

**Harvard University**

# **Connecting Students to Sustainability through Hands-on Learning in the High School Science Classroom**

**Joe Orzali**

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**Abstract**

This paper supports the deliverable work product comprised of ten high school science lessons, which were developed to provide hands-on activities and multiple learning modes to teach key science concepts connected to the field of sustainability. The concepts were identified and lessons developed through interviews with science and technical educators and participation in the Summer Sustainability Institute training. The results were used to organize the concepts into science topics relating to sustainability. The concepts and topics informed and guided the development of the activities, experiments, assignments, and other resources that make up the ten lessons. The project will be shared with other science educators and used in the high school science classroom beginning in the fall 2009. It will be an especially useful resource for science educators with limited materials and budgets and function as a starting point for incorporating the science of sustainability into many science classrooms. The lessons will also function to connect students to opportunities in the emerging green technology fields.

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## **Introduction**

Sustainability continues to grow in importance in education and technology fields, and it is increasingly important for high school students to gain exposure and experience with the concepts that underlie these fields. Global climate change, ecological preservation, energy efficiency, alternative energy, green building, and systems thinking are all science topics within the field of sustainability (science sustainability topics) and share many overlapping, fundamental concepts. High school science students would benefit in many ways by learning these concepts through hands-on activities and activities.

There is a lack of free, cohesive, and accessible science-based curricula that address topics within the field of sustainability for alternative high school science teachers in Portland, OR. In addition, the text books used by Portland Public Schools (PPS) do not provide adequate resources and information on these subjects (Bigelow, 2009). Teaching sustainability and integrating the fundamental concepts of science into a high school class is a major challenge because it is not the traditional approach, but it can be addressed through the inclusion of well-planned and researched classroom activities. Utilizing such activities in the science classroom can provide students with guidance and preparation for post-secondary technology programs and apprenticeships in green technology fields. These “green jobs” are rapidly expanding, as are the opportunities for high school graduates who have interest and some training (Holland, 2009).

This Capstone project includes written lessons geared around student activities and assignments that aim to expose students to science topics associated with sustainability. The activities and activities were designed to be user friendly and only require readily available and affordable materials. The lessons are the deliverable portion of the project and are supported by

this paper, which outlines the need for such lessons, the methods used to develop the lessons, and the way the lessons will be used.

Alternative high schools in Portland, OR lack many of the necessary resources for conducting important science activities. The benefits of quality, innovative hands-on activities and activities in the high school science classroom are well documented (Griffard, 2006) and as a national issue, there is a growing need for more science education that relates to the versatility of the American workforce (Leshner, 2007). Hands-on science activities enable active participation of learners in the teaching process and connect students to the world of science, which plays a substantial role in the contemporary world (Obadović, 2007). High schools should assume the responsibility to provide quality hands-on learning opportunities in science and expose students to the field of sustainability.

There are many barriers to quality science education in high schools. For example, PPS experienced a 15% cut to programs state wide for the 2009-2010 school year. This budget shortage creates many difficulties for individual schools and resulted in the reduction of teaching and support positions at Mt. Scott Learning Center (Mt. Scott), an alternative high school in southeast Portland where the lessons will be taught, and a tightening of the budget for science and other supplies.

The PPS Physical Science curriculum, which covers physics and chemistry, is *Physical Science Concepts in Action* from Prentice Hall publishing. Some alternative schools, such as Mt. Scott do not receive the full gamut of supplies that should accompany the curriculum. For example, a classroom may have twenty students, but only fifteen books, which causes some students to have to share books. The activities and activities in the curriculum do very little to expose students to the science sustainability topics.

America currently lags behind many other industrialized countries in preparing tomorrow's labor force and is absent from the list of top-ten science and math education countries (Leshner, 2009). This holds true for Mt. Scott, where the most recent graduating class of seventeen students included no students planning to attend a four year college in the fall of 2009. Most graduates are planning to attend Portland Community College (PCC), which is dramatically growing their program offerings "to serve emerging green technology needs" (Holland, 2009).

The high school science classroom is ideally suited to expose students to the growing opportunities in green technology fields (Joiner, 2009). In addition, students who gain experience that is relevant to green technologies may have an advantage in being accepted to and being more successful in these post-secondary green technology programs. Lessons complete with activities, activities, and resources that expose students to science sustainability topics will undoubtedly give students a deeper understanding of sustainability and advantages in pursuing higher education or jobs in the green technology field.

These lessons focus on activities and activities that are designed cheap and accessible materials that can easily be utilized by other educators. Information for the lessons was gathered through Internet searches, interviews with eight educators, and the Summer Sustainability Institute training for technical educators. These methods were used to identify and prioritize hands-on activities and activities that illustrate science concepts important to sustainability. The lessons were then organized and expanded to fit the Learning Cycle Planner, a lesson template that facilitates inquiry based learning, from the State of Oregon Department of Education.

