, no development
  - Indicate pollution that flows into the lake (a number that we would have). For example, reduce 50%, so how much do we have to cut?
  - Go around the shoreline and point out that there aren't very many acres of functional wetland
  - Go to North end of lake, concentrate on all the roadways going halfway up the mountain, point out how brown it is b/c of soot and dirt
  - 15% of land is developed, but 15% is necklace around the shore of the lake and has biggest impact. Amount of road coverage and where it is [Tim Minor may have that visualization]

    - Impervious cover and sub watershed without impervious cover, show the difference between more and less developed. Can show plume of pollution based on rain and going down into lake.
    - How much is being preserved and how much isn't. How much is public development and how much is in land trust?

- Different audiences, how to reach tourists?

Suggestions for Viz Lab:

- Have water first, then take the water out. Would flow better.
- Show some of the types of fish, etc. or tree trunks
- Have pop-ups for the Viz Labs – Steve is working on that right now. Tailor the map with overlays.
- Need more visualization
- Have Bob narrate places in Tahoe on Google Earth
- Let's figure out how to reach tourists, and different audiences
- See digital elevation of Fallen Leaf Lake, Cascade Lake
- Turn on something that labels specific sites
- Would really like more content
- It would be nice if we had a simple, pretty rugged joystick that we could plug in to allow visitors to control the program themselves.
- The Viz Lab would be easier for younger students to relate to reality if they could see the waterline.
- Add a water level
- More realistic coloring, or coloring based on elevation so the topography is more apparent and appealing.
- Fix the "data anomalies" so people will stop asking about the huge pine trees.

Does the presentation vary depending on the docent? Does this matter?
Generally, there was not a sense that there is any problem with the fact that docents vary what they do and talk about during the tour. It was seen as pretty much just a positive. We should examine to what extent the variation affects specific objectives and outcomes of the program.

- There is no down side to it, is always unique. There are always different audiences you need to tailor it to them
- If you don't cover something they want they will ask questions
- Each docent brings a different perspective
- Each tour is reflective of the audience – they ask different questions
- Emphasis changes depending on visitor group

How does Viz Lab fit together with other exhibits?
The docents thought that the Viz Lab does a good job of fitting together with the other exhibits, and that it ties things together very nicely as a final station. There was some comment about people possibly being ready to leave when they get to the Viz Lab or that as the last station people sometimes lost interest. One docent raise the concern that if the Viz Lab is upgraded drastically then it may take away from the other exhibits – with people just wanting to see the Viz Lab.

- Fits really well, first talk about it, then can see how it fits in. If people join at the Viz Lab
- Viz Labs ties it together – if starting view matched the Viz Lab. Need a visual reinforcement of our talking points
- One place where you can jazz it up, if you could show mixing
- If you start with the map, then boat, then lab, then Viz Lab allows you to connect all these

What is working well in the visualization lab?

Docents really like the flexibility of the visualization, the fact that they can respond to visitors' interests and questions, and that it's not canned. Some specific areas (River Canyon, General Creek, Emerald Bay, Sand Harbor) were mentioned, as well as features of the visualization such as being able to fly through areas or go to a peak and look back or down at the lake. It was also seen as being able to demonstrate features of the lake like faults, the bottom and debris from the landslide. It is generally seen as a useful tool that for the most part works well (one exception is when the technology doesn't cooperate).

- Basic presentation
- Curtain is awesome
- Interactive part, can respond to questions well
- Intimate setting, they can react, easy to ask questions
- Can stop and address something that comes up, not a canned presentation
- Very flexible
- Novelty, it's something they've never seen before
- 3D glasses
- Unusual that you can see basin without the water
- Depiction of the debris from McKinney Bay landslide
- Emerald Bay, to be able to go in there is neat (although there's a gap that gets misunderstood – it's an artifact of the program)
- Can fly through the mountain and the rock – kids really enjoy this
- Can see roads and urban areas, show the development (could even be enhanced)
- Truckee River Canyon
- Shallow depths, magnitude of the lake
- Can see the lake without the water

- Witell (mansion) – preserved entire shoreline except for Incline Village
- Sand Harbor
- Get to see the 3D video of Lake Tahoe, exaggeration is helpful to point out specific geological points
- In general students respond very positively to the visualization, although there are few places where students ask questions.

Criticisms of the Viz Lab (comments at various points in the conversation)

- Technical difficulties – it is not always working
- Huge difference between what individual docents say and show
    - Need handful of issues that we touch upon (main talking points)
    - Shared discussions
- Is Earthquake Viewer connected… does it really add anything?
- Shallows (LIDAR) data missing
- Data anomalies cause confusion
- Noise problems
- Exhibits are not working

VISUALIZATION LAB - USE / REACTION

- Used by highly educated people (generally), museum-going visitors
- Can get nauseous with the movement.
- Very important to be able to tie in what it looks like from the top to underneath

What do you think people are getting out of the visualizations?

Docents commented about how unique the experience is, and that visitors may not be aware of the amount of work that goes into this. It was also seen as a place to learn about the lake and how it was formed and that people are working to understand and conserve the lake.

- There is technology that exists that can map a lake and surrounding land in this manner
- How much of an impact the small group of people working on this is impacting the lake. Realize information and research can help preserve
- Is something memorable, can picture what it looks like and will take that with them when they leave
- Is unique – never had people say they'd seen something like that before
- Mystery of the lake revealed
- Learn some geology
- They're connected, Lake represents how we are affecting the environment – documenting what we're doing, our impact

- Can tell which desert residue in Lake comes from, how particles from far away are making it to the lake
- Personal connection
- Clean Water Act, see where some of the money is going
- Sense of place – best way to orient people in space
- Air quality
- Tahoe is a deep lake, natural occurrences, watershed and working to protect the lake

Are there any specific pieces of information you think most people are coming away with? What should they come away with?
Comments from docents focused on showing visitors features and then explaining how they came to be. For example, docents thought it was important for visitors to see and understand faulting, sediment, shelves, glacial features, etc. There may be an opportunity to tie these in more specifically to outcomes; that is, talking about why understanding these features is important. Perhaps this is already occurring, but the focus in answering this question was more about what they were showing visitors rather than why the information is important to understand.

- Sediment at the Bolt, don't visualize sediment at the bottom of the lake without the model
- How deep the lake is, the sense of it
- Faulting
- McKinney landslide, and that it can happen again
- Showing the shelving – people don't understand how cold the lake can be, shelves are warm b/c shallow, but 50 ft.
- Steep drop-offs
- Depiction of Emerald Bay, see that and compare it to cascade and fallen lake (being similar geologically)
- How the glacier formed the lakes
- Hanging valleys
- Contrast the Carson range and Sierra range – glacier vs. not
- Sandy beaches on east side but not on west side
- Tahoe has faults; there was a landslide and tsunami (which could happen again); the world has a lot of earthquakes.
- Certainly the extraordinary size of the lake tends to stick with people, as well as the seismic information from the faulting under Tahoe.

What are the most difficult parts to talk about? Which are the most challenging concepts for people to understand?
There were not that many issues that came up, but some focused on looking at the impact of humans and urban development on the lake. There seemed to be a desire to

show and explain how that happens. Also, without the water in the model docents find it difficult to talk about the impact of pollution and other factors on the water quality of the lake.

- Graben faulting
- Anything to do with the water, like mixing, since there's no water in the map
- Identifying the shoreline when looking at the map (because the water is removed), maybe use color coding to do that
- Effectiveness of marshes and wetlands to take out nutrients
- Effect of urban area, non-urban areas on the lake
- Marking out the watersheds, showing what a watershed is (sub watersheds)
- How the west shore is glaciated and the east shore isn't
- Vertical exaggeration
- Understanding what they're looking at
- Why isn't East Shore glaciated? (Reshadow effect process complex – would require the right tools to describe)
- The "what can you do" part
- Geologic time, talking about things that happened so long ago
- Sometimes trying to explain the different geologic processes that formed Tahoe is difficult. We can show people the results of those processes with the DEM, but not what actually happened.
- Time scales on which the geological events are happening

How do you know visitors enjoyed the tour? What are the indications that it was a successful tour?

Engagement was a big theme – if visitors were asking questions or sticking around after the tour to talk or look at the exhibits, this was an indicator of success. Verbal feedback, like comments about how much they enjoyed the lab/tour, as well saying they were going to bring people back or recommend to others that they visit.

- Those that ask questions
- If not excited, do some barrel rolls
- When they have some familiarity
- You're giving them information they can't see anywhere else
- Linger afterwards, ask more questions, go look back at geology map
- If they stay longer than they said they had
- Say that was really great, learned so much, recommending a visit (Net Promoter Score, www.netpromoter.com)
- Top handful of places to visit in Tahoe
- When a visitor asks "What can I do to save Lake Tahoe?"

Key questions to ask before the tour:
There were a handful of questions that people ask before the visit, but in general docents thought that gathering feedback to tailor the tour and Viz Lab experience was ongoing. They used a variety of ways to figure out how to modify the visit to make it the most engaging and enjoyable one they could.

- Where are they from, have they driven around the lake, particular interests
- How much time do they have?
- If they're a tourist, where are they staying?

General comments/requested improvements about the EARTH VIEWER AND EARTHQUAKE
95% of the conversation focused on the Digital Elevation Model, but there were a few comments about the earthquake model. One docent uses that to take it from a global to a local perspective, and the other docents thought this was a good idea. Some docents said they rarely used this visualization during tours and spent all their time on the DEM.

- How does the earthquake tie into the other things, it's global
- Was a little hard to figure out how to use it, so it's underutilized.
- Drill down from earthquakes, then focus on Lake Tahoe. Try to connect earthquakes to the lake itself
- Need different laser pointer so it's not showing through to the back
- Could change transparency
- Alternative globes
- Easier to use mouse
- How to tie this demo into what we are doing here?
- Link the two visualizations… go from earth and zoom down to Tahoe earthquakes
- Need Lake Tahoe earthquakes to DEM for connected the two visualizations
- KECK cave direct interactive style?
- Add small images, cartoons, photos (glaciation maps, graben faulting model, rain shadow model)
- Selectable overlays (roads, development/impervious surfaces, glaciers, depth, zooplankton, fish, etc.)
- Hard to use the laser pointer, to show if you're talking about front or back part of globe
- Font is hard to read
- Finding areas with largest earthquakes, unless you know where to look
- Visitors really like the earthquake model. I usually get more excited comments (like "Neat!", "Cool!" "Whoa!") for that one.
- Most adults have at least heard of plate tectonic theory before, and most school groups seem to have at least touched on it before.

