

Enriching and Evaluating Sustainability Education

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Abstract

Through innovative partnerships, programming and platforms, sustainability education can be enhanced. Unique approaches as crystallized in a Sustainability Seminar, an annual Dialog on Sustainability, and an annual Sustainability Conference have enriched sustainability education at Kansas State University and throughout the region. Multidisciplinary members of diverse partner organizations of the Consortium for Environmental Stewardship and Sustainability (CESAS) and others have assisted with and participated in these efforts to advance progress towards sustainability. Undergraduate students participating in the NSF-sponsored Research Experiences for Undergraduates program on sustainable energy were actively engaged in an effort to identify perspective transformations associated with sustainability. Transformative learning theory is used together with other methods to evaluate some of the sustainability education activities.

Key words: sustainability, education, enrichment, evaluation