The final product is a series of lessons focused on hands-on learning through activities with clear instructions that will be used at Mt. Scott and can be utilized by other high school

teachers. Some of the lessons will be posted on the Center for Health and the Global Environment website (<http://chge.med.harvard.edu/programs/education/secondary/index.html>) to supplement existing lessons and activities. These lessons and activities can be expanded to form the basis of a cross-curricular collaboration of teachers that involves math, social studies, language arts, and art. In addition, students who complete the lessons will have a heightened understanding of crucial concepts associated with science sustainability topics. This should function to provide successful students with an advantage in the pursuit of higher education or jobs in related green technology fields.

## **Background**

### **The Students**

Students at Mt. Scott and many other alternative high school programs in Portland, OR have similar experiences. These experiences are characterized by a year or so of overwhelming struggles in the traditional public high school setting. The root of the students' struggles varies, but the result is commonly held as a sense of failure and falling behind that can be very defeating and depressing. Since high school is, in many cases, the highest level of formal education these students will complete, it has become increasingly important that their education be applicable and relevant for student success in the "real world" beyond the walls of high school.

Small alternative schools such as Mt. Scott struggle to provide a diverse array of career pathway options, especially given the homogenous background and the low numbers of staff. The staff members regularly have discussions regarding the best ways to serve our student body. This often leads to brainstorming around the most important skills and information students should learn in high school aside from college preparatory academic skills. We continually emphasize the need to connect students to jobs, career pathways, and job skills. Many of the

graduating students from alternative schools will not attend a four-year college fall after graduation because they are ill-prepared and/or do not have the financial resources to consider the option. A much more accessible and frequently exercised option is for graduates to attend one of the branches of PCC or other local community colleges. PCC has the ability to respond quickly to industry needs and, therefore, is closely connected to available and emerging jobs markets in the green technology field (Holland, 2009). The green technology course offerings at PCC include renewable energy systems, alternative fuels, solar voltaic manufacturing and sustainable building. These courses are part of the following educational pathways: Electronic Engineering Technology; Facilities Maintenance; Microelectronic Technology; Civil Mechanical Engineering Technology; Automotive Services; Chemistry, Architectural Design and Drafting; Interior Design and Building Construction Technology (Holland, 2009). Students are more likely to successfully pursue a degree in these green technology fields if they gain an interest in sustainability in high school.

### **The Teachers**

Providing interesting and relevant hands-on experiences in the classroom is a common challenge for science teachers. Even teachers with many years of experience are challenged because science is not static and the issues impacting students today are different than those of the past. Many teachers feel a responsibility to provide insight to their students and help to make sense of increasingly contentious issues that have become increasingly contentious as the flood of advertisements, news reports, television shows, radio shows, online videos, movies, tweets, Facebook posts, and Myspace posts inundate us. The varied media by which we obtain information requires, more than ever before, the ability to use critical thinking to evaluate fantastical claims that are often outside the accepted bounds of peer-reviewed science. This

misinformation is very powerful and can overwhelm students and deter their interest in science (Holland, 2009). To equip students in today's information-laden world with critical thinking skills, science education must provide opportunities for inquiry through hands-on learning and experimentation (Oregon Department of Education, 2007).

### **The Schools**

There is often a lack of resources and equipment for science activities in the alternative high schools, which creates a disproportionate impact on at-risk and disadvantaged youth who do not have access to appropriate technology and hands-on science experiences as compared to many of their peers in mainstream public and private schools. Also, the rapidly changing economy in Portland has extended the wealth disparity and created groups of people who are unable to access the environmental, social, and economic amenities enjoyed by those near or above median income levels (Kevin Odell, personal communication May 18, 2009). The wealth disparity could be partially diminished by developing a curriculum that connects students from marginalized communities to the emerging green technology fields. As a result of students learning about energy efficiency, marginalized families may have more access to resources, as well as better strategies for conserving energy and lowering utility bills.

PPS mandate that seniors have a full credit (four quarters) of a senior pathways course. Beginning in the 2009-2010 school year younger students will also be required to amass several documented Career Related Learning Experiences (CRLE's, referred to as "Curlies") before graduation. Much discussion and planning has gone into the planning of courses, electives, field trips, and extra curricular activities to meet these emerging requirements. At the same time, new requirements for teaching a foreign language have caused staff to take on more responsibility and be creative with the schedule to allow students to meet all the requirements of a PPS diploma.

Along with meeting new requirements, the Mt. Scott staff are dedicated to maintaining and, in some areas, increasing the rigor of academic programs. In science, rigor can be added in terms of new student skills, not just knowledge. Skills are best developed through hands-on learning.

### **The Science Classroom**

Science classes focused on hands-on activities that develop skills and facilitate the understanding of the concepts behind the science sustainability topics would help to connect students to the field of sustainability. In addition, science courses built around these hands-on activities would increase students' preparedness and, hopefully, interest in the green courses and career pathways at PCC and other colleges.

After teaching for five years and working in three alternative high schools as a science teacher, I recognize the need for quality hands-on activities as the focus of high school science classes. I also acknowledge the challenge of providing quality hands-on activities when schools have very limited budgets and new teachers have limited access to resources. Beyond teacher preparedness and budgets, environmental studies and sustainability have become increasingly important global issues and students want and need to learn current, relevant information and skills. Due to these issues, the larger goal of the lessons developed for this Capstone project is to inspire students to become life long learners and inspire their interest in science. To support this goal, students will be afforded flexibility and can be assessed according to any one of several assessment methods. These methods will include the regular tests, quizzes, and papers, but can alternatively be fulfilled by a well prepared presentation, song, experiment, demonstration, or other means approved in advance.