General comments/requested improvements about the DIGITAL ELEVATION MODEL (DEM)

- Sometimes there is some disappointment with seeing the lake itself, it's only a bunch of rocks there. They may want to see more fish and animals.
- Three criticisms: 1) technology, using the stick, 2) huge difference between what docent A and docent B are talking about, 3) know going to do earthquake, tend to cram and hurry the lake visualization
- Comment about dry lake viz, bringing everything together. Problem is that the dry lake viz doesn't show the problems that are occurring. Showing color, that could show contamination – turning black, green when you have pollution effects
- More watershed labeling, labels that kind of hang in space because the water's not there. Talk about overturning, the mixing.
- Could there be a hydrologic component, where it shows the effect of rain on the lake?
- Not much for young kids (7 or younger)
- Need to be able to tie in what you see on shore with what is down below
- Hard to use the joystick
- Fix data anomalies ("Transamerica Building") – they are distracting
- Water in the lake
    - Provides context
    - Can show various lake levels
- Vertical exaggeration – toggle through various vertical exaggeration
- Modify shading/fog settings
- Names of places (pop-ups) - How to identify locations (press a button for id)
- Need to reinforce visually the wall map starting point (start at overview of Lake Tahoe)
- Need visual reinforcement of our talking points/structure
- Show other pictures/features
    - Sunken boats
    - Show fish
    - Tree trunks
    - Tahoe Tessie
- Show color to show pollution (lake turning green or brown)
- Watershed labeling
- Stream flow
- Stratification
- Show mixing – what would happen with climate change
- Where is algae? Where is zooplankton? Where are the fish? Any sunken boats?
- Animated creeks
- Tahoe Basin earthquakes & animation
- Color corrected
- Enhance road grid to show impacts (Tim Minor of impervious coverage)
- Visitors find the Tahoe DEM very interesting, but not necessarily exciting, unless you are flying through a mountain or doing barrel rolls.

- I'd love to have a program that shows those changes happening over time. I don't know if visitors understand what I am trying to explain or not.
- Getting used to the joystick and moving around is the most challenging part. Also, knowing where you are in Tahoe and what features you are looking at.

Docent Manual/Training Improvements

- We learn mistakes from each other
- Need to recalibrate among docents
- If docent goes to fast, can get motion sick
- Ask three key questions (how much time do you have, where are they from, have you driven around the lake, etc.) to refine tour
    - How much time do they have?
    - Where the guests are from?
    - Have they have driven around the lake?
    - What are their interests?
    - Ask them if they would like to move on…
- Performance values – trying to win over non-interested visitors
    - Historical information
- Don't forget about the Demonstration Garden or Creek
- In my limited experience running the lab it seems that people tend to interact when the lab is begun with introductions (where is everyone from? Have you spent any time here? If so what did you do in Tahoe? As well as a self-introduction).

What to do with kids?

- Shorten tours
- Crayons and coloring books
- Puzzles (large floor map puzzle – watershed, fish)
- Other activities?
- Start a fund for small kids activities

Appendix C
Student Focus Group Notes: March, 2009

FOCUS GROUP #2: 6th grade students (Used Joystick):

1. Reaction to Program – Lake Tahoe 3-D Visualization

2. Like about Lake Tahoe
    - 3D – gave more of a reality, looking at the world
    - It was 3D, wouldn't have it if it wasn't 3D
    - Felt realistic – should have motion seats – rock side to side
    - Fun – was 3D and closer you got to touching it, the farther it would get away

3. Never knew that…
    - I could clap
    - That there were so many earthquakes
    - Big chunks at the bottom were sediment,, thought they were boulder
    - There were so many earthquakes and that they went that deep into the surface
    - The water level was so low for a while

4. Someone from audience using the joystick
    - It was fun
    - Should make it be a plane, transforms into a submarine
    - Hard at first
    - Kept crashing
    - Graphics could be better, have trees, roads, colors
    - Kind of just grey, more color, have cars driving by
    - More fun watching someone from the audience
    - Might not learn as much – but she could tell you where to go

5. Suggestion: mimic west shore falling into the lake, see the tsunami

6. Animation –
    - Glaciers coming down and receding too
    - How low the water went in the lake
    - Buildings and trees to see what the tsunami would do
    - Mount Rose exploding

7. Suggestion: Border between water and land needs to be clearer

FOCUS GROUP #3: 6th Grade Students (Did not use joystick)

1. Prior visits to TERC (this may not be relevant to some groups)
    a. Have you been to TERC before?

    Only 2 of the participants had been to TERC before, 11 were visiting for the first time

    b. Expectations (those who hadn't been)
        - Boring, it would be just talking about things
        - More museum-like, just walking around looking at pictures – it's much better than that, more fun, like watching the 3D globe
        - Boring and just talking the whole time, someone talking to you
        - It's better because it's more interactive, way more fun, especially the 3D
        - Thought it would be a museum, ,thought the little ship display in front was cool, to see the disks and then you went to the next thing and it was something interesting

2. Reaction to today's TERC visit

    a. Favorite thing:
        - Go on the plane thing and crash into the ground
        - Seeing the plankton – the real plankton in the lab under the microscope
        - How it was 3D instead of just a boring video, it felt like you were there
        - In summer I've seen the red things floating in the water, so you were learning a lot of things from before (the visit)
        - The plane thing [Lake Tahoe visualization], looks like you're actually doing it
        - The boat because you get to see what they use to look for changes and stuff
        - Boat, but the video would be cooler in 3D so it felt like you were on the boat
        - Learning more about the watershed and Tahoe because I didn't know that much
        - Boat and the lab, but it would be cooler if they had the little screen in the lab in addition to have the talking person [like they have for the boat – screen with person + screen showing different graphics/video]

    b. What would you say TERC does?

- Environmental research center of study and learn about clarity of lake, depth of the lake, learn about the lake
- Learn about earthquakes, faults and plates
- Field trip about the lake and the birth and the tectonic plates
- Gives you an idea of what the scientists are doing, shows examples of lab and boat, and learn what they're doing and how you can help them (tells you how much it matters)
- Environmental center that tells you about and does experiments about what causes the lake to lose clarity or stuff like that
- Talk about the lake and what's affecting it [Follow-up question - What is affecting the lake?]:
    - Runoff and soil
    - You can't see as far down in the lake as you used to , used to be 100 feet, now it's 70 feet
    - How there are new animals introduced to lake and that didn't help
    - Invasive species are starting to take over a little bit, like trout
    - How the shape of the lake has changed

c. Thinking about today's visit to TERC, please complete the following sentence. "I never knew that…"
    - We had plankton in our lake
    - There were so many earthquakes around the world
    - So many invasive species
    - 3D could make you so dizzy
    - The clarity of the lake was decreasing so quickly
    - Deepest part of the lake was 1,644 feet
    - The big bay on the west side used to be land but then an earthquake came in and it sank in and that's why it has that bay
    - If you stand by Calneva and you kept walking it would drop like that
    - Scientists used specific tools to measure the clarity of the lake
    - Scientists used a simple white disk to measure the clarity [of the lake]
    - Since they wanted to study the plankton they took it out of the water
    - There was an incline, like a fault
    - There were three ridges by Tahoma and Emerald Bay
    - The west shore was the only shore that had glaciers that were carved out

d. TERC tries to explain some of the science behind the lake and how it works. Which parts do you think it did a really good job explaining?

- Earthquakes
- Clarity of the lake
- Work in the lab – the second one, with the plankton [how they do the research]
- How deep the lake is
- The tools that they used to test the lake

e. Is there other scientific information TERC could or should be explaining?
   - How Lake Tahoe formed
   - Didn't cover how much water was in the lake – it's up to your knees if it covered California, so what's the difference between 2 feet and 6 feet
   - For the "covered in water part" California's not flat so what does that mean for valleys and mountains? Would the mountains be covered in water?
   - What about the other lakes in California? Would they be included?

3. TERC and families

   a. Would you come back to TERC, outside of a field trip?
      - Maybe with family, but not with a sports team
      - If I were a tourist would want to come here and could learn a lot about Tahoe
      - While you're here, how you could help the lake, even if you're just here for a week
      - ??What kind of new things (let us fly!!!!)

   b. What do you think your friends could learn from visiting TERC? *[Probe: What can you learn here that you can't learn at other places?]*
      - They'd learn the same things we would [mentioned above]

4. Reaction to Program – Lake Tahoe 3-D Visualization

   a. What was the point Lake Tahoe visualization:
      - To show the depth of Lake Tahoe, what was there, how it was formed, what was not there when it started [e.g., mountains, features]
      - To show that there are faults in Lake Tahoe, the drop-offs, some of the earthquakes, rocks at the bottom of the lake
      - To learn about Lake Tahoe, you should have showed how the glacier did it

b. One suggestion someone had for improving the visualization was to have someone from the audience use the control to fly around the lake.
    - Have everybody get their own screen
    - Groups could do it, everyone takes a turn
    - Have somebody do an example, for water clarity could have a little lab
    - At the end, do a review where she [docent] chooses one person to find the McKinney Bay, person has to find it
    - Maybe half the time is the audience flying it, half the time the docent

c. Specific suggestions:
    - Have one model with water and one without
    - Put houses in and see how it affects things in the lake
    - On Lake Tahoe, have different colors for how deep it is
    - Have screens on the side, or wrapping above your head, and it would be like you're actually there (to make it seem more 3D)
    - Add color instead of having everything all green and brown – color the lake blue, shoreline (was hard to figure out where the shore line was), mountains have green and white on top
    - If you put water in you should be able to take the airplane underwater
    - More animation [Follow up question – what should be animated?]
        - See the glaciers and lateral moraines form
        - See the bay crashing into the lake
        - People and what they're doing at the lake (throwing trash, things like that)
        - How the color of the lake changes over the years
        - When it rains, how the sediment goes down and where it goes
        - How the marshland turned into Tahoe Keys
        - See people putting non-native animals in and a lot of fish and someone fishing
        - Boats in emerald bay
        - She [Heather] said there was one plant introduced in South Shore, show how it spreads throughout the lake

d. How would including animation help you learn:
    - When you watch the animation it makes it more interesting and you actually want to learn

- Would help because then you could see all the fish and how it's really affecting us and you would want to stop it. You'd see it and want to stop what you're doing so your trash doesn't blow out into the water.
- If you know where the shoreline is then you could really see how deep the lake was. When I looked at it I thought that the mountains were really tall, and sticking out of the lake (thought it was still in the water)

5. Earthquake visualization feedback:

    a. Never knew that…
        - That there were so many earthquakes
        - Some random earthquakes, not in chains
        - The thing that measures earthquakes was introduced in 1963 but before there were little dots and all of a sudden everybody knew, was a lot different

    d. Suggestions for the visualization:
        - Should point at it with her finger or a stick, laser doesn't work
        - For pointer problem, you could make it darker in the front so you can't see the back as well, then have the back part turn darker when it comes around front
        - The menu on the side, hurt my eyes, there was a red line that popped out and hurt – it looked better farther back
        - When you show outer core and inner core have it be different colors, like orange and yellow
        - Show a really big earthquake, emphasize the bigger earthquakes
        - Have a legend to tell what magnitude it is – she told us the colors for which magnitudes but then I forgot what they were

FOCUS GROUP #4: Youth Science Institute Program

1. Prior visits to TERC (this may not be relevant to some groups)

    [Program involves multiple visits to TERC, so all had been to TERC before and were more familiar with TERC than your average group]

2. Reaction to today's TERC visit
    a. What did you like?
        - exhibits were lifelike (people talk to you),
        - how it's environmental,
        - programs for high school students (N. Tahoe doesn't have a lot of science classes),

    b. Visual learning, why it's better –
        - definition of something,

- learn if you see it,
- things in school, doesn't feel like a class,
- is more engaging,

c. Different topics -
   - comparative planetology,
   - boat – go out in the boat,
   - Secchi disk,
   - to learn about where you live,
   - observe the lake,
   - everything here is more in-depth for a certain subject (school is broader, doesn't go into as much depth);

d. Misc. comments
   - Teachers here are more engaging,
   - Their tone of voice, love for subject , etc. and this affects the experience.
   - There's no homework;
   - they want to be in the program and want to set it up, not just here for the money, to teach you new experiences;
   - know what they're talking about instead of reading from a book
   - Science expo – see same exhibit, got to teach little kids and they were interested, to see their faces light up when you did something

