Connecting Formal and Informal Learning Experiences

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A dissertation
submitted in partial fulfillment of
the requirements of the degree of

Doctor of Philosophy

University of Washington

2010

Program Authorized to Offer Degree:
College of Education

University of Washington

Graduate School

This is to certify that I have examined this copy of a doctoral dissertation by
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Abstract

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This learning study reports on part of a larger project being lead by the author. In this dissertation I explore one goal of this project—to understand effects on student learning outcomes as a function of using different methods for connecting out-of-school experiential learning with formal school-based instruction. There is a long history of assuming that "experience is the best teacher"(e.g. Aristotle, 360 BC; Dewey, 1934; Kolb, 1997; Pliny, AD 77). As a practical geographer I endorsed that assumption throughout my teaching career, paying attention to local topography, physical features, and natural resources in the geographic hinterland. I was particularly interested in understanding the impact of the physical landscape on humankind, and reciprocally, noting humankind's widespread impressions on the natural world. Until I began this research project, I assumed that everyone else paid a similar attention to immediate surroundings. The work that I describe in this dissertation emerges out of a conviction that there are many degrees of truth to the idea that experience is a great teacher. Its effectiveness seems to depend on how one's "experience" is mediated, and how "learning from it" is defined. This motivated me to think about design principles for linking people's experiences to learning. I began to explore, experimentally, how I might enhance people's abilities to notice, represent, and discuss their experiences in order to better learn from them. This study investigated how different ways of connecting outdoor learning experiences to formal schooling impacts students' performance. I studied high-school students in outdoor settings as they engaged in evocative issues of learning pertaining to consequential everyday life encounters. Different kinds of "expert mediation" were introduced and tested as the students engaged in investigative activities around the science of dam removal and habitat restoration. I measured outcomes with the aid of pre- and posttests, progressive self-assessments, and ethnographic observations. Since I argue that the idea of learning from experience is underspecified, I

present empirical findings to show that experience *per se* is not enough. I discuss tools and other artifacts that help learners notice key dimensions of their experiences, and demonstrate how they link these to other aspects of their culture and lives. Findings indicate that a mediated approach does in fact help students outperform participants who only received the experience. A time for telling was also advantageous for students to improve learning and using technology to reduce cognitive load was instrumental in further improving their learning. Future plans are discussed to follow up on these findings and to implement new tests as the dams are removed and the natural habitat is restored.

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ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to the professors and colleagues at the University of Washington, College of Education for their extended long-term support and interest in my work. In particular, I wish to thank my committee members Reed Stevens and Phil Bell who were painstaking in their comments and very generous with their time and assistance while preparing this dissertation. I am especially grateful to Professor John Bransford for his broad world-vision and deep knowledge, which he so graciously shared with abundance and humility.

This dissertation would never have been completed without the encouragement and devotion of my family and friends. I acknowledge their steadfast support and sustenance during this process and journey.

DEDICATION

To my children

Darragh Shane
Ronan Daniel
Madelein Caoimhe Anne
Noel Finn

"We lost contact with the Earth when our food and sustenance was no longer immediately and obviously dependent on the weather" (Lovelock, 2009, p. 226).

Background and Rationale

In the learning sciences, researchers are paying increasing attention to learning in out-of-school as well as in-school settings (e.g., Bell, Shouse, Lewenstein, & Feder, 2009; Bransford, et al., 2005; Life-slc.org, 2010). One reason is the amount of time spent in these two kinds of settings. Figure 1 shows a representation from the LIFE Center (LIFE stands for Learning in Informal and Formal Environments, see LIFE-slc.org) that illustrates the approximate amount of time during a year (assuming approximately 16 hr days of awake time per day, no school during weekends and summer vacation) of typical opportunities for in-school and out-of-school learning (Stevens, Bransford, & Stevens, 2005).

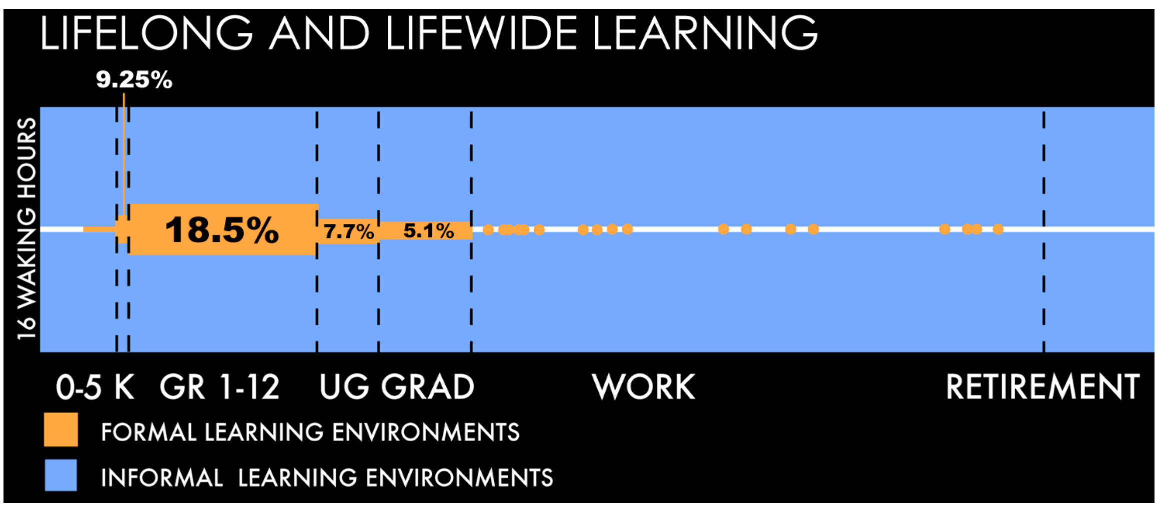

Figure 1, Life long, life wide Learning

This diagram shows the relative percentage of their waking hours that people across the life span spend in formal educational environments and other activities. The calculations were made on the best available statistics on how much time people at different points across the life span spend in formal instructional environments (NRC, 2009, p. 29). A notable feature of Figure 1 is the vast "sea of blue" showing out-of-school time that has the potential to provide learning opportunities that can boost people's social and academic successes and self-concepts as learners (e.g., Banks, et al., 2007; Bell, et al., 2009; Bransford, et al., 2005; Gordon, Bridglall, & Meroe, 2005). An especially important conjecture, and one that is tested in this study, is that some ways of connecting informal and formal learning opportunities are better than others for strengthening learning (e.g., Banks, et al., 2007; Bell, et al., 2009; Shutt, Phillips, Vye, Van Horne, & Bransford, 2010; Stevens & Hall, 1998). As we shall see, however, it is important to separate formal and informal as **places** for learning, from formal and informal **processes** for learning. Life researchers have made this point (e.g., see LIFE discussion in Bransford, Vye, Stevens, et al., 2005; NRC, 2009). The present study explores this point in more detail.

Research Focus

Places of Learning versus Processes of Learning. In the discussion above most of my discussion referred to formal and informal learning opportunities in a place-based manner (i.e. in-school versus out-of school). As LIFE members have explained (Bransford, et al., 2005), their work focuses not only (nor even mainly) on <u>where</u> learning occurs, but also on <u>how</u> it occurs in a variety of different settings. For instance, one can use worksheets in school, or use them outside during informal "experiential" outings (later I show an example in practice).

Similarly, formal in-school curricula can be devised so that students can benefit from many of the natural "learning arrangements" (Bell, et al., 2009; Stevens, 2000) that are often seen in informal settings where learners tend to experience success. Often, informal learning settings also involve criteria for "being successful" that seem to be more personally and culturally relevant and diverse than assessments found in the typical tests often used in schools (LIFE-slc.org).

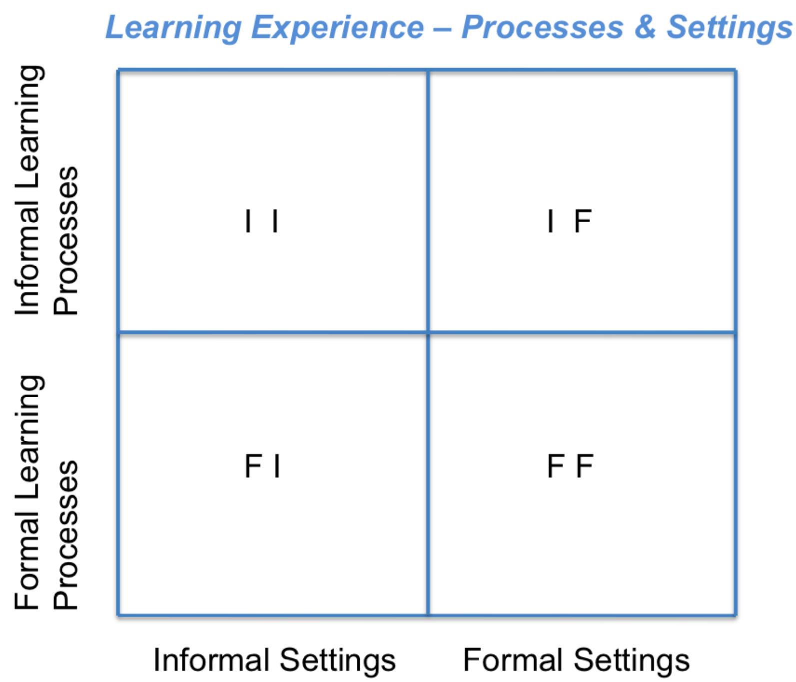

Figure 2, Learning Experience Grid – Processes and Settings

Using I for Informal and F for Formal, Figure 2 (above) shows that there can be:

A. I I experiences, where informal environments support informal learning processes by individuals and groups who often create their own goals, learning arrangements and metrics for success.

B. F I experiences, where formal educational environments facilitate and support many of the opportunities for learners' agency, sense of identity and learning arrangements found in informal settings (Banks, et al., 2007; Bell, et al., 2009; Calabrese Barton, 2002; Shutt, et al., 2010)

C. I F experiences, where students are outside (e.g. on field trips) but hearing lectures, filling out worksheets, and doing other school-like activities that are sometimes helpful, but at other times take learners' attention away from important phenomena that their opportunities to be outside were designed to accentuate.

D. F F experiences, where students are in formal settings (e.g., school), engaged in activities that range from lectures (with no opportunity to ask questions), to teacher-initiated "inquiry, response, evaluate" (IRE) interactions (Mehan, 1985), to group-work, effective uses of technology, and other attempts to foster learning.

In the present study, all four of the quadrants in Figure 2 were observed, but only certain combinations were successful. Understanding, when, where and why is a major goal for this research.

Settings

My study required learning about the area where I choose to do my work. This included learning both about the geography and the people. Students' high school drop-out rates were very high (around 50%) and teachers and others in the community wanted to help students connect important concepts of science and local history to their environment (which was especially rich for developing deep and lasting knowledge and 'habits of mind' for lifelong learning).

I was fortunate to have many opportunities to interact with the community of non-native and Native American children who dwelt in the Elwha River valley of Washington State. I held multiple meetings with the inhabitants of the area (including Tribal elders) in order to learn from them and also make it clear that the work I was doing would become their story and not mine. The story of the dams coming down, the restoration of the habitat will be told, and according to the design of this study, it would be ideal if the students were the tellers of that story. I would help with equipment (cameras and other tools, stipends for teachers), with providing audiences and expertise (e.g. U.W. students and professors as audiences for local children's school science work), and other needs that emerged as we did our work. Both geographically and culturally, this was a unique area where a confluence of historic events is having a major impact on the local community today and in the near future as well.

Figure 3, *Elwha River and study population*

Figure 3 shows the location of my work relative to Puget Sound. Their valley had changed in the previous one hundred years. Where once the Elwha was a fast moving stream (see Figure 3), and a major food source for the inhabitants of the valley (a pre-eminent spawning ground for all five species of salmon, especially steelhead), today it is neither. In 1913, "settlers" built two dams on the river to create hydropower for the burgeoning industrial town (Port Angeles). Here tradesmen met an increasing national demand for paper products with three new mills.

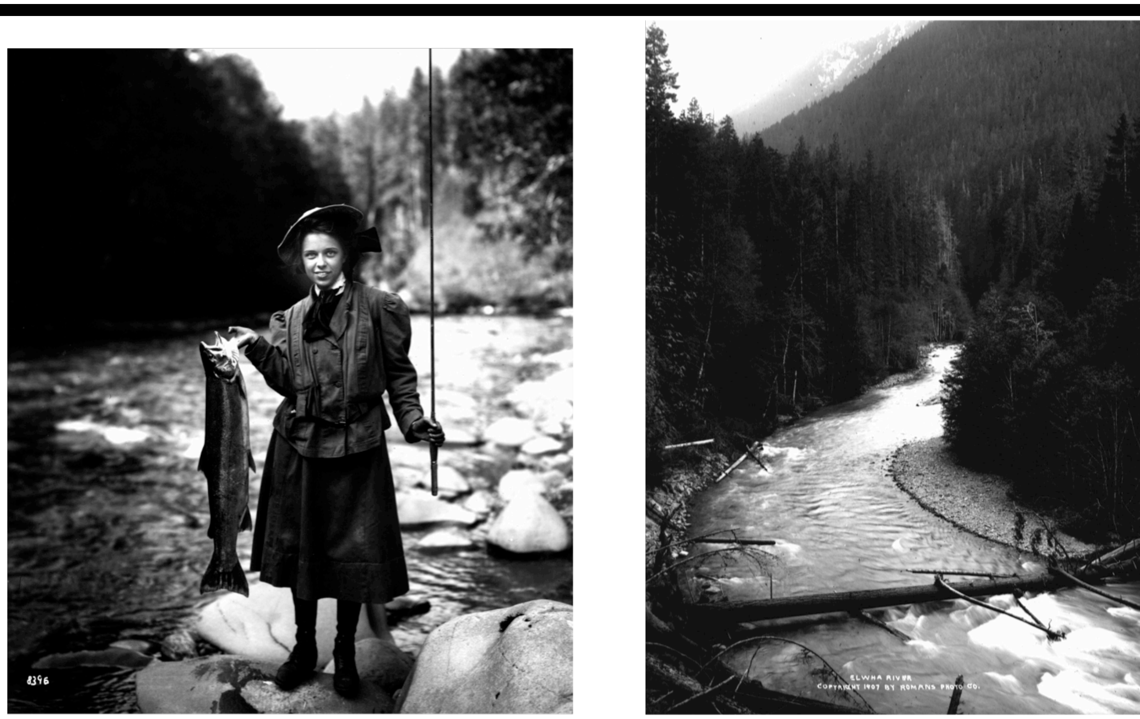

Figure 4, *Before the Dam Local People fished the Elwha*

Before the dams were built, local people (and new settlers) fished the river (see Figure 4). In the accompanying photograph for instance, Elinor Chittenden (Curtis, 1909), a newcomer who was instrumental in bringing progress (at least in the eyes of the white settlers) to the Puget Sound region[1] displays a steelhead at a site on the Elwha where the dam stands today. The second photograph (also circa 1910) shows the river in its natural state before the first dam (and Lake Aldwell) was built.

Concerns about School Achievement: As noted earlier, one issue I encountered involved strong concerns about school achievement in this area. The students were bright

1 Elinor Chittenden was daughter of General Hiram M. Chittenden who was responsible for the construction of the Ship Canal that linked Lake Washington and Puget Sound 1911-1917. Following the failure of several private canal schemes, U.S. Army Corps of Engineers Gen. Chittenden (1858-1917), advanced the project, and his name was later given to the Government Locks linking the Sound and Salmon Bay at Ballard.

and inquisitive; the schools (there were two in the area) were extremely well equipped (see Figure 5).

The teachers seemed exceptionally excited and motivated to do all they could to help their students. For example, on one occasion they worked on science projects with their students so that they could travel to UW to present their findings to an audience of UW honors students, graduate students and Professors. The presentations were all strong and well prepared, and so were the students' abilities to answer questions from the audience. The teachers called the day "one of the best of our lives". Their motivation and commitment were absolutely essential for the success.

Figure 5, Students' Homeroom

Outside work as motivation: These students can't come to UW every day of course, so the Elwha Valley teachers were constantly looking for ways to motivate learning. Some teachers opted for time for students to explore the amazing environment that surrounded them. Often this happened in summer camps. As one teacher stated: "They learn more in the summer than during the rest of the school year" (Valadez, 2010). However, although there were lots of things they undoubtedly did learn, I discuss later how there were also a number of important elements of their environment that apparently escaped their attention. This raises interesting and important questions about "experiential learning" and processes needed to make its effects optimal—questions I explore later on.

In other cases park rangers and other outside experts were hired to connect in-school learning to out-of school learning. I walked some of the curriculum trails and noticed that most of this education took the form of formal training in an informal setting (FI in Figure 2). I especially noted that worksheet and other tasks often seemed so attention-demanding that they detracted from allowing students to experience the rich phenomena that surrounded them. The phenomena were not novel to the students, since they spent most of their adult lives in this area, but their existence seemed to go blithely unnoticed by them. In addition, and there was no overall driving question such as helping students relate their work to the potential implications of their findings once the dam was removed. I also noted that, when students returned to their classroom from these outings, there was generally a lack of spontaneous discussion about their "discoveries". As I show later, this picture changes when students have different kinds of opportunities to explore and learn.

Overall, I noted several kinds of learning issues that seemed to keep the opportunities for blending formal and informal settings and processes learning from being optimal. Especially noteworthy were: (1) Shortcoming of the curriculum practices for helping students become self-directed learners, "noticers" and question askers in II and IF (2) attention overload with some of the "school measurement activities" and a disconnect between what they were doing and why; (3) ineffectiveness of lectures when they were given before students' had had important experiences, and (4) a lack of explicit attempts to prepare students for roles of leaders who teach others rather than simply learn what others direct them to learn.

In the next section I provide examples of the kinds of evidence I noticed that suggested the presence of each of these problems. I then discuss an intervention for connected formal and informal learning processes and settings and show how they provide information about how, when and why various combinations of activities were particularly important for helping students learn.

Barriers to Effective Learning

In the previous chapter I noted the high drop out rates of students, the attempts to motivate them by making use of their pristine surroundings and thoughts about the future when the dams would be removed. I introduced Figure 2, which showed four cells of a grid where chances to bridge formal and informal learning settings and processes were possible. I also noted that none of these bridging attempts seemed optimal and I wanted to test some combinations of processes and settings that, based on observations that related to important research literatures, should improve learning. In this chapter I discuss in more detail some of the potential problems regarding diminished learning opportunities that I observed.

My observations fell into the II quadrant of Figure 2 (Informal settings and informal learning processes) and hence were not constrained by any formal curriculum. This allowed me to notice a number of features that seemed to have the potential to be changed so that learning could be improved. Attention seemed to me a critical component in the exercise. When students' attention was focused intensely on worksheets and terminal objectives (learning processes that are typical of a formal classroom) there was neither time nor space to notice anything else. For example, I could not help but notice the routinized nature of the work amidst immensely interesting and quite unique landscape. Who could fault teachers who were pleased that the students are using Mathematics and Science in compliance with State Grade Level Expectations (GLEs), and fulfilling other state and national standards for proficiency in STEM-related schoolwork? Many teachers realize the tensions inherent in maintaining high standards at the expense of over-standardization, mentioning that they are constrained by need to cover "all this material" for these GLEs (Hosselkus, 2009; Valadez, 2010). I began to think about implementing certain educational experiments to test the most effective way to surface some of the issues around teaching and learning in a blended environment with formal and informal.

Even, when students were getting the experience of being outdoors where they could explore naturally, what they explored did not appear to be guided by a focus on history and future implications of the dam removal. For example, despite the fact that dam removal was constantly in the news, I noticed that much of the younger generation did not appear to ask why the dams were there in the first place nor what impact they had on previous cultural life. A fifteen-year-old student's statement sums this up succinctly when she elaborated her thoughts to her peers, parents and teachers at a presentation of her school science project (which was a baseline study concerning the ph of the river at three locations before the dams come down). She said it was a pity to remove the dams, because:

> "The dams were there first, and why would they make a National Park in a place where there are two dams. It makes no sense."
> **(Excerpt Transcription: Dam Presentations tko)**

What fascinated me was that this student's grandparents had depended on the river, the valley floodplain and forest environs along an adjacent coastal strip, for their very survival, their livelihoods, going back centuries over multiple generations (Young, 2009). But many of the youth did not seem to have a deep appreciation of this fact.

An especially important discovery for me was how I I experiences (see figure 2) of daily life and school outings allowed seemingly "obvious" aspects of the environmental setting to be ignored. Having read about the enormous silt deposition

(Allaway, 2004) at the head of Lake Mills,[2] I was curious to know what the students understood about it—could they comprehend that size? I knew that these students had been the recipients of several talks about the impact of silt on salmon, on coastal habitats and on the turbidity of the river and resulting drinking water for the townspeople. Apart from the broader impact of silt dispersal on ecosystems and species' habitat, since these students were the townspeople just mentioned, I wondered if they understood the direct impact on their drinking water. According to scientists (e.g., Allaway, 2004) it would take several decades to clear out the more than 20 million metric yards of sediment from both sites.

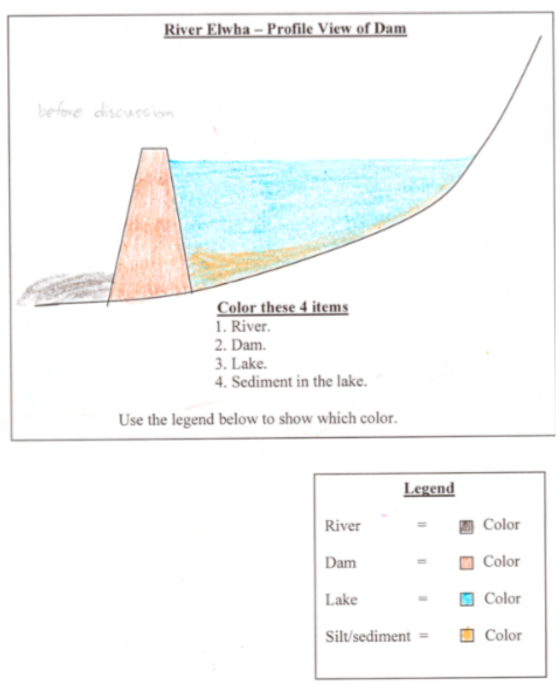

Figure 6, Stanley's crayon Sketch of Lake Mills and Glines Canyon Dam

[2] There is upwards of 18 million cubic yards of silt deposited at the head of Lake Mills (Upper or Glines Canyon Dam). This silt will be redistributed by the river down stream and on the coastal foreshore over the coming decades as the dams are removed and the river continues down to the sea unimpeded. Another large silt buildup (approximately 5 million cubic yards) has occurred at the head of Lake Aldwell (lower dam). That load too will be transported down to the Strait of Juan de Fuca.

Since a large portion of the students' activities were centered around Lake Mills and the Glines Canyon dam which contained it, I designed a simple two-dimensional sketch of the river, the lake and the dam and used it to capture subjects preconceptions about the outdoors landscape. Figure 6 is an example of one student's (Stanley's) sketch. It is clear from his drawing that Stanley understands that the surface of lakes are flat and fill back upstream where the river used to flow equal to the height of the dam (actually a little below the top of the dam to include the spillway). He also clearly knows that the barrier that contains the lake (on the downriver side) is in fact the dam. Stanley is aware that the river flows into the lake but exhibits a little confusion with regard to where the river exits the dam. Even though he was standing looking at the water cascading through the spillway in spectacular effusion, he indicated that the river emerged from beneath the dam wall. This part was fairly typical of all the students—they were able to understand some of the big ideas in relation to flowing water, dams, and lakes. However, when I compared Stanley's comprehension of the deposition of silt in the lake with his peers (also with his teachers and other adults), I was surprised to discover that 100% of them could not fathom the idea that the silt was at the upper end of the lake. This was where the river entered from the narrow confines of its valley into the wide lakebed—as far away from the dam wall as one could get. The students had spent many hours playing in the lake but apparently did not notice this point.

Science teachers saw the dam removal as an excellent opportunity to introduce 'real' science to the 7th and 8th grade learners by tying it to an Inquiry Cycle for science in the outdoors. Typical questions that are asked include, what is the temperature (or PH) of the water above the dams, between the dams, and below the dams? Predictions in relation to what will happen to the fish when the dams go away are also fielded. This kind of investigation lead me to ask: What if, teachers expanded their thinking a little to include a model that instilled a 'preparation for future learning' (PFL) while in the outdoors? What if, while introducing science methods to the students, teachers could also develop 'habits of mind' around doing science that would involve noticing, self-directed attention to the landscape and to their own learning, so that the students would gain solid metacognitive habits that would prepare them for future learning? This kind of learning sciences thinking is aligned with twenty-first century skills through agency and metacognition in action. I resolved to test a progressive and formative self-assessment tool in the outdoors during the intervention. This was the genesis of the crayon sketch on the bus idea that was designed to created positive habits of mind around metacognition and noticing.

Figure 7, Spillway for Glines Canyon Dam

A second question arose as a result of the students' failure to understand the physical machinations of the dam itself. They were standing on the dam in full view of the lake and the mountains. A chute spilled excess water from the dam into the steep ravine below (see figure 7, Spillway for Glines Canyon Dam). There was a huge amount of energy in full view (white energetic flow) and the students had to shout to be heard above the deafening roar of the spill. Someone pointed out the track on top of the dam and the little train that was shunted out over the chute to lift one of the three gates that released water from the lake when needed. One of the gates was in fact raised and water emerged from the lake in a white spume, just a few inches beyond where the lake was a placid pristine pond (see figure 8). It is interesting that no one seemed to have asked about this issue before.

When discussing the generation of electricity using hydropower (back from the structure and at a vantage point where they could talk with ease and still see the entire panoramic view), the students seemed to comprehend that a dam was necessary so that enough water could be directed to the turbines where kinetic power was converted to electric power. The students had been shown the lake, and they had walked along the top of the wall. But when I asked them to show me where the electricity was generated, I was met with a blank stare. They looked around again, at the dam, the lake, the mountains, the huge noisy spill chute. One student volunteered that the electricity was generated in the chute. Many heads nodded in agreement. They had no thought about locating the intake tower, finding the turbine house, or even locating electric wires. It just seemed obvious that all that flow going through the chute must be the power that creates electricity. And once again I was surprised that none of them seemed to have asked about this issue on earlier outings.