With my education from the Sustainability and Environmental Management ALM from Harvard Extension School, this Capstone project, and a classroom at Mt. Scott Learning Center,

where I plan to stay for the foreseeable future, I intend to continue to develop innovative science activities and lesson to teach sustainability.

## **Methods**

Internet searches for a review of existing literature were performed by searching Google Scholar, Google Advanced Domain .edu, Harvard libraries quick search with the “education” quick set marked, and EBSCO searches. The following terms were used in the searches: “secondary science education activities,” “secondary science education activities renewable energy,” “benefits of learning through hands on science,” “hands on activities in high school science.” The environmental librarian at Harvard provided guidance for searching deeper into the research subject and helped to identify and bridge gaps in the research.

## **Evaluative Framework**

Lessons found through literature searches were analyzed for the level of instruction provided, the complexity of the topics covered, and the applicability to the general topics consistent with the questions number four and five from the interviews (on page 13). These questions were focused on the broad topics of climate change science, species loss, and understanding and reducing the ecological impacts of humans. These topics were the focus because they are directly related to sustainability. Many excellent resources were found through the literature searches, but none provided a set of hands-on science activities that would explore the host of concepts related to the science sustainability topics. Additionally, those sample activities that were found in the Internet search failed to address the budget and material limitations of most schools. The lessons developed for the capstone aim to use readily accessible and affordable materials or materials that could be obtained at minimum cost. In addition, the restrictions of the science classroom and grounds at Mt. Scott were considered. For example,

there is no gas line for the use of Bunsen burners and only four functional microscopes in the Mt. Scott science classroom.

The direct methods of data collection utilized were interviews and participation in the Summer Sustainability Institute (SSI), a training for science and technical educators at Portland Community College and the Earth Advantage headquarters in Portland, OR for the week of July 13 to 17, 2009. Utilizing these two methods allowed for a broad and thorough exploration of sustainability topics, especially given the wide range of sustainability issues covered at the SSI and the specific knowledge and experience of the educators interviewed. It also facilitated the development of the list of specific science sustainability topics on which the project is based: global climate change, ecological preservation, energy efficiency, alternative energy, green building, and systems thinking. These topics were selected due to their relevance to sustainability, high school science, and green technology fields.

The interview questions were carefully selected and vetted by other students in the Capstone course and by Professor Buckley. It was an advantage to have multiple educators in the class as well as Professor Buckley. The specific interview questions can be found at the end of this section. Interviews were conducted in an open, conversational manner. This allowed for in-depth exploration of topics with which the individual interviewee had particular interest or experience, and each interviewee provided more specific resources and ideas for activities. Interviewees were given the list of questions prior to the interview and encouraged to review the questions before hand. The only recording of the interviews was notes taken by the investigator.

The interview responses were utilized to identify key concepts that should be covered in high school science to help students grasp how climate change is impacting the earth and how the ecological impacts of humans might be reduced. After identifying the most important

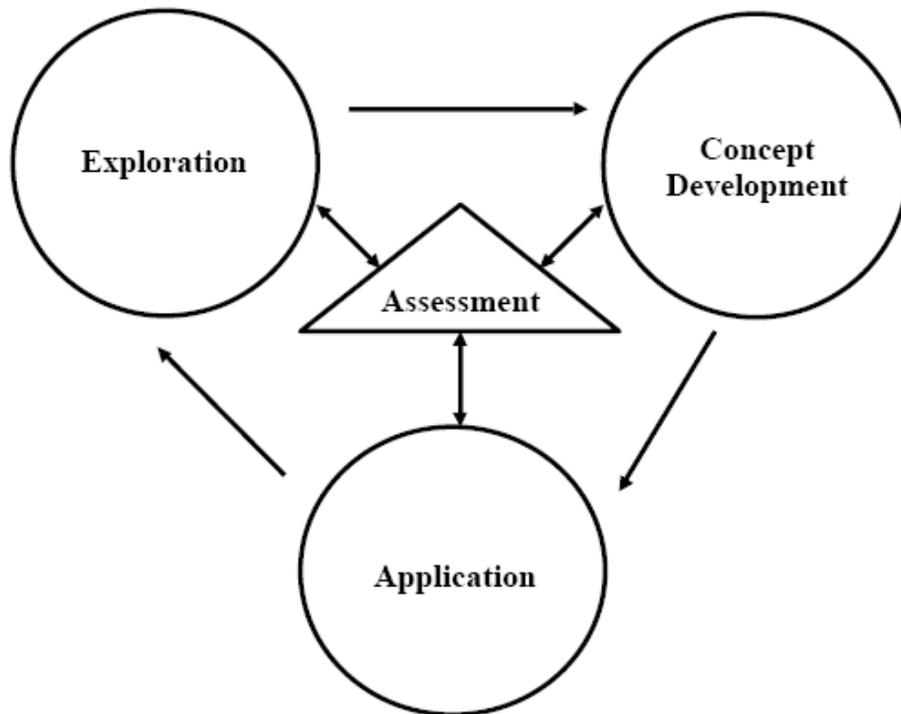
concepts, interviewees were also asked to help identify effective activities, activities, and lessons that illustrate the identified science concepts. Using the important science concepts, information from literature searches, interviews, the SSI, and the investigator's teaching experience and sustainability education a list of activities was assembled. Activities were selected to provide students the opportunity to discover and gain insight into the identified concepts through hands-on inquiry, trial and error, and cooperation with other students. Lessons were then developed with the emphasis on the activities. A diversity of resources, such as websites, activities, videos, articles, simulations, films and assignments were included in lessons to support the activities and provide learning through multiple modes. This diversity of resources was compiled through the literature searches, interviews and the SSI. The format of the lessons follows a resource template described by the State of Oregon Department of Education called the Learning Cycle Planner. The Learning Cycle Planner places emphasis on the hands-on portion of each lesson, which fits the focus of this project.