3. Reaction to Program – Lake Tahoe 3-D Visualization
   a. On a scale from 1 to 10, where 1 is poor and 10 is excellent, how would you rate the 3-D Visualization about Lake Tahoe? [For each person, if 9 or lower] What would make it a 10?
      - 8 or 7 (makes me feel sick a bit),
      - 7 or 8 (makes a little dizzy, make it like in the astronomy lab, could see things that were out there),
      - 6 (smoothing out the turns – a little bland looking, features be more distinct, see cities as different colors), water option, could see through the water – make the water semi-transparent; show the cities, 8 (show features and colors),
      - 7 (like changing the exaggeration, give an explanation – cool to animate a small earthquake, when it dropped, etc., have a pop-up of animation or movie),
      - 8 (no labels and colors),
      - 8 (color, would be easier to see where the shore line was),
      - 8 (reference points more helpful, more distinct features),

- 8 (bland, cruising to bottom of lake tahoe is cool, crash sequence at end), 7 (same reasons, like transparent water, labeling colors, exploding plane), 8 (animate the glaciers, forming of emerald bay),
- 9 (simplicity compared to earthquake, not as confusing – if features were added, important to be able to add and subtract them),
- 7.6 (should be a special color instead of a water line, special color for land that is covered with water, special color for beaches – sandy color. Color for water should get darker blue as it gets deeper, green for trees, label mountains, boat or person so you can see the scale.

b. [Controlling it yourself – set some ground rules for controlling, it's a privilege to do it [they liked the idea of controlling it yourself but thought there should be some ground rules. Just letting people do it on their own didn't make sense. And that it should be maybe the last 5 minutes so the large majority of time it was mediated by a docent]

c. Suggestion for younger kids – have cartoon characters.

4. Earthquake visualization rating:

- 9 (laser hard to know where it was),
- 9 (confused about how earthquake set up, hard to distinguish colors – different sizes), 8 (glasses headache),
- 8 (distinguish dots),
- 9 (catches eye and keeps eye),
- 8 (looking for magnitude 8's, could see through to other side a little confusing),
- 9 (hard to distinguish continents),
- 9 (color of dots hard – liked how earthquakes lined up with plates),
- 9 (different sizes),
- 9 (continents more distinct),
- 9 (should be able to show the color of the dots),
- 8 (presenter in front of screen instead of behind, also points of reference for cities, as an option; liked the depth and being able to turn it),
- 9 (green and yellow dots alike). Could zoom on different parts of the planet.

FOCUS GROUP #5: College Students

Focus groups:

1. Prior visits to TERC (this may not be relevant to some groups)
    a. Have you been to TERC before?

        1 yes, 6 no

2. TERC and Engaging College Students

    a. What do you think TERC could do to get them to visit?

        - One student goes to TERC to use the lab to show incoming students. Students from around here like the 3D visualization of lake; explaining the biology section
        - Incorporate with future student tours or orientation – talk about watersheds
        - Thought there were scheduled times, but always kids in here
        - Advertise a little more
        - Connect with SNC teachers, like helping with Expo
        - Offer extra credit for students to come
        - Inform kids that TERC is here
        - Communication:
            - School paper
            - School web site
            - One of the sandwich boards – right outside the building, on the walkway
                - By the library, like for Pete's
            - Mass email
            - Sandwich board just for UC Davis
            - Guest lecturers coming to c lass
            - Have it be a part of class
        - Awareness:
        -
        - Allow individual classes (Environmental Systems, for example) to come and do a tour-

    b. Additional engagement opportunities:
        - Possibly as docents
        - Mornings, once a week have big groups of kids
        - Put board with events in area down here – here are opportunities in environmental science going on around the lake

- Open lines of communication between TERC and Science Communications

c. Monthly lectures:
   - Wed. evening time slots, timing is challenging
   - Topic: why it's a weird winter
   - Topic: anything environmental, conservation side of treating our earth well, incorporate that into what we've done with the building
   - Put out more that we have them, make it an event and put it on the sandwich board

d. Feedback about sandwich boards
   - Too much going on
   - Have a simple one announcing programs that day or week

3. Reaction to Program – Lake Tahoe 3-D Visualization

   a. On a scale from 1 to 10, where 1 is poor and 10 is excellent, how would you rate the 3-D Visualization about Lake Tahoe? [For each person, if 9 or lower] What would make it a 10?

      - 6 – content is good but color is quite dark difficult with eyes
      - 8 – color, not too much color b/c it would distract, but just being brown/grey it was blah, talking about glaciers if could put some labels – not all the time but could activate them
      - 7 - could be more color, not bright ones but lighter blue for lake – funny to see Keys but nice to see where the shore ends, even where watersheds are, going slower would be good – getting a little nauseous, a lot of good information; like the exaggeration
      - 8 – very nice but a little confusing where earthquake was pointing
      - 7 – really awesome idea, how you could drive around look at it in real time with no rendering, but the basic fault lines are there but nicer to have more detailed graphics, some landmarks, identify things around the lake
      - 8 – color, no graphics, labels, rock type, also if elevation wasn't so profound; topographic lines to label elevation
      - 7 – a lot said, but more layers: road, stream, vegetation, would be really cool – historical overlay for glacial, forming of lake, make it 3D, build Tahoe 3D like the earthquake – learn visually so this is great

- 7 – nice to have color gradation to indicate depth, desolate wilderness areas – may not need as much exaggeration if you have colors to help – have a glacier animation; tsunami in 3D, show it happening; for human development show different ski resorts to engage people, even a blue sky
- 7 – color kind of flat, not from here so hard to tell where we're looking at – labels would be good; a you-are-here when you start would be good

b. Please complete the following sentence about the visualization. "I never realized that…"

- Upper Truckee river was responsible for so much sediment, so much transport
- How big the upper Truckee wetland or watershed was – edge of the earth was the Truckee outlet
- There was a problem with the wetlands in south lake, Truckee river
- Was freshwater tsunamis – seems like a really hard thing to create
- There were some small lakes near lake tahoe
- The deepest part of the lake was on north shore
- McKinney bay was formed by a landslide
- There is a place to see two different lakes at the same place – makes me want to go there
- There were rock projections going out from the lake (bottom of the lake)

c. One suggestion someone had for improving the visualization was to have someone from the audience use the joystick to fly around the lake.

- Maybe after the presentation – would be fun to show people
- 3 minutes, 5 minutes – would just be reckless
- See if get to a certain reference point: your house, glacier, emerald bay, big landmarks

Earthquake Visualization

a. On a scale from 1 to 10, where 1 is poor and 10 is excellent, how would you rate the 3-D Visualization about Lake Tahoe? [For each person, if 9 or lower] What would make it a 10?

9

8
9 – stop or slow it down to present certain things; more time out to ask what want to see – with northern hemisphere
8
8
7 -
7
8
9 – decrease transparency when pointing to certain areas

b. What did you like?
   - Tsunami at the end – seeing where it was in Thailand
   - Going through time and seeing the earthquakes
   - 3D –
   - Fact that you could turn the whole world upside
   - Gave you rough approximation of where epicenter is
   - Have a key or legend at bottom of corner

c. I never realized that….
   - Everywhere got seismographs in 1960 and once they did and it showed it for atomic bomb detection
   - There were so many earthquakes around the Himalayas (I'm from there)
   - There is such a great difference in the number of earthquakes as when plates are converging vs. separating
   - Connection between atomic bomb and earthquakes

d. Suggestions for improving:
   - Legend about magnitude of earthquakes
   - Point out some of the significant, historical earthquakes (like Loma Prieta, 1962 Alaska Earthquake, SF)
   - Here are the red dots only
   - Heather: start with red dots, then build from there. When maximize dots, resolution is bad
   - Don't like the transparency, hard to figure out

e. Use other visualizations for the globe:
   - Deforestation
   - Ice caps
   - Carbon emissions

- Development timeline (for earth and also tahoe)
- Volcanoes on the ring of fire
- Population
- Maps of lights

4. Overall comments on visualizations –
    - Cool medium, wanted more – overlay on the 3D DEM, see the streams, see the roads – could do some really cool watershed
    - Could look at development
    - Helped a lot with the earthquakes, could see how deep they were, a big improvement over t.v.

Appendix D
Community Focus Group Notes: August, 2009

FOCUS GROUP #6: Local Environmental Agency Staff

Agencies

- California Tahoe Conservancy – work closely with TERC on research and research findings. Worked on interpretation
- Tahoe Resource Conservation District – work on Asian clam and boat inspection, work closely with TERC. Creating same messages
- Nevada Tahoe Conservation District – storm water monitoring and research
- Forest Service – Taylor Creek visitor center, conservation programs, school field trips; summertime visitors (don't really send visitors here)
- Tahoe Resource Conservation District – storm water on private property, installing BMP's at fish hatchery; water clarity and quality
- Tahoe Resource Conservation District – education and outreach, water quality
- USGS Nevada Water Science Center – studies dealing with water quality
- Forest Service – Taylor Creek Visitor Center director – conservation education during the year
- California State Parks – recreational access at lake shore, interpretive programming, guided and self-guided, educational exhibits; one exhibit at Sugar pine Point, junior ranger program
- Visitor Center – send visitors over
- North Lake Tahoe Chamber of Commerce – want to get more people at TERC, getting front desk people excited about the program; bus field trips
- Nevada Division of Environmental Protection

Overlap with mission (1g)

- Changes in seasonal personnel, getting them trained with adequate information; weakest in natural sciences [OPPORTUNITY FOR TRAINING]
- Seasonal summer staff up at TERC, thought it was valuable, can continue doing it
- Provide a takeaway – something printed
- Small laminated card stock, durable, could go in and out of a pocket
- Weekly publication, a section about the history of the lake
- Sky Journal – could do something in there
- International visitor center are looking for the nature-oriented things to do, get them more information
- Coordination with school district curriculum needs
- More technical side, TERC could host groups for information exchange
- Agencies could use TERC as a place to communicate the science information out to people

Suggestions for adding topics (3h)

- What people can do to keep Tahoe blue
- Visitor-friendly information about personal responsibility. Two tiers of audience:
    - Residents – how to do their gardens
    - Tourists – do they not realize
- Residents who are second homeowners, hard group to reach, an in-between group
    - Lots of them have no avenue for reaching them, even for critical things like defensible space – they're a real challenging group
- At Rainbow Trail we ask them what they can do with water – have a brochure we can give them. Something people can ask for. So something for how to protect Lake Tahoe
- Connection between Tahoe and their local watersheds
- Heather – some of the materials could be developed collaboratively, so we're all handing out the same thing
- Include the positive things that are going on (e.g., forest restoration, boat inspections) – to leave TERC on a positive note would be great
- You need a theme/main message that's stated before you come in, in entry, in exhibits – should be throughout. Should be what it is you want people to say. One thought, one sentence.
- Girls in science curriculum or programs

What is unique (3f)

- There's a real neutrality – research for research, describes what's happening
- Wall of photographs of people doing science now – exhibit could be improved by including videos or a slideshow that shows different phases of the research (e.g., Scott in the stream at General Creek, here's General Creek at flood stage, blurb about what Scott does, etc.). Do this as a student intern project, or AmeriCorps