Figure 8, Intake Tower where water is channeled into the turbine house beneath

Imagine their shock when the National Parks' ranger pointed (facilitated their noticing) to the intake tower behind them, towards the front of the lake and behind the dam by a good thirty feet. Later, I was surprised when the ranger mentioned to me that he was shocked that no one noticed the intake tower. It never occurred to him that children would mistake the water released through the chute (to protect the dam from the weight of the lake), with water generating electricity. "There aren't even any turbines here" he nodded in apparent disbelief.

The foregoing examples of students' understanding of these normal, if somewhat counterintuitive, features of their environment reveal a 'disconnect' between their natural landscape and their theoretical knowledge within their own community. It also reveals a disconnect between the tacit knowledge of the Park Ranger and his novice students who became unwitting victims of his expert blind spot. Similar observations are charted about the students' failure to notice 'no sand' on the beach, the failure to notice the connection between cobbles in the bluff behind them and similar cobbles under their feet.[3] In addition, they failed to notice the prominent winter beach berms,[4] even though they struggled to climb them (steep-sided loose cobbles that were very unstable) underfoot in the course of their transect work. They also failed to notice the frequency of waves in relation to longshore drift,[5] and a host of other features and processes that were imminently present on the short walk to and from the beach. In these instances of naive science, I document a failure to notice what seemed obvious to an expert, and I realize that the apparent 'disconnect' connects to literature on noticing and expertise.

This experience served to problematize for me the idea that learning from experience is the panacea that some people suggest it is e.g. Aristotle, 360 BC; Dewey, 1934; Kolb, 1997; Pliny, AD 77). Many people have different meanings for what experience means—obviously they probably mean different things by it For instance, the teachers who routinely take students into the outdoors to "do" science, often express the idea that they are learning from the real world (Dewey, 1938; Kolb, 1984; Rogoff, Paradise, Mejia-Arauz, Correa-Chavez, & Angelillo, 2003; Sobel, 2005). So how should we view experience from a learning sciences standpoint?

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[3] These cobbles were key to gaining an understanding of the big idea that could explain what was going on around them physically. The matrix on the bluff was totally unlike anything else in the area, and to an observant expert, it was clearly deposited when the ice (from the recent ice-age 15,000 years ago) retreated into the sea in front of the Elwha River, and since it began to quickly melt, it dumped its load. This then was probably a terminal moraine from the last ice age.

[4] Storm beach high above the regular beach, as a result of stronger wave action during winter storms.

[5] Wave action tends to distribute any loose materials (including pebbles, sand and driftwood) to one end of the beach or other. This is caused (especially on cuspate beaches or where the waves approach the shore at an angle) by a differentiation of the force of the wave on its swash stroke as opposed to the gentler return on the backwash stroke. Careful observation will reveal a bit of driftwood rushing ashore at an acute angle under the full force of the incoming wave, but returning under gravity at a more right-angled gait. Over time the piece of drift wood will appear to drift lengthwise along the beach in what is known as longshore drift.

Three experiments were conducted that tested various aspects of the quadrants in figure 2, so that attention, cognitive overload, and agency were looked at. Each of the quadrants of figure 2, the Learning Experiences grid, was explored in order to understand the contribution to learning sciences that working with a blend of formal and informal might offer. I investigate each of the sectors separately.

F F - Formal School and Formal Teaching Processes

Most students and teachers are very aware of the F F dimension of the learning experiences grid shown in figure 2. Notwithstanding the "sea of blue" shown in figure 1, the school classroom is a fixture in the lives of most teachers and students for the majority of their daily work together. The school in this study had typical classrooms as could be found in any part of the US, with bright, spacious rooms that were accessible and replete with modern equipment to help children learn.

The teachers in this study were dedicated professionals who worked hard to help their students to achieve in whatever area of their lives they opted to go. They provided assistance to the students so that they might reach good grades and be successful in life. The science teacher went so far as to organize a day trip for the students so that they could show their science projects (which dealt with implications of dam removal and habitat restoration in the Elwha region) to faculty, and graduate students at the University of Washington. Afterwards the students had the opportunity of visiting scientists and experience cutting-edge science in the Human Interface Laboratory at the University of Washington. This kind of dedication and extra effort was meant to connect the students with career choices and develop an appreciation for why they should stay the course to finish their high school diploma.

I noted earlier that in spite of the best equipment and very committed teachers and parents, there is an unacceptably high drop out rate (approaching 50% annually) reported for this school district. Motivation is high to alleviate some of the problems that lead to high drop out rates. Consequentially, there is a growing perception among teachers that a solution might be found in an approach that blended the formal classroom learning with informal outdoors data collection and interpretation. Thus, they theorize that an increase in the amount of time students spend in the outdoors doing science might have an ameliorating impact on the high drop out rate. Local tribal teachers are convinced that the two weeks that the students spend in experiential outdoors learning in the summer months is equal if not better than the drudgery that the students have to endure for the remaining nine months of formal schooling (Hosselkus, 2009; Valadez, 2010). In their view, school is too focused on GLEs and State Standards that have very little meaning for the tribal children or their non-western worldview. Consequently, they associate this "meaningless busy-work" with a difficulty in motivating the children to stay in school long enough to achieve their high school diploma (e.g., Bruner, 1960).

I I – Informal Settings and Informal Learning Processes

As mentioned, my initial explorations included many opportunities to interact with places and people in the Elwha area and, based on my own choices and perceived needs, I read articles and reports on the history and future of the area. My personal experiences were strongly affected by my expertise as a geomorphologist and as an immigrant with many cross-cultural experiences. I never took a formal course on the Elwha Nation, their culture or geography, but I was exceedingly interested in the effects of dams on displaced communities. Both geographically and culturally, this was a unique area where a confluence of historic events is having a major impact on the local community today and in the near future as well.

The local children also had opportunities for outdoors experiences that were shaped by the I I space in figure 2. Family outings and some after-school activities often brought the students to the outdoors area around the river Elwha where they played in the water, walked the lake shore and hiked or camped in the upper valley. Many students took part in summer school programs, which were usually weeklong residential programs where the children could engage in canoeing, hiking, and backpacking in the outdoors environment by the Elwha lakes and dams. I was part of several of these programs and witnessed the students' reactions to the summer school programs, as well as their engagement and attitude to the work therein. While they had real outdoors experiences and engaged in many fun-filled and adventurous activities (some of which were designed around data collection for science projects) the students failed to notice some very simple and obvious things about the lake, the dams and the valley. They were present in the outdoors landscape, but they weren't present in their noticing subtle things about their landscape. It seemed they lacked the 'habits of mind' around attention and noticing that would be useful for learning.

I F – Informal Settings with Formal Learning Processes

During the regular school year (not summer courses), I was able to examine many outdoors classes in the I F quadrant of the grid in figure 2. This is a condition where a teacher places the children in Informal settings (outdoors), but continues to use Formal learning processes that might have worked well in classroom situations. It's as if nothing had changed but the location of the classroom. I was present for many such class excursions into the outdoors where students were given out-of-school experiences that were designed to meet GLE and state requirements for science or mathematics (many GLEs and State requirements are written with such vague wording that it is possible to "cover" the requirement by going into the outdoors to "do" real science experience). On these occasions, I observed children receive hands-on instruction through inquiry-based approaches to learning. There were many moments of positive engagement, a sense of adventure and fun that the children seemed to enjoy while doing "science" in the outdoors.

The children, who were delighted to be outdoors away from the classroom (and freely admitted it), seemed highly engaged in the work. The science was first rate, involving data collection, measurements and copious note-taking in pre-set worksheets. I witnessed the children taking measurements from the riverbank and interviewed many of them along the way. It was obvious that, even while the students were in the outdoors engaged in sound scientific work, they were so focused on worksheets and on completing preset handouts that they failed to notice even rudimentary phenomena that were right before their eyes. This could be a reason why many teachers expressed frustration at their difficulty to capture any measureable learning outcomes (other than recitation of occasional facts) from the experience (Hosselkus, 2009; Skerbeck, 2010; Young, 2009).

My observations primed a conjecture that, as a result of this misalignment in dimensions between learning processes and settings, the students were constrained from noticing many key aspects of their environment. If it wasn't related to the worksheet or handout, it didn't count. Students needed to complete their list of terminal objectives and, seemingly, were prevented from noticing any of the subtle phenomena that were everywhere in their immediate surroundings. For instance, students were busy documenting the "size" of cobbles on the beach, but failed to notice that there was no sand under their feet. Likewise they didn't notice that the same cobbles were also to be found in a very visible matrix on the bluff ten feet behind them. This constraining aspect of misalignment I describe as a "penumbral effect" of one dimension over another. When the effect is negative as in this case just described, it tends to have a dulling impact on learning outcomes. Such a penumbral effect occurs when learning settings and processes are poorly aligned.

Figure 9, *Students at work on Beach Transect*

Even if one argues that the students' primary task had nothing to do with noticing things around them, that they were supposed to gather data about water temperature and ph levels, it is virtually impossible for the children to understand the contextual significance of their data unless they notice the real world phenomena within which they are existing. So what if the ph level is 5 or 10? What does that matter? How does it fit into the real world in which the data is being collected? In my experience, the science classroom in this outdoors event seemed to be overly school-like where the worksheet became the critical component and metrics used for a successful outing.

Similar “misunderstandings” lead to naïve science even when teachers are well-intentioned and undeniably expert in their content knowledge domains. One such learning event occurred during a hands-on experience when students had the opportunity to accompany a wildlife scientist to help her set traps and study otter habitats in a river location (Lieberman, 2010). The content was spectacular, the experience was amazing, the science was first class, but when the students discussed the science for their worksheets (back in the classroom afterwards) more than half the students were convinced that otters (i) loved to look at cameras by night, and (ii) lived in natural habitats called “latrines”. Somewhere along the way, it didn’t occur to anyone to explain that otters could be found, studied and tracked (with the aid of modern nighttime cameras) by beginning with the latrine and working backwards to find their dens (which usually have two entrances—underwater and above water).

Increased awareness of environmental education and activity-centered inquiry-based science has resulted in more and more classrooms heading into the outdoors every year—and none more visible than in the Elwha hinterlands. The momentum of activities and the public image that a project of this enormity produces has engaged local school administrators and science teachers so that students are increasing being taken on field trips to the Elwha valley and coastal region.[6] While many teachers express a deep interest in having their students experience the outdoors, hence becoming engaged with the pristine ecology of a wilderness region, they deliver a seemingly 'tunnel-vision' focus on building this interest around relatively narrow aspects of scientific inquiry related to STEM by using it to gather data in the wild (e.g., to measure the acidity of water in various places, degree of dissolved oxygen, etc.) These kinds of activities fit requirements for state standards for science, and being able to actually conduct these studies in the wild seems especially helpful. The students' geographic area lets them go beyond "kit" based science such as those in Foss kits where "nature" arrives in boxes containing fishes, plants, etc., that can be used for inquiry. Foss represents a step above simple textbook learning about science (Shutt, et al., 2010); but learning key concepts in one's own homeland is an advantage that most would agree represents an addition to kits that is an opportunity for more meaningful learning to occur.

As I continued to observe the students and teachers, it became clear that actually learning "in the wild" was not necessarily superior to kit-based or even text book learning. In the curricula I saw that were built around the dams, lakes and beach, the approach was didactic and intensely formal in nature—the same kind of book work, handout material and activity sheets that the children were used to getting in the classroom setting. For example, an exercise in mathematics and science asked students to measure the slope of a beach using tape, level and meter sticks (see figure 9). Students were asked to plot the resulting graph on squared paper with a view to understanding how beaches are affected by wave action. Most of their attention seemed to focus on the

6 The litany of superlatives in connection with this project is mind boggling—the largest dam removal event in the world, the largest watershed area, most important spawning grounds for steelhead trout, the most pristine national park, two dams coming down brick-by-brick at the same time, largest lakebed area, largest habitat restoration with focus on native pants, more than 20 million cubic yards of sediment …

worksheets, with much less attention on exploring their homeland, generating questions, and benefitting from the kinds of instructional activities that could help them understand important aspects of their past, present and future lives as the dams came down.

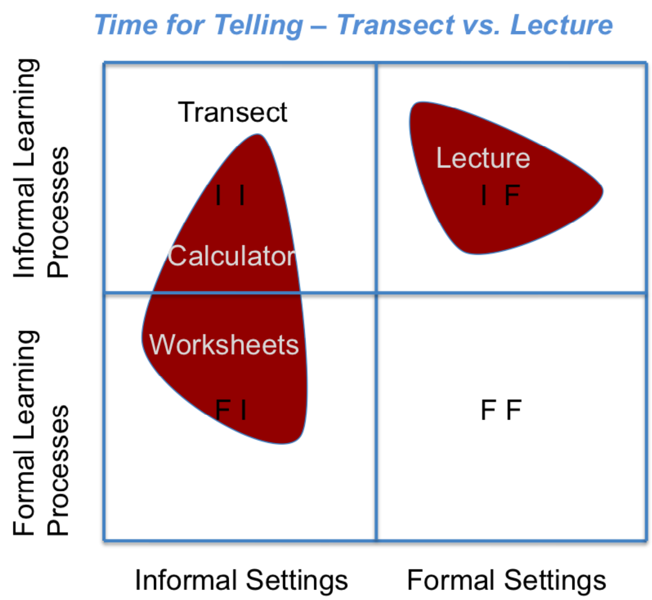

Figure 10, Time for Telling – Transect vs. Lecture

As a result of these attempts to teach children in the informal outdoors setting with varying success and, it seemed to me, many missed opportunities, I was prompted to introduce a manipulation in the intervention so that a "time for telling" was created. This was arranged to test the effectiveness of learning situations in FI versus IF (See figure 2). In the first instance, the control group was in informal settings (Lake Mills) and the learning processes were formal based on classroom experience (a lecture). At the same time, the experimental group was in an informal setting (beach) with informal learning processes (transect) that in fact detracted from their noticing because it was so intensive on data gathering. Informal environments are often more complex than formal classroom settings, and tools are often needed to make them clearer to observer. The calculator (because students got their worksheets filled early) appears to have allowed the students pay attention to their surroundings in a much more meaningful way than the traditional pen and paper model.

F I – Formal Settings with Informal Learning Processes

In this quadrant of figure 2, the students are in their classroom and the teacher deliberately makes use of teaching techniques and artifacts that are Informal in nature and spring from an informal encounter with learning. For instance, the students arrive back to class after a field excursion, and the focus of their work is to explain and make sense of what they experienced in the field. This was not my experience for this study, where the focus was on completing the unfinished parts of their worksheets and writing up a report of what happened. At no time were the students focused on their own observations, their feelings or thoughts about issues that were not on the syllabus for the particular worksheet.

Attention: We rarely notice what people fail to notice. I noticed many things that remained hidden for the students in this study. This was disturbing since the objective was for them to make connections with the physical elements in their own backyard. In the expertise literature this kind of noticing, or lack thereof, is not uncommon. Novices (especially book-oriented novices) are often not prepared to notice important clues, including marks in natural shapes and specific location that sometimes appear to be counterintuitive to one's thinking, and that experts immediately pick up on. In this study, I created a time for telling to investigate if learners would be better prepared for noticing if they experienced hands-on activities before a lecture.

Educators have known that attention is critical for learning at all levels, a fact that is particularly meaningful today when there is so much discussion about children multitasking, distributed expertise, and effects on learning. William James (1890) was one of the first educational psychologists to elaborate on the importance of attention as a function of noticing. Referring to the "teeming multiplicity of objects and relations" (p. 224) that constitute consciousness, he prescribes that what are perceptual phenomena to humans come as a result of "discriminative attention" taken to a high degree. In the following passage (which has close meaning for this present work in Elwha) from his classic work *The Principles of Psychology* (1890), James describes why the "mere presence" of an experience is not enough, why noticing and attention are critical components to connecting with an experience:

> "… one sees how false a notion of experience that is which would make it tantamount to the mere presence to the senses of an outward order. Millions of items of the outward order are present to my senses which never properly enter into my experience. Why? Because they have no *interest* for me. *My experience is what I agree to attend to*. (p. 403)

Accordingly, for James, mere exposure to an experience does not appear to suffice in the acquisition of expertise. Without "selective interest" (or guided noticing) which is attained through noticing and attentional focus, experience can be ambiguous at best and often lapse into what he referred to as "utter chaos" (p. 403). Clearly, James is of the opinion that experience without mediated noticing and guided perception is less than optimal.

Others also focused on "attention" as a model for understanding complex cognitive processes and improving learning. Gibson (1969) focused on experiments that helped explain perceptual learning and development. She theorized about multiple opportunities to see similarly structured phenomena in order for a learner to differentiate them. For her, learning was closely tied to a perception of the world around her, together with its permanent properties, its furnishings and ongoing events. She prescribed that it was the “education of attention” that mattered when it came to differentiating elements of learning. From this standpoint Gibson was an advocate of experiential learning and her work advances James’ theories by tying the attention concept to a process that could achieve deep understanding.

Differentiation is recognized as an important component for understanding and learning, and is incorporated into the philosophical writings of many educational theorists (Bransford, Franks, Vye, & Sherwood, 1989). In particular, by creating an opportunity for students to explore contrasting cases (Schwartz & Bransford, 1998), they gain a fresh perspective on phenomena and aspects of the environment that may have been previously inert. According to Bransford and colleagues (1989), these theories propose that opportunities to analyze sets of contrasting cases can “help people become sensitive to information that they might miss otherwise” (p. 470). This translates for the experiential teacher into ways of organizing the environment so that contrasting cases are readily accessible for students so that they can first, notice them, and second, comprehend the differences. By focusing attention on contrasting cases the landscape suddenly can have meaning for the learner. A second experiment in this study focused on learners’ ability to pay attention to differentiated data by using technology to help reduce the cognitive load.

Changes in noticing as a function of changes in expertise are a key element to the development of what the educational theorists, Stevens and his colleague Hall (1998), refer to as ‘disciplined perception’. For them, attention is still critical but is something that is learned from culture. From these theories, it is clear that there needs to be some kind of guidance for helping people notice things. Mediated cultural activities leading to sound learning prompted the third experiment – creating 'habits of mind' so that students could be better prepared for future learning. This was envisaged as a learning situation that completed the successful blending of formal with informal (Settings and Learning Processes) so that children showed a capacity to abstract theories from concrete observations and begin to surface measureable action with regard to their own learning.

The idea of mediating the learning moment is echoed by many theorists in different educational areas of expertise, but especially by Feuerstein (2010). He theorized that optimal learning for children comes not simply from direct experiences but, instead, from carefully scaffolded, intentionally mediated interactions from mentors that are designed to connect everyday experiences to the broader cultural and academic settings within which children live. His work on "cognitive modifiability," which was based on assumptions about carefully mediated learning opportunities with pedagogic tools that are appropriate to the context and the subjects (Feuerstein, Rand, & Hoffman, 1979) help to illuminate the issues around cognition and cognitive processes in a blended environment. For Feuerstein, and for kindred theorists such as Vygotsky, Piaget and the applied developmental psychologist Andre Rey (Feuerstein worked closely with Piaget & Rey) these mediations often included pedagogical tools and artifacts (Feuerstein & Feuerstein, 1991). Thus, his ideas are central to this study because, even if the students in the Elwha valley do not show similar cultural disconnects that he witnessed in his work (e.g. due to being children of the holocaust), they nevertheless show signs of disconnect from historical cultural and societal mores of their ancestors—and stronger connections would be assumed to help them in their ability to assimilate (Banks, 2007).

Accepting change is a critical aspect of learning, especially when applied to overcoming existing conceptions of events and phenomena in relation to the physical environment in which we live. In this next section, I will focus on the literature that illuminates conceptual change with respect to attaining expertise in a given knowledge domain.

This rich literature in expertise and its relation to "noticing" has implications for teachers and the learning sciences that lie in the connection between noticing and understanding as knowledge moves from abstraction to perception. When the learner articulates an abstract understanding, it enables him or her become more perceptive with respect to nuances of what is being looking at, and connections can be generated with meaningfully disparate concepts around that phenomenon. Changes in noticing do not necessarily manifest themselves *in vacuo*—hence the learning experiments in this study. Having problematized the idea of experience as a panacea, I began to look at ways to connect informal and formal learning with a view to understanding the complexities and affordances that they offered for young people and learners.

Methods

This dissertation began with a question regarding young people's failure to notice nuances in their natural landscape. For instance, even when children were in an informal learning environment (F I, in figure 2) they were so busy with their worksheets that they failed to notice even the most obvious of features in the physical landscape. This attentional overload was not eased any by subjecting the students to long knowledge intensive lectures in the outdoors that dealt with dams, lakes and electricity. In essence the students did not have an opportunity for any independent inquiry while they were engaged in "doing science" in the outdoors.

It is a design experiment that takes place in the real world where student outcomes are consequential to the participants (Brown, 1992). I first described the settings, the physical locale and the blended formal/informal environment in which the study took place. Then I offered several overlapping conceptions that frame a theoretical perspective for the research and its potential implications. In this next section I outline design methods that I use in bridging the formal and informal worlds of learning. I investigate challenges and implications of this kind of blended environment, paying especial attention to outcomes by designing several different approaches to teaching. First, I introduce a time for telling, to find out if this approach will have an effect on student learning. Next, I document an attempt to reduce cognitive load (Sweller, 1988) by using technological advances in computing and calculators. Finally, I investigate the idea of "priming" students to ask highly relevant and meaningful questions that uncover a deeper cognitive landscape around learning and metacognition.

This research project uses a mixed methods approach. Ethnographic data are collected over a two-day field exercise in a blended formal and informal environment. During this time, participants carry out a science/mathematical project in an outdoors setting that was expected to enhance their normal schooling activities. Two University of Washington graduate students from the learning sciences accompanied the students in the execution of the various portions of the study, taking measurements in the classroom both before and after the outdoors portions of the intervention, on buses, and at various sites. Participant observers accompanied students while they were carrying out scientific work at several sites on the river. These trainee-ethnographers were also note takers and camera operators. All data were compiled and analyzed at the end of the two-day collection period.

Student quantitative data were also collected through various test instruments that were administered before, during and after the outdoors field activities. A pre-test consisted of twenty-three questions that focused on manipulation of mathematical and scientific concepts deemed appropriate by the team of teachers and researchers who collaborated in preparing this instrument. A posttest was administered at the end of the second day. The pre and posttest were identical (see appendix 2). All participants completed both pre and posttest and were administered in the students' homeroom at Valley High (see figure 5). Finally, a demographic survey was administered at the time of the pre test. It was used to elicit information about individual participants who took part in the study.

Participants

Participants in this research (N =16) came from a local high school in Northwestern Washington (Valley High-a pseudonym). They consisted of 8th grade science and mathematics students—equal part male and female. All sixteen students volunteered to take part in the research. Signed consent forms were obtained from both the parent/guardian and individual students. University of Washington IRB was granted for this research. Each student's identity was protected and all data were collected anonymously. Data for the research was stored safely on-site in the University of Washington, College of Education. No other person(s) had access to the data besides the research team.

Males and females were included in the research just as they were represented in the classroom—eight boys and eight girls, each aged sixteen years. The students were fairly typical of local students in this valley. The demographic survey indicated that the students fit typical patterns of high school students from the local region. The tendency of students in this rural community has always been to remain in the area to find work locally and pursue their livelihoods after high school (Hosselkus, 2009). Over the past decade, more than half of the graduates from Valley High have stayed in the local area, many of them finding employment in the local town and in the Casino nearby. Of the 16 students in the study, four plan to attend a four-year college outside of the area, two plan to attend a junior college (one in the area, one outside), two plan to enter the military, and the remaining eight plan to either stay in the area and work, or they do not know their future plans.

Study Settings. Much of the research took place over two days in a rural outdoors area of Northwestern Washington. A physical map of this locale and region is displayed in Figure 11. In this map the Elwha River is shown, with annotations that point out the important sites for this study. To orientate the reader, it must be noted that the river Elwha flows from south to north, or as depicted in the accompanying figure, from the bottom to the top of the page. I point out also that in the interest of showing critical details for the two sites that are pertinent for this study, neither the source nor upper course of the river is shown.

Accordingly, the river appears on the picture just above Lake Mills (shown at the bottom of the map with a red arrow). This is the site where participants in this study received a traditional lecture about lakes, dams and electricity generation, and from where they could safely stand and look out over the lake and dam. From this entry point at Lake Mills the river flows down to another lake (Lake Aldwell) trapped above the lower dam (shown with red arrow).

The area of the river between the two dams is contained in a narrow valley between upland topography. Just south of the lake at the lower dam, the river is crossed by the state highway (SR 101) and just below the lower dam another highway crosses also (SR 112). Between the lower dam and the Strait of Juan de Fuca the river meanders in its lower course, before entering the sea through a delta. The second site where participants of this study carried out a beach transect is shown near the mouth of the river (marked by a red arrow). A transect is essentially a physical mapping of a landscape by taking measurements over a linear distance and transforming those measurements into a mathematical representation. By interpreting the resultant shape of the beach profile students can identify various processes at play in the physical environment.

The Upper dam, which causes Lake Mills to back up into the naturally formed narrow gorge, is also the site of one of the counterintuitive phenomena associated with this study. The far end of this lake is marked with a red arrow and the word SILT. This is where the river enters the lake, slowing down as it does, and thereby depositing its load.

Figure 11, *Map of Elwha River System with two Dams*

The participants of the study were taken to a vantage point at the upper dam where they were shown the dam structure and told about the large deposit of sediment (SILT). The third site of activities for this study was at a typical formal setting—the students' homeroom in Valley High (See Figure 5). All participants began their day each morning and ended each afternoon in the homeroom. Project preparation, including instructions for special equipment used in the research (e.g. training in the use of the advanced graphing calculator, TI-Nspire™) took place in this room. The pretest was administered here also, as was the posttest and report-out session that brought the two-day activity to a close. School buses were used to ferry the students from Valley High to the various outdoor sites where they undertook their scientific investigations as prescribed by the day's activities. Instructors from Olympic Park Institute, (OPI) operated the buses. Classroom teachers acted as chaperones for the two-day event, but did not do any teaching. They were however, available for questions and to help students when questions pertaining to their data collection arose and other management issues, as needed.