Lessons were organized to fit the learning cycle identified in the learning cycle planner, which is represented in a diagram in Figure 1 below. The learning cycle is designed to provide students with the opportunity to explore a subject and, in doing so, practice science skills, gain knowledge, master concepts, and demonstrate newly acquired skills and knowledge. The teacher's role is to guide the explorations and introduce skills and knowledge that underlie each learning objective. In order to pull the lesson together, the teacher provides opportunities for students to apply their new skills and knowledge through activities and assignments (Oregon Department of Education, 2007). The lessons prepared for this project are designed to allow for flexible assessment procedures. In the classroom, students will be assessed through a variety of means including tests, game-show style group quizzes, and/or authentic assessment. Authentic

assessment provides students with the opportunity to present the skills developed and concepts mastered through presentations, songs, posters, or other ways which are generated by individual students.

**Figure 1: The Learning Cycle**

(Oregon Department of Education, 2007)



The application of skills and knowledge is demonstrated by students' ability to complete assignments and build their knowledge base over time as concepts and topics overlap and reinforce one another. If a student can make the connections between and domestic energy use and global climate change and articulate the need to conserve, for example, the student will be successful in the class because he or she is applying their knowledge.

**Limitations**

The true test of the success of the methods will be the execution of the activities in a classroom with students. If it had been possible for a group of high school students or teachers

to test each experiment in the classroom where the lessons will be taught, there would be more definitive data available. The activities and lessons that were developed are not an exhaustive list of hands-on sustainability science lessons. Rather, the lessons are a collection of hands-on opportunities for learning that can function as inspiration for more activities to explore the science behind sustainability.

### **Interview Questions**

1. Describe your education and teaching experience.
2. What is your experience in teaching climate change, energy and water conservation, renewable energy and related subjects?
3. How have you put lessons together around these topics? For example, how have you handled the challenge of using text books, state framework standards, and other resources to create lessons that are up to date, engaging, and relevant?
4. What do you think are the most important science concepts (fundamentals) that high school students need to understand in order to grasp how climate change is impacting the earth and species?
5. What do you think are the most important science concepts (fundamentals) that high school students need to understand in order to grasp (internalize) how to reduce our ecological impacts?
6. What science activities/activities are you familiar with that demonstrate these concepts?
7. Can you show/share with me the materials and assignments you've used? What are the best resources you've found? Text books, Websites, etc.?

8. Have you been involved with teaching climate change, energy and water conservation, renewable energy and related subjects in a cross curricular manner, working with other teachers? If so, describe the experience.
9. How do you avoid conveying a feeling of hopelessness when teaching about problems that can seem overwhelming? And, how can the lessons be geared toward positive, opportunities for change?

## **Results**

The information and ideas for the lessons could have been obtained exclusively through Internet searches given the wealth of educational resources available on the Internet. However, the deliverable product of science lessons for this Capstone project has a place-based focus and is geared to benefit a specific group of students. With that said, the lessons could be used by any science teacher who has an interest in teaching sustainability and using hands-on activities. Interviews and information from the SSI training were particularly relevant because science and technical educators have direct experience with activities and lessons that actually work for students in a classroom setting. In addition, the educators interviewed were adept in identifying the most important concepts involved with the science of sustainability. The literature searches provided many sample activities and resources, as well as research supporting the need for improved science education as America continues to lag behind other industrialized countries in preparing young people for jobs in the technology fields (Leshner, 2009). The following four lessons were discovered through Internet searches: Solar Cooker Pringles Can, Ocean Currents, Making a Solar Air Heater, and Energy Efficient Homes.

Interviews and the SSI provided direct contact with educators and organizations striving to improve science and technical education at the high school, community college, and university

level. The following six lessons were discovered through the suggestions of interviewees: Ecosystem in a Bottle, CO2 Aquariums, Making Electromagnets, Electricity Audit, Product Disassembly; and Tracking the Sun's Path in the Sky. In total, ten lessons were developed and are identified by the name of the experiment on which each is centered, see Figure 2 below.