Way to get more residents here

- Signage – hard to find building
- Parking
- Outdoor something – easy to access, gardens
- Second homeowners are a tough crowd. They come here and they have their typical things that they do (golfing, gambling, etc.). You need to develop a secondary thing – festival, something like that to draw them. Something to get them excited and plan something ahead. Maybe one day a year in the summer
- Set up for groups, not so friendly for drop-ins. If local visitors drop in, will there be someone there to take them through or will they have to wait?
    - Suggestion: for drop-ins you can have some exhibits that are self-guided
- Get in touch with the local homeowners associations, organize it so you're not trying to target individuals. Put it in newsletters
- Certain tourists and visitors won't be interested

    - Families with young children or teenagers, those who are visiting the historic sites
- Audio tours
- What is your mission – what are you trying to accomplish? When try to broaden your appeal you may dilute your purpose.
- Lecture series does draw local residents, that's great
- Should you allow it for private events?
- Have actual fish in an aquarium, or Asian clams, or milfoil – that would keep my interest until the next tour comes around
- Web site with more engaging content, downloadable material. Pre-visit information
- Audio files for iPods/MP3's, so could put together self-guided tours pre-visit. Small photographic images and blocks of text
- Some kind of a live feed, to the boat, something like that. Feed it into the schools, since no one has money for bus trips any more
    - Suggestion – could you get RSN to help with that?
    - Suggestion – pick one specific class, live feed, directly answer questions while they're looking at the resources
- Have a booth at various festivals

Suggestions:

- Sort of a museum setting, a drier thing, want something more exciting. Labs are great, but for a visitor on vacation they want something different
- Use technology that allows for more frequent updating. A geographic map and you could touch it and see a video – you can update things as they happen (e.g., videos of a fire)
- For an aquarium, have a local class adopt it

FOCUS GROUP #7: Homeowners

NOTE: This group is not representative of Tahoe homeowners in general. Almost all have connections to TERC: as collaborators, docents, volunteers, or one person on board when it started. Majority were also involved in or at least very aware of environmental issues surrounding Lake Tahoe.

- Tahoma – work with TERC, main campus of UC Davis
- 2002 full time, coming 40+ years, Nevada Tahoe Conservation District, Board Nevada Conservation League
- Lived whole life Tahoe City – environmental studies and biology, water quality, volunteered at TERC
- 6+ years, background in biology, worked for conservation district in BMP's
- 6+ years, engineering and data visualization
- 20 years or so, working geologist and geophysicist, environmental geologist, use science to make decisions

- Truckee 20 years, volunteer docents, taken tour groups through here, home school so it's a learning opportunity
- 9 years, south shore, background env resource planning, Tahoe Resource…, compliance inspector for building, running watercraft program at TMPA
- 20 years, work for visitor's center, send people here
- 10 years, King's Beach/Incline Village, hunger relief agency
- South Lake Tahoe, teach K-12, earth science classes, part of first docent training

Suggestions:

- Focus on Tahoe as an ecosystem – people may not remember the science, give people a primer on the ecosystem
- Find ways to take current information and take it deeper – aren't a lot of reasons to come back and visit again. It's one thing. Find ways to extend the information deeper
- Look at unintentional consequences and the lake

What is particularly relevant?

- Laboratory, Daphnia, ask questions about how to protect the lake
- Spend so much time defining and regulating based on clarity, opportunity to integrate all the impacts that affect clarity, things that get people who live here upset – it's an educational tool for connecting, what, why and how these things are related: place for community to come and gain information, get them to feel like a resource
- Forest health and defensible space are the top issues; maybe 10 years ago clarity was more important, but not as much now
- Thinning of the forest – example of creating a problem while we're trying to solve them – is very little understanding of the ecosystem; is a powerful place to have those discussions
- Sustainability – hard to get people to do their BMP's, people don't understand what that means for practical and user-friendly decisions. Resistance to maintenance would be a good topic.
- Need a cooperative endeavor, with diverse groups
- Consistency of information, repeating the messages in different places

Overall:

- Example how data used by scientists
- Wall space with a couple more flat screen t.v.'s – might work for some of the information

Digital Elevation Model suggestions

- Example of how the data are used by scientists (e.g., geological history of the basin). Show them how these maps are being used by scientists – take one little area
- Emerald Bay – vertical face that had sine waves on it (problem with stitching), showing it as a steep drop-off when it's not a steep drop-off
- Stuff around the Tahoe Keyes, dent there can distract – the distortion
- People like being able to see their house
- Don't need to know where they are, but some way to familiarize with location. Less energy figuring out where I am and more about geology
- Make the lake blue
- Buried forests in the lake
- Animation suggestions:
    - Formation from volcanoes that plugged it up
    - Mysis shrimp – show food column, how much it travels
    - Sediment coming in, follow it through
    - Invasive species
- Want to drive it myself
- Way to go in and have something could go and look at certain places

Why haven't people visited?

- Lack of awareness
- Don't know the building is here
- Timing – get them to visit in fall and spring
- Don't think of it as a kid-friendly place
- Expected to see a campus building (but it's very engaging)

What would increase awareness

- Identify specific people or specific groups of people
    - Service clubs
    - Residents
- Groups, have something to give them – ticket for something, get a free something that's meaningful
- Adult-level to give to take away
- Increase efforts on south shore
- Increase efforts on homeowners, second homeowners
- Direct mail – attractive enough, for something
- Focus on those 5 or 10

FOCUS GROUP #8: Spanish-speaking Residents

Notes from Spanish speaking focus group (conducted in Spanish)
August 28, 11:00 to 1:00

Información sobre como seria el lago si no estamos cuidandolo
En México, los lagos están destruidos, debemos hacer cosas para las cosas aquí

1.f. Ya que hoy estamos hablando en español, quisiera hacerles una pregunta sobre el idioma. En su casa, ¿cuántos de ustedes hablan español e inglés por igual? ¿Principalmente español? ¿Principalmente inglés? ¿Sólo español? ¿Sólo inglés?

4 solo español, 1 igual, 1 principalmente español (unas palabras en ingles con los niños)

3.d. Piensen en la visita de hoy e indiquen qué cosas conocían ya.

3di. ¿Dónde conocieron esas cosas?

No sabíamos nada
El barco, que está haciendo investigaciones, pero no sabían como

3.e. ¿Hubo cosas aquí que les hayan sorprendido? Si la respuesta es afirmativa, ¿cuáles?

El Secchi disk
Las algas en las piedras
Las algas, que necesitan quitar con un barco
Las especies invasores – que van a hacer con ellos?

4.e. A TERC le interesa mucho ser acogedor (dar la bienvenida), útil e importante para la comunidad hispana/latina aquí en Lake Tahoe. ¿Hay cosas que TERC pudiera hacer para que la comunidad hispana/latina lo visitara? (conceptos, actividades, festivales, otras cosas)

Publicidad en español (ingles y español)

- Periódicos - Bonanza
- Tiendas mexicanas, Raleys
- Invitaciones de la gente quien trabaja aquí
- Casinos
- En la iglesias
- Por correo
- Debe ser
- Cual tiempo – dos semanas antes

4.e.iii ¿Qué debería hacerse específicamente en el caso de las personas que hablan español? ¿Qué puede hacer TERC para acercarse a la comunidad hispanohablante aquí?

Human Resources, Tahoe Women's Center, Eileen?

SPANISH LANGUAGE DAY: Un Día de Hablahispana, es decir un día donde ofrece mucho en español, para las personas quien habla español – en septiembre u octubre

Sera el tour guiada en español, también comida. Cuales otras actividades deben incluir?

Snacks, comida no es necesario, pero snacks si.
Actividades interactivas (participación) – dibujar, hacer cosas
Didácticas –
Actividades sobre el agua, como mantiene limpio
Habla de las especies invasores– de donde vienen

Cual día? No domingo, tal vez sábado – el fin de semana es mejor? Durante la semana – cual dia? A que hora?

El horario – durante la semana por la tarde, jueves o viernes por la tarde (empezando a las 5)

TERC necesitara personas quien hablan español para ayudar con este día. Como debe encontrar a estas personas?

Estudiantes – del colegio, avanzados, unos de las universales
Voluntarios – en las universidades, reciben
Es una cuestión de la tener la información

Si unos de ustedes seria amables de ayudar este día deben hablar con Rachel.

5.a. En una escala del 1 al 10, donde 1 es pésimo y 10 es excelente, ¿cómo calificarían ustedes la visualización en 3D del Lake Tahoe? [Pregúntele a cada persona que diga 9 o menos] ¿Qué haría falta para que la puntuación fuera 10?

Todo dice 10, muy impresionante. Le gustaron ver el lago sin agua.

Mejorar:

- Muestra con agua y sin agua
- La carretera 28, otros sitios
- Hablar de las piedras de Mount Rose y porque las piedras
- No saben el lago bien y fue difícil saber donde estuvieron en la visualización

FOCUS GROUP #9: Tourists

9 Tourists (1 resident) – where from and what was relevant

- Orange County – 5th/6th grade teacher, interactives, plankton under miscroscope, the visualization
- L.A. – like the 3d visualization, saw discovery show called Draining the Ocean and discussion of underwater geology, reminded me of that
- Bethany Beach, Delaware – Tahoe is easy to do compared to challenge of Chesapeake Bay – worry about nutrients, animal waste, industrial waste, sewage, high level of nitrogen. Where is the money going to come from and how will that money be used – involved in this kind of thing seen things started and stopped, then been eased off from. Education is good but you have to know what's going to happen. Also view conflicts that take place between the environmentalists and economics – threaten stopping of harvesting, others need it to make a living. Need to find out who's going to be the referee – who balances all that
- Resident (friends of two tourists who came here) – learned that where I thought the deep part of the lake was is not where it is. Never realized it was right off of Stillwater Cove. Do you get a lot of tourists here? Is that your goal, to get people here? I didn't know you existed.
- South Florida – first noticed algae a little while ago, construction and architects we know are talking about it. Submarine photographs, would like to know where the fish are. Found it interesting – topography of the mountains, learning about the lake. Relevant – the pollution, that people can cause pollution so easily and the microbiology of it all. We live on the Intercoastal (waterway), used to be able to catch sailfish, our development of our area has caused pollution there. People don't think of swimming in it any more. How you introduced that little shrimp – they were catching the lake trout and they were killing off the cutthroat trout.
- South Florida – think of the Savannah River and the silting effect. Want to keep it clean and pristine. Introduce something to get rid of some of the fish or something, do experiments over the years. Don't like seeing what's happening down by stateline, we've been seeing it over 30 years. Hope things could be done a little quicker, protect some money for that.
- Hendersonville, N.C. – we have a lot of trout, water's pretty clear. Always heard about Lake Tahoe and the water's blue. First time seeing it, was impressed, could see the 3 shades of color blue – now understand it a little better. Didn't know it before – didn't realize all this was going on.
- Hendersonville, N.C. – been here about a week, around by car – helps us understand what we've seen.

- Bethany Beach, Delaware – think it's very well done. Somehow if you could just get it out to the public what you're doing. Think everyone around the lake would be interested.

Would all tourists be interested? Which groups of tourists would be more interested?