Study Design and Instruments

The study was implemented using a 2 X 2 design. Students were first randomly assigned to one of two groups—control and experimental cohorts that received different instructional treatments. Within each group students were then randomly assigned to the use of one of two different mediating tools during implementation. As a manipulation of attention, a control group used traditional pencil and paper to aid their collection of data in the beach area while the experimental group used technologically advanced graphing calculators (TI-Nspire™) to collect their data. As mentioned earlier, it was hypothesized that the device would help reduce the complexity "load" involved in mental processing during the beach transect and interpretation of the observed and collected data in the field.

Both groups approached the two-day activity from an opposing position with regard to time and place. The control group did one activity first on day one, and the second activity on day two, while the experimental group undertook the second activity first on day one and the first activity second on day two. All students took part in and completed all activities.

Separate activities took place at each of two sites over two days. Once the students had completed the pretest (and instruction relating to the use of specific equipment), the study was carried out predominantly in the outdoors. Instructors remained at their appointed sites (beach or dam) for the duration of the activities.

	A	B	C	D	E	F
1	Summary					
2			Beach on Day 1	Beach on Day 2	Calculator	No Calculator
3	Bubble Girl	1001		X		X
4	Candi	1002	X		X	
5	Caterpillar	1003		X	X	
6	Chupqueso	1004	X		X	
7	Jay	1005	X		X	
8	JHM	1006	X			X
9	Leigh	1007		X		X
10	Littleman	1008		X	X	
11	Ramon	1009		X	X	
12	Rowdy	1010		X	X	
13	Reina	1011		X	X	
14	Russell	1012		X		X
15	Silent Bob	1013	X		X	
16	Stanley	1014		X		X
17	Tech 9 (HI??)	1015	X			X
18	Trickey Boo	1016	X			X

Figure 12, *Operationalizing the Outdoor Research Design*

In this way, an instructor provided the same instruction at a particular site for both cohorts. Stated differently, the students moved from site to site while the instructors remained in place. As noted already, the control group used paper and pencil for record keeping, while the treatment group used the TI-Nspire^{TM} device. The research design is summarized from an operational point of view in figure 12.

Geographically, the beach is situated on the Strait of Juan de Fuca on the northwestern shore of the US (see figure 3). A counterintuitive phenomenon is encountered here on the beach. The River Elwha spills into the sea at this juncture. Since the river reaches its endpoint at the sea it tends to drop its load. Deposition at this location is not what one would expect however, since the majority of what should be sediment is still trapped in two lakes behind two dams upstream (Allaway, 2004; Casey, 2006; Randle, Young, Melena, & Ouellette, 1996). There is however, some evidence of deposition at the juncture of sea and river (see figure 13, that shows the deposition at river end) but not nearly what should be there.

Figure 13, River Elwha deposits silt upon arriving at sea

Even if the deposition in the photograph might appear to look like sand, in fact it is not. Sand, which is fine in texture and light by weight, has over time been eroded and dispersed out to sea by tidal channels in the strait and also as a result of wave action in the intertidal zone. For instance, there are anecdotal accounts (Charles, 2010; Valadez, 2010) of a time when the local tribal people were able to build houses and live on Ediz Spit,[7] something that is impossible today since the spit has mostly been eroded away (and receives no new sand).

Figure 14, The lower dam site before and after

The beach area is distributed with large cobbles and small pebbles that were deposited here from a high bluff that runs parallel to the shore. This bluff has been severely eroded by the river and sediment from this erosion is scattered all along the

[7] In the late 1800s and early 1900s Elwha and Klallam people lived on this sandy spit where there was a lot more sand than today.

mouth and subsequently selectively distributed (through wave perturbations) along the beach.

The counterintuitive aspect of this exercise is immediately evident when the students arrive on this beach. There is no sand on the beach—just large cobbles and polished pebbles. The students never mention this observation nor do they realize that it is a huge anomaly (It must be remembered that not a mile away there is the Ediz Spit which is an all sand deposit in the bay, and around the next headland and very familiar to the students are several all sand beaches). Neither do they connect the fact that the large cobbles they are trundling over on the beach are similar to the cobbles in the bluff behind the beach.

The lower dam (see Figure 11) is five miles upriver from the beach. It was built in the early decades of the twentieth century (1913), but has become untenable to maintain in recent years. It too will be removed in 2011. The area of river between this lower dam and the river mouth is the lower course of the river. It is here that most of the fieldwork is accomplished on the beach and river estuary.

The detection and understanding of the implications of silt (sediment) comprise an important element in this study. The lower section has very little sediment and woody debris because the dams prevent its transport via the river. In between both dams, there are no salmon, not much woody debris and very limited sediment deposits. It is at Lake Mills above the upper dam that greatest quantities of depositional silt accumulated.[8] The location of this silt is central to "noticing" phenomena in the natural environment and in making connections with aspects of the real world. Several different instruments were

[8] Here, a large accumulation of silt is deposited at the point where the river enters the lake—eighteen million cubic yards of sediment, or enough mud to fill a line of dump trucks that could stretch bumper to bumper from New York to Seattle three times over (Randle et al., 1996; Casey, 2006).

utilized in this study. Here I describe their constituents and execution, and discuss their importance for the study.

Instruments

Silt Measure: In addition to a pretest, which was administered in the classroom, each participant entered initial conceptions relating to dams, lakes, flowing water and sediment on the silt measure. To execute this preconception device, I designed a one-page sketch, which was useful to discover participants' knowledge coming into the two-day activity. This sketch was meant to capture participants' existing knowledge in relation to general topography, the work of rivers, including transportation and deposition.

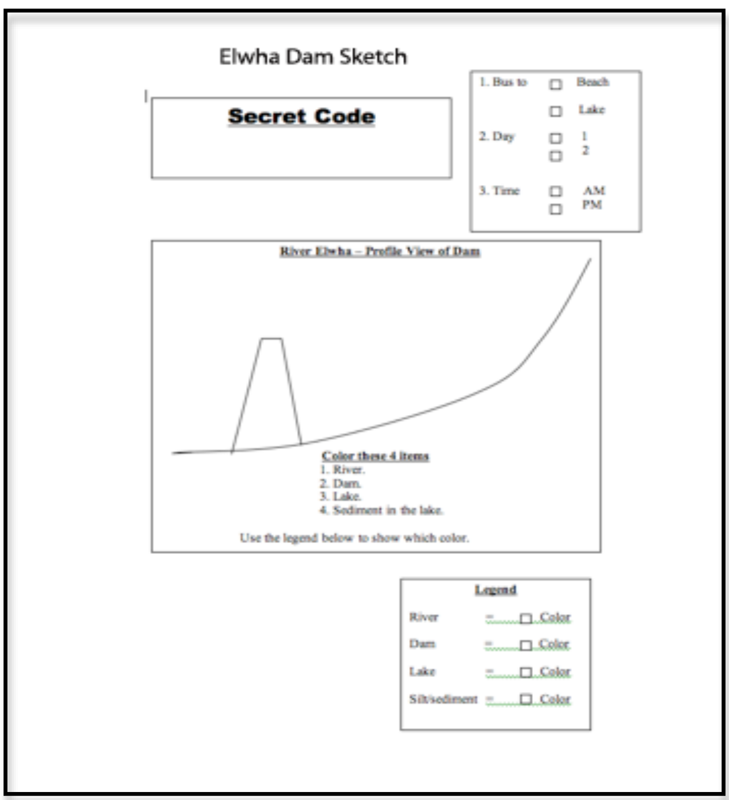

Figure 15, Elwha Dam sketch

The objective of the sketching exercise was to verify that students understood that rivers flowed from higher to lower ground; that a lake would form behind the dam, and that silt would accumulate in the lake in predictable ways. This simple map sought to 'make visible' what the students understood about rivers and dams. Before they started, participants were asked to write their secret code in the appropriate space. This insured their anonymity from the research team. Next, they were asked to identify their time and location, by checking off the boxes for bus to beach or lake, day one or two, and morning or afternoon. This helped the research team locate the particular individual in relation to the operational chart shown earlier (see figure 12). Getting down to the business of describing the river, dam and lake with silt, each participant was asked to choose a color for each differing segment. Finally, the sketcher was required to complete the legend so that the color scheme would make their work decipherable to the research team. Participants completed this diagram at least three times, always when they were on a bus either going or coming from a particular activity. As an instrument for making visible students preconceptions, this instrument worked incredibly quickly and intuitively every time.

Pretest: The pretest consisted of twenty-two questions specifically aligned with learning goals in the science and math program at the participants school and were meant to test the subjects' knowledge of science and mathematics' concepts that emanated from the river study. Questions were chosen as part of a collaborative design between the research team, teachers from Valley High, and instructors from Olympic Park Institute. A copy of the pretest study instrument is available in Appendix 3. There was a strong concentration in the pretest on graphical representation and the ability to convert raw data from tables to graphs and charts for interpretation. Several questions referred subjects to concept maps for the completion of a narrative or mathematical interpretation of real data within the local environment. Following is a detailed description of the content of the questions, which were used in this study.

Questions 1 through 9 focus on a demographic survey and constituted an effort to know more about the background and aspirations of the subjects. Results of this demographic survey are to be found in the section that describes participants. The first two questions are short essay type questions that allow subjects give personal details about themselves (all information was anonymous and subject privacy was respected). The remaining seven questions consist of a survey that is designed to explore the learning preferences of the subjects on a 5-point Likert scale centered on an agreement model—*Agreement with a Statement*. For example, a subject can strongly agree, agree, be neutral, disagree, or strongly disagree to a statement like this: *I like working in small groups when doing math.*

Questions 10 through 22 deal ostensibly with the mathematics and science that are in evidence in the two-day field experience that is described in this study. Question 10 focuses on making visible the child's ability to understand and follow instructions, by connecting the knowledge provided in a familiar food area (Peanut butter & Jelly) to another familiar food area (Pizza) through constructing the elements of a conceptual diagram—a concept map. This was included because the idea of a mapping diagram was central to completing the pretest and it was deemed important to assist the student, and offer an opportunity to practice making and manipulating concept maps from the outset. All students completed this exercise successfully.

Subsequently, question 11 asked the student to draw a concept map (similar to the previous food examples), to make predictions about the River Elwha in a post dam era—focusing particularly on changes that will happen after the dams are removed. Question 12 asks subjects to delineate the work of rivers on a map, indicating clearly areas of erosion, transportation and deposition. Question 13 deals with mathematical concepts in this same river area. It consists of a table of height and distance markers that enable a scientific rendition of a beach profile. In this question, the student is required to draw a beach profile (a transect) using the data supplied, from high-water mark to a point twelve meters back from the waterline. The scale is provided, but it presumes that the student understands the concepts involved in representing numbers on a graphical scale.

Question 14 requests a clarification of the difference between change in elevation and absolute elevation. Understanding these concepts is critical and prepares the student for constructing a beach profile later at the beach site. Question 15 refers to the relationship between pebble size and shape of beach profile. This is an attempt to elicit if the student is making connection between cause and effect in terms of process and wave pattern. The prevalent (two) types of beach profile make up the kernel of questions 16 and 17. Students are asked to give reasons for their answers, thus connecting their drawing with a logical explanation. Questions 18, 19 and 20 bring subjects face-to-face with the idea of doing science. The concept maps and linkages depict an *in vivo* scientific process essentially allowing the subject voice their ideas about conducting a scientific inquiry and implementing the different phases. Question 21 takes into account the social nature of science and the impact of change (post dam removal) on the local community. Subjects are asked to articulate their thoughts on the impact of dam removal with respect to local inhabitants, their families and friends as well as any impact on the local environment. Finally, question 22 is a closure type question that elicits knowledge from the students regarding their understanding of the issues involved in the two-day learning experience. This pretest was administered to the students in Valley High homeroom before they were taken into the field to either receive a lecture on specific dam related topics or collect real data from a hands-on beach transect. After they completed the pretest all students were taken into the field in buses that went to one of the two sites.

Data: The experiment employed a repeated measures two by two design. Pretest scores were used as a baseline, against which were measured improvements in student performance as reported in student posttest scores. A within-subject factor compared the effects of traditional tools versus a technologically advanced graphing calculator. A between-subjects factor tested for effects of two different exposition methodologies exercised during the intervention. The control group received a lecture first on the implications of dam building and electricity generation before they had an opportunity to collect samples and carry out hands-on field observations. The experimental group carried out this hands-on field observational data capture first before receiving a lecture on the implications of dams and generating electricity. In this way a classic "time for telling" (Schwartz & Bransford, 1998) was instantiated.

Members of the research team designed a scoring rubric for participants' pretest and posttest answers. Ten points were assigned to each question on the test. Three scorers, each "blind" to treatment group and time of test, independently used the rubric to score a common set of 4 pretests and posttests. Scorers then divided-up and independently scored the remaining tests. Disagreements were resolved through discussion with subject matter experts in the particular area of attention (mathematics or Science). Scorer agreement on the set of four training tests was 91.3%.

Traditional Lecture. Typically, school fieldtrips tend to be to areas that are interesting because of their scenic views or physical phenomena. Very often, teacher lectures (with some pointing and showing) orient the students to the important features of the phenomenon under investigation.

Figure 16, Students being shown the beach cliff (bluff)

At these outdoor fieldtrip occasions, it is usual for a teacher to use a didactic approach where students 'look' at the physical feature in question, 'listen' to the teacher and then make some entries in preformed worksheets. In figure 16, subjects from this research are being shown the bluff (with the cobbles) at the back of the beach.

Data Collection Devices

Participants collected data over the two-day event using several different devices. Some were low-tech traditional (e.g., pencil, paper, measuring tape) others were high tech advanced (e.g., TI-Nspire™ Calculator, Gravelometer). The Gravelometer is a measuring device for establishing the middle axis dimensions of large cobbles or small pebbles.

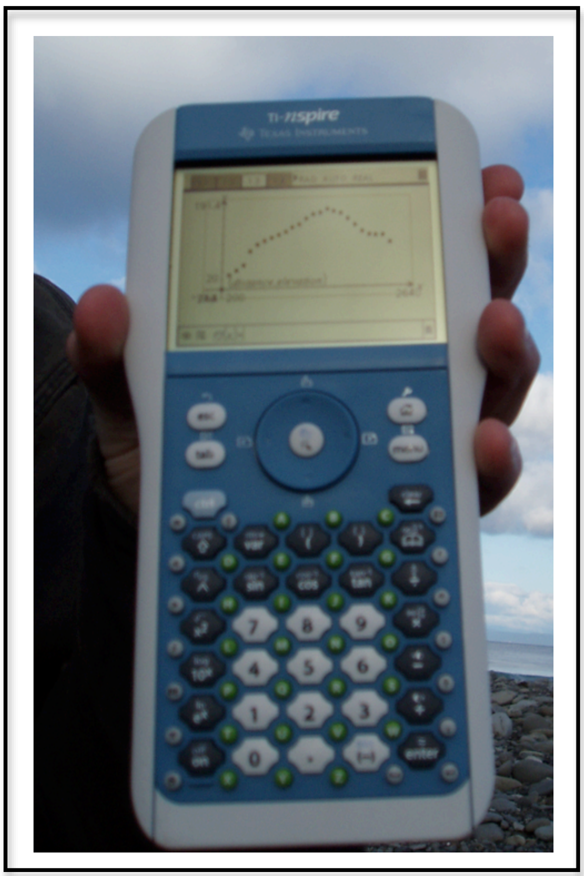

Figure 17, Advanced Graphing Calculator

The experimental group's graphing calculator was used both to collect, store and share data. It was pre-programmed to accept subject's raw data in a spreadsheet-type document window. As the data were entered in the appropriate pre-programmed fields, simply pressing a key gave a visual representation of the beach profile that input measurements described.

This is illustrated in Figure 17, Advanced Graphing Calculator, and demonstrates what the students could see after entering data and pressing the requisite ‘calculate’ button. Students received training in the rudiments of operating this device before leaving the homeroom in the morning of their data collection activity on the beach.

The technological instrument that the experimental group used for mediating the beach experience constituted the only difference from the control group. Participants of this latter group (who only had access to pencil and paper) were asked to manually plot the results of their observations relating to the beach transect on graph paper. This effort afforded them a similar visual representation of their work, but much delayed.

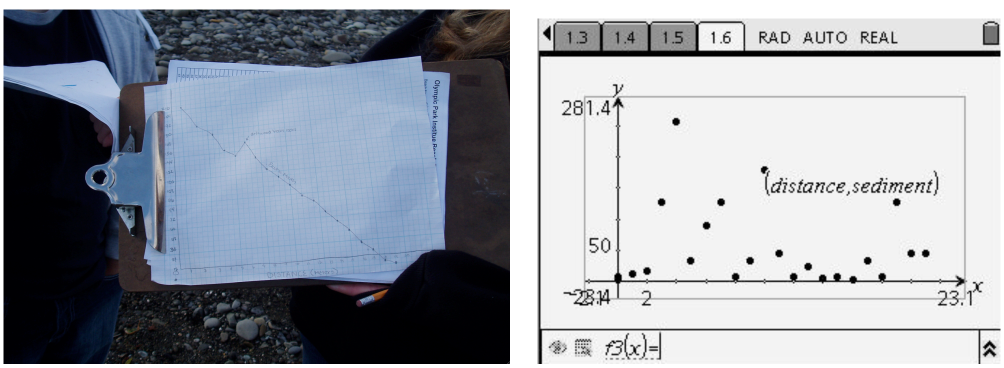

Figure 18, Example of output from 2 methods

Figure 18 shows a sample of both outcomes. The control group used pencil and paper to plot their graphs while the experimental group pressed a button to view the output from their beach profile instantaneously (see also, Figure 17).

The theoretical basis for using this pedagogical tool stems from a need to reduce cognitive load (Linn, Layman, & Nachmias, 1987). I hypothesize that a mediated learning technology could help reduce novice’s load, answering the question: Could an advanced graphing device that immediately transforms mathematical tables into graphs help reduce the cognitive load for novices in the outdoors learning environment? The learner is given a visuo-spatial (on-screen) prompt to help realize the elemental interactivity between raw data and actual landscape that thereby assists with both the immediacy of the feedback as well as the connection to the shape of the landscape. Given that there are limits on active (short term) memory during learning and that these limits can be exceeded by additional complexity it made sense to help reduce the cognitive load by mediating the learning experience with technological tools. I argue that both the immediacy and specificity of the feedback is a primary activator for deep understanding and meaningful learning.

Procedures

On the first morning, students, if they were in the treatment group, received training on the capabilities and use of the TI-Nspire™ graphing calculator. Training consisted of a hands-on trial-and-error immersion, prior to instructor's lecture dealing with user interface, and common operation of the instrument for collecting and managing data in the field. From there the students assembled in the appropriate bus and were driven to the site of either the lecture condition (Lake Mills) or the hands-on condition (Beach Transect).

At the end of the data collection and outdoor field activities all subjects arrived back to their formal classroom setting where they took part in a grand report-out session that was used to bring a conclusion to the events of the previous two days. The debriefing effort was mediated through report-out model of a phase in the Legacy Cycle learning strategies (Brophy, Schwartz, & Bransford, 2001; Martin, et al., 2006), specific use of which can be, not only reflective and collaborative, but also generative (Brophy, et al., 2001; Martin, et al., 2007). At this point also, all students are administered the posttest. All participants are interviewed by the research team and had an opportunity to discuss their ideas and findings with the research group.

Subjects remained in the same small groups that they were in during the field experiences. The report-out session was an opportunity for all members of the learning experience to reflect on the activities of their work over the two days. All field instructors (OPI) accompanied the students into the final report-out session, effectively changing the normal learning environment in the homeroom by bringing many vestiges of the informal environment with them. Students elected a spokesperson to represent the ideas and views of each small group and they discussed three questions while in their small groups. The three questions related to the work they had completed in the outdoors that day and the previous day, and each student was asked to answer:

1. What was surprising to him/her?
2. What was not new but now he/she saw it in a different light?
3. What did he/she not understand and still needed to be explained?

After small group discussion had come to a close, the teams assembled into a large group for a final report-out. This was an opportunity for each group, represented by a group leader, to report any thoughts, questions and ideas to the larger group. The students decided on a format for holding-the-floor by allowing the person who held a rock (large piece of cobble brought from the beach) in his/her hand the privilege of addressing the entire group. Instructors remained on the sideline playing a two-part role. They were primarily facilitators of the discussion by creating the space, enforcing the 'holding-the-floor' rule; and, secondly, assisted with information if they were asked or if the discussion became hopelessly lost. In general, the plan was to encourage students to try to answer one another's questions and to raise new ones, but also to provide enough information so that questions could be reconciled and difficult mathematical or scientific principles explained.

Qualitative Design

I felt that the complexity of the blended educational landscape in which these subjects came to experience their outdoors world could be better captured and elaborated through a mixed methods approach. Accordingly, ethnographic data were collected through interviews, student notebooks, researcher observations and detailed field notes, and through individual interviews, participant observations of fieldwork activities, and a final report-out session. In the next section, I outline the framework and methods that I employed from a qualitative viewpoint.

Learning ecosystems are typically complex messy places where individual interaction and social interconnections take place in and around learning situations (they are also deeply cultural). They differ in their shape and intensity depending on the activity and the structure. Mehan (1985) describes a typical structure of discursive elements between actors in traditional school classrooms. Like many educational settings, what he describes is grounded in many interconnections between academic and social encounters, each with implications for learning and teaching. It is a complex relationship where learning is seen as a combination of both academic practices as well as complicated social issues that execute around moments of learning and performance. He states:

> "…the intertwining of [academic and social issues] is relevant for effective participation in the classroom community." (p. 119)

The connection between academic content and social knowledge is just as important in the outdoors as it is in formal classrooms. In fact, many would argue that the socio-cultural aspect of school is more critical in informal environments where there is an even greater opportunity for the unexpected to occur and where children's safety and welfare are at a greater risk (Borzak, 1981; Hutchins, 1995; Sobel, 1996). In addition to situating this study in the domain of social interaction in informal environments, I draw also on perspectives of Jessor, Colby and Shweder (1996) whose cognitive ethnographic methods help make sense of complex learning environments, both formal and informal, in an attempt to understand learners' cognitive processes.

Many theorists describe schooling as overt socializing in a dominant culture (Brayboy & Castagno, 2008; Freire, 1970; Shutiva, 2001). They infer that during the transmission of information, it is virtually impossible to escape dominant themes that are prevalent in the classroom, where an unspoken (often hidden) curriculum pervades learning situations. This is often personified in methodologies that foster an entrenchment of dominant cultural and ethnic biases (Banks, et al., 2007; Heath, 1983). In his classic chapter, *The Structure of Classroom Discourse,* Mehan (1985) outlines a commonly-used IRE approach to teaching—an approach that is prevalent in many classrooms today and which presupposes a particular societal view of learning.

> "… [instructional] units are interactional in that they are a joint production of teacher and students; they are sequential in that they occur one after the other in interaction. These sequences have three interconnected parts: an initiation act, a reply act, and an evaluation act." (p. 121)

The initiation—reply—evaluation sequence (IRE) that Mehan describes permeates much of modern teaching methodology (Rogoff, et al., 2003). From first hand experience in Valley High, I can attest that IRE as an interactional event is a persistent element in teacher's repertoires of knowledge transmission (Hosselkus, 2009). Moreover, since most IRE interactional sequences are organized around topics, "the instructional phase of classroom lessons can be characterized as a progression of topically related sets of interactional sequences" (Mehan, 1979). The localized "funds of knowledge" (Gonzalez, Moll, & Amanti, 2005) that are present in many places (especially in this valley), the diversity of knowing and understanding from a different perspective are often overlooked in classic IRE situations.

Participant observers followed the subjects as they undertook STEM related learning activities, over the two-day experience from early morning until they went home after school. In the process, field-noted accounts of instruction, interactions, journeys, lunchtime and work-time stories, and primary interpretations of their data were collected as subjects and research assistants navigated together the various settings. The ultimate goal was to capture the learning environment in as much of its complexity as was possible, and to amass a corpus of relevant materials that would help the research team make sense of the activities in subsequent analysis.

Subjects were observed as individuals engaging in their work in a number of instances. They were observed while they listened to a lecture delivered by instructors. They were also observed when they carried out beach data collection and transect activities—collecting specimens and measuring slope from sea to cliff. Beyond observations as individuals, they were also observed working in small collaborative groups involving several noteworthy exchanges during the outdoors activities. Finally, they were observed as they brought closure to each day in their homeroom.

By examining constructs to determine the efficacy of several experimental methodologies via engagement and questioning, I was influenced by a framework employed in everyday cognition research (Bell, Bricker, Lee, Reeve, & Zimmerman, 2006) that looked at high school children who learn in an informal out-of-school environment. Participants in this study also worked alone (individual), or in small groups (social). I found the theoretical foci relating to cognitive and conceptual understandings that underlie children's learning in everyday settings, useful for looking at the interrelationship of subjects and their settings. Connecting with individuals, I was able to examine a child's identity, interests, goals and motives within a cognitive ecology that made visible their range of knowledge and understanding.

Many skills come into play in this outdoors experience. Consequently, this investigation is not limited to classroom interactions and the skills associated with these interactions. It also includes interactional skills in the outdoors, literacy skills in both settings, social and cultural knowledge that the students use to manage two very different and complex environments, technological awareness and abilities, and the study is anticipating many other skills that may emerge during analysis of the data. I approach this study, not with a specific hypothesis, but rather I employ a grounded theory perspective (Glaser & Strauss, 1967) since this approach seemed most appropriate to making sense of the blended environment. This approach also seems suitable for theory creation about concepts and processes that emerge during the data analysis.