### **Raw Data**

The information gathered during the eight interviews and participation in the SSI training was used to establish the list of science sustainability topics: global climate change, ecological preservation, energy efficiency, alternative energy, green building, and systems thinking. Information from the interviews was used to draw out the most important science concepts involved with teaching these topics. Interviewees and other SSI participants brainstormed useful activities and identified resources that could supplement and extend activities to be hands-on and relevant to the key science concepts. This process has become self-supporting, as ideas lead to activities and activities lead to more ideas. Interviewees and others from the SSI training continue to pass along relevant and innovative information. A summary website dedicated to the SSI has become a valuable tool and is updated regularly by the SSI organizers at Portland Community College. Questions four and five in the interviews focused on the key science concepts related to sustainability, the full list of interview questions are on pages 13 and 14. The notes taken regarding the answers to these questions are listed at the end of this section.

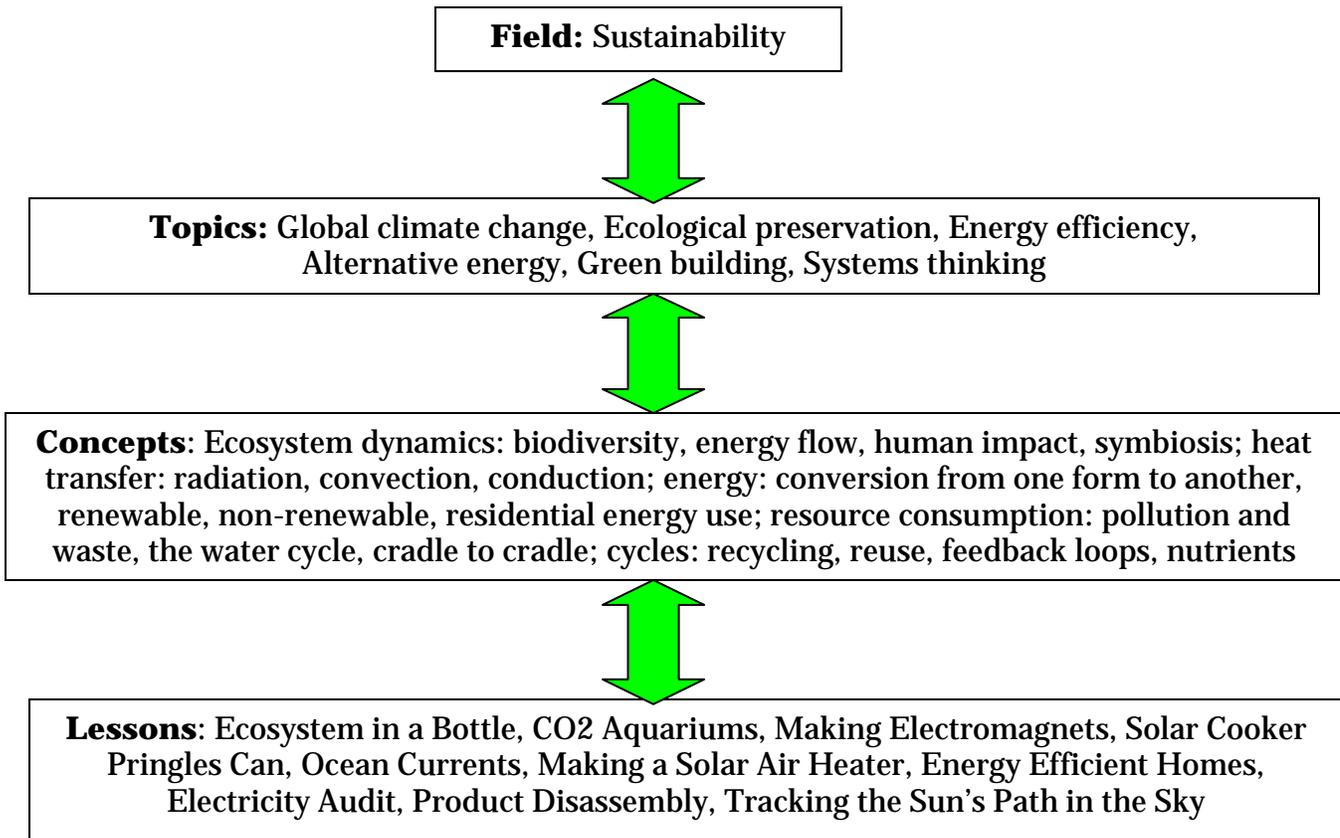
The key science concepts identified from the interviews are categorized and listed in Table 1 below. The overarching science sustainability topics are listed in the left hand column, the major concepts are listed next, and the associated or supporting concepts are listed in the other columns.