- Two types of tourists:
  - Have a main thing in mind – ski, fish, hike, gamble. They're focused on one thing and wouldn't necessarily be interested
  - Go to a place because lots of interesting things to do, one day go to one area, next day another. They would be more interested in a museum or science education center.
- Most people who come here would have to have some interest in the outdoors, water, fishing, boating, something of that nature. If you're coming to ski or gamble it's a slow day in hell before you get them over here.

Residents:

- It's 50/50, half of them would be interested and half not. Are lots of tree huggers. At least in our complex, we've gotten awards for BMP's, we all want to see it clearer. (resident commented)

Digital Elevation Model, improve

- Color – that is truly wild (3D image of Lake Tahoe)
- Put a compass to keep you oriented
- Labels of roads, show landmarks
- Do an overlay, don't want to ruin it as it is
- Make the lake blue, then have the water drain out (that's what they did in Discovery Channel)

Overall Tour suggestions:

- Something needs to be there to appeal to younger people, not just kids, like teenagers, college kids, maybe just seeing the water lower, animation
- More tech and effects
- Didn't understand why the globe was here, what relationship does it have to the lake, other than the couple faults
- Neatest was when you show the pier, the Hyatt, which should be enhanced – it was kind of grey. Like when you see a movie, and recognize the location, it means more.
- Key views, have a side monitor of what you're looking at – the actual picture of what you're looking at – that would have an impact because you can look at the other monitor and say "Oh, this is what that is." You can draw a connection between the two.

Why haven't people visited?

- Don't know about it

Other scientific info should be covered

- Comparisons with other lakes in the world, something about clarity, what other lakes are that clear? Water volume within, other things that make Tahoe unique. "It's a very special place and obviously if you're coming here then you must think something of it, but just to remind you how special it is to be here."
- You could show the different types of lakes, like glaciers

What would increase awareness?

- Have a traveling display that could go to local fairs, local pageants, not just environmental things – may have to invite yourself to them
- Maybe a wine festival, the wood boat show, anything on the water. We're very aggressive that way
- Something called the Lake Day? In Delaware, we have Coast Days, have fish, tanks, kids can see the fish, many of the environmental organization – they set up a whole day geared for younger children – geared for families. Research boat open, coast guard there, for the Delaware Bay
- Visitor center – that's how we found out – what is there more than a brochure that would get people excited.
- You're not going to get the hotels or restaurants to do it
- Visitor centers are your best place – those would be your best bet
- Campsites
- Sugar Pine
- Rangers at the state parks
- Different types of organizations – provide them the education

What would get them to visit?

- Maybe do a diorama – have students create them, put them in the visitor's center – a family with kids might be interested
- Audiovisual over at the visitor center, a flat screen t.v. over there and have a tagline "would you like to learn more" about Lake Tahoe

Appendix E
Student Survey

Student Survey
UC Davis Tahoe Environmental Research Center (TERC)

Thanks for answering questions about your visit. We want to hear what you think about TERC, so please tell us how we're doing.

1. **Please rate how satisfied you are with your <u>entire visit</u> to the Tahoe Environmental Research Center (TERC) today, using the following scale:**

   1 2 3 4 5 6 7 8 9 10
   (very dissatisfied) (very satisfied)

   1a. If you rated it 9 or lower, What would make it a 10?

2. **Now we want to ask you some questions about how much you knew about some topics before you visited, and how much you know now.**

	How much you knew <u>before</u> the visit				**How much you know <u>right now</u>**			
Topic	**Nothing**	**A little**	**Some**	**A lot**	**Nothing**	**A little**	**Some**	**A lot**
Size of Lake Tahoe	□	□	□	□	□	□	□	□
Shape of Lake Tahoe	□	□	□	□	□	□	□	□
What affects how clear the water is	□	□	□	□	□	□	□	□
How the lake has stayed clear so long	□	□	□	□	□	□	□	□
How Lake Tahoe was formed	□	□	□	□	□	□	□	□
What a watershed is	□	□	□	□	□	□	□	□
How a watershed functions	□	□	□	□	□	□	□	□
What a "fault" is	□	□	□	□	□	□	□	□
Boundaries between tectonic plates (Plate Tectonics)	□	□	□	□	□	□	□	□
How glaciers change the landscape	□	□	□	□	□	□	□	□
What you can do to help Lake Tahoe	□	□	□	□	□	□	□	□
Research going on at Lake Tahoe	□	□	□	□	□	□	□	□
The science of how Lake Tahoe works	□	□	□	□	□	□	□	□

3. **Some people say that the water in Lake Tahoe is getting less clear or dirtier each year. Do you think that's true?**

   □ Yes
   □ No
   □ Don't know

   3a. Why do you think it might be getting less clear or dirtier?

4. **Please let us know about your interest in the following topics, both before visiting today and now that you have visited.**

	Your interest before the visit				Your interest right now			
Topic	**No interest**	**A little**	**Some**	**A lot**	**No interest**	**A little**	**Some**	**A lot**
Science in general	□	□	□	□	□	□	□	□
Using science to study Lake Tahoe	□	□	□	□	□	□	□	□
Learning what you can do to protect Lake Tahoe	□	□	□	□	□	□	□	□

5. **Please let us know about your interest in the following topics, both before visiting today and now that you have visited.**

	Your concern before the visit				Your concern right now			
Topic	**No interest**	**A little**	**Some**	**A lot**	**No interest**	**A little**	**Some**	**A lot**
Your concern about protecting the environment	□	□	□	□	□	□	□	□

6. **Whose job do you think it is to protect Lake Tahoe and make sure it stays clean?**

7. **From the topics below about Lake Tahoe, please tell us which would you be interested in hearing more about? Tell us your top three choices:**

First choice: ___ (you can just write the letter)
Second choice: ___
Third choice: ___

A. Biology of Lake Tahoe (what lives in the lake)
B. Climate change impacts at Lake Tahoe (weather, temperature, invasive species)
C. Development affecting the lake (roads, buildings, people)
D. Forest health in the Lake Tahoe Basin (trees, animals, fire)
E. Geology of Lake Tahoe (rocks, earthquakes, glaciers)
F. History of the lake (Washoe tribe, Pioneer families, post 1960's development)
G. Physics of Lake Tahoe (changes in temperature, water level, mixing)
H. Other _____

EARTHQUAKE VISUALIZATION:

8. **How about the 3-D Visualization where you saw where the Earthquakes happened. Would you say that 3-D Visualization was…**

   □ Great
   □ Good
   □ Okay
   □ Bad

   8a. What did you like about it?

   8b. What would make it better?

9. **Please complete the following sentence about the Earthquake Visualization: "I never knew that…"**

LAKE TAHOE VISUALIZATION:

10. **There was also the 3-D Visualization where you flew around Lake Tahoe and went underwater. Would you say that 3-D visualization was…**

    □ Great
    □ Good
    □ Okay
    □ Bad

    10a. What did you like about it?

    10b. What would make it better?

11. **Please complete the following sentence about the Lake Tahoe Visualization: "I never knew that…"**

12. **Did seeing the Lake Tahoe 3-D Visualization change how you think about the lake?**

    □ Yes
    □ No

    12a. If Yes, how?

13. What would you say about seeing the 3-D Visualization about Lake Tahoe. Do you think it…

- □ made you care more about what happens to Lake Tahoe.
- □ made you care less about what happens to Lake Tahoe.
- □ didn't change how you feel about Lake Tahoe.

14. There are some things we can add to the 3-D Visualization of the Lake. Which of the following would best help you understand what affects the lake?

Check your top two choices:

- □ Animations (pollution, lake currents, amount and location of fish, etc.)
- □ Labels of places (cities, roads, streams, points of interest, etc.)
- □ More map information (north arrow, legend, location of roads, boundaries, etc.)
- □ Enhancing the colors on the map (shades of blue for water depth, etc.)
- □ Water in the lake (see where the shoreline is)
- □ Other _____

15. In terms of what you actually did, was the Lake Tahoe 3-D Visualization more like…

- □ Watching a movie in the theater (passive viewing)
- □ Choosing which video segments to watch (passive viewing with choices)
- □ Watching someone play a video game and giving some directions (semi-active viewing)
- □ Playing a video game yourself (active viewing)

16. Do you think it should be even more interactive?

- □ Yes
- □ No

16a. If Yes, how could we make it more interactive?

Now just a few questions about you.

17. Are you a….

- □ Boy
- □ Girl

18. Compared to other students in your class, how are your grades?

- □ Better than other students
- □ Not as good as other students
- □ About the same as other students

19. Which grade are you in? _____

20. How long have you lived in the Lake Tahoe area?

- □ Less than 1 year
- □ 1 to 2 years
- □ 3 to 4 years
- □ 5 or more years

21. How often do you do outdoors activities like going hiking with your family?

- □ A lot
- □ Some
- □ A little
- □ Not much
- □ Never

22. How often do you do activities on or right next to Lake Tahoe with your family?

- □ A lot
- □ Some
- □ A little
- □ Not much
- □ Never

23. At home, how often do you talk about science with your family?

- □ A lot
- □ Some
- □ A little
- □ Not much
- □ Never

24. At home, how often do you speak English?

- □ All the time
- □ Most of the time
- □ Some of the time
- □ A little bit of the time
- □ Not at all

Thanks for your time!

Appendix F
Student Survey Open-ended Comments

1a. If you rated it 9 or lower, What would make it a 10? [Overall experience at TERC]

a little fun
active
active activities
activities
add water to the lake tahoe image
animals
ative activities
ative ativitys
by not taking the test
by not taking this test
color
do more experiements where we can see how it works
exhibits that we could do more things
fun and games and less lecturing
funnier games to encourage us to learn even more
games that is os leaing
geting to sit in chares mostly activities
Have more friends in my group
have more fun things
have more graphics to help us visualize
having us do activities
I am just not that into science, they did a great job
I don't know
I don't know
I don't know, more activities
I think that we would need more exitement!
I think they should have better activities
I think to make it a 10 you should have animals
I think you would make it more [illegible] for more time at experiement and more hands on experiements
I would like to see gravity
I would make the activities more funish such as more hands on stuff
if it had funner stuff to do
If it was 3-D in color
If there was more examples of what we were learning
if they had more activities
If they had more activities
If they had snack and soda machines
If they put water in the 3D video
If we could hold fish
If we could see more samples
if we did more activities
If we did more learning about things we don't know
If we got to look at all the types of different kinds of species in the lake
If we had more time

If we had more time it would be better but it's good
If you made it a little more funnier or kid friendly
if you put water in the 3D video
if you saw live animals. Giftshop.
If you saw magma
If you told us some more about some fish in Lake Tahoe
it was probably a little [illegible] and more human
It would be a 10 if we had more time
It would help if there were hands on activities for us to do along with all the lectures
Katie acted like she didn't care and that made it boring
learning games
less talking and more activities
maby if we could look at all the other kind of shrimp and things
made it more fun and sit on cumfy chairs
make all the classes shorter and not so many questions
make I exciting
make it more fun by letting us do more activities
make it more interesting
make more activities to do (educational)
make the boat more interesting
maybe a little more information
maybe showing some fish who eat the shrimp
maybe some nicer stream tables would make the stuff work lots better
more 3D stuff
more activities
more activities
more activities with your hands
more activity to do here
more details and maybe mountains
more do it yourself
more fun activities
more fun activities
more fun activities
more fun stuff make it fell fun
more funer
more games
more games
more hands-on things
more interactions with fish
more interactive activetisy
more samples
More socially involded activities so we can talk with each other
need better system for the boat so it doesn't mess up
not too boring
on the 3D show you should add water
on the 3d thing you should show one with water
probibly if we could a little more activities
probly less talking and more doing
put water in the 3D show
sad
soft seats