I studied narratives of the students' work in a multifaceted, grounded manner (Becker, 1998; Lareau & Shultz, 1996) in an effort to discern what the students understood about the landscape (i) when they came to the field exercise; (ii) what they learned during the data collection activities; and (iii) what they took away from the experience after the intervention. I was particularly interested in how the students began to frame questions around science (Dillon & Wittrock, 1984; Duschl, Schweingruber, & Shouse, 2006), the kind of questions and the thinking that they displayed around their self-knowledge within the community and the landscape (Lee, 2008; Shutt, et al., 2010). Were these questions layered into any kind of cognitive framework that would help me make sense of the conceptual thinking that underlay their actions and the processes they utilized in their learning effort? I identified cognitive constructs around questioning to elicit information regarding how connections are formed between theoretical declarative knowledge (from the classroom and books) and physical observations in the landscape. I kept track of who initiated the questions. Were they on task and relevant to the science around the Elwha dam removal project? I was interested in discovering how meaningful the question was and what was the outcome?

Data Analysis

Using standardized transcription conventions, content logs and field notes, I reconstructed in writing what the focal learner said and did in relation to what other subjects say and do. I attempted as best I could to preserve the temporal sequence of the interactive flow between and around actors. This corpus of data became the basis of extensive review and discussion. Subsequently, I extracted events of narrative import using analytic notes and memos. Examples of categories that began to emerge reflect the outdoors learning environment and the preconceptions that the students held with regard to the landscape and the processes. For instance, there are many examples of naïve science about weather, rivers and beaches. Also, evidence of the teaching strategies (especially IRE) began to surface even in the outdoors settings. Another functional category presented itself around student self-knowledge and metacognition. Humor and fun seemed to be a large important aspect of their two-day event in the field. Noticeably, the theory making, ideation and eventual 'making connections', categories seemed to blossom in the report-out session of the legacy cycle at the end of the second day. From an initial inspection, content logs were created to facilitate the location of examples of interactivity during the two-day experience at the beach and lake. These areas were tagged using a tagging nomenclature that reflected the fieldwork and the children's interactivity while working in the different environments. These segments were then examined turn-by-turn by the research team. What resulted was written up in reports and appears here in the findings section.

One unit of analysis for this study centers around "type" and "order" of questions. In particular, I was interested in discovering the 'depth' of question and 'initiator' of question appropriate to the theme of making connections between observed phenomena in the outdoors environment and theoretical declarative knowledge that the subjects brought from formal schooling. This included the application of the question to the students' own observations, the relevance to the study in hand, and the penetrating capacity of the question to get at the deep meanings surrounding difficult concepts of the physical landscape. Exemplars of the questions that demonstrated connectivity are detailed in the findings section. I argue that an engaged subject will ask deeply relevant questions that are neither teacher inspired, initiated or advanced (Brice & Johnson, 1999; Duschl, et al., 2006; Grosier, 1964), and that he/she will be interested enough to pursue the question to a conclusion so that meaningful knowledge will ensue for that individual and his/her cohorts (Vye, et al., 1999). In this study, I demonstrate that subjects' question type and order changed with time over the two-day course of activities. Furthermore, I show evidence of engagement, interest, and deep understanding tied to the type and order of subjects' questions.

I analyzed field-notes, seeking out interactivity episodes where the students made meaning of their physical landscape; often inducting theory related to the difficult concepts they were studying (e.g., was the beach constructive or destructive). Such interactivity episodes were coded within the data using an open coding system (Strauss & Corbin, 1997). Once the episodes were identified, another pass through the data further defined and caused the categories to be articulated using discourse analysis (Becker, 1995; Shweder, 1996).

I drew from Creswell & Miller's (2000) definition of validity in qualitative research design by judging how accurately the students' accounts represent reality of the 'social' or in this case physical phenomena within the social setting, and was credible to the expert field investigator. A convincing and articulate grounding in the evidence made for good validation and added to the freshness of the assertions in this process. I used a combination of triangulation from quantitative results described earlier, thick description (Geertz, 1973) and a search for disconfirming evidence across the data set (Erickson, 1986).

In summary, this study uses a mixed method, drawing techniques and procedures from traditional statistical paradigms in addition to nuanced interactive techniques from an ethnographic investigation. This is a blended study model—using formal and informal measures of inquiry. Participants and settings are described in formal classroom arenas as well as are tools and artifacts that were used in the out-of-doors portions of the work. Frameworks, measures and procedures are outlined and data capture and analysis is described. In the next section, I outline findings and discuss the implications in relation to the frameworks and settings that are outlined here.

Findings

In the last section, I described the methods used to investigate how best to bridge the formal and informal gap that exists in the learning environment for the participants in this study. The intervention introduced three learning experiences in control and experimental conditions. In the first instance, an advanced technological tool was used in an attempt to investigate if "cognitive load" could be reduced for computational / interpretative work. Second, a "time for telling" was incorporated into the field activities over a two-day interval to understand if student performance would be better in one condition over the other. And finally, conceptual change was anticipated in a "priming" exercise where students were encouraged to be generative and metacognitive.

Findings from these three experimental conditions are reported here. The first two findings are reported through data and analysis carried out in a quantitative paradigm. T-tests and Analyses of Variance using SPSS (V.13) were used. Student discourse was analyzed using a grounded theory approach. In brief, findings make clear four things: (i) All participants showed positive gains in pre to post scores; (ii) Participants who had access to graphing calculators outperformed students who only used pencil and paper; (iii) Order in which students were exposed to the learning intervention mattered—a finding that seems to advance the idea that a "time for telling" impacts learning outcomes even in an informal environment outdoors; (iv) An analysis of students' discourse in formal settings documented how they spontaneously began to make tentative connections between their personal observations in the field and theoretical knowledge that they either learned in formal classroom or already knew as preconceptions, or even naïve science.

Cognitive Overload - Calculator Effect

The TI-Nspire™ is categorized as a handheld computer that allows students access to a set of mathematical and scientific applications. None of the students had previous experience with this kind of device even though all students had typical ‘formal’ schooling access to simple calculator devices through their normal mathematics lessons. Students were able to enter data into pre-created documents—essentially, embedded pages that stepped them through a process of entering data and creating plots. The screens were readily available to the students who were able to quickly and easily convert hard data to beach slope and profile view. Other fields and ‘document pages’ allowed students to capture data about pebble size and distribution with relation to distance and elevation along the beach and from the water (see appendix 3 for example of beach profile and pebble distribution). Students were assessed on their ability to discriminate between river, lake, dam and silt in the Silt Measure (described elsewhere in this dissertation.)

Descriptive Statistics represents change in scores from pretest to posttest between the groups (calculator/no-calculator), as follows: 0 = No Calculator; 1 = Calculator. The mean score—change in score from pretest to posttest on the mathematical/science measure—for the “no calculator” group is 10.29. The mean score for the “calculator” group is three times greater, 32.44.

Table 1, *Descriptive Statistics*
Testing the difference or change in scores from pre to post test by group

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0	7	10.2857	7.06433	2.67007	3.7523	16.8191	1	19
1	9	32.4444	21.47738	7.15913	15.9355	48.9534	3	66
Total	16	22.75	19.87125	4.96781	12.1614	33.3386	1	66

By using the pre-test as a baseline student measure, the design resembles a repeated measure because it takes into account the baseline achievement of each student. As indicated by these scores it is evident that the Calculator Group had a standard deviation just over three times the No-Calculator Group.[9] Levene's test of homogeneity of variance failed. We will discuss some implications concerning this below.

We carried out a one-way ANOVA test using SPSS. This test identified a significant treatment effect meaning that students who were randomly assigned the use of the calculator learned significantly more than those who used paper and pencil. In other words, using the advanced graphing calculator made a difference for student learning, in an informal setting using informal learning processes (I I in figure 2). The between group variance or the Variance accounted for by the difference between group 0 (No Calculator group), and group 1 (calculator group) is compared to the variance found within groups, taking into account the degrees of freedom. The result is an F value of 6.784 and a significant finding (p=0.021).

Table 2, *One-Way ANOVA Difference between Pretest and Posttest*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1933.349	1	1933.349	6.784	0.021
Within Groups	3898.651	14	284.975		
Total	5923	15			

The mean difference between groups is shown in figure 19. 0 = no calculator group; 1 = calculator group. In this figure the X-axis is the treatment variable and the Y-axis is the mean difference pre and post scores.

[9] As discussed later, for all students, taking the pretest could well be reactive in the sense that it primed students to notice certain features during their interventions. A Solomon's 4 group design would be ideal, but the small number of students in the class made this impossible to run.

It is worth emphasizing that these groups were randomly created, with students randomly assigned to either the *No Calculator* (0) group or the *Calculator* (1) group. This experimental design result indicates that a treatment effect did occur and suggests pursuing a larger study with a greater N that would allow for cluster effect to be considered, such as the effects of nesting within a group of students who were all given the calculator.

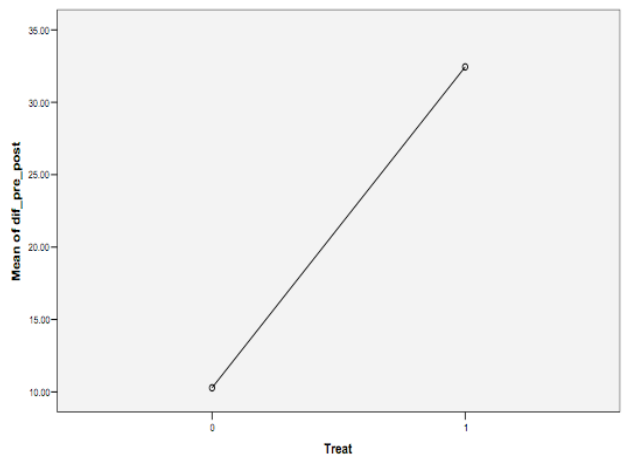

Figure 19, Mean Difference Pre- and Post-test

The significant effect found in this small study is an interesting finding, and is congruent with previous studies about the use of calculators in mathematics and mathematical representations (Greenfield & Cocking, 1996; Roschelle & Kaput, 1996; Scardamalia & Bereiter, 1993).

It is worth noting that the students with moderate pretest scores seemed to have gained the most in the Calculator Group. Below (fig. 20) is a revised table to help visualize the gains made by student by treatment.

We noted earlier that there was a discrepancy in the homogeneity of variance measures. It is clear from Fig. 20 why Levene’s test failed. There is far more variation in the calculator group where the greater gains were made. We should keep in mind that there is also a ceiling effect in which students, who are already pre-testing high, have less room to show improvement.

Power was calculated at 67%, using a DDS Research online tool (DDS Research, 2009). A 33% chance of making a type II error can be attributed to the small sample size and the unequal variances. Because this is a pilot study, I interpret these findings lightly, suggesting however, that they are noteworthy enough to warrant further study.

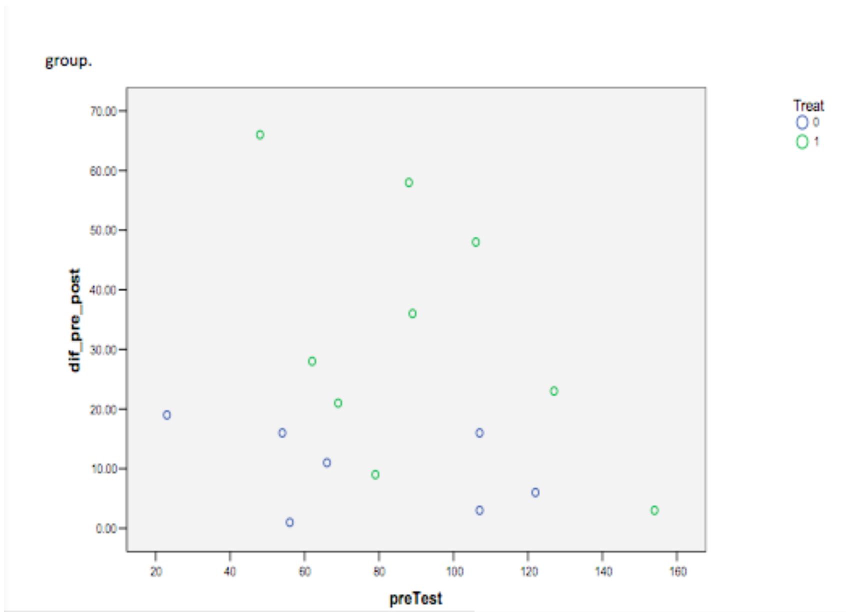

Figure 20, Gain in Scores by Pre-test and Treatment Group
Note: Blue = No Calculator; Green = Calculator

From an ethnographic viewpoint, students had a lot to say about the advanced graphing calculator and the technology that it entailed for their study. While no student stated outright that the calculator actually helped them make connections between the physical landscape and the data that they captured, the research team documented many occasions when the students physically connected the shape of the beach with the data-emitted profile that appeared in their calculator screen. The tool seemed to act as a common connector for participants. Subjects were studied in this shared space where their joint visual attention moved from the calculator to the physical landscape and back as needed. In the photograph in figure 21, for instance, two students enter data and view the output right away. In the left hand panel two students are sharing a data input moment. She calls out the number from a measurement (long axis of a piece of beach cobble) “0.7 cm” and he keyed it into the document page of the calculator.

1 Girl: Axis length point seven
2 =Boy: wait. Ok point (0.1) seven
3 Wait (0.2). Wow
4 =Yeah. Cool

(Excerpt from Field Notes: Beach Day 1 TB)

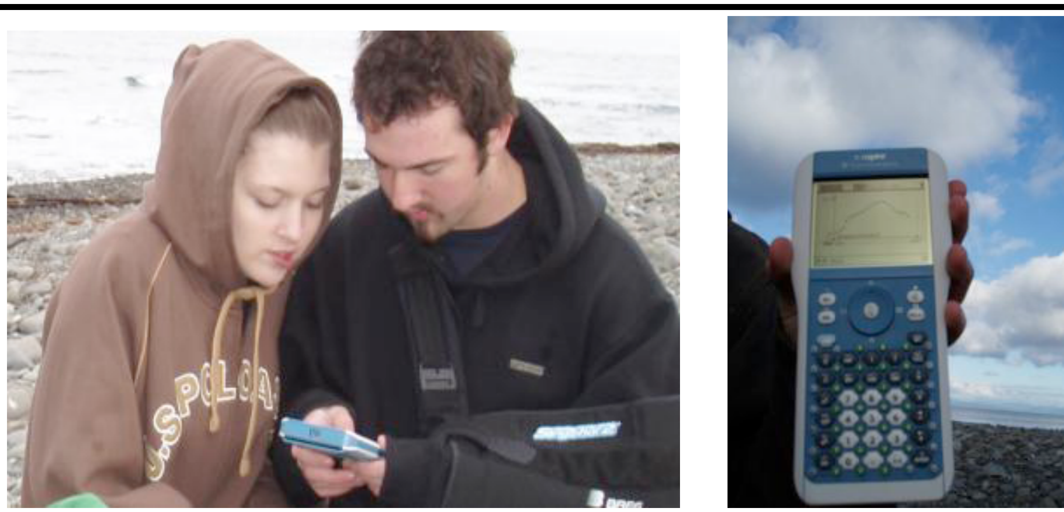

Figure 21, *Connecting the Beach Profile to the Calculator Screen*

The second panel shows a view of the representation of their data as it is configured into a graph through preset calculation algorithms. From this screen shot the students shift their gaze to the beach and check the authenticity of the shape with the actual physical structure right before their eyes. The shared attentional moments involved in inputting data, viewing the output immediately and associating it with the physical landscape, which was the focus of their actions, helped the students make meaning out of their data numbers and the shape of the beach. This is borne out in many observed interactions with the calculator and the beach transect which they had just documented.

In this way, the handheld device supported a shared common goal among students, between students and the research team, and between students and the instructors (e.g., Elllington, 2003; George, Neale, Van Horne, & Malcom, 2001; Heller, Curtis, Jaffe, & Verboncoeur, 2005). Students were asked to investigate if the beach was a constructive (convex shape) or destructive (concave shape) variety. To interpret the results of their data, instructors directed focusing questions to the students, such as "do you think this graph is a true representation of the beach you are standing on." This question would engage students in focusing on the screen of the calculator and then changing their gaze to the physical landscape—checking the connections between the image on screen and the real world outside them.

For the majority of the students, the handheld device was a new and very "high-tech" instrument that they enjoyed. Many of the students in this group outwardly expressed delight at being able to use a device that they perceived as a "cool" with "wow" affect. In the field, the research team documented how students were intently focused on working with the devices and took pleasure in teaching each other how to use them. Baer (2009) describes one group of students who, having finished entering their data, switched to the next tab to view the data plots. Their immediate response was "wow!" and they quickly began asking each other what the plots meant in relation to the beach they were standing on. The short excerpt below from the report-out session verifies this impression about the calculator.

(Note: in all collaborative discussion sessions the person holding the rock has the floor.)

LB: They are way high tech.
(the rock is passed to LB) Uhmmm (0.2)
they are really high tech and uhmm (0.2)
they had different screens like tab pages, and everything you tried to
do you had to go to someplace else to get to it.
Like a little computer. (0.1)
yeah… way cool.

(Excerpt from Report Session: Debrief Day 2 tko)

Several students agreed with LB's remark - "like a little computer" (line 6) as a way of expressing how capable the device was in the field. One student wrote at the end of the posttest: "the calculators were super high-tech but in the end they weren't that hard to use." This statement is consistent with observations in the field and during the report-out session; students were excited to see that such a high-tech tool was not beyond their reach (Baer, 2009). From this standpoint, it seemed clear that the handheld devices enhanced students' fluency at connecting between direct observation, numerical measurements captured in real-time, and multiple representations of data *in situ*.

Creating Time for Telling

The second experimental condition focused on the timing of the mediated experience for the two groups of students. I was interested in learning if, by creating a 'time for telling' in an informal outdoors environment, students who carried out a beach transect first (before receiving a lecture) would outperform students who received the lecture first (before carrying out the transect). On day one of the experiment, the experimental group was taken to the beach where they were asked to collect data and carry-out a beach transect[10]. The control group were driven to the lake where they were administered a lecture in a traditional fashion. Day two saw a reversal of this

[10] A beach transect is essentially a longitudinal profile that is described in a two dimensional plane, when real data is captured in situ and represented in a typical bi-axial graph. Slope and shape of the beach becomes obvious when the data are interpreted in this kind of mathematical representation.

transaction—the experimental group received the lecture while the control group went to the beach to partake of the transect work there.

A T-test (using SPSS v. 13) was used to investigate differences between 'order' on data collected in the post test—what is referred to as the Silt Measure. Table 3, is a descriptive measure that outlines differences between groups on this silt measure. Order is defined in this measure as either "1" (practical hands-on beach transect first), or "0" (theory group received lecture first). This model represents the different orders in which students were administered the mediated learning experience.

- Order 1, the *practical group*, experienced the beach first and the lecture last.
- Order 0, the *theory group*, experienced the lecture first and the beach last.

Table 3, *Group Statistics on the Silt Measure*

Order	N	Mean	Std. Deviation	Std. Error Mean
Silt_Final 1	7	20	0	0
2	9	16.11	4.167	1.369

Group statistics indicate that the mean difference between 'Order' is 4 points higher for the group that received the practical hands-on work at the beach first. An analysis of variance revealed a significant main effect between groups on 'Order' in which subjects experienced mediation, with $t = 2.800$ and $p < 0.023$. The students with the calculators significantly outperformed the pen and paper group on the silt measure.

Table 4, Independent Samples Test on the Silt Measure

	Levene's Test for Equality of Variance		t-test for Equality of Means					95% Confidence Interval of the Difference	
	F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
River_Final Equal variances assumed	2.046	0.175	-1.765	14	0.099	-2.619	1.484	-5.802	0.564
Equal variances not assumed			-1.901	12.676	.080	-2.619	1.378	-5.604	.366

Levene's test for Equality is not greater than 0.10 (see: Table 4, Independent Samples Test on the Silt Measure), it is thus assumed that the two groups do not have equal variances and the second test is used for this measure.

Conceptual Change

As mentioned earlier, all students displayed similar preconceived ideas about the location of the silt in Lake Mills behind the upper dam. In this next section, I outline how students' conceptual change was displayed in their crayon drawings over three iterations.

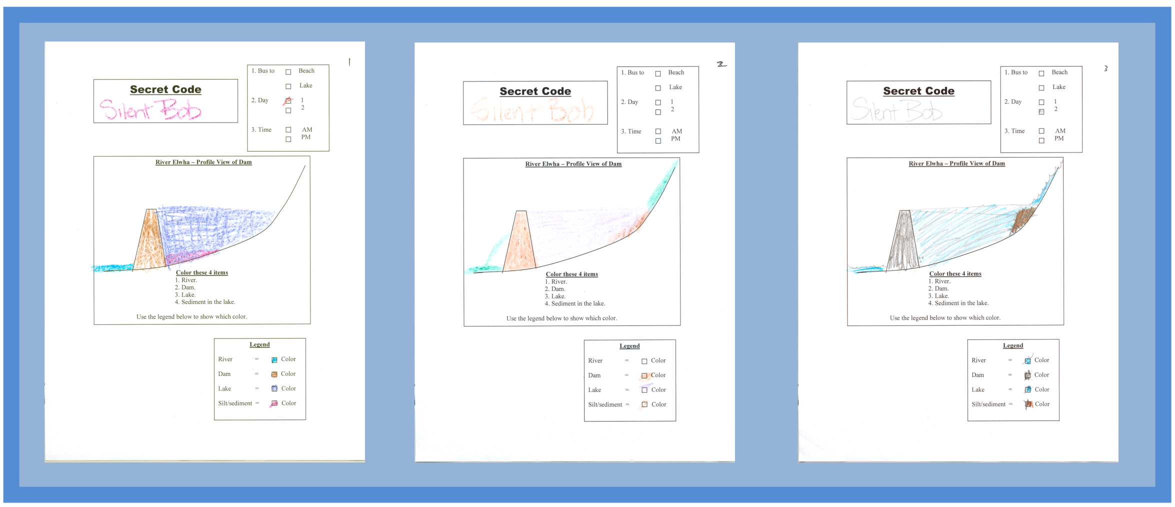

Figure 22, *Three Dam Silt Sketches from one Student*

At pre-test, all students placed the silt in the same location—right up against the dam wall (refer to the first sketch in figure 22, to recall how this sketching exercise made visible and captured students' preconceived ideas and changes over time).

This predicted location could not be farther from fact. However, as is shown in the scores from this measure, all students' drawings subsequently reflected a shift in their thinking. For more examples of student sketches relating to the position of silt in the lake please see *Appendix 3, Exemplars of Dam Sketches*. In the three sketches (Figure 22), (sketch number 1 is on the left and sketch number three is on the right) the crayon markings indicate where this student (Silent Bob) locates features in the dam sketch for each of three iterations. In each sketch four items are clearly marked in colors based on the color key that the student provided. First, the dam is clearly marked. In each case, the lake is correctly placed behind the dam. There is a little confusion (as evidenced in a comparison of the three sketches) about where the river spills out over the dam (top or bottom). And finally, the silt is clearly marked in the lakebed—at first right up against the dam, then in sketch number two a little farther away from the dam, and finally, in sketch number three, where the river enters the lake. There is an obvious 'shift in thinking' for this student over time, as described in the changes in this sketch. In the first sketch, a number of preconceptions are visible and suggest themselves easily to the expert geomorphologist. First, the river is shown to reappear in a place inconsistent with the physical environment—at the bottom of the dam rather than over the top via spillway. Second, while the lake is represented accurately—flat surface reaching up-valley from the dam wall—the silt deposition is shown at an end of the lake that is not consistent with how the world works. This rendition is not an unusual first sketch for a novice since the concepts relating to silt and dam outflows are rather counterintuitive.

In his second sketch, the student adjusts the river outlet, making it appear over a spillway located atop the dam. Meanwhile, he also adjusts his thinking in relation to the location of the silt in the lake. His second diagram documents the silt further back in the lake towards the far end. The location is essentially correct, but I argue, the tentative coloring and size of the deposit suggests an uncertainty about the change. He rests the silt deposit along the bottom of the lake in spite of the fact that he could see it on the surface, touch it and walk on it. By the time he makes the third sketch (end of second day of mediated experience), he accurately and more forcefully locates the silt in a solid mound at the correct location where the river enters the lake.

The lake is drawn correctly in all three diagrams. It seems however, that Silent Bob was not happy with the decision to change the outlet from the bottom to the top of the dam and consequently, we perceive that the outlet for the dam is once more replaced by the original (inconsistent with observed view) depiction in the final sketch—a probable reversion to the preconceived notion of how the physics of dams works.

From this perspective, a thoughtful inspection of the three drawings might suggest the following interpretation: In drawings one and three, the student was pretty definite about his depiction of the silt. This is tentatively determined by equating the texture and tenor of the drawings in these two episodes with that of sketch two. Solid and heavy wedge of crayon color was used to indicate the preferred location. The second sketch however, appears less definite and more ambiguous. Of course, it could be argued that at the time the bus was going over a bump or something and interfered with Silent Bob's concentration and the tentative use of colors had nothing to do with the content. In a learning situation, anything is possible, but the shift in thinking that seems to repeat itself in this sketch is equaled in most of the other sketches by Silent Bob's classmates on the same bus over two days.

In addition, this apparent shift in Silent Bob's thinking is confirmed in interviews and discussions during the sketching exercise. The ambivalence detected in the second sketch appears to demonstrate a 'letting go' of preconceived ideas and an emergent cognitive change that takes place in the student. In the final sketch, the silt is quite definitively drawn in an accurate location at the point where the river enters the lake. This seems to be a clear example of a shift in Silent Bob's thinking. This shift is further amplified by a conversation on the bus on the way back to school after visiting the dam on day two. The following is an excerpt from this conversation between Silent Bob (SB) and a fellow student while they are actually coloring the third sketch on the bus.

SB: We were totally wrong last time.
(Looking at the sketch) (0.3) Chooses a different color crayon.
We put the silt in the wrong place.