**Table 1: Topics and Key Science Concepts**

<b>Topics:</b>	<b>Major Concepts</b>	<b>Supporting Concepts</b>		
<b>Global Climate Change, Ecological Preservation, Energy Efficiency, Alternative Energy, Green Building, Systems Thinking</b>	<b>Ecosystem Dynamics/Biodiversity</b>	Energy Flow	Human Impact	Symbiosis
	<b>Heat Transfer</b>	Radiation	Convection	Conduction
	<b>Energy</b>	Conversion from one form to another	Renewable vs. Nonrenewable	Residential Energy Usage
	<b>Resource Consumption</b>	Pollution and Waste	Water Cycle	Cradle to Cradle
	<b>Cycles</b>	Recycling/Reuse	Positive/Negative Feedback Loops	Nutrients

The key science concepts (listed in Table 1 above) were used to identify the activities that would best illuminate the science sustainability topics. Many of the supporting science concepts apply to multiple major concepts and there is a high degree of overlap as multiple concepts apply to the different topics. The activities are the hands-on learning components that make the concepts come to life for the students by providing opportunities to: interact with materials; engage in first hand experience with phenomena; use the scientific method; and solve problems. In each lesson, the key science concepts and the overarching science sustainability topics covered are clearly identified in the Learning Cycle Planner. The field, topics, concepts and lessons are shown as they are interrelated in Figure 2 below.

**Figure 2: Interrelated Areas**



## **Discussion**

This Capstone project has been a fitting end to my coursework in the Sustainability and Environmental Management ALM program. Designing lessons and collaborating with other educators has been my main interest over the five years I have been taking classes in the program. This Capstone project has provided the formal opportunity to develop a work product that is drawn from the experiences of science educators who are working to bring sustainability into the classroom. Collaboration with other educators facilitated the organization of a deliverable work product composed of ten science lessons, which will be effective guides for teaching key science concepts connected to science sustainability topics. This work product has

immediate real world applicability as I will use the Capstone activities and lessons during the upcoming school year and share the lessons with other educators.

The Capstone lessons developed will serve as a platform for the continuing development of new lessons with more activities, thus expanding the hands-on learning experiences for high school students. Some ideas for other potential lessons to develop in the future include: teaching cell biology and incorporating a section comparing cell membranes to the walls of a building; comparing and contrasting photosynthesis and photovoltaics; borrowing ideas from the emerging study of biomimicry and developing models to explore these concepts. It is more likely that these ideas will develop into useful activities if educators continue to collaborate through events like the SSI. Through the search for educators as interviewees, I have become part of the “Earth in Crisis” group in Portland, OR and plan to continue working with these educators to teach about global climate change and sustainability. I will be sharing the ten lessons developed through this project with the “Earth in Crisis” group.

Given the timing of the SSI training, my participation was a stroke of good luck. Connections made through the SSI training will ultimately help me to facilitate larger goals of connecting students to apprenticeship programs, job shadowing, and career pathways. Throughout the SSI training, the group of educators often drifted into big picture discussions where the free flow of thought led to common threads. The common threads are summarized in the following statements.

1. “Students will be successful if they accept that ongoing learning/ life-long learning is the key to success.”
2. “Just because the modern method of development and fossil fuel use is the way we’ve done it for a long time, doesn’t mean it’s the way we have to continue.”

3. “Modern institutions were created by humans, they can and will be changed by humans.”
4. “We’re now working to preserve our culture, but move away from the exceptionalism that has dominated our ecological relationships.”

These statements are important to recall when faced with the often overwhelming task of teaching sustainability to high school students. Sustainability is an idea that’s difficult to define and most high school students prefer things to be black and white or to have direct relationships.

During the SSI training, a recurring debate surfaced regarding design features of green buildings that require people to be aware of outside conditions and manage the mechanics of the ventilation system and other systems versus automated systems that require no human input. The issue comes down to control and trust. Many designers did not feel that people could be trusted to manage their own house’s systems effectively. Each time this debate surfaced, I was reinvigorated to continue my work to educate young people on the science behind issues like heat transfer so that they could not only manage their own home ventilation system, but also utilize passive heating and cooling strategies, use less energy, and save money.

Conducting interviews was a valuable experience and provided some surprising results. Interviewees were asked in questions four and five: “what do you think are the most important science concepts (fundamentals) that high school students need to understand in order to grasp how climate change is impacting the earth and species and what do you think are the most important science concepts (fundamentals) that high school students need to understand in order to grasp (internalize) how to reduce our ecological impacts?” The goal was to identify specific concepts that are relevant to high school science, but most answers tended to focus on the bigger picture of ecosystem dynamics. This key science topic is very challenging to convey through small scale activities and activities in the classroom. When the questions about concepts were

followed by questions about specific lessons, activities, and activities for teaching these concepts, it is not surprising that many interviewees were at a loss. The discussion focus had become too broad and, in some cases, we began to discuss systemic problems well beyond the science classroom. Ultimately, using follow up questions, the interviewees provided ideas and resources that led to six out of the ten activities in the lessons developed. The value of the interviews truly comes across in the lessons, which explore many overlapping concepts and topics through a variety of teaching methods in order to aid students' vision of the bigger picture and to make appropriate connections between the science sustainability topics and key science concepts.