The classes are too long
The tv's should work better
There should be a few more exhibits or labs to see
there should be more things to see
to have fun
trying to learn more
waterfalls or something else outside
what would make it a 10 is id you could add water and make it bigger
when we did the 3D movie maybe we could do a 3D hands on model with earthquake colors
yes
you can have more information about everything
you can have more interesting people and more information to learn
you don't have to do anything

3a. Why do you think it might be getting less clear or dirtier? [Lake Tahoe]

algie
all the run off
because
because a lot of people throw food and garbage
because all the dirt that the rain picks up
because alot of people polute
because dirt and sediment is getting eroded in to it
because it rains and rain water affects the water of the lake
because it rains and the rain gets dirty
because more sediment gets carried into the lake
because now days people through trash out on the street which goes into the lake
because of all of the algey
because of all the boat
because of all the erosion and of people changing the environment which hearts the earth
because of all the pollution
because of all the pollution
because of all the pollution and littering and more
because of all the sand and dirty being carried in the lake
because of contamination
because of erosion
because of erosion and it bring sand and mud and put it in the water like deposition
because of gas from cars and the pulloting from the (cosinos?)
because of people dumping trash in the lake
because of peoples gas
because of pollution
because of pollution
because of pollution
because of pollution
because of pollution
because of pollution
because of pollution and because the sand is getting eroded
because of pollution and littering
because of polution
because of polution and the angera fires ahes

because of rain and snow erison
because of runoff and cars pollutants
because of the bots and the trash goes to the lake
because of the cars and the polition and another way is that when it snows the snow gets dirty and then it goes in to the water
because of the dirt
because of the landslides
because of the non-native algey and fish and plankton
Because of the non-native species, the algea, and the stormwater
Because of the people and because of the storms
because of the people and of pollution
because of the pollution and run off
because of the rain water
because of the rocks and water, the water is making the rocks sand!
because of what people do to they do construction and bike riding
because people are getting trash in there
because people are leaving trash and it gets in the lake and differinte fish coming in
because people are littering
because people are littering and not helping the environment
because people are polluting
because people are polluting it each day with boats
because people are polluting it with oil from cars and boats
because people are poluting
because people are putting trash in it
because people aren't treating the lake good. and the mysis is eating creatures that keeps the water coming green
because people don't care about our economy and our situations
because people don't recycle what their throwing
because people get it dirtier
because people is throwing trash in it
because people keep litering
because people litter
because people might not recycle
because people put trash in the lake
because people through trash on the lake
because people throw trash in the water
because polution
because sand falls and it makes it dirtier
because some people litter and make it wors
because some people polute the air
because streams are not swerving as much
Because the creatures living in the lake create alge
because the fish are dying and they cleaned parts of the lake
because the gases in the air from cars and littering
because the mysis is eating the Zooplankton which eats algae
because the new fish are eating the alge
Because the pollution around the lake
Because the water is getting paluted by the miniute from people leving trash on the beach and such
because the wetlands are gone and we are polluting so much
because there's more people so more pollution

because they litter and they cant put trash in trash cans
because too many people litter
because we are polluting so much
because we aren't being good to it and aren't trying to keep it clean
because we aren't taking good care of it. We need to help and stop pollution
because we dump our trash in the water
because when we polute it mostly goes in the lake
Becuase people put trash in the water. That's what makes it dirtier
becus the weatlands are being coverd up. so the filtering sister can not work
by people throughing trash into the lake
cause eriosion is bringing the dirt to lake
cause of polution
cause of shrimp
dirier because people put trash
dirtier because of the boats
dirtier because of the dirt and a lot of stuff
dirtier because people put trash
do too non-native fish, the shrimp boats that have been used in other lakes
don't know
don't know
erosin
Erosion
from trash or erosion getting into the lake
garbage in the lake people pollute
I'm not sure
I cant reallt tell if its geting dirtier or not
I don't know
I don't know
I don't know
I don't know
I don't know
I don't know
I don't know
I don't know!
I don't know, maybe because some people are putting trash in the lake
I don't really know if it's getting cleaner or dirtier
I don't relly no why
I not quite sure
I thick its a clean
I think because are polution
I think it's getting dirtier because of the activities in the water; fuel, e.t.c.
I think it's getting dirtier because the water is taking the dirt
I think it's getting dirtyer because it doesn't look as clear as it use to be and the resherch shows it geting dirtier
I think it's getting less clear and dirtier because of polution and some oil that goes into the water
I think it's the same
I think it gets dirty because they throught trash
I think it is because the water level is shrinking and more dirt and stuff is getting in it
I think it is getting less dirtier because people might be helping the environment
I think it might be getting dirtier because trash an other stuff
I think it might be getting less clear because of the pollution

I think it might be getting less clear by not taking care of it
I think it will get dirtier because there will be more people and more pollution
I think Lake Tahoe is getting less clear because of the dirt from erosion
I think so because the air is getting more polluted and is causing the lake to get dirtier, also the ground is dirtier and the runoff picks it up
I think that breezus. IDK.
I think that it is getting less clear because of pollution
I think that the water is getting less clear because of soil and algae
I think that when people swim they kick up sand and that might be making it dirtier
I think the water is getting dirtier because some people are throwing trash around
It's dirty beause fish that bee intradused to tahoe axadentle
It's getting dirtier because it rains and makes it dirty
It's getting dirtier because of the algae.
It's getting dirtier because when the snow melts
it is clear
it is getting dirtier b/c of the increased population
It is getting dirtier because of the rain
it is getting less dirtier because some of the measers are working
it is more dark
It may be harder to see sometimes
It might be getting dirtier because of pollution or other stuff
It might be getting dirtier because people might be throwing trash in the lake
it should get it less dirtier because [illegible]
its getting dirtier because we keep dumping garbage on the lake
its getting more dirtier because we are poleuted
lack of wetlands in watershed, externam contaminants - milfoil - erosion
landslides, erotion
littering
maybe pollution
maybe when it's raining and rain wipes dirt into the lake
more pollution and algea in the water
more polution each year
More sediment in the water?
mudslides
no because it's not
of the dirt it gets when it rains
people are not being courtors of are lake
People are polluting water with trash
people are puting gabch in the lake
people are troing things on the leke
people fiers trash
people just treat it like nothing
people keep on litiring
people pollute and the trash goes into the lake
people poluting the lake
pollution
pollution
pollution
pollution
pollution
pollution

pollution and the way people are treating it
pollution from boats, cars, motocycles, run off from sewers after it rains or the snow melts. The garbage is washed down into the lake
polution
polution
Polution!
poulution from cars
puloosoh, ferlighser, urotion, bots, fires
pulution, dams, choping down trees, and oil
rain and waterfalls pick up sediment and brings it into the lake
rain, littering
runoff
shrimp
small bit of pollution
the boats where they are driven because of the oil in them might spill out and pollute the water
the dirt is coming into the water and growing algae.
the effects of destroying wetlands
the limnologist helping the lake
the rain might be getting the water less clear
The rivers bring sediment to the Lake Tahoe. The wetlands that were filtering the sediment was destroyed. So the sediment now can get into the lake making it less clear
The run off of the river
the water is getting a lot dirtier
There is more algea and dirt particles
There might be more erosin
tourists like to throw trash. Casinos are everywhere so people are littering bottles and buds
trash and acid rain
We are starting to have coal pollution which we didn't have in 1960
we have lost 30 feet of clarity
well maby because people are poluting it
Well with all the casinos around here and cars driving everywhere it might be making acid rain which probably reduces the lake clarity
yes because lots of people come here
yes because people leave food which is dirt in ut and the waves pick it up
yes because the weather is causing the dirt and sand from mountains comes down into the lake

6a. Whose job do you think it is to protect Lake Tahoe and make sure it stays clean?

"US." We should like put trash or other thing that aren't soppost to be in it
a police
all of ours
all of ours
all of the people that live in lake tahoe
all of the people that live in Lake Tahoe
all of the people who live in Lake Tahoe
all of us's job. Everyone
all of us
all of us!
ALL OF US!!!
all the people in Lake Tahoe!

All the people who live in Lake Tahoe
All the people who live in Lake Tahoe.
by cleaning the lake
by not littering and by recycling
Capet brant
clean the lake
do not litter
don't know
don't put trash in the lake
EPA
ever one's job
everbodies
everbodys
everbodys job
every body
every body close
every body in the community
every one who comes here and lives here
every ones!
Every person that comes to Lake Tahoe and the people who live here
everybodeys job to clean Lake Tahoe
Everybodies!
Everybodies!
everybody's
everybody's
everybody
Everybody
Everybody
Everybody
everybody in the basin
everybody who lives in lake tahoe
Everybody who lives in Lake Tahoe
Everybody.
everybodys
everybodys
everybodys
everybodys
everybodys
EveryBodys
everybodys because we all need to help pick up trash to keep tahoe clean
everybodys job
Everybodys job to keep the lake clean
everyone's
Everyone's
everyone's job
everyone's job including you and me
everyone
everyone
everyone
everyone
everyone

everyone
Everyone
Everyone
Everyone and mother nature because it's part of earth
Everyone can do something to help
everyone in Lake tahoe!
everyone in the community
everyone in the community
everyone in the community
everyone who lives in lake tahoe
Everyone who lives in Lake Tahoe
Everyone who lives near or uses the lake
Everyone!!! and Me (Everyone who lives on the lake)
Everyone. It is everyones job to make sure the lake stays clean.
everyones
everyones
everyones
everyones
everyones
everyones
everyones
everyones
everyones because there luky enough to live here so they should help
Everyones.
evrybuty
forest service
forest service
garbeg guys
government the president and the scientist
I can not [illegible, paict?]
I don't know
I don't know
I don't know
I don't now
I donno
I think every human that lives in Tahoe
I think everybodys job to protect lake tahoe
I think everyone who visits the lake has the job
I think it's everybody's job to make sure it stays clean because everybody can also pollute it
I think it's everybody's job.
I think it's everyone's job to keep tahoe clean
I think it's everyone's job to make sure the lake stays clean
I think it's everyone
I think it's everyones even people who don't live here
I think it's everyones job becuase we all can contribute to helping
I think it's everyones job to help Tahoe and the whole world
I think it's everyones job to keep lake tahoe clean
I think it's my job
I think it's my job to protect lake tahoe and keep it clean
I think it's our job to help make shure the lake stays clean
I think it's our job to keep it clean