(Excerpt from Field Notes: Bus from dam Day 2 TB)

This unsolicited comment (lines 1, 3) captures the change in action for this student as he continues to improve in the progressive self-assessment tool. This shift in thinking was captured in the report-out session also. A student (CJ) indentified and articulated the exact shift in thinking, admitting his earlier preconceptions and capturing the conceptual change as follows:

CJ: But uhmm what was uhmm for me. I already knew this, but I was
wrong. It was different (0.1)
was a little bit to me. Was uhmm (0.1)
(hand pointing far away someplace over there beyond the room) (0.4)
I thought all sediments behind dams would be piled up against the
dam, (0.2)
but it was dropped off at the beginning of the lake uhmmm
(elaborate hand actions to point to the far end of the lake)
and there isn't (0.4)
hardly any against the dam.

(Excerpt from Field Notes: Debrief Day 2 TB)

This student (CJ) admits that his preconceived ideas concerning the position of the silt in the lake were totally wrong (Lines 1 and 2). It seems to be a solid learning moment when he not only realizes his mistake, but he is afforded an opportunity to articulate and explain (lines 5 and 6) in a rather public manner to his fellow students, thereby encouraging them also to understand the conceptual change in progress. There is however, no evidence of the underlying causal mechanism at this time, and further inquiry with the student revealed that he had in fact understood that the river dropped its load when it slowed down upon reaching the lake.

Results of students' dam sketch drawings are tabulated and appear here in Table 5, Raw Scores of the Dam Sketch for Silt. The three dam sketches described here reflect the shift in learning that is evident from the scores in Table 5, Raw Scores of the Dam Sketch for Silt. This table describes three empirical data points S_1, S_2 and S_3, and represents students' predictions about where silt is deposited in relation to the dam wall. The fourth column represents the difference (gained scores) between the first and final measure. In the first reading, students drew their sketch before they had partaken of any activities at either the lake, the dam or on the beach. S-1 refers to that first "baseline" Silt Reading.

Table 5, Raw Scores of the Dam Sketch for Silt

S_1	S_2	S_3	S_D
5	20	20	15
5	10	20	15
5	15	20	15
5	15	20	15
5	20	20	15
5	10	20	15
5	15	15	10
5	10	10	5
5	5	20	15
5	15	15	10
5	15	20	15
5	10	15	10
5	20	20	15
5	10	10	5
5	15	20	15
5	15	20	15

All students placed silt in the location that described their preconceived conceptual image of the dam as a barrier to moving sediment in the river. This misunderstanding is aligned with most people's idea of such a counterintuitive phenomenon (typically people think the silt is somewhere below the surface of the lake and not visible to the naked eye).

The persistence of preconceived notions pertaining to how the world works is a pervasive constant in the learning literature in relation to conceptual change (diSessa, 2002). In the pie chart, Figure 23, *Dam Sketch before Mediated Experience*, which describes the students' preconceived ideas before they were exposed to any mediated experiences associated with this study, the 'ocean of blue' represents individuals' predictions that the silt would be right up against the dam wall.

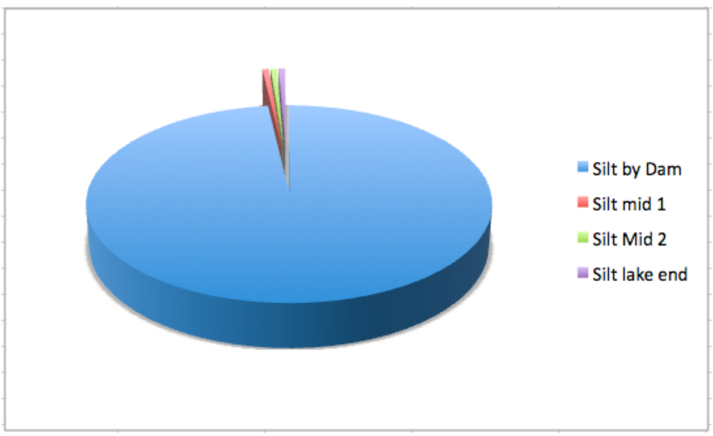

Figure 23, *Dam Sketch before Mediated Experience*

The other colored segments represent locations either farther out in the lake (red, Silt Mid 1), towards the middle of the lake (green, Silt Mid 2), and at the (correct location) far end of the lake (purple, Silt lake end). As will be shown in the next sequence of pie charts, the students who undertook a progressive self-assessment exercise around the dam sketch began to undergo a conceptual change in their approach to the location of the silt in the lake.

In the diagram, Figure 24, *Dam Sketch after First Mediated Experience*, this pie chart reflects the next iteration of the self-assessment sketch—an intermediate data-capture point.

At this stage in the mediated experience, half of the students had spent a day in an outdoors informal learning environment doing a beach transect and capturing data, while the other half visited the Glines Canyon Dam and Lake Mills where they received a lecture about electricity generation and hydroelectric dams (in which the story and location of sediment was broached at length).

This pie chart reflects (for almost all students) a changed interpretation of the landscape of their experience. Notice, for instance, the abandonment by nearly all the students of the idea that the silt was deposited right up against the dam wall (the ubiquitous 'sea of blue' from the first pie chart is much shrunken).

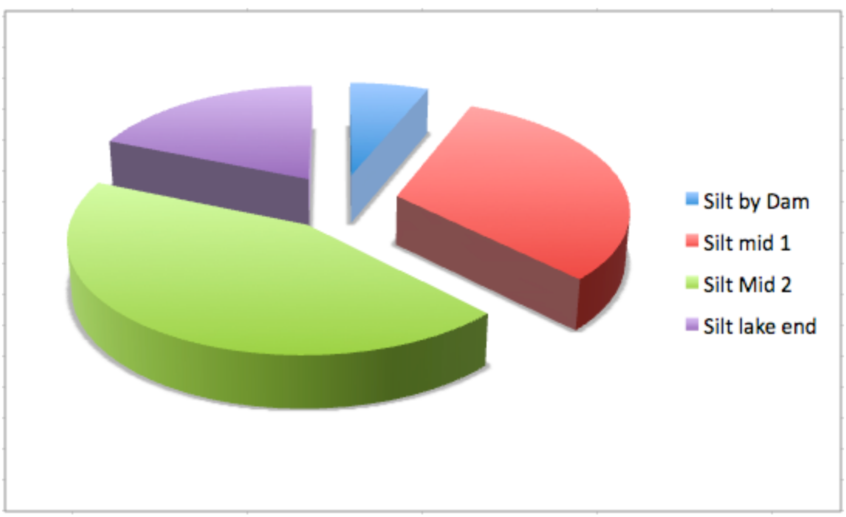

Figure 24, *Dam Sketch after First Mediated Experience*

The majority of the students began to question their preconceived ideas—they edged their predicted silt location halfway up the lake. 75% of the students moved away from the dam wall and closer to, but not quite at, the end of the lake. It appears that very few of the students were willing to risk moving their silt knowledge to the far end of the lake, preferring instead to play safe—to move just a little farther from the dam, or out into the middle of the lake (only three students -18.75% - were prepared to accept that the silt could be that far away from the barrier).

The final pie chart is shown in Figure 25, *Dam Sketch after Last Mediated Experience*. It reflects the results of the final data point after the students had (i) mediated experience and practice on the beach, (ii) the benefit of a lecture at the lake, and (iii) the self-knowledge derived from a metacognitive iteration through the progressive self-assessment tool. Scores here reflect updated locations for the silt deposit; based on new knowledge they had gained in the meantime. By this, their third iteration, none of the students place their silt drawing by the wall of the dam; a couple are not convinced that they should go too far from the dam, but the majority (68.75%) correctly apply the silt deposition to the far end of the lake (where it is visible to the naked eye).

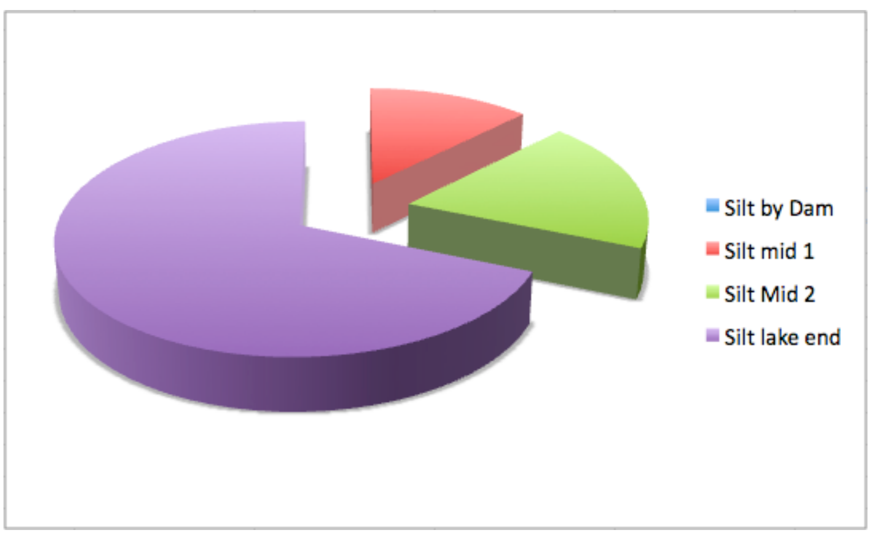

Figure 25, *Dam Sketch after Last Mediated Experience*

The final column, S_D in Table 5, Raw Scores of the Dam Sketch for Silt enumerates, the difference in score from the first data point through three iterations of self-assessment sketches. Not only did the mediated experience in the outdoors enhance a conceptual change in the students in relation to the silt measure described, but also, as can be seen from this data, all scores are in a positive direction. No student reverted to his/her preconceived ideas. Further, it appears from the scores that some students learned faster than others, and some students refused to go more than half way at letting go of their preconceptions. How sure am I that the students didn't just copy one another or guess at the silt location? This, of course is not the real issue. Sure some of the students might have looked over the shoulder of other students to get this location exact. The key issue has to do with if the students actually understand what is going on with the silt and deposition. In order to really get at the kernel of the issues, a discourse analysis reveals the conceptual changes that are on-going during the report out session at the end of day two.

Discourse Analysis

From these findings (just reported) it would appear that all subjects improved their grades as a result of the scientific inquiry that they attended over two days in the Elwha valley. This in itself is laudable since, in the past, many researchers failed to find any noticeable differences in pre and posttest scores for students on similar field activities in the same dam removal site and with the same instructors (Skerbeck, 2010; Young, 2009). Both Skerbeck and Young expressed frustration at their results, because they were very adamant that the "students were actually learning a great deal" about other things that were not being measured in narrow-focused tests. On the other side of the coin, I knew through observation and interviews with them, that the subjects who scored well in the posttests still failed to explain even the most rudimentary observations that they were encountering all around them (e.g., Why is there no sand on the beach? Where did these cobbles come from? Why is the beach this shape? And why is the silt at the far end of the lake?) In light of this insight, I hoped a mixed methods approach would go deeper in the investigation through an ethnographic paradigm to learn if the students were, in fact, making any connections between their observations and the real world around them.

Conceptual change is a good indicator of learning, particularly if it involves letting go of preconceived ideas that have little bearing on scientific veracity. In this section, I examine the degree to which conceptual change is reflected in students' discourse as portrayed in an interactive debrief session at the end of the intervention. During the course of the field activities, subjects worked either alone or in small groups. However, in the final report-out session, the entire cohort were repatriated, as it were, to their original homeroom where they had the opportunity to share ideas, discuss issues and wrap up the experiment. From selected scraps of discourse, evidence is strong that effective blending of two learning environments (the informal form Ediz Spit earlier in the field trip and formal in the homeroom report-out session) resulted in very solid learning outcomes, where the students introduced thoughtful questions, articulated reasonable theories and sought solutions to problems that emerged from their own observations. In this respect, I argue that the students were adopting a metacognitive stance and crafting habits of mind that are ideal for a preparation of future learning.

Part of the intervention called for finishing the outdoor activities in the homeroom with the same instructors that were with the subjects in the field for two days. The classroom teacher was present as chaperone and guide (if needed), but most of the interaction was in the realm of instructor/student or student/student. From this point of view, the model fits the formal settings dimension with watermark preexisting from the informal world (see figure 26) of outdoors that spilled over into the classroom.

This decision to replace (for the duration of the report-out activity) the homeroom (formal) teacher with the outdoors (informal) instructor seemed to protract an Informal Learning Processes "watermark" into the Formal Settings dimension. Consequently, this resulted in the traditional IRE model being displaced by a more HPL-centric model (NRC, 2000), principles of which were designed to facilitate a co-creation, with the students, of a safe (and it would seem innovative) learning ecosystem.

An interview with the instructor (Nattinger, 2010) revealed his intentions of designing in that space an environment that was expected to promote preparation for future learning (Bransford, et al., 2005). One of the most notable features of the outdoors instructor was his attire.

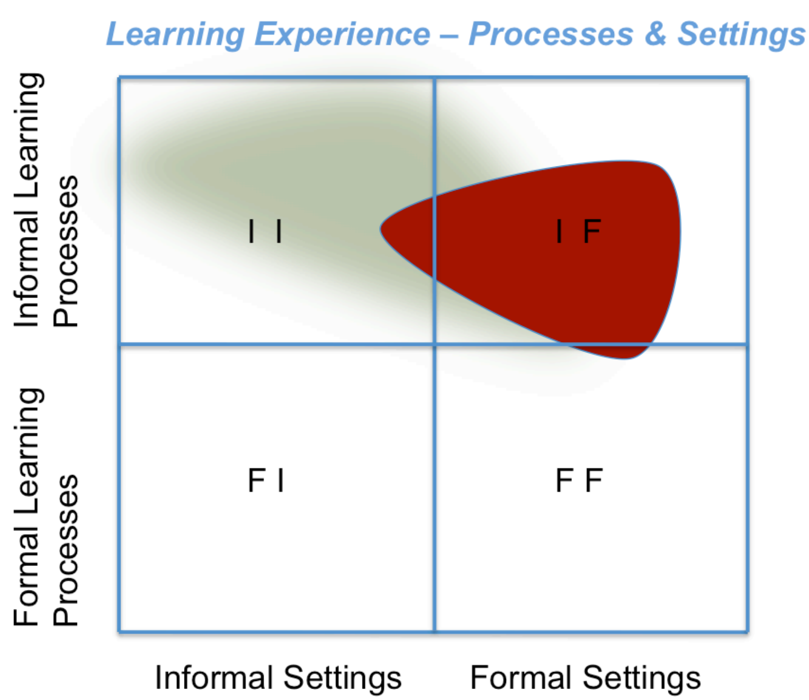

Figure 26, Formal Setting, Informal Learning Process "Watermark"

The students remarked about it many times during the two days (the instructor wore his hair in a long ponytail and it was obvious from his physical demeanor and actions that he spent a lot of time under the sun). His heavy outdoors boots, his fleece outerwear and rugged features spoke volumes about his way of life and his desire to be out of doors. By comparison, the homeroom teacher, who dressed for the outdoors that day, managed to look like a homeroom teacher as soon as he got off the bus and removed the outer layer. The penumbral watermark of the workplace was thus a substantial factor in the presentation of the leading characters in this plot.

At least one outdoors informal artifact emerged organically as the report-out session began to take on a momentum of its own. The “talking rock” was a quirky surprise that helped ground students’ thinking around the beach and the tides.

Figure 27, Hand-off for the ”talking rock”

It came to my attention afterwards that many students had in fact brought various outdoors artifacts back to the classroom as if personalizing and holding the moment in a particular space and place of honor. These included an eagle’s feather, a piece of driftwood that looked like a snake, a shiny bit of discolored quartz, and other sundry "forget-me-nots" that appealed to the individual collector. The "talking rock" was the most public "outside" informal footprint to make its way into the formal classroom. A large chunk of kelpy cobble, it still smelled of the beach and had a physicality and weight about it that immediately captured the imagination of the students. As soon as the discussion began to flounder (at the first discursive moment), the consensus (vociferous and unruly at the time) called for a way to give voice to a speaker who would "hold the floor" while he/she held the rock. One of the students (WPC) produced the large rough cobble out of his daypack. "Use this," he was grinning from ear to ear. It was as simple as that. Everybody wanted to use it—well not everybody. The classroom teacher was horrified at the idea of this potential weapon being passed around his class. A student had the bright idea to call it the "Talking Rock" and its nomenclature and utility immediately took. A social contract was agreed in an instant—whoever has the rock has the floor. This was one of the most surprisingly successful spillover effects from the informal learning experience to the formal setting, and arguably was instrumental in paving the way for the explicit theory-making and knowledge-building session that ensued. (I learned many weeks later that even though the talking rock itself was banned from the class, the "holding the floor" concept still holds today.) From this experience, it seems that a tangible aspect of the blended environment, which contributed directly to conceptual change, emerged from cognitive analogues that followed the students out of the field (informal) and into the classroom (formal).

Hand-off also happened organically. Figure 27 is an example of a hand reaching over to accept the emblem of owning the floor. When a student wanted to say something he/she asked for the talking rock before taking a stance in an argument or asking a question. The few times when people inadvertently missed the rule, began to talk while the rock was still in someone else's hand was cause for class censure. There was one occasion where a serious discussion was ongoing and the rock couldn't keep pace with the discussants. In that case the rock stayed with one person until the speech of the other individual became protracted. As it lengthened, he was interrupted by another voice; then the class chimed-in in agreement. "Hey you have no right to talk, you don't have the talking rock."

Bridging the Formal and Informal. Many intersecting elements appear to contribute to a shift in thinking that is described here. Analysis of discourse between subjects, and between subjects and instructors documents the shift in thinking in many areas. Evidence is presented to show that carefully scripted pedagogies did in fact help to bridge the formal and informal space in the education of students that experience field trips for science learning. It seemed possible that, by making observations on the beach and by attempting to connect them to theories in the classroom, students could let go of preconceptions and begin to change their naïve science.

Naïve to Normative Science. In the process of documenting conceptual change, the research team noted a progression from students' naïve science concepts toward more realistic or commonsense science as they interpreted the data available to them. What surprised many of the students themselves was the realization that they seemed to improve rapidly with practice. In the next section, I will report on several instances where students grappled with difficult concepts around counterintuitive issues, and in the process exposed (indeed made visible in a very public forum) a number of meaningful truths. First, they began to perceive their own naïve science (and in some cases actually take ownership of it), but, in addition, they clearly differentiated old ideas from new ones. As they began to make connections between their observations in the field and their prior knowledge (and just-learned ideas from their peers), students came away with new knowledge and newly constructed understandings about themselves and the world around them. Invariably what transpired was an emergent theory-making initiative, incorporating ideas and innovative solutions that sought to solve open challenges. In this first interaction, I examine the process of a 'shift in thinking' that is exhibited during a student discourse that spontaneously presented itself from a rather innocent exchange.

To put this first excerpt in context, a student initiated a question that swelled into a deeper exploration of the connection between science and nature. The following exchange began innocently, but quickly deepened to frame outdoors fieldwork in real-world phenomena (the river) that changed as the seasons changed (winter versus summer conditions), in a decidedly counterintuitive way. The question, which began: Why do we have to do fieldwork in the cold, morphed into a much deeper and richer issue. Why was there so much water in the river at a time of year (summer) when it should be running at its lowest? Preconceptions were made visible in a series of naïve science observations that certainly made the instructor aware (and possibly some students aware also) just how much was not understood about moon, tides, seasons, and snowmelt.

Boy: I still don't understand why we have to do these field trips in almost winter.
(Broad smile, pointing finger at instructor)
Instructor: (laughs) ha, ha (0.2)
=I mean (0.2) come on (0.2) couldn't they have made it for the summer or something? (0.2)
(Still smiling, eye contact with instructor, shifts gaze to peer)
Girl: well like when it is warmer

9 (She looks around the class too. Concerned look on her face.) (0.2)
10 New boy: if its warmer maybe, (more serious demeanor)
11 but not the summer when that's my time to be out of school
12 (0.2)
13 First Boy: OK well June or something (not smiling now)
14 = Instructor: OK. Well. That (0.2)
15 that's something that even you could write about
16 you know, write about (0.3) still need explain
17 (trying to get their attention) (0.4)
18 Girl again: Yeah that actually is a question (serious, nodding)
19 First Boy: Yeah. That needs to be explained. (serious)
20 Instructor: is there (0.2)
21 and actually, uhm there are things that you would see in the winter
22 that you wouldn't see in the summer and vice versa
23 Boy: because the moon or
24 (grimaces, looks around for help, rubs his eye) (0.1)
25 position of the tides or
26 Instructor: yeah
27 (0.3)
28 Girl: well science is
29 (.02)
30 First Boy: because it's going to be raining a lot. And there's snow on
31 the mountains and everything (0.3)
32 ahmmm Spring (satisfied grin at presenting a resolution)

(Excerpt from Report Session: Debrief Day 2 tko)

The inter-actor exchange above (lines 1 – 32) documents a gradual shift from something that started off as impudent humor and almost 'disdainful whining' (why we have to do these field trips in almost winter (lines 1 – 3) to becoming a legitimate scientific question that sought a solution, "Yeah that actually is a question" (lines 18 and 19). The shift is clearly visible in the facial and embodied actions of the boy (lines 3, 7, 13, 19, and 32) who brought up the issue in what could be interpreted as a typical classroom disruptive stance, and of the girl (lines 9, 18) who unwittingly assisted. Something important that is personal, with consequences that have real-world meaning, appears to be the prime driver of this issue. Ostensibly, it was the cold that got his attention (lines 1-2) and hers (Line 8)—a factor that was deeply consequential to their comfort and wellbeing. But being in the real world suddenly had its own consequences, because the act of changing a school event to interfere with a student's personal summer time was meaningful and personal for everybody (lines 10-12). A somber voice of caution forced a deeper investigation of the problem (Line 13). The implied compromise with the words "ok" and "well" (line 13) seemed to begin the "shift" in this students thinking (perhaps all the students' thinking). Indeed, it seems that things were more complicated than one might suspect, in the real world outside the classroom. Negotiation ensued (line 13).

With an astute re-crafting of the lens of activity, the instructor is able to reorient the discourse by anchoring his guidance off the original (line 13) "ok" by adding his own "ok" and intuitively probing with a carefully positioned interrogative "well" (line 14). By suspending the discourse with an open-ended interlocution, the original question was effectively realigned to a meaningful scientific observation and interpretation. The focus changes to making connections between the time of year and the conditions in the river and beach.

The role of the instructor was important in this exchange, where a tentative shift began to emerge in the thinking of many students as they followed the exchange attentively. Having opened the space to everybody with an acknowledging and inclusive use of humor (line 4), the instructor welcomed the remark into the classroom discussion. Next, he invited the student to answer (the student's own) question from a new perspective, "that's something that even you could write about" (lines 15 - 18). With the help of a new voice who agrees with the teacher (line 18), the student begins to shift his approach and agrees in turn with his fellow student and teacher (line 19). This short sequence was propitious to open a theory-making space. Nothing bad had happened so far—judging from the interest and engagement, it seemed to be a safe and intriguing space. This is an active moment where it is possible to witness a merging of an informal world of observations in the field to a formal world of theory-making from prior knowledge and interpretation. A tentative penumbral cloud envelops both worlds.

What is presented in this exchange is not necessarily great science or great knowledge by any scholarly standard, but I argue it is solid engagement and possibly the first tentative steps for meaningful learning. The sequence of garbled utterances (lines 23 - 32) concerning the impact of the moon and tides on the river and beach is utter nonsense from a scientific point of view, but it is the first time this student 'makes visible' his ideas about the effect of melting snows on the flood situation in the river. It is also a moment in the classroom discourse, which, coming as it does after two days of outdoors observation and data collection, seems to facilitate theory-making and hypothesizing. The normal classroom IRE model is on its head. Students, not the teacher who has taken on a facilitator role, initiate questions (Line 23); theories emerge that are grounded in prior knowledge (Line 28). Naïve scientific facts become visible (Lines 30 – 33) as instructor and students co-create a new learning landscape. This is the beginning of a very different scientific inquiry process. Students are able to hone their skills at articulating new ideas. By using scientific vocabulary they were able to explain their views and ask relevant questions. In this way, a generative theory-making episode emerged that seemed to help students begin to make connections between their field observations and declarative knowledge that they brought with them from formal school and elsewhere.

Theory Making. Conceptual change is also documented in two other episodes of learning that were instigated with an HPL model of teaching. The first involved small breakout group discussions that afforded participants an opportunity to be reflective about events in the field. Students are given time to reflect on their final charts and written tests with a view to making edits and additions as a result of new information that came from the field. Over the course of a reflective discussion in small collaborative groups (e.g., Brophy, et al., 2001; Martin, et al., 2007), students are able to surface issues that they did not understand so that the group could help bring about a solution.

In this first short excerpt, a girl begins to make a connection between her physical comfort and the local weather at the beach. In reality, she is beginning to move from a formal school world of concepts and inert declarative knowledge to a world that has cause and effect, real-life implications and meaning. The talking rock is a central aspect of her report out.

Girl: (takes talking Rock)
Instructor: so you've got the floor. (0.2)
Girl: (Stands, holds rock) (0.2)
(plays with rock between both hands.)
Before, (0.2) I used to see the beach as somewhere really nice to go to
relax and stuff (0.1)
Now I don't
(shaking her head and smiling at classmates, rock, hand to hand)
(laughing) (0.2)
(few more giggles)
It was really cold. (0.2)

(Excerpt from Report Session: Debrief Day 2 tko)

While it might seem strange that someone who has lived her entire life in this river valley would suddenly notice the climate, I suggest that the mediated experience brought many things to the fore that would otherwise have been ignored or remain below the radar. Further, I suggest that this consequential observation, a first connection with the real world through weather, causes this student to begin to make deeper connections between her observations and existing knowledge that has lain inert and disconnected in the past. Recalling James Lovelock's (2009) eerie conclusion about losing connection with one's landscape by breaking the connection with weather and the production of food, we are reminded that a primal urge for survival and comfort prevails over classroom hand-outs, worksheets, spreadsheets and calculators. This first grounded connection between the sky and the girl, I argue was the beginning of "noticing" for her, a first tentative step on the path to deeper learning where she is "expert" at connecting her personal wellbeing to an outside event. Her use of colloquial speech and naïve science is peripheral to her conclusion, but beyond these deficiencies, there is a solid connection between her primary survival instinct and her own observation. She describes how the beach has changed for her as a direct result of the mediated experience of the previous two days. In the past, she explains, "I used to see the beach as somewhere really nice to go to relax and stuff" (lines 5 and 6) - her non-mediated view of the beach. But from now on, the beach is different, perhaps a place where observations, even noticing, can occur.