The goal of inspiring students to be life-long learners and stoking their interest in science was determined by the investigator and the interviewees to be more important than fine tuning skills for specific procedures. For this reason, the identification of key science topics through the interview process was emphasized in the investigation instead of focusing on specific technical skills. The Mt. Scott science classroom will be a place to ask why and uncover the answers, all while identifying more questions as they arise. It will not necessarily be a place where students learn to install solar hot water heaters, for example. Identifying science sustainability topics also provides a way to discuss the focus of a lesson and to relate information to other teachers and administration. In addition, the topics provide a big picture perspective for the students and show how concepts and topics often overlap.

Due to the large amount of overlap between subjects, a major challenge in teaching these key science concepts will be deciding where one subject ends and another begins, because ultimately students must be evaluated and grades will still be due at the end of each quarter. One way to address the overlap may be frequent review of past lessons to show how subjects are

interrelated. This review is not only useful for the students, but supports some of the basic concepts of ecosystem dynamics. Like a healthy ecosystem, the classroom should function to support learning from one topic to the next, much like a positive feedback loop, in which learning and hands-on experiences beget more learning and new opportunities for hands-on experiences. Some students have complained that I tend to teach concepts that are beyond high school level. It is not my intention to teach over the heads of some students. My interest is to present the basic science concepts in the context of new approaches to old problems. Teaching concepts connected to sustainability provides a framework for the focus of lessons and modern approach to the mounting environmental problems that today's students will face. The success of these efforts will be judged by the contributions these students make to the sustainability movement.

## **Conclusion**

The methods employed in this Capstone project were interviews with educators, literature and Internet searches, and participation in the SSI training. The methods were effective for gathering information about teaching sustainability in the high school science classroom and have been used to build a set of lessons that will connect students to the key science concepts involved with sustainability science topics. This Capstone project will be used to provide students with hands-on learning experiences and expose them to opportunities in the emerging green technology fields. Through completing the lessons in this Capstone, students will also be served by learning to conserve energy for their families, sharpening their critical thinking skills and becoming life-long learners. The benefits students receive of learning science through hands-on lessons about sustainability are vast, but the need to create relevant and applicable curricula for sustainability is a substantial challenge to educators and schools. This Capstone

project is one step toward a larger, cross-curricular effort that is needed to provide students with the knowledge and skills to push our societies toward the goal of a more sustainable future.

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Pathway: <http://nyelabs.com/> > Home Demos > Planetary Science > Earth Science > Current Event

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## **Appendix I**

### **Notes from questions four and five from interviews:**

Each interviewee is represented by a number 1 through 8.

1. Basic physics: heat transfer/thermodynamics, fluids, gas law, pressure and temperature relationships
2. Population dynamics, evolution, scientific inquiry, peer-reviewed/legit. Science and the nature of science/ Energy/ Biodiversity/ Connection to the larger world = dispel idea that “science is something that other people do”/ Environmental science – making decisions about resources/ Biology – genetics/ Ocean science- ocean as an indicator of environmental health (due to size)
3. Climate change: global inequity and indigenous people/ Ecology- everything is connected = all actions have impacts/ Feedback loops- permafrost, physical connections/ dispel linear thinking, focus on multiple results and systems
4. Basic “common sense” Carbon cycle- emissions and capture (accumulation of C in the atmosphere in ppm), basically taking sequestered C and releasing it, humans are altering the system/ This has many impacts- on life, ecosystems etc./ “Political issues should be avoided, focus on the science” and let the students put the pieces together/ Symbiosis- living in balance, students DO impact the world around them, no actions occur without impacts, we should try to make our impacts beneficial/ Web of life- all connected, “self-motivated” –become aware of

individual impacts = makes it harder to continue wastefulness/ Biomimicry (we should utilize) = the build environment, organization of cities

5. Begin with Earth Science (foundation) then teach physics, chem., and bio through earth science = allows for understanding of ecological systems/ “Physical processes drive earth’s ecological systems”/ Utilize technology so students are familiar...

Basic Biology = ecosystem dynamics/food web/ Dependence of species on one another, for example, shared chemicals/ We all need to reduce our impacts

“It hasn’t already been done”- lots of room and need for innovation, be positive, and look for solutions/ Familiar with environmental leaders: Rachel Carson, Tom McCall (PDX mayor, waterfront park)

6. Scale of issues (of consumer waste/volume), for example, the Rebuilding Center (in Portland, OR) takes in 8 tons and 8 tons are put out (of reusable materials)/ Need for innovation in all areas, interior design, automotive = get everyone on board/ Waste management – investigate the waste stream/ Origin of products- upstream and downstream = investigate “greenness” of products/ Recycling- what is this really?