I think it's our job to protect Lake tahoe
I think it's the govener and us also the president
I think it's up to everyone
I think it is actually everyones job who lives in Tahoe. To help it is the job and everyone should do that
I think it is everybodys job to keep it clean
I think it is everyones job because everyone litters at some point
I think it is the people that live in Lake Tahoe
I think it is us, we need to protect it
I think it should be everyones job
I think its everyones job to keep the lake clean
I think that it is everyones job
I think the job is everyone!
I think the job is where you take samples of water and analyze it then stop the chemical
in my opinion it is every citizen that lives in the basin's job to make sure it's clean
inviromental protecters
It's everybodys job to protect the lake
it's everyone who lives in Lake Tahoe. There responsible for there own living
it's my and all the peple in the lake
it's our job
It's our job t protect our environment
It's our job to keep the lake clean by being enviromentally friendly
it's our responsibility to recycle and help the world. And S.T.U.P
it are job to do it
it is everybodys job to try and protect the lake
it is everyone's job
It is everyone's job to protect the lake
It is everyones job
It is evrons job to help
It is mine and everyone close to keep the lake clear
it is my job to protect lake tahoe and keep it clean
it is our job
It is our job
Its our job to take care of lake tahoe
Limnologist
locals and toursts
mine and everybody else
MINE!
My job because humans are destroying Lake Tahoe and making it hard to live at
no clue
our job
our job
our job
our job
our job because some of us might not care
our job because we or some us don't really care
our job so the lake can stay clean
OUR Job!!
OUR JOB, EVERYONe'S JOB
Our own selfs. Do what you can to help, and if everyone helps we could be so much cleaner ours

ours
ours
ours
ours
ours
OURS Because were the people that ruin Lake Tahoe
ours jobs
OURS!
OURS!
owers because we live there
people and trash cans
people need to stay clean in our lakes
people that can recycle and help the environment
recyclers and car makers
residents, local, state and federal govts
reuse plastic bags, save energy, reuse, reduce, recycle
scentists
sciencetest
scieni
scientest
scientists
T.R.P.A (they aren't very good at it)
The citizens and the tourists and others have the job
The community
the families in lake tahoe
The go green Tahoe people, but mainly us.
The Govener of california
the Governer
The government, president, scientists, and every body that lives in south Lake Tahoe
the governor and us
The people and fish of Tahoe
the people in Lake Tahoe
the people in the whole world
The people of lake tahoe, I think everyone should help
the people of tahow
the people or the goverment
the people that clean the lake
the people that lear there and the people in the wohe weald
the people there don't
the people who live here
The people who live here
The people who live in Tahoe
The people who live in Tahoe
The person who takes samples from the lake
the recycleing people
The residents like us
The scientest.
the scientists
the teachers
the tpra should protect it
the wildlife protectors

the world
This college
to keep tahoe clean
TYPA
uors
us
us
us
US
us and people
us people have to help
us people of the earth
us ppl of lake Tahoe
us.
us.
use
Vereyones because we poullt to!
we the people
well i think it was becuase we need to help clean our waters

7a. From the topics below about Lake Tahoe, please tell us which would you be interested in hearing more about? Tell us your top three choices:

OTHER write-ins:
fish
germs and pulutents
Lake Tahoe
more animals
more exspierements
ocean, crawdads, insects
solar power
the population of lake tahoe, what kind of animals we have in the lake, animals health in the lake
the study of algey and what we can do to provent it
underwater
underwater
water species living in Lake Tahoe
wildlife

8a. What did you like about it? [Earthquake visualization]

3D
3d effects
about what hit ther
about where they were spreding and coming to other continents
all
all the affects of south Lake Tahoe
all the dots on the earth
All the info and the awesome effects

all the things it up close
all they showd because it was 3D
because it accualy made it that you were there
because it was 3D
everything
everything
everything
everything
everything
everything was very discriptive and interesting in 3-D
how it poped out
how it popped out
How it show the way the lake formed
How it showed you the past
how it was 3D
how it was poping out at you
how it would pop out
how the earth got big
how the earth got big
how the earth rotutes
how the earthquakes grew bigger and bigger
How we saw our earth
How you got to see underwater
I like how it goes right then you put the glasses on upside down and it goes the opposite way
I like how it seemed it was right there but it was further away
I like how they took us on a trip into the lake
I like how you brought it around the lake
I like how you could see the earth in 3D
I like that it showed symbols of the visualization
I like that it was 3-D
I like that we saw all the mountains
I like the 3-D
I like the 3D thing
I like the earthquakes and the crushers
I like the feel of how you think your in the picture
I like the lake part
I like when stuff popped out
I liked because you could of saw the earth better
I liked how it made science more interesting
I liked how we got to see the lake without water and where the earthquakes happened
I liked how you can see earth in 3D
I liked it because it showed you wher bad or heavy earthquakes happened
I liked it because it was in 3D
I liked that it was in 3D and that it showed us the iner core and outer. Another thing I liked was the earthquake dots
I liked the 3-D part and the way it showed all of the earthquakes
I liked the earth and how it showed where earthquakes happened
I liked the part were all the earthquakes happened
I thought it was kool from the 3-D
I was so real
it's good because it's a cool leke

it gave u a better look
it had good effects
It is 3D
It looked like a hologram
It looked real
It made it easier to understand
It made me want to protect the lake
it seemed way more real than I expected
it showed us how earthquakes form and happen
It shows a visual of Lake Tahoe
it told exactly where the earthquakes happen
it was 3D
It was 3D
It was 3D
It was cool how they found the earthquakes
it was cool to see and looked like it was popping out
it was interesting
It was interesting and educational
nothing
seeing where all the earthquakes were
th earth
that 3D
That it looked really realistic
that it was 3D
that the glode was transparent
that we could see the world in 3-D
that you can almost touch it
that you saw inside the earth
The 3-D
The 3-D affects
the 3-D part and learning
The 3-D shape
the 3 D
the 3d
the 3D
the 3D and the zoom
the 3D effect, seeing the shallow ranges of the ocean, the difference between surface and deeper earthquakes
The 3D got me interested.
The 3D part
The 3D video the way it rotated
the 3D was awesome and I like geology
the colored dots and the time you see the eathquakes taking place
the dots
the dots
the dots got bigger
The Glasses
the lake part
The reality
The seeing Lake Tahoe
the way it looked

The whole experience
tracking of earthquakes
when I saw the lake without water
When it showed the glowing points of the earthquakes
when we saw all the mountians
where it showed how many earthquakes there are in the world
you can almost touch it
you can see a lot
you can see techtonic plates
you could almost touch it
you feel like you can touch the movie as if you're in it

8b. What would make it better? [Earthquake visualization]

all the moving went slower
be me doing it
being more detailed
better form of earthquakes
better glasses
better seats
better seats
better seats
bigger screen
clean water
color
color
color
color and related activities
different pictures
differt pictures
for it to not hurt your eyes so much
Have more options that you can see
have the second part colored
How the person says where to look
I'm not sure. It doesn't need to be better
I don't know
I don't know
I really can't think of anything
I would like to us the joy stick.
If it showd how they felt
if it was a ride
if it was closer to you
if it was in color
if it will be bigger
if it would name the most important things
if the whole room was 3-D
If there was a continuous video
If there was more things to see
If there were more things to see
If they put the names of the cities

if we could go closer to the earth
if we could touch it
if you could touch it
Its good the way it is
less moving
longer
make it bigger
make the earth move
Maybe have earthquakes appear most in Lake Tahoe
more 3D close up
more color
more colorful
more coloring
more colors
more colors
more details
more dots
more feeling like it is really there
more graphics
more graphics and more mountains
more interactive
more into it
more stuff
more time to see stuff
more water and mountains
N/H
N/H
not so many dots at a time
Not to much confusing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing it's perfect!!!
nothing really to change
nothing, it's perfect
Nothing. Maybe to add more of the interior
overlay cities and country boundaries

perfect already
put water
putting some comfterble seets
see through water
show disasters
show disasters of the earth
sound
the coloring
There should be color
to be bigger
to explain why there were earthquakes in the middle of the ocean that were shaped like (continents?)
Trying to do the future earthquakes
water, see though water
watte (?)
what would make it better would be to show the mantle
you should be able to disect things

9. Please complete the following sentence about the Earthquake Visualization: "I never knew that…"

"I liked a lot"
A bunch of eathquakes happened in 2004. Second I never knew how much there was
a earthquake could make a sunami and mostly make lake Tahoe worst
a fault can break and cause a tsunami
a lot earthquake
a Tsunami had hapened in lake Tahoe
a Tsunami hit lake tahoe
abut the urth on the pas
Alaska had so many earthquakes
daphina was a fish
Earth quakes happened so much
earthquakes are going on everywhere
earthquakes caused sunamiis
earthquakes could happen at once or be very heavy
earthquakes could happen in so many places
earthquakes happened so much
Earthquakes happened so much
earthquakes went in so deep
earthquakes were in the sea
Earthquakes would be better if they existed in the water
Glaciers created mountains called fingers but I forgot the scientific name
glaciers formed the lake
good visualization
hundreds of earthquakes appear each year
I knew something about Lake Tahoe like volcanos and earthquakes
I know that the plankton cleaned the water
I never knew about this
I never knew that there were 3 types of plate tectonics
I never knew that there were a lot of dots

I never knew that there were so many earthquakes and where they were
I really liked it
it could seem so real I learned a lot from it
it was deep
lake tahoe has 3 faults in it!
lake tahoe is one of the deepest lake
Lake tahoe was one of the 11 deepest lakes in the world
Lake Tahoe was shaped like that underneath
Lake Tahoe was the 11th deepest lake in the world
picture could feel so real to you.
sismographs were (craters?) for missile testing
so many areas in Alaska has had earthquakes
so many earthquakes could happen at one time
so many earthquakes happen
So many earthquakes were in the 1960s
so many places have earthquakes
south Lake Tahoe had great water
tahoe had faults
that (is?) alot alot of earthquakes
That most of the earthquakes that were in the past were in the 1960s
that much earthquake happen in the earth
that so many earthquakes happened in Indonesia
that the earth had creatures the size of a piece of dirt
that the lake formed with a glacier
that there was a lot earthquakes
That there was so many earthquakes at one time
that there were so many earthquakes
that we had a suhamiy in 2004
that will happen
the core had nickle in it
The core was very hot
the earth was full of earthquakes
the earthquake in 2004 on Indonasia was that big and caused a big tsunami
the erth was so big
The Hawian hotspot moved and The Trench is real
the lake getting dirty would cause our environemnt bad
The lake had faults
the lake had trees underwater
the layers of earth
the little plyntin at the bottom of the ocean ate alergy
the water in Lake Tahoe can fill California up to my knees.
their were alot of earthquakes in the world
their were volcanos
there are a lot of earthquakes
there are more earthquakes than I thought
there are so many animals in the lake
there are so many earthquakes in so many places
there are volcanoes
there have been so many earthquakes
There is lots of earthquakes around the world. Also the crust is on magma
there was a fault by New Zealand

there was a glacier that scooped out the land in Tahoe
there was a lot of earthquake
there was a lot of earthquake
there was a sunomy
There was a tsunami in Indonesia which created a chain reaction
there was alot alot alot of earthquakes
there was earthquakes
there was so many
there was so many Earthquakes
there was so many earthquakes that happened around the world
there was so much dots in the world
there were a lot of earthquakes in the world
there were a lot of earthqualkes happening
there were earthquakes
there were flats in lake tahoe
There were more than 100 earthquakes in the world
there were so few simographs
there were so many earthquakes
there were so many earthquakes
there were so many earthquakes
there were so many earthquakes
there were so many earthquakes
there were so many earthquakes
there were so many earthquakes
There were so many earthquakes
there were so many earthquakes as the earth got older
there were so many earthquakes each year
there were so many earthquakes in the world
There were so many earthquakes that occured
There were so many places that had so many earthquakes
there were so many problems with volcanoes
there were that many earthquakes
there were that many earthquakes around the world
we were so pluted
what the plate boundaries looked like
when earthquakes went deeper in the earth when it happens
why the U.S. placed sismographs