From a theoretical standpoint, the report-out session took place in the students' homeroom "formal" setting, but was influenced as shown in figure 25 by a visceral effect that included images and artifacts from the outdoors "informal" environment near Ediz Spit. Standing in a position of respect with the talking rock in hand, each student had opportunity to contribute to a "current best theory" in relation to any of the questions that were emerging as a result of the discussion. This is borne out in a final example of active student theory-making in the report-out discussion. When the vestiges of the outdoors setting perseverates into the classroom, it appears that the learning experience from the outside experience becomes an innovative actor that spills over with real images and meaningful resources. To facilitate a progression in this rather lengthy discussion, I have extracted several primary episodes from the interactive exchange.

Boy with white peaked cap (WPC): Ok uhm (makes gesture to his friend that he didn't want to let him out – include him visually and intellectually. (0.2)

(WPC): The thing that was most surprising was (0.1) on the first beach we thought there would be huge rocks away from the water and small rocks close to the water (0.2) but they were all the same size. It was kind of weird. (fingering the rock). (0.3) uhm. Because the water doesn't pick them along.

=Instructor: and so, what do you think today. What do you know now

=WPC: I don't know. (0.2) I still don't know why those rocks are the same size in that space. (0.1)

Instructor: That is one of the things that still needs to be explained. Can anybody help him? (0.2)

WPC: Why are all the rocks on that one beach the same size? (0.1) The (turns to his classmates) first beach that we did… (0.2) uhm (0.2) all the rocks were the same size

=Girl: (spokesperson for her group) where we were yesterday? (Looking up at him directly).

=WPC: Yeah. All the rocks were the same size. We thought they'd be bigger the farther away from the water. (0.1)

What is noteworthy about this opening exchange is that the student (WPC) initiates the problem (lines 4-7), stating that it was "kind of weird". Apparently there was sufficient disequilibrium associated with his observation (distribution of large and small cobbles on the beach) so that it didn't sit well with his prior knowledge (preconception) and he felt strongly enough about it to bring it forward in a rather public forum. At first, not all the students were as engaged as WPC (in fact he had to state and restate the problem at least three times) but he held on, not letting go until he had a reasonable explanation. He began by offering one himself, but soon others joined in and a robust theory-making session ensued. The concentrated interest and engagement was captured by the over-talk and sequence of turn taking that didn't let up until the matter was settled.

WPC: Maybe because of the tide. (0.2) The tide comes up and pushes all the rocks the same (0.4) (Heavy silence)

Voice. Would it be the uhmmm

=Girl voice: maybe the shape of the beach has something to do with it

=WPC: Where we first did our transect of the rocks on the beach all the rocks were the same size (0.2) I was expecting all the rocks to be bigger away from the water, and smaller near the water (0.2)

(Lots of voices jump in with more theories and possible explanations)

Girl #1 offers a brief explanation (inaudible).

(SH: A new boy who hasn't spoken yet - boy that WPC included in his opening - began pointing and talking. Body language is of deep engagement. He has short hair. When he talks it is inaudible)

=Classroom Teacher: Yeah. Say that louder (0.2) (he is near to him)

SH: (pointing with outstretched finger back and forth in a shape that resembles Ediz Spit). That little spit goes out around (0.2) and water goes on both sides of it.

Instructor: Stand up - pass him the rock.

SH: (deliberately remains sitting, refuses the rock). There is water on both sides and, and if the tide is high enough it is easy to get to those rocks in the middle (0.1) and erode them more. I think. (0.2)

Girl – 2nd Leader: So wouldn't that kinda be like because uhmm (0.1) the day that the tide is high (0.2) it's all under water and also like it's all kinda like the land (0.2) its always there. It's covered and it was pushed up there (0.1) from the waves coming in. (Makes shape with fingers to resemble waves coming from two directions and moving rocks together to the beach).

WPC's theory about the tide (lines 29-30) "pushing" rocks around is a good beginning, but quite obviously does not go far enough to explain the distribution pattern of cobbles on the beach. Many individuals contribute alternative solutions (lines 31-32, and again lines 37-48). In a moment of shared disequilibrium, SH is motivated to enter the public debate. SH is normally reticent, shy (line 46) and has a reputation for rarely contributing in class. Yet WPC, (who was a close friend), made such a strong case for trying to figure out an observation that was incongruent with his preconceptions that SH took the initiative to offer a solution (lines 38-48). The fact that SH entered into the debate seemed to be a cause for other sideline students to opt-in also. This resulted in WPC having to restate his original challenge time and again (even to the annoyance of the early adapter students who were already aware of the issues some of whom had already contributed a theory towards solving it). SH's use of his arms to indicate a prominent physical feature from the landscape, Ediz Spit, contributed to the argument since everyone had a fresh image of the spit from earlier in the day. As he pointed to the arc-shaped ring of sand that protruded into the Strait from the shorefront, each student had a visceral imagining of their own walking along the white strand, some skipping rocks in the lagoon, others looking for shiny quartz and shells, from solid experience. The blending of both environments in this argument was a robust representation of an emergent bridge between the informal fieldwork (with associated observational learning processes) and the formal classroom discussion (with associated theoretical knowledge). As before, the science assumed in the explanations is very suspect, but the theory-making and engagement is notable.

As mentioned earlier, the students who engaged with WPC's challenge from the beginning and who were deeply motivated to find a solution, showed a little annoyance at the latecomers to the quest. When WPC had already clarified the issues on three or four occasions in public (as well a privately to various individuals), they made their feelings known.

68 =Voice: why they are all scattered around? (0.1)
69 Instructor: the question is (0.2) Why they are all the same size
70 =Boy up front again: Why the rocks are the same size?
71 =Chorus of classmates: Yes. Yes.

Meanwhile, alternate theories are produced (with small pockets of side-panel discussions taking off on their own in an effort to verify stories and understand points of view. The following exchange brought the report out session to a plateau where the discussion approached a conclusion.

Girl Blue Poloneck (Polo) Maybe it's because. uhmmmm
when we were measuring it out there, it was all (0.2)
we were on a gaining beach (0.2), and so it's being built up (0.2)
and it obviously had to start somewhere. (0.2) So those big rocks were
brought in to start it, and they keep being brought in (0.2)
So, maybe that's why the rocks are big and (0.2) small (0.1)
everywhere. (Short conversation - she and the boy next to her as he
tries to interpret (inaudible). She says hmmm, and then Yeah)
Voice: maybe a storm! (0.1)
=Instructor: A new theory has arrived. You mentioned storm. That is
the first time we heard storm. (0.2) (looking around the class)
Do you think storm had something to do with it?
=Boy up front again: probably. Because there was that big storm not
so long ago. Had pretty big waves that brought a whole bunch of new
rock in.

(Excerpt from Report Session: Debrief Day 2 tko)

Polo's argument, circular and illogical though it might seem, is nevertheless grounded on several observations that are (i) her own, and (ii) real, coming from her measurements (line 78) at the informal setting on Ediz Spit. Introducing technical vocabulary—a gaining beach (line 79)—she manages to bring off a conclusion that is somewhat meaningful with regard to the processes and features on the beach. When she argues that the rocks were brought in to "start somewhere" (lines 80-81) she can omit the implied words "by the waves" because she is offering this knowledge from the shared space that she and her classmates experienced together in the informal setting earlier in the fieldtrip. Likewise when the word "storm" appears (Line 85) without any explanation, it connects with students' shared physical experience in the outdoors, so that a cognitive abstraction around waves and wind on Ediz Spit is present in the classroom formal setting. The distribution of cobble on the beach is tied to wave action (lines 89-91) and a solution seems to be making itself acceptable to the theorists. At this point the instructor, aware of time constraints, summarized the theories and brought the report-out to a conclusion.

The foregoing theory-making session made a remarkable bridge between two very different learning environments—an informal outdoors setting and students' formal homeroom setting. It was accomplished with careful alignment of pedagogic tools and learning processes that brought personal observations from one setting to bear on theoretical knowledge-building in the other. For a brief moment, a penumbral watermark from Ediz Spit resided in the classroom occasioning a transformative learning moment. A naturalistic mixture of informal and formal learning processes bridged with informal and formal settings in a seamless confluence of method and place to create a lively, self-directed learning moment across contexts, in which students excelled.

Conclusions and Implications

While thinking about learning science concepts at LIFE (Learning in Informal and Formal Environments) it seemed to me that it was generally assumed that a bridging between both sets of environments (described as **learning places** and **learning processes**) would produce positive outcomes for learners. From years of experience moving from formal classroom (F I) to outdoors informal environments (I I) with many hundreds of students, I was convinced that this idea was worthy of deeper explanation. People who might try to teach in a blended environment like this (Formal and Informal), without deeply thinking about the strengths and weaknesses of each could easily misinterpret the challenges and miss some of the opportunities for learning. I was thus prompted to investigate what it would take to create a useful bridging between the two settings.

Having been introduced into the Elwha landscape myself through informal learning processes—self-directed and with guidance only when I choose to ask for it—I am prompted to look initially at the strengths and weaknesses of this I I (see figure 2) experience from the point of view of learning sciences.

While there are many features and issues that this informal methodology allows one to learn, and indeed enjoy, there are many drawbacks as well. If I did not have a prior expertise in geomorphology and a penchant for reading topography in relation to the bigger picture that I carry from experience, I too would have missed most of the nuance of this landscape. When I wished to deepen my knowledge, I was glad to have a mentor (National Parks scientist) to walk the terrain with me and explain the items that were new and un-noticed by me before. For novices in this area (including all school children and many teachers) the need for a guided experience is obvious (Goodwin, 1994). For subtle features in the environment that do not readily spring to the novice's eye, primed, just-in-time mediation seems relevant (Many people have made this point (Feuerstein, et al., 2010; Feuerstein, et al., 1979; James, 1890; Mestre, Thaden-Koch, Dufresne, & Gerace, 2005) However, it is a delicate balancing act to align effective informal experiences with "mediation " processes" in ways that allow novices the opportunity to take advantage of the outdoors environment without lumbering them with busy-work and fear of failure on tests that can easily detract from the usefulness of the environment.

This study seems to indicate that creating a time for telling was significantly more instructive for the students when in an informal outdoors environment. This learning model has also been shown to be effective in formal school environments (Schwartz & Bransford, 1998). However, a nuance that seemed to emerge in this setting involved the use of technology. I conjecture that, because of the increased complexity of informal settings, the use of technology seemed to help the students get through their formal work quickly, and put them in a advantageous position to connect their findings (mathematical graphs and charts) with the shape of the landscape they were studying. As shown in figure 10, the transect work (while firmly rooted in an informal setting – beach), seemed to bridge formal and informal learning processes. Meanwhile, the lecture (which was also in an informal setting – Lake Mills) was delivered via formal learning processes (as if the students were in a classroom). Clearly, results show that the students who carried out the beach transect before the lecture outperformed the 'lecture' cohort. This could be construed as an opportunity to inform the learning scientist that a careful alignment of settings and learning processes is optimal.

Creating a ‘habit of mind’ to notice, observe, test and eventually ask is an important way to build PFL for the future. This is very different from many typical school and even non-school settings where docents lead children through an “informal” designed curriculum and point out things to them in the form of mini lectures. Such a pedagogical format misses the opportunity to learn to ask questions that can create a ‘time for telling’. This is a conjecture about teaching and learning that deserves more research.

My work on this projects leads me to strengthen the importance of my initial question; namely what does an experience need to look like for students to begin making connections between observed phenomena in informal settings, and declarative knowledge they obtain in formal classroom settings? This question sought to bridge informal settings of experiential fieldwork in the outdoors with formal classroom knowledge and processes of regular school. How could students live in an area with a strange structure in the middle of a lake (i.e., a dam and power house) and never ask what it was or why it was there? Why is it that students cannot connect the fact that the beach in their backyard is devoid of sand with the seventeen million cubic yards of silt, trapped up-river behind a dam? Why do students fail to see that the cobbles they are tripping over on the beach are similar to cobbles in the cliff matrix literally ten feet behind them? Why do students fail to understand that the frequency of waves crashing ashore impacts the shape of the beach?

I have come to the conclusion that a more meaningful question might be: What does an experience need to look like for students to first notice phenomena, so that they might then make connections that are meaningful and real? Essentially, this insight involved problematizing the idea that experience is a panacea for learning and requires other support as well.

In this study, and with the foregoing in mind, I introduced three experimental conditions to test the effectiveness of elements of experiential education in the outdoors for students. I introduced a model for looking at the way formal and informal learning might be bridged by aligning "settings" with "learning processes" in order to achieve satisfactory learning outcomes.

During the intervention, it became clear that the subjects were more than familiar with traditional models of pedagogy (e.g., IRE) and did not make relevant and obvious connections between physical features of the landscape and their own observations. In effect, their knowledge appeared to be inert—disconnected chunks of knowledge that existed unused (Dewey, 1938; Egan, 2002; Whitehead, 1929). It also was clear to me that just taking the children into the outdoors environment was not enough. Something additional was needed also, an intentional aligning of settings with learning processes. This point forms the basis for theories such as Feuerstein's about how people effectively learn (2010).

It appeared that a number of learning and teaching processes often 'spilled over' from one setting to the other (e.g., from the outdoors (Informal) to the classroom (Formal), and vice versa, from the classroom to the outdoors). In other words, effects (sometimes negative, sometimes positive) affected the learning in both situations. For instance, a negative effect spilled over from Formal to Informal when the children were so focused on completing worksheets at the beach that they had no time to take in the landscape and notice subtle phenomena all around them. They were required by their formal learning processes to fill in numbers in their notebooks (paper or electronic) that had to do with the size of cobbles on the beach. At the same time, they had no idea what cobbles were, what their impact on the beach was, or even from whence they originated. A positive effect was felt to spill over into the Formal classroom from Informal settings when a student-initiated question about the distribution of cobbles on the beach caused disequilibrium for a number of students. Thus, when given the opportunity, these students used a creative approach to robust theory-making and were able to articulate their ideas and solutions with meaningful vocabulary—a blend of both environments—to good purpose.

Several important considerations came to light as a result of the intervention. Since students worked in small group collaborations they were observed teaching each other and learning from one another. They took advantage of opportunities to work together, to discuss their work, (what they saw and experienced), while on the bus, walking to and from a site (beach or lake), or actually carrying out the transect on the beach. The dam sketch connected with the counterintuitive nature of many of the physical features of the landscape and the concepts associated with them. For instance, the relation of the rate of flow of the river and deposition in the lake was not immediately obvious to students. The sketching exercise was a means of mediating self-directed instruction relating to these difficult concepts. It served to make their preconceived ideas visible, and was also useful as a shared cognitive artifact where they could discuss the shift in thinking that emerged over time. Interestingly, it appears from the data in this study that there was a tendency for more conceptual change, if the lecture came after the experience, rather than before.

Limitations

This study has several limitations that restrict its generalizabilty to other areas of learning. Consequently, it is best viewed as an initial study that helps illuminate the complex field of blended learning environments in an attempt to bridge informal and formal settings. In addition, its overall capacity for comparison across geographic areas or learning science settings is questionable for reasons, which stemmed from population size and variability. A major source of variability among students appears to be differences in their experiences prior to participating in the study. In particular, some students have taken more math courses than others, and some have spent more time recreating in the Elwha River and along or off the coast than others. This was a two-day study, consisting of fieldwork in the outdoors with some extra hours in the classroom before and after. This limits the usefulness of the study for purposes of comparison to larger samples in different locations. Future work is suggested that is spread over several months with follow-up surveys and discussions that would confirm that the students were in fact making the tentative connections and understandings that this study describes and presents.

Future Work

As mentioned at the very outset of this dissertation, this study was one part in a multi-part undertaking that is ongoing in the Elwha district during a dam removal and habitat restoration effort. Next steps for this work will involve a larger sample size over a longer period. Since the dam removal momentum is already underway, and effects (both physical work and social upheaval) will be felt in this community for decades more, research work is warranted in the learning sciences within the neighboring schools. Further, it is hoped that results can contribute to learning theory beyond the local region.

Already, work is afoot to carry out research with up to 100 students in the same geographic area in similar settings—blended formal and informal that includes the beach, the dam site and the (soon to be disappearing) lakes.

Future directions will address some of these issues by engaging Native youth in activity-based schoolwork that is both meaningful for them and culturally sensitive. In the follow-up project I propose to increase their capacity for storytelling in innovative ways with technology. The plan envisions helping students become owners of their own story, in effect giving them agency to "notice" their landscape, to tell the story of the revitalizing of their valley after dam removal and through active participation in habitat restoration. By being part of the story they become the tellers of that story and contribute to their own wellbeing and that of their community through diffusion to the world outside their valley.

This can only be accomplished by listening to the tribal elders who urge an alignment of teaching models with the Native ways of knowing (Barnhardt & Kawagley, 2005). This might mean placing some of the learning in the Informal/Informal dimension of the Learning Experience Grid (see figure 2). In this way we hope to be able to give voice to the native story (Calabrese Barton, 2002; Riggs & Riggs, 2003). In the end, it is their story. Native youth identity with the region, the river and with the science of the new process is a key objective. Students will incorporate a culturally sensitive historic module, where they interview and collect historic artifacts from grandparents and elders associated with tribal communities and beyond. In addition, students will learn skills associated with videography and video presentations so that they can spread their story to visitors at the National Park, and disseminate it on the web and to schools outside the local area. Finally, it is hoped that students who go deep in any aspect of the science involved in dam removal or habitat restoration will opt to stay in school and pursue education to third level, and from there to take up work and livelihoods in environmental fields, like geosciences, habitat sustainability, or environmental management where there is a growing need today.

Many areas of schooling and learning converge to make this a sizeable challenge going forward. From a broad overview of relevant literature, we know many of the issues and some solutions. A pervasive view exists that formal schooling (e.g., texts and worksheets, etc.) often presents lists of topics that are a "mile wide and an inch deep" (e.g. see Bransford, Brown, & Cocking, 2000) a factor that contributes to a general lack of engagement among high school students (especially Native and minority students) and eventually to high dropout rates in local school districts. We also know from the literature that experts have extremely well-connected knowledge organized around big ideas like lifecycles (diSessa, 2002; Stevens, 2000) and a critical component of developing expertise is the ability to go deep in a particular domain (Darling-Hammmond, Barron, Pearson, Schoenfeld, & Stage, 2008; Sabelli, 2006). In order to develop expertise it is important to focus on learning with understanding so that students can get to the fundamental differences between surface characteristics and deep knowledge. Very often, school is about surface features, decontextualized and barren—preset formulae or bare facts (Freire, 1970; Rogoff, et al., 2003). The challenge is very real and we are excited about the prospect of introducing a study that can contribute to the community and to the learners. We know that both go together.

Dozens of scientists and scientific projects (Mapes, 2010) are already present in the Elwha valley looking at questions about fish, bears, vegetation, sediment, laminar flow, and so on. Our project is about people; in particular, about a new generation of Native young people whose story this is, and whose future is so inextricably immersed in this dam and river. I began this dissertation believing that experience was the best teacher. Now, I am not so sure. Experience in itself is probably not enough, but a mediated experience with alignment between settings and learning processes offers a nuanced view that provides breadth and depth for learning. Many people try to explain why it is so important for us to connect with our world, to be grounded in the experience. Intuitively we know we must. A senior National Parks Service ranger (Freilich, 2010) who is chief scientist for all research in this dam removal project, and who has spent a lifetime in the most spectacular wilderness areas, sums up the value of these kinds of experiences for all humans but especially for our children:

> "This is the greatest imaginable paradise. I can't imagine that most people, no matter how their normal life is lived, even the most urban dweller, the most citified person, when they come out here and see this blue sky, smell these flowers; and they look at this spectacular scenery; they just have a great moment of self realization. It's something deep-wired into humans to appreciate places like this" (p. 1).

Ultimately, an increasingly sophisticated set of findings about different ways to connect formal and informal learning should be useful not only for these people in the local area that hosted this study (the Elwha Nation) but, also for groups that are attempting to increase an interest in science and nature through opportunities for "experiential learning," e.g., places, both local and national that express a deep interest in outdoors learning programs, which promote a connection with the environment.

I mention a few that I have had the privilege to work with in the past, but the list is large: Islandwood (http://www.islandwood.org/), Nature Bridge and Olympic Park Institute (http://www.naturebridge.org/olympic-park), the US National Park Service (http://www.nps.gov/index.htm), and the National Geographic Society (http://www.nationalgeographic.com/).

The dams will come down, the river will be restored to its one-time pristine course, and in the process the local Native scholars will become the storytellers of their lives, but the future of their learning is unsure. Can an awakening sense of agency help them transform society even as society makes them? Hopefully, despite its small N, this study will help spark conversations among these groups and others so that learning opportunities become more grounded in places and processes that positively impact peoples' lives.

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Appendices

Appendix 1. Pre-test and Demographic Survey

Code Name: ___________________________

Answer ALL questions to the best of your ability.

1. When you finish school for the day, what do you most like to do with your time? Answer in the space provided.

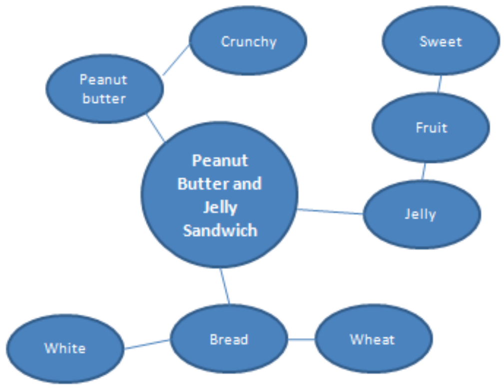
2. When you graduate from high school, what would you like to do? Answer in the space provided.

For questions 3-9, circle 1-5 to indicate your agreement or disagreement with the statements. Use this scale:

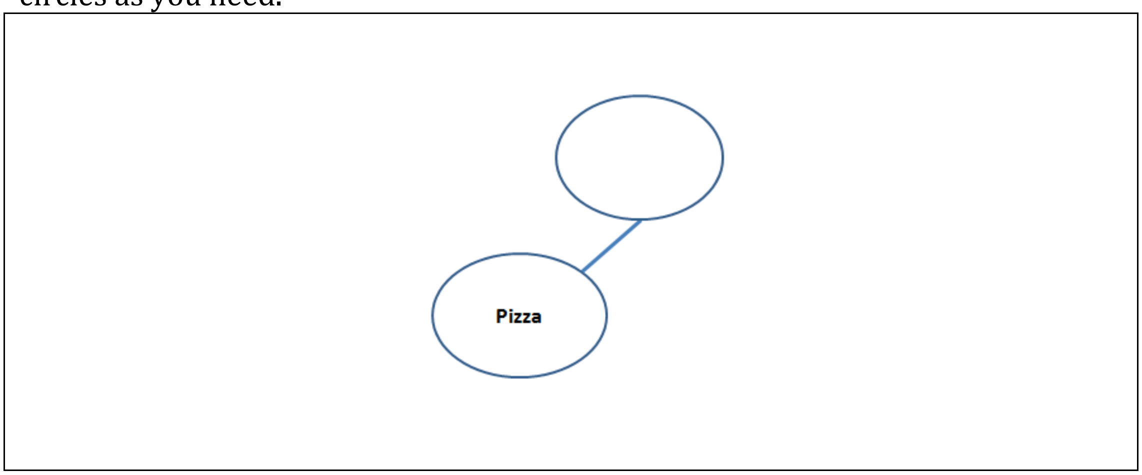
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

3. I am good at math.				
1	2	3	4	5
4. I am skilled at using graphing calculators.				
1	2	3	4	5
5. I like math at school.				
1	2	3	4	5
6. I like working in small groups when doing math.				
1	2	3	4	5
7. I like to do math alone.				
1	2	3	4	5
8. I would rather do more math outdoors.				
1	2	3	4	5
9. I think that removing the dams on the Elwha is a good idea.				
1	2	3	4	5

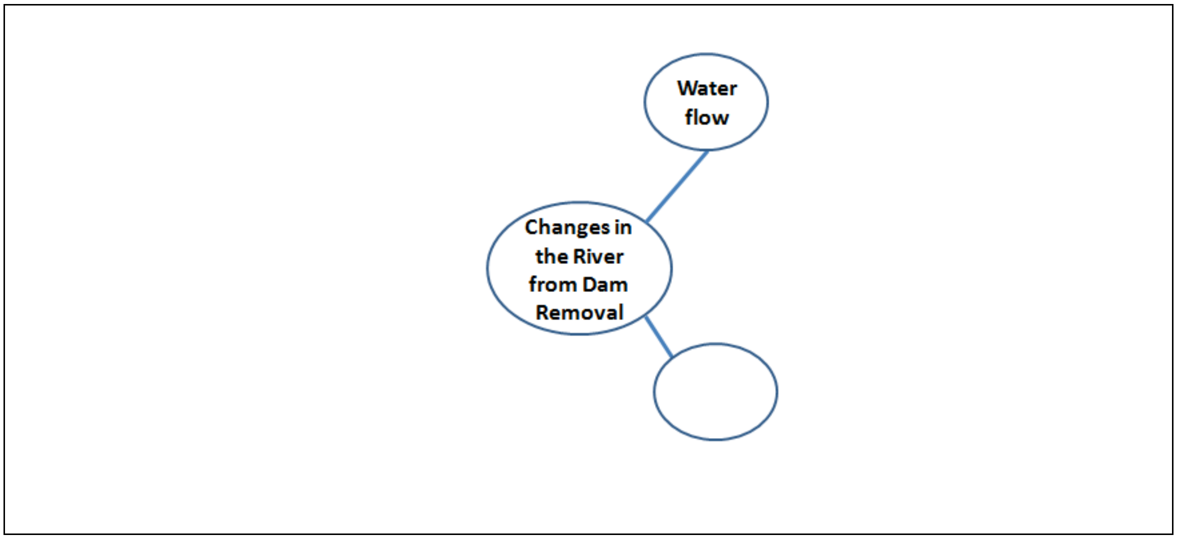
10. Here is an example of a *concept map*, which is a diagram that shows how a person's ideas are related. This example shows one person's concept of "peanut butter and jelly sandwich." The main idea is in the center, and related ideas are connected to it:



In the space provided, practice making a concept map that shows your main ideas about pizza. The map has been started for you; add as many lines and circles as you need.