Connection to other schools/ Things can change, culture can change

7. Complex causalities effects = varied/invisible changes/ Cause and effect = impacts of personal decisions, driving sea level rise in Bangladesh (not apparent in our everyday lives)/ Models = what does a global 1-2 degree temp change mean? For example, 10 degree temp change = difference between modern epoch and last ice age/ Vocabulary = language of science = “may” “probable” “uncertainty”/ Interpreting/ Statistics, reading graphs, understanding scale / Evaluation of sources = credible, peer reviewed (IPCC) vs. other websites and mis-information, process of/ arriving at certainty = rigorous/ Renewable vs. non-renewable/ Fossil fuels =

depletion of finite resources (oil/fish stocks)/ Fossil fuels = connected to food systems (energy intensity of decisions)/ Energy audit = we can use less/ Ecofootprint calculators

8. Rate of change/ Carbon cycle/ Factors that force climate change (terrestrial and solar)

Real and proxy measures of temperature and the way that scientists determine what phenomena can be used as proxies/ Adaptation (plus what is known about how species have responded to climate change in the past)/ Modeling/ Systems thinking/ Material Cycles (one species waste being another species food; plus water, carbon, nitrogen, etc. cycles)/ Energy flows/ Feedback loops/ Community and relationships/ Species diversity

## Appendix II

### Online Resources Listed by Lesson

#### CO2 Aquariums:

NPR videos “It’s All about Carbon” <http://www.npr.org/news/specials/climate/video/>

Bath Tub Simulation: [http://www.sustainer.org/tools\\_resources/climatebathtubsim.html](http://www.sustainer.org/tools_resources/climatebathtubsim.html)

#### Ecosystem in a Bottle:

Edible Portland article: “More Than Meets the Eye” Ecosystem services provided by farmers: <http://edibleportland.com/content/currentissue/>

Other resources for extensions beyond Ecosystem in a Bottle Lesson:

[http://www.bottlebiology.org/investigations/terraqua\\_main.html](http://www.bottlebiology.org/investigations/terraqua_main.html)

[http://www.bottlebiology.org/investigations/terraqua\\_fill.html](http://www.bottlebiology.org/investigations/terraqua_fill.html)

[http://www.bottlebiology.org/investigations/terraqua\\_observe.html](http://www.bottlebiology.org/investigations/terraqua_observe.html)

[http://www.bottlebiology.org/investigations/terraqua\\_explore.html](http://www.bottlebiology.org/investigations/terraqua_explore.html)

Introduction the Ecosystem Services Review video:

<http://www.youtube.com/watch?v=HbU41UhnWN8>

#### Electricity Audit:

Building Value in a Net Zero Home article:

<http://www.financialpost.com/story.html?id=1531054>

Portland News Program: Energy Makeover with the Energy Trust of Oregon  
<http://www.youtube.com/watch?v=vaQQ4P9msSg>

Energy Trust of Oregon Energy Audit  
[http://www.energytrust.org/forms/BE\\_FM\\_CommercialSelfAudit.pdf](http://www.energytrust.org/forms/BE_FM_CommercialSelfAudit.pdf)

### **Electromagnets:**

Virtual tour of a Wind Farm: <http://www.midamericanenergy.com/html/aboutus3c.asp>

Hands-on science <http://marshallbrain.com/science/index.htm>

Film: Who Killed the Electric Car? Resources for teachers:  
<http://www.sonyclassics.com/whokilledtheelectriccar/electric.html?detectflash=false&>

### **Energy Efficient Homes:**

Virtual Tour of Harvard's Blackstone building:  
<http://www.uos.harvard.edu/blackstone/tour/#tour>

Social Studies: Green Building Adds to Affordability Portland Tribune article:  
[http://www.portlandtribune.com/sustainable/print\\_story.php?story\\_id=117346649527258600](http://www.portlandtribune.com/sustainable/print_story.php?story_id=117346649527258600)

### **Product Disassembly:**

Video: The Story of Stuff: <http://www.storyofstuff.com/index.html>

The Earth Day Network Footprint Calculator: <http://earthday.net/footprint/flash.html>

Video: Deconstruction Time Lapse <http://www.rebuildingcenter.org/deconstruct/>

Video: Mountain Top Removal Coal Mining in West Virginia:  
<http://www.youtube.com/watch?v=ziuFW-7h1LM>

NY Times article: *On the assembly line, learning how things are made*  
[http://www.nytimes.com/2008/03/13/arts/television/13hale.html?\\_r=1&ref=arts](http://www.nytimes.com/2008/03/13/arts/television/13hale.html?_r=1&ref=arts)

60 Minutes News article and video, Following the Train of Toxic E-Waste  
<http://www.cbsnews.com/stories/2008/11/06/60minutes/main4579229.shtml>

### **Ocean Currents:**

Videos: The Global Conveyor Belt:  
<http://www.youtube.com/watch?v=L9zjmC8InKA&feature=related>

Detailed information on water density, salinity, and the global conveyor:  
<http://www.youtube.com/watch?v=FuOX23yXhZ8&feature=related>

### **Solar Air Heater:**

Solar Pool Heater video (see second half of video)

[http://www.youtube.com/watch?v=HVjJE0\\_Ok0c](http://www.youtube.com/watch?v=HVjJE0_Ok0c)

Video *PS 10 Solar Thermal Power Station* provides an extreme example of harnessing the solar thermal energy. <http://www.youtube.com/watch?v=0OkqJw1oTMk>

**Solar Cooker Pringles Can:**

National Geographic Videos watch Solar Cooking and Solar Power:

<http://video.nationalgeographic.com/video/player/environment/energy-environment/solar-power.html>

Build your own solar cooker at home: <http://solarcookers.org/programs/educres.html>

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