10a. What did you like about it? [Lake Tahoe visualization]

seeing our school
[illegible]
3D
all
all of the details
all the animation and the feeling that you were there
all the cool things
cool
cool, fun
crashing into places

everthing
everything
everything
everything
everything
everything
everything
everything
everything
everything
everything!
flying
flying
going through the lakes and seeing the cities
going underwater
how it seemed how you can dive right into it
how real it looked
how we could go in the mountians
how we could go under the lake
how we could see our school
How we went around the places
how we went though mountains
I'm not very sure
I don't know, I like all of it
I don't now
I how it showed the glaciers underwater and the little hills
I like about the glaciers that we were learning about
I like how it shoed us the mountains and how deep it was
I like how the water was really clear
I like that you can see underwater in 3-D
I like that you could see how big the mountains were
I like that you could see it without the water in the lake
I liked going through Lake Tahoe
I liked how we got to see the plate bounderies
I liked how you could go inside the Earth
I liked seeing the mountains
I liked that it showed the surface with no water
I liked that we went up the mountains and saw bumps
I liked that you can see underwater in 3D
I liked the flying
I think this is cool
if was very visual if your up front
interesting to see the ridges/cliffs under the H2o
it's 3D
it felt like you are in a helicopter
It felt like you were flying
It gave more detail
It got my attention
It had good effects
it looked cool without the water in the basin
it looked so real and it felt like you were flying

It looks real
It showed where the faults are
it was cool
It was cool
it was detailed
it was kool and you could see the faults
it was popping out
It was realistic
It was supercool
its cool
land [illegible word]
learning about the faults
nothing
nothing
riding underwater
same as 8 (you feel like you can touch the movie as if you're in it
that it can fly and go underwater
that it was under the lake and I have never seen that
that moraines caused by glacers
That we saw our school
that we saw places
that you could see the inside of the earth
that you could see the underwater landscape
the 3-D
the 3d
the 3D part
the 3D part
The 3D was awesome and I love seeing lake tahoe
The awesome effects and info
the earthquakes
the fault and [illegible word]
the flying
The graphics and the way that the mountains were showed
the joy stick
the lake had no water
the lake part
the landscape
the landslides that it showed
The montznee
the mountains
ther was no water
to go in the lake
to see where everything is
we can zoom in and out
we flew
we saw all the elavation in the water that was cool
went we crush in the rocks
what I liked about it was that I learned there are 3 faults in the lake
when the world was moving
when we went inside a rock
when we went into the mountains

you can go through stuff
you could go through rocks
you could go through stuff
zooming in

10b. What would make it better? [Lake Tahoe visualization]

a little more description
add some water
add water
add water
add water
being able to see inside the mountains and ground
better pictures
better seats
breing water
color
color
color
color
color
color
color
color
color and water
colors
conducting related exparaments
different pictures fun pictures
even more graphics and details about those mountains
for it to not hurt your eyes so much
had different colors
Have it colored
have more color
have some water
I do not know because it is so great
I don't know
I want it to look like a game
I would put color in it
I wouldl like to see green trees and blue water and glaciers
Idk
Idk
if it seemed like the was water
if it seemed like there was water and your going deep in the depths
if there was dots
If there was water
If there was water in the thing
if they put more grafics in it
if we could see a seismograph
if we could touch it
if we got to see the (contries?)
if we started to learn more about glaciers

if you added water
if you showed the water line and color
it had water
it would make it better if we could see the different living things
less moving
longer
look clear
make in longer and more like a rollercoaster
make it bigger
maybe showing were the scientists mostly stufy.
more 3D
more color
more color
more color
more color
more colorful
more colorful and hope the map will be more detailed and be the whole state of Cali
more colors
more graphics
more info
more info of earthquakes
more interactive
more mountains and valley
more time to see more stuff
N/H
N/P
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
nothing
Nothing
nothing is awesome!
nothing it's perfect!!!
Nothing really
nothing really to change
nothing will make it better
put water in it
puting the water and the green trees
putting water in
same as 8 (you should be able to disect things)

show it with water too - show the south shore too
showed the water
showing the water
that it had a little bit of water
that we could see our school better
the clearness when you zoom
to be bigger
to know more about it
to show the water
touch it
trees
Trying to make more data inland
using the joystick
water
water and closer zoom
water and colored eathquakes dots
water in the Lake Tahoe animation including glaciers

11. Please complete the following sentence about the Lake Tahoe Visualization: "I never knew that…"

"cool"
"that was cool"
[illegible]
a falling piece of earth can cause great damage
about galciers. I never knew it was that big
block movement formed most of the lake
Earthquakes caused tsunamie
earthquakes could of been so dangerous
Emerald bay was made by a landslide
erthqake were all aroud I word
Glacier make Thoe
glaciers effect everything
Glaciers formed Emerald Bay
glaciers formed ranges
Glaciers is what created Tahoe
glaciers made Tahoe
Glaciers made Tahoe
had so many faults
how deep was the water
I didn't know that had happened in Lake Tahoe
I didn't know that there was little animals that eat allge
I learned that there were a lot going on in the earth
I never knew that an earthquake made a tsunami in the lake
I never knew that there was earthquakes in Lake Tahoe
I never knew that there were faults in the lake
I never knew that there were so many glaciers in Lake Tahoe
I never knew there was earthquakes in tahoe
I never knew there were [illegible word]
in 1963 there were a lot of earthquakes around the earth

it could seem so real I learned a lot from it
it did so much damage
it should be more clear
it was going to be so much fun
it was the second deepest lake in the world
it would be cool
Lake Tahoe had a landslide
lake tahoe had a tsunami
Lake Tahoe is so big
lake tahoe was 12 miles across
Lake Tahoe was deep
lake tahoe was formed by earthquakes and glaciers
lake tahoe was made from volcanoes
Lake Tahoe was so deep
Lake Tahoe was that big
Lake Tahoe was the 11th deepest Lake in the world
lake tahoe was the bluest lake in the USA
lake tahoe was the clearse wate
Mt. Kinney was formed by a underwater slide
our school look so big from space
science could be so fun
some go into the earth
Tahoe was deep
That there were so many merains
That we came a long way from South Tahoe to incline
the bottom of tahoe was flatter than on land
the climate of Tahoe
the deepest part of the lake was 1644 feet
The deeps spot in lake tahoe was in North Shore
the earthquakes cause tsunami
the earthquakes make Tsunami
the finger thing
the glaciers melted and scratched the sides
the lake drop off
the lake was 1600 feet deep
the lake was clean (fesr?) all that
the lake was deeper than I thought
the lake was really deep
The shape of the mountains looked like someone ran their fingers through them
The snow can make [illegible inranse?]
the urth had no water
the was a tsunami in lake tahoe
the water was 1,644
Ther were 3 faults in lake Tahoe
there are riges in the lake
there are so many things to see in LT
there are volcanoes, layers of earth
there is an underwater cliff and that glaciers spread into fingers
there under water
there was [illegible] on the bottem of lake Tahoe
there was a big drop

There was a drop like that
there was a fault under a elementary school
there was a landslide in the past
there was a lot of mountains
there was a major earthquake in lake tahoe
there was a rige in water
there was a tsunami in tahoe
there was an earthquake in Lake tahoe
there was faults
there was rock under water
There was so much earthquakes
There was soo many earthquakes
there was three faults
there were 3 faults
there were cliffs underwater
there were earthquakes underground
there were little mountains at the bottom
there were rocks at the bottom
There were so many earthquakes
there were so many glaciers
There were so many glaciers in Lake Tahoe
There were so many lakes here
there were so many mount. underwater
there were that many faults
there were volcanoes in Lake Tahoe
there where 3 faults
volcanoes
water was so dirty
we could locate the school
we could see lake with no water
we could see our school from high up
We had a few faults
we had an earthquake in Lake Tahoe
you can go in side of it

12a. Did seeing the Lake Tahoe 3-D Visualization change how you think about the lake? If Yes, how?

becas I didn't know that
because earthquakes
because how you can make it better
because I can see the faults
Because I didn't know there were so many drop offs
because I saw how it looked underwater
because if we keep going on our regular lives the lake would be different
because it make you think about the earth
because it rotated
because lake tahoe has a huge lake when I saw that 3-D image I was like wow I didn't know the lake was that big
because now I see how clean it is

Because of all I learned
because the way we saw the (ure?)
because we could just leave nautre do it, but if we don't help our water is gone
because you can see were they are and location
because you could see what did happen
becuase I didn't know that there are different levels in the lake
before I thought the lake was just a lake but now I know that we really have to take care of it
by how the lake is old and how it was created
by seeing how deep it was
cause you would never really think about the lake
cuz it was cool
depth size and history
do not pollute as much
how deep and large the lake was
how we saw the are and the mountains of it
I did not know a lot of things about Tahoe
I didn't know it was caused by glaciers I thought it was just like that
I didn't know there was so much pollution
I don't know
I got a better look at it than normal
I learned how deep and what's under there
I learned more about the lakes
I learned things I didn't know
I never knew it was so deep
I never knew that glaciers made mountains called fingers
I never knew the bottom was bumpy from dibrie
I never knew there was a landslide
I never know how deep it is
I now appreciate the lake more. (I already did a lot)
I said NO!!
I was surprised how the bottom of the lake looked
I will try to ride my bike and stop people from littering
it's big
it's interesting
It helps you learn
It looked like a bunch of craters in the ground
it made me think the streams would leave the lake
It make me realize how big the lake is
It makes we want to make less fuel cars
It showed how the lake actually looked inside
It was funny how we could act like the [illegible word] were [illegible word]
itwas cool
land slides
learning more about Tahoe
make me more comfortable
makme move about the earth
not sure
not sure
nothing
seeing how the lake gets dirty
seems like the terrain is more dynamic than I thought

the depth
the glaciers changed the lake
the lake is so deep
ya, since the lake has so much trouble from earthquake and it affects life
yes because we got to see the inside of the earth

14. There are some things we can add to the 3-D Visualization of the Lake. Which of the following would best help you understand what affects the lake?

OTHER write-ins:
color
nothing

16a. If Yes, how could we make it more interactive? [Lake Tahoe visualization]

3D
Actually show the houses and buildings
add color
add vegetation and water
add water in the lake
ask questions
better seats and better glasses
bringing it to schools
buy showing the water
by being good
by doing a game
by having cool stove
by making it more colorful
by puting more stufe
by putting more graffics
by yesing a psp
color
games
get psp's or hand controls
giving more detail
had them drive the joystick
have choises and see what would happen
having the water and the animated fish, shrimp, plankton
I dk
I don't know
I don't know
Idk
if we could dive it
if we could drive it
if we could drive it
if we got to move the movie around
if were learned more about Lake Tahoe and keeping it clean
it should talk about other animals
It would be cool if it was like a PsP
let everyone try it

Let kids try mocing the earth!
let some of the kids play
let the students decide a couple things about what to do
let us use the control
Let us use the joy stick
make it more colorful
maybe we could be able to see the magma inside the groups (you could also turn it off)
more color
more color
more color and to get up move
more explaination on it of cool things
more images and visualization
more pictures
more visultion images
moving it yourself
not sure
put people in it
show a lot more colors on the lake
the trees and water
to move better
we get to fly
we point to stuff and answer questions
with more fun
you could so something
you should make more joy sticks so that everyone can try