11. In the space provided, create a concept map that shows the existing ideas you might have about how the Elwha River will change when the dams are removed. The map has been started for you; add as many lines and circles as you need.



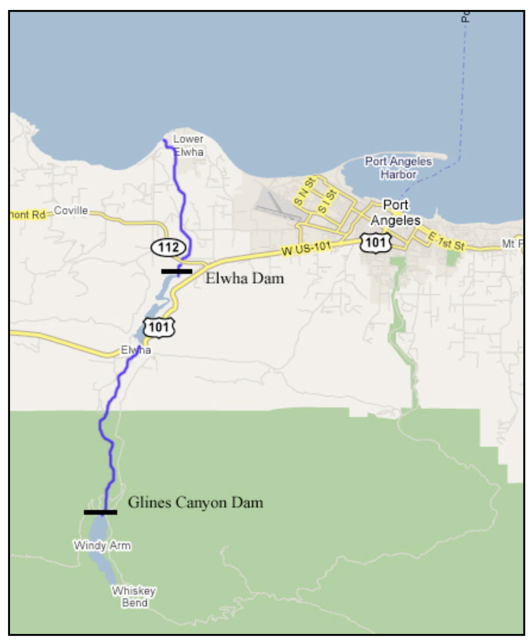
Extra blank page for drafts of concept map, if needed

12. This map shows the lower Elwha River and the Strait of Juan de Fuca, as they exist today. Label the areas where rocks and dirt are probably being:

   a. Eroded (taken away)

   b. Transported (moved along with the water)

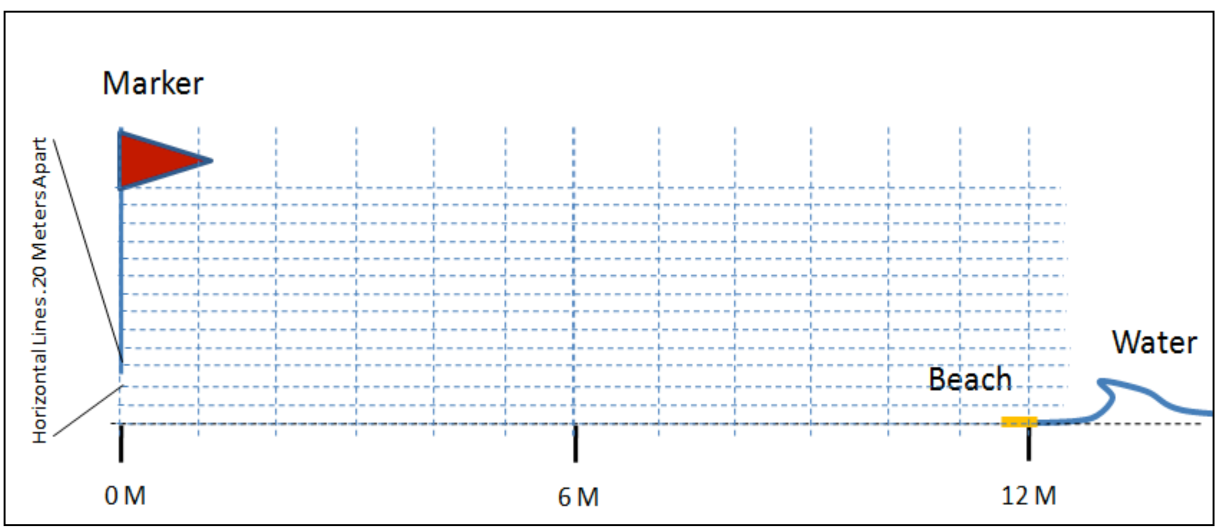
   c. Deposited (dropped out of the water)



13. This table shows height measurements of a beach, taken at 1-meter intervals, from a marker on shore to the waterline, 12 meters away.

Distance from Marker (Meters)	Change in Elevation *between* Measurements (Meters)	Absolute Elevation (relative to marker)
1	+0.2	+0.2
2	+0.2	+0.4
3	+0.2	+0.6
4	+0.1	+0.7
5	0	+0.7
6	-0.2	+0.5
7	-0.4	+0.1
8	-0.1	0
9	-0.2	-0.2
10	-0.1	-0.3
11	-0.1	-0.4
12	-0.1	-0.5

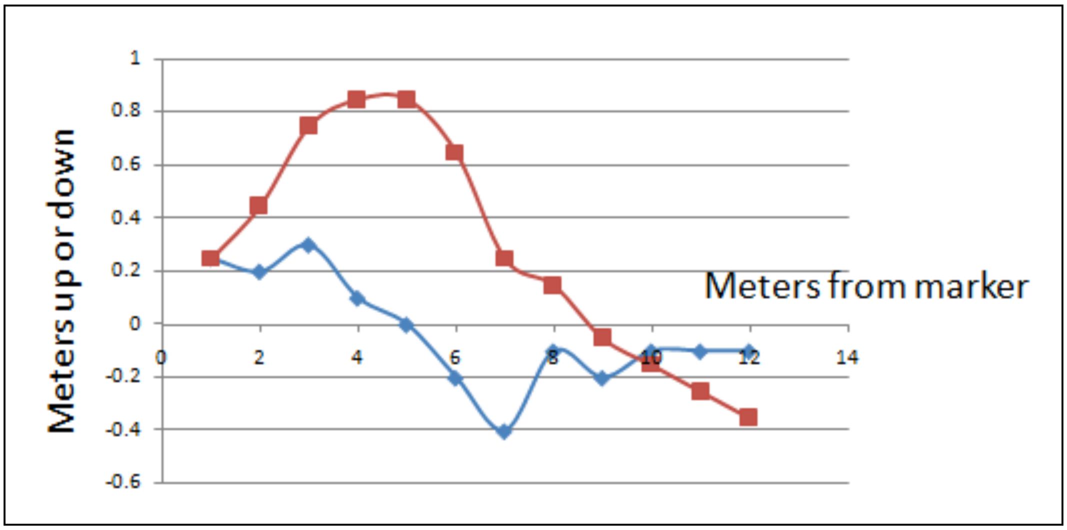
Draw a profile of a beach that would be consistent with the data table above. (Note that the vertical lines are 1 meter apart, and the horizontal likes are .20 meters apart.)



14. This table shows height measurements of a beach, taken at 1-meter intervals, from a marker on shore to the waterline, 12 meters away.

Distance from Marker (Meters)	**Change in Elevation *between* Measurements (Meters)**	**Absolute Elevation (relative to marker)**
1	+.25	+0.25
2	+.2	+0.45
3	+.3	+0.75
4	+.1	+0.85
5	0	+0.85
6	-.2	+0.65
7	-.4	+0.25
8	-.1	+0.15
9	-.2	-0.05
10	-.1	-0.15
11	-.1	-0.25
12	-.1	-0.35

Here is a graph of the same data.



a. What does the blue line show and what does the red line show?

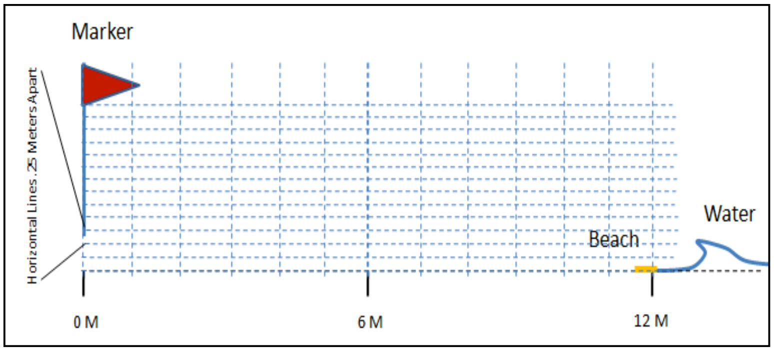
b. At 10-12 meters from the marker, why is the blue line flat while the red line is descending?

15. This data set shows elevations, along with measurements of the average size of pebbles in the sediment.

Distance from Marker (Meters)	**Change in Elevation *between* Measurements (Meters)**	**Absolute Elevation (relative to marker)**	**Average Sediment Pebble Size (Meters)**
1	+.25	+0.25	.01
2	+.2	+0.45	.07
3	+.3	+0.75	.08
4	+.1	+0.85	.06
5	0	+0.85	.05
6	-.2	+0.65	.01
7	-.4	+0.25	.001
8	-.1	+0.15	.003
9	-.2	-0.05	.001
10	-.1	-0.15	.003
11	-.1	-0.25	.002
12	-.1	-0.35	.001

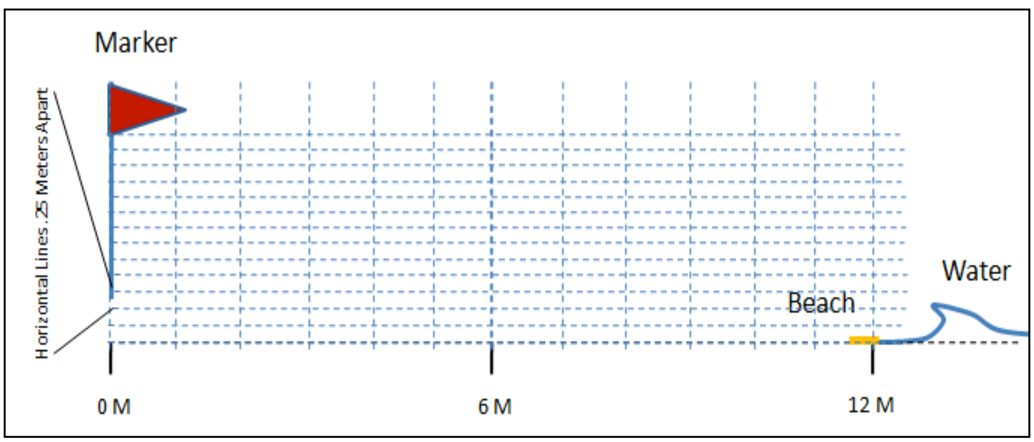
Describe, in your own words, the relationship between the sediment pebble size and the beach shape:

16. a. What would a beach profile look like if sand and gravel were being eroded (taken away) by waves? For your answer, draw such a profile:



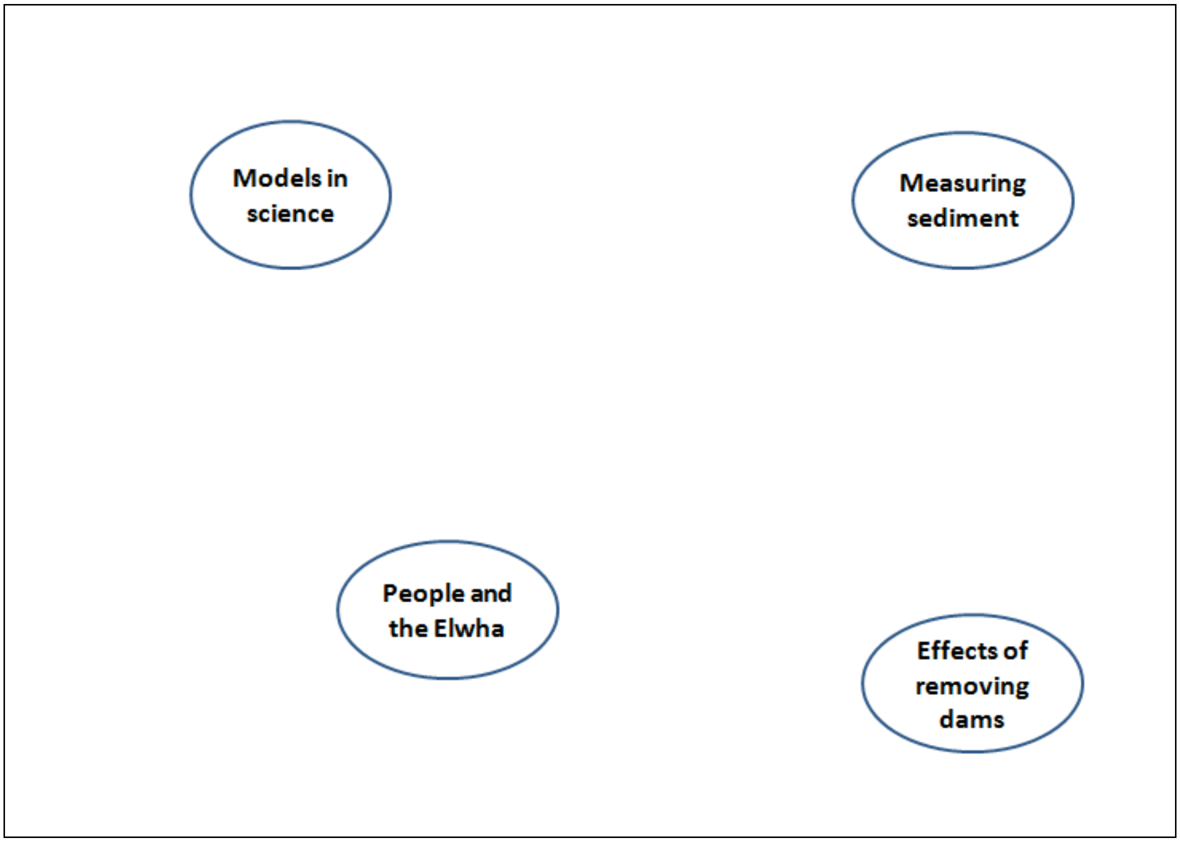
b. In your own words, give a reason why the beach would be shaped this way, if sand and gravel were being eroded away by waves.

17. a. What would a beach profile look like if sand and gravel were being deposited (added to the beach) by waves? For your answer, draw such profile:



b. In your own words, give a reason why the beach would be shaped this way, if sand and gravel were being added by waves.

18. In the space provided, create a concept map that shows how these concepts could be related. You can either use the arrangement here, or start over in the blank space provided on the next page.



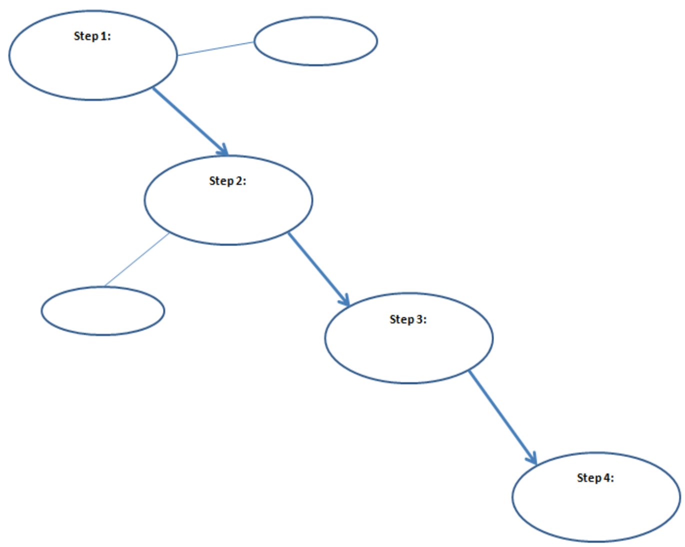
Extra blank page for drafts of concept map, if needed

19. Imagine that you are investigating this hypothesis:

    "Beach gravel tends to include larger pebbles as you move farther from the water."

    Create a concept map that shows the main steps you would take to gather data, analyze it, and present your findings. The map has been started for you; add as many circles and lines as you need.

Also, you do not need to use all steps if you wish to present in fewer than four steps.



Extra blank page for drafts of concept map, if needed

20. Describe in your own words why it could happen that larger pebbles are farther from the shoreline. It seems odd, but it could happen. Come up with your best theory as to why that might occur. in the following box labeled: Current Best Theory, describe your ideas.

Current Best Theory:

21. As a young scientist you make observations, collect data and discuss your findings with your fellow young scientists. Now give

some serious thought as to what will happen to the following stakeholders when the dams are taken down. Write one sentence for each of the stakeholders below as you see it. What will happen to (the):

a. town where you live (or nearest to where you live).

b. City of Port Angeles (if you do not live in Port Angeles).

c. Lower Elwha Klallam people.

d. shoreline in the Strait of Juan de Fuca.

e. land that used to be under the *Upper* Lake.

f. land that used to be under the *Lower* Lake.

g. trees in the Elwha watershed.

h. salmon.

i. bears.

j. any other stakeholder that you would like to mention that is not referred to here.

22. Write in your own words two short sentences for each item below:

a. What was the best part of today's activities?

b. What surprised you the most?

c. What do you still not understand and would like to bring up in a class discussion?

Appendix 2. Dam Sketch

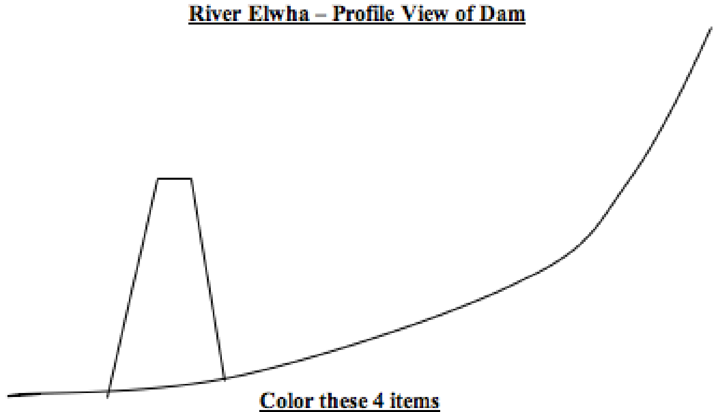
Secret Code

1. Bus to ☐ Beach
☐ Lake

2. Day ☐ 1
☐ 2

3. Time ☐ AM
☐ PM

River Elwha – Profile View of Dam



Color these 4 items

1. River.
2. Dam.
3. Lake.
4. Sediment in the lake.

Use the legend below to show which color.

Legend

River = ☐ Color

Dam = ☐ Color

Lake = ☐ Color

Silt/sediment = ☐ Color

Appendix 3. Exemplars of Dam Sketches

Three Drawings (Dam Sketches) from Silent Bob

Secret Code

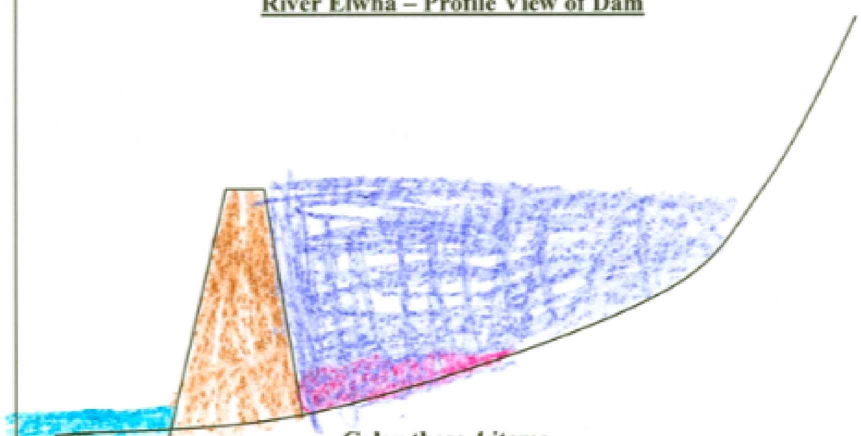
Silent Bob

1. Bus to ☐ Beach
☐ Lake

2. Day ☑ 1
☐ 2

3. Time ☐ AM
☐ PM

River Elwha – Profile View of Dam



Color these 4 items

1. River.
2. Dam.
3. Lake.
4. Sediment in the lake.

Use the legend below to show which color.

Legend

River	=	☐	Color
Dam	=	☐	Color
Lake	=	☐	Color
Silt/sediment	=	☐	Color

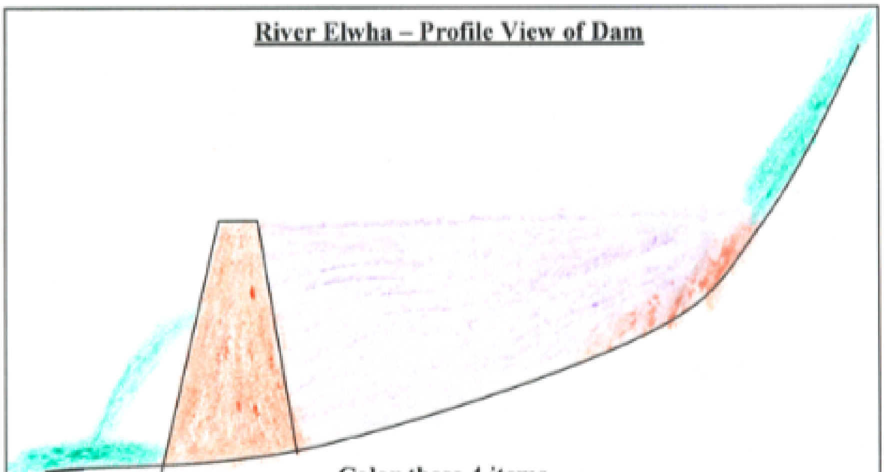
2

Secret Code

Silent Bob

1. Bus to	☐	Beach
	☐	Lake
2. Day	☐	1
	☐	2
3. Time	☐	AM
	☐	PM

River Elwha – Profile View of Dam



Color these 4 items

1. River.
2. Dam.
3. Lake.
4. Sediment in the lake.

Use the legend below to show which color.

Legend

River	=	☐	Color
Dam	=	☐	Color
Lake	=	☐	Color
Silt/sediment	=	☐	Color

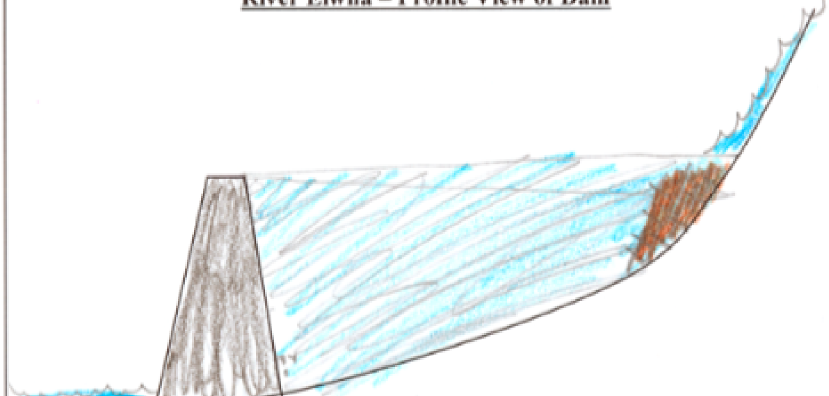
3

Secret Code

Silent Bob

1. Bus to	☐	Beach
	☐	Lake
2. Day	☐	1
	☑	2
3. Time	☐	AM
	☐	PM

River Elwha – Profile View of Dam



Color these 4 items

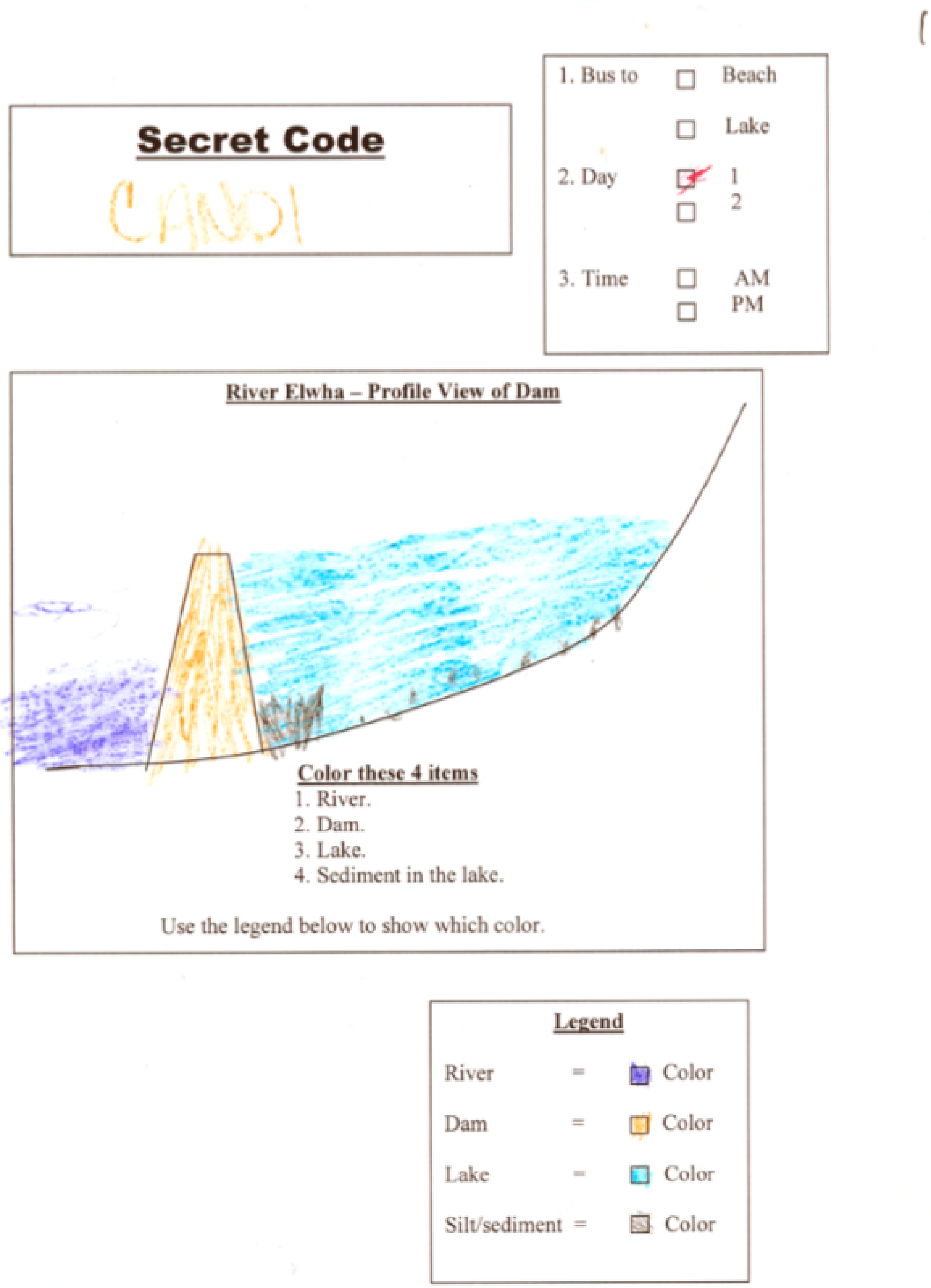
1. River.
2. Dam.
3. Lake.
4. Sediment in the lake.

Use the legend below to show which color.

Legend

River	=	Color
Dam	=	Color
Lake	=	Color
Silt/sediment	=	Color

Three Drawings (Dam Sketches) from Candi



Secret Code

CANDI

1. Bus to ☐ Beach ☐ Lake
2. Day ☑ 1 ☐ 2
3. Time ☐ AM ☐ PM

River Elwha – Profile View of Dam

Color these 4 items

1. River.
2. Dam.
3. Lake.
4. Sediment in the lake.

Use the legend below to show which color.

Legend

River	=	☐	Color
Dam	=	☐	Color
Lake	=	☐	Color
Silt/sediment	=	☐	Color

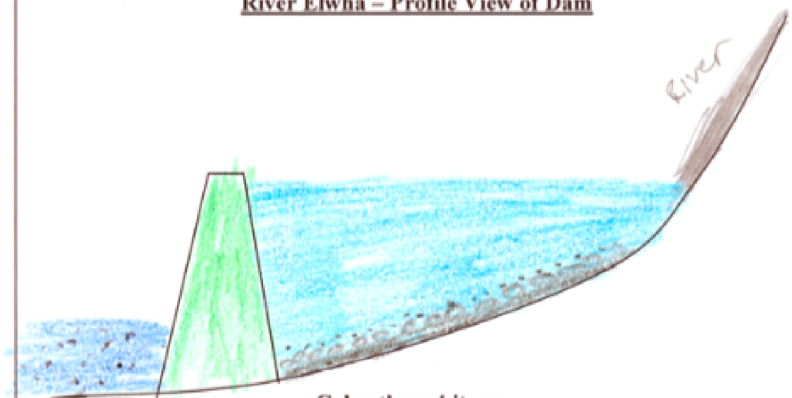
2

Secret Code

CANDI

1. Bus to
   - ☐ Beach
   - ☐ Lake
2. Day
   - ☐ 1
   - ☒ 2
3. Time
   - ☐ AM
   - ☐ PM

River Elwha – Profile View of Dam



Color these 4 items

1. River.
2. Dam.
3. Lake.
4. Sediment in the lake.

Use the legend below to show which color.

Legend

River	=	Color
Dam	=	Color
Lake	=	Color
Silt/sediment	=	Color

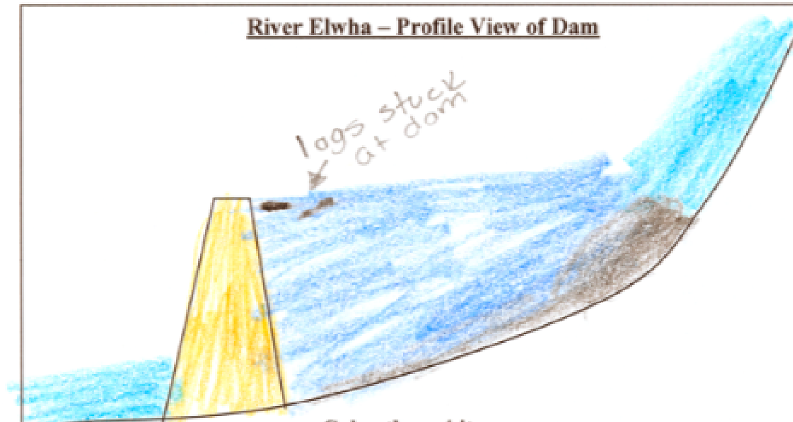
3

Secret Code

CANDI

1. Bus to ☐ Beach ☐ Lake
2. Day ☐ 1 ☒ 2
3. Time ☐ AM ☐ PM

River Elwha – Profile View of Dam



Color these 4 items

1. River.
2. Dam.
3. Lake.
4. Sediment in the lake.

Use the legend below to show which color.

Legend

River	=	■	Color
Dam	=	■	Color
Lake	=	■	Color
Silt/sediment	=	■	Color

Appendix 4. Recruitment Letter

UNIVERSITY OF WASHINGTON
CONSENT FORM

University of Washington/Olympic Park Institute/Texas Instruments

Elwha River Math & Science Activities

6/14/08

Re: University of Washington/Olympic Park Institute/Texas Instruments Elwha River Math & Science Activities

Dear Parent,

Our names are Kieran O'Mahoney and Tom Baer, doctoral students at the College of Education at the University of Washington. We are working with the Olympic Park Institute on a research study about how students learn math, science, and geography outdoors.

We are looking for high school math and science students to be part of a study, and Mr. Mowe at Crescent School gave us your name as someone who might be interested.

This study will be part of a field trip to the Olympic Park Institute attended by Mr. Mowe's students. Participation in the study is voluntary, and will not stop your child from fully participating in the field trip. Your child's grades will not be affected by whether you choose to have your child be in the study or not.

As part of the field trip, the class will graph the shape of a beach. Participation in the study means that your child may get to use a new type of calculator, and that your child's work will be collected. We will not collect student names, so the work will be anonymous. We will analyze the student work to help improve math and science education. We will give your child an Olympic Park Institute T-shirt and a University of Washington Huskies T-shirt for your child's time and inconvenience.

If you are interested in having your child considered for participation, or would like more information about the study, please review and sign the attached parent consent form. Then return one copy of the signed consent form to Mr. Mowe. The forms give additional details about the study, to help you decide whether you wish to have your child participate.

If you would like more information about the study, please contact Mr. Mowe, or Kieran O'Mahony at tko2@u.washington.edu. (Please note that although we keep e-mails private, we cannot ensure the confidentiality of information sent via e-mail.)

Thank you for considering participation in our study.

Sincerely,

____
Timothy Kieran O'Mahony, FRGS

____
Tom Baer, M.Ed.

Appendix 5. Consent Letter – Parent

UNIVERSITY OF WASHINGTON
CONSENT FORM

University of Washington/Olympic Park Institute/Texas Instruments

Elwha River Math & Science Activities

Researchers:

Stephen Kerr, Ph.D., Professor, College of Education, 206-616-4480, stkerr@u.washington.edu
Timothy Kieran O'Mahony, Doctoral Candidate, College of Education, 206-484-6014
tko2@u.washington.edu
Tom Baer, Graduate Student, College of Education, 206-947-1471,
baert@u.washington.edu

Please note that we cannot ensure the confidentiality of information sent via email.

Researcher's statement

We are asking your child to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to allow your child be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask your child to do, the possible risks and benefits, your child's rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want your child to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF THE STUDY

We would like to teach a class 2 different ways and see which way is better. The classes will be very similar, but different types of calculators will be used.

PROCEDURES

As part of the study, your child will participate in an outdoor education lesson related to how rocks and sands are eroded, transported, and deposited by the Elwha River. The lesson will be structured around learning how scientists monitor the river, and students will act as scientists by going to the river and taking measurement of a sediment deposit.

We will teach the lesson 2 different ways. Students will be assigned to a lesson by chance, such as through the toss of a coin. Although we want to know which way of teaching the lesson is better, students will learn about science from either lesson.

Your child will complete an anonymous questionnaire before and after taking measurements and analyzing data. He or she will also present will also present what he or she learned. Your child might be asked to participate in small group and class discussions and might be asked follow up questions.

If you choose to allow your child to participate in the study, we would like to use your child's tests and class work (such as his or her presentation of findings) as data to analyze for the study.

If you do choose to not allow your child participate in the study, then your child will participate in the same activities, but your child's tests and class work will not be used for the study.

We would also like to watch each group to see how the teaching is going. We will take notes of what each group is doing. We are more interested in how the group is doing, so we won't follow any particular person.

RISKS, STRESS, OR DISCOMFORT

Some people feel that providing information for research is an invasion of privacy. We have addressed concerns for your privacy in a section below.

BENEFITS OF THE STUDY

We hope this study will tell us how to better teach outdoor classes and to make outdoor learning more fun.

Although we hope the findings from this study benefit society, your child might not directly benefit from taking part in the study.

PRIVACY

Your child's test data will not be linked to your child's name. Your child will choose a secret code that only your child will know. Information about your child is anonymous. Your child will not be identified by name in any published reports of this research.

Government or university staffs sometimes review studies such as this one to make sure they are being done safely and legally. If a review of this study takes place, your child's records may be examined. The reviewers will protect your privacy. The study records will not be used to put you or your child at legal risk of harm.

OTHER INFORMATION

Taking part in this research is voluntary. Your child may stop at any time. Choosing to be in this study or to not be in this study, will not affect your child's classroom grades in any way. If you choose not to allow your child to participate, the research team will not have access to any of your child's work or test data.

If you have questions about the field trip or wish to see any of the field trip materials, please contact Mr. Mowe. (If he does not know the answer, he will refer you to one of the researchers at the top of this form.)

Printed name of researcher	Signature of researcher	Date

Participant's statement

This study has been explained to me. I volunteer to have my child take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers. If I have questions about my child's rights as a research participant, I can call the Human Subjects Division at (206) 543-0098. I will receive a copy of this consent form.

Printed name of participant	Signature of participant	Date

Appendix 6. Consent Letter

UNIVERSITY OF WASHINGTON
ASSENT FORM

University of Washington/Olympic Park Institute

Elwha River Math & Science Activities

Researchers:

Timothy Kieran O'Mahony, Doctoral Candidate, College of Education, 206-484-6014
tko2@u.washington.edu
John Bransford, Ph.D., Professor, College of Education, 206-616-4480,
bransj@u.washington.edu

Please note that we cannot ensure the confidentiality of information sent via email.

Researcher's statement

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF THE STUDY

We would like to teach a class 2 different ways and see which way is better. The classes will be very similar, but different types of instruction will be used.

PROCEDURES

If your child chooses to be part of the study, which takes place during the regular field trip to the Elwha River valley, your child will participate in an outdoor education lesson related to how rocks and sands are eroded, transported, and deposited by the Elwha River. The lesson will be structured around learning how scientists monitor the river, and you and other students will act as scientists by going to the river and taking measurement of a sediment deposit. To do this you will use rulers and gravelometers to measure the slope of the beach and the size of cobbles along a transect line. At the second site, you will receive a lecture about the impact of dams on the landscape. You will document both of your science gathering sessions (beach and dam) by taking notes, filling in the worksheets and using video cameras to capture features of the landscape that you deem appropriate for the project you and your partners are preparing.

You will complete an anonymous questionnaire before and after taking measurements and analyzing data. You might be asked to participate in video and audio recordings of scientific features of the landscape by your classmates while on field trip and you might decide to interview scientists and other people to create your story of the Elwha restoration. You will also present what you learned. You might be asked to participate in small group and class discussions and might be asked follow up questions.

If you choose to participate in the study, we would like to use your tests and class work (such as your presentation of findings, videos and interviews) as data to analyze for the study. We would also like to watch each group to see how the teaching is going. We will take video recordings and notes of what each group is doing. We are more interested in how the group is doing, so we won't follow any particular person.

ALTERNATIVES

If you choose to *not* participate in the study, you will participate in the same activities, but your tests and class work will not be used for the study. Neither will your video clips be used in the study and no video recording of you or your work will be used in the study.

RISKS, STRESS, OR DISCOMFORT

Some people feel that providing information for research is an invasion of privacy. We have addressed concerns for your privacy in a section below.

All students will attend the Olympic Park Institute field trip. Students who agree to allow UW use their data in their research will be involved in the same risks as those who do not. These risks involve walking on backcountry hiking trails and walking on a beach, similar to field trips you may have gone on in the past. If you have concerns about the physical activity involved, you may contact your teacher or any of the researchers listed at the top of this form for more information.

BENEFITS OF THE STUDY

We hope this study will tell us how to better teach outdoor classes and to make outdoor learning more fun.

Although we hope the findings from this study benefit society, you may not directly benefit from taking part in the study.

PRIVACY

All data is anonymous. Your test data will not be linked to your name. You will choose a secret code that only you will know. Information about you is anonymous. You will not be identified by name in any published reports of this research.

Government or university staffs sometimes review studies such as this one to make sure they are being done safely and legally. If a review of this study takes place, your records may be examined. The reviewers will protect your privacy. The study records will not be used to put you at legal risk of harm.

OTHER INFORMATION

Taking part in this research is voluntary. You may stop at any time. Choosing to be in this study or to not be in this study, will not affect your participation in this course or your classroom grades in any way.

Video recordings will be used in two ways. First you will use your own video recordings to create the end of quarter project about the Elwha restoration narrative, which will be a deliverable for you. Secondly, the research team will use the video recordings to assess which of the two teaching methods that we used was better for helping you learn. We will store the videos for up to two years after December 2010 in a secure cabinet at the university of Washington. Only members of the research team and University auditors will have access to these videos.

Printed name of researcher	Signature of researcher	Date

Participant's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers. If I have questions about my rights as a research participant, I can call the Human Subjects Division at (206) 543-0098. I will receive a copy of this consent form.

Printed name of participant	Signature of participant	Date

Appendix 7. Sample Data – Participant Observations

9:10 AM, Group A Bus to River Mouth
Partly cloudy
Seating:

- OPI Beach Instructor 2 was driving.
- I sat in rear right
- OPI Beach Instructor 1 in rear left
- Most other seats in bus filled by students.

As bus pulled out from parking lot, I asked OPI Beach Instructor 1 if I could start them on the dam coloring activity. He said to go ahead.
I asked for everyone's attention, held up the packet of worksheets and crayons and said "I have an art project for you to do on the bus." One student asked what it was and I said that this is a drawing activity, using crayons, to draw what they think the dam and lake looks like. The students responded positively and one said "sweet!" I told them that part of the reason for using crayons and not pens or pencils is that I want them to be creative and have fun with it; draw however they think the dam and lake looks, and there is no right or wrong answer as long as they give their honest impressions of what they look like. I reminded them that we are interested in understanding how they think, and how their thinking changes before and after they see the dams. I passed out the sheets and asked them to start by filling in secret codes.
Students worked quietly for about 10 minutes, and would talk to each other to trade crayon colors.
They passed back their sheets and I collected them.
About halfway between the school and the river mouth, a student said her house was near there and asked (as a joke) if we could go there and stop.
As the bus neared the trailhead to the river mouth, one student remarked that the houses are very nice and they'd like to live there. Another student pointed to a house near the trailhead and said her friend lives there but she hasn't been there in a long time.

Approx. 9:35, walking across the dike to the beach
It's cold, and OPI instructors ask if anyone needs a fleece jacket, students say "no"
OPI Beach Instructor 1 and I are walking in front, students trailing behind us. The smell of rotten eggs becomes apparent, and one student says in a fake southern accent "this don't smell too good," another student makes a joke about passing gas. OPI Beach Instructor 1 turns back and says "anaerobic decomposition," and the student nearest to us says "huh?" and OPI Beach Instructor 1 repeats "anaerobic decomposition, when there isn't much oxygen and things decompose, it makes that smell."

9:45-10:40 am, on the beach
We broke into calculator/non-calculator groups.
The non-calculator group headed down the beach with OPI Beach Instructor 2, about 100 meters to the West.
OPI Beach Instructor 1 and I stayed with the calculator group. Each student had their own calculator, and I carried one as well.

Our transect was on a spit approximately 26 meters wide, between the freshwater lagoon adjacent to the main river channel and the outer shore.

Near the breaking waves on shore, one student commented on the sound of pebbles rolling down the beach as the waves pulled them down. "I love that sound" she said. Other students agreed. About 30 minutes later, a student said "it sounds like old bones rattling."

OPI Beach Instructor 1 explained how to use the measurement tools and I explained how to enter it into the calculator. In the bus, I had made a visual aid with crayons, showing where to enter data on the spreadsheets. They gathered around and I reviewed with them how to enter the data.

OPI Beach Instructor 1 suggested that just one student enter the data in the calculator while the others handled the measuring. They quickly self-organized so that one student handled the gravelometer (the measuring tool for measuring sediment size), another handled the upland meter stick, and a third handled the water-side meter stick and the level. The student with the gravelometer usually took the actual elevation reading from the meter stick. The fourth student entered the data into the calculator. I entered the same data into my calculator, so I could help double-check and also help them with the procedure.

Students have questions about how to measure sediment size, and OPI Instructor explains the concept of the medium axis, as the one that most likely affects whether the rock could fit through the opening. Measuring sediment size involves the student turning the rock all around, assessing the shape and identifying the medium axis.

Throughout our time on the beach, many students were cold and shivered. They shivered less while doing the transect measurement work.

Conversation focused almost entirely on the transect measurements; students were on-task almost 100% of the time, and they often joked as they worked.

At the crest of the main beach berm, the shape changed from ascending to descending, and the students were not sure how to change their measurement configuration. The student Silent Bob noticed that the measurement can be taken off the upland stick instead of the water-side stick, and they began measuring again.

Transect measuring took about 40 minutes for 22 observation points. After they had taken all of the measurements, the data entering student and I compared our calculator data and we both had the same thing.

OPI Beach Instructor 1 told the other students to get out their calculators so they could enter the data. I reviewed how to open their documents and enter their data, and they opened their documents without problems.

The student who had first entered the data then read the numbers to the other students. Occasionally I student would get confused about how to enter into the correct row or column, or how to bring the formulas down to additional rows. I or another student would give help as needed. One student had to start over again after we had entered almost every row; another student showed him the correct procedure and he quickly entered the data by looking at another students calculator spreadsheet.

I explained how to view the graph of the beach profile, and all students were excited to see it appear on their screens. I then explained how to view the sediment size vs. distance and elevation graphs.

For about 5 minutes we discussed whether the graphs match what they observe directly on the beach, including the lack of a strong relationship between the sediment size and position and elevation, and they agreed that the graphs did match although some students thought that the sediment higher on the beach tended to be bigger than those closer to the water, and that if we took many more measurements the graph would probably show this.

The students graphs arbitrarily showed the starting point as elevation = 0. So the zero elevation showed the water level in the lagoon, and the ending point was "hovering" about one meter above the starting point because students did not measure in the surf zone on the outer shoreline.
I asked them how the profile graph could be shifted upward, so that the curve is higher on the y-axis. (Before doing the workshop, I had assumed that the students would start measuring at an elevation higher than the water level, and we would need to shift the graph upward to make the water level at y = 0 so that the graph would be easier to understand. However, because they started at the waterline in the lagoon, the water level was already at y = 0.)
One student said you'd multiply or add to the y-axis numbers. I showed them how to add a column with a formula to the y-axis and we performed a simple transformation to shift the graph upward.
We met with the non-calculator group and OPI Beach Instructor 2, and compared graphs and noted that the non-calculator graph was a shape that indicates losing sediment, while the calculator graph was a shape that indicates gaining sediment.
The OPI instructors explained the significance of "gaining" vs. "Losing" shapes.
OPI Instructor 2 asks OPI Instructor 1 if it is reasonable to assume that the beach toward the West could be losing sediment while the beach section toward the East could be gaining, and OPI Instructor 1 said that is reasonable.
We walked toward the dike trail and many in the group noticed how the rocks at the upper beach were oriented the same way. OPI Instructor 1 named the phenomenon "imbrication." A student said "huh" and he named it again and explained that the wave action during the storm caused the orientation. From Tom: I emailed the instructor, and the term was "imbrication." He had heard the term from another educator. One use of the term I found online: http://geology.about.com/library/bl/images/blimbrication.htm
Many students were shivering with cold, and said they wanted to go back to the bus to get warm. The group walked back to the bus.

Curriculum Vitae

Timothy Kieran O'Mahony
Curriculum Vitae

Education

Ph.D. – Learning Sciences
University of Washington – Summer 2010

M. Ed. – Curriculum and Instruction (Psychology of Education)
National University of Ireland

B.A. – Education (Secondary Science and Language)
National University of Ireland

Research Interests

Socio-cultural perspectives on cognition, learning, technology in formal and informal learning environments. Diffusion of innovation systemically in different learning environments. Teacher professional development in informal learning environments and other areas that impact student performance and engagement.

Dissertation Topic

The title of my dissertation is "Connecting Formal and Informal Learning Experiences". This study investigated how different ways of making connections between outdoor learning experiences and classroom learning impacts students' performance. Different kinds of "expert mediation" were introduced and tested as the students engaged in scientific activities. This work convinced me that there are many degrees of truth to the idea that experience is a great teacher. Its effectiveness seems to depend on how one's "experience" is mediated, and how "learning from it" is defined. This motivated me to think about design principles for linking people's experiences to learning. I began to explore, experimentally, how we might enhance people's abilities to notice, represent, and discuss their experiences in order to better learn.

Publications and Presentations

O'Mahony, T. K., Bransford, J. D., Vye, N., Stevens, R., Linn, K., Stephens, R., Ritchie, M., Sulleiman, M. (2010) (In press) Creating environments for continuous learning: Adaptive organizations and adaptive expertise. *Journal of the Learning Sciences*.

O'Mahony, T. K. (February, 2009) A visuo-spatial learning ecosystem enhances adaptive expertise with preparation for future learning. Proceedings of T^3 International Conference. Seattle, WA.

Mertl, V., O'Mahony, T. K. Honward, S., Herenkohl, L. R., Hoadley, C. (June, 2008) Analyzing collaborative contexts: Professional musicians, corporate engineers, and communities in the Himalayas. Proceedings of International Society of Learning Sciences. Utrecht, The Netherlands.

O'Mahony, T. K., Gawel, D. (March, 2008) Learn how you learn. Presentation and workshop as part of NSBE (*National Society of Black Engineers)* Convention, Orlando, FL.

O'Mahony, T. K. (April, 2008) Dam removal has implications for learning sciences: Elwha river dam removal project. Proceedings of Association of American Geographers. Boston, MA.

O'Mahony, T. K. (2005). Dam considerations and the world bank: TVA, Three Gorges & Elwha river reconstruction, *The Geography Teacher*: published by the Mercyhurst Institute for Geography Education. Erie, PA.

O'Mahony, T. K. (February, 2006) Adaptive expertise: Implications for learning at community colleges. Workshop as part of *CITE*, Case based teaching, Nashville TN.

O'Mahony, T. K., Hood, B. (June - September, 2006) Practical teaching methods: New designs for meaningful teaching and learning. Presentation and workshop as part of *OSPI Summer Institutes*, Spokane, Bellevue, Seattle.

O'Mahony, T. K. (July, 2006) Innovation & teaching methodology for community college students: Interactive workshop as part of *Synergy 06*, Boston, MA.

Professional Positions

2010 - *Co-Principal Investigator*: with John Bransford to NSF funded RAPID grant (NSF DRL, Rapid Grant 1014508) in informal learning environments. Title of research project: Making Connections: Integrating Formal and Informal Learning Experiences. Partners in this project include**:** Elwha Klallam Tribe; Jamestown S'Klallam tribe; National Park Service; Port Angeles City Schools, Joyce Schools, Crescent Schools; National Geographic Society; SRI International.

2004 – 2010 *Research Assistant*: NSF funded LIFE - Science of Learning Center. Worked closely with Prof. John Bransford (Co-Principal Investigator) who was my supervising faculty and committee chair. Also worked with Prof. Philip Bell and Reed Stevens who were my committee members. Other members of the LIFE Center collaborative who influenced my work and were helpful colleagues in my research endeavor include: Dr Nancy Vye, Dr Patricia Wasley, Hank Clark, and Dr Andrew Shouse, College of Education, University of Washington; Dr Daniel Schwartz, Dr Roy Pea, and Dr Brigid Barron, from the faculty of Education at Stanford University; Dr Nora Sabelli, Dr Bill Penuel, SRI International; and Dr Patricia Kuhl and Dr Andrew Meltzoff, ILABS, University of Washington.

2007 – 2008 Grant Scorer. OSPI Environmental Education Grant Applicants Scoring Consultant. K-12 students beneficiary of a statewide educational grant/funding community.

2000 – 2007 Coach. Teacher workshop and lectures series in geography methodology for the classroom. Field trips on social, economic, physical and environmental geography. Lecture series on World Geography, with particular reference to Africa.

1980 – 2000 High School Teacher. Responsible for geography education in inner city high school.

Dissertation Committee Members

Prof. John Bransford (Chair), College of Education

Prof. Philip Bell, College of Education

Prof. Reed Stevens, College of Education

Prof. Kuen Lin, College of Aerospace and Aeronautics

Conference Service

Reviewer AERA 2006. Division C. Educational Technology. Social Studies SIG.

Memberships

AERA (American Educational Research Association)

ICLS (International Conference of Learning Scientists)

RGS (Royal Geographical Society), Chairman Northwest Branch, Seattle.

EARLI (European Association for Research on Learning and Instruction)

Awards

Advancement of Literacy. Adult Lifelong Learning Section of the Public Library Association, 2002

Washington State Book Award. Seattle Public Library – Center for the Book: Terra Incognita: The True Story of How America Got its Name. Senior Editor with Rodney Broome, history author, Educare Press, 2002.

Distinguished Scholar. For publications and work that contributes to the advancement of geography education. Pennsylvania Geographical Society, 2003.

Geography Book Award. Association of American Geographers: *Holy Land, Whose Land? Modern Dilemma, Ancient Roots*. Senior Editor of geographical, and geopolitical edition (authored by Professor Drummond), and published by Educare Press, 2003.

Fellowships

FRGS. (Fellow of the Royal Geographical Society) Lifelong fellow, UK.
FEGU (Fellowship for Enhancing Global Understanding) MSU, 2009/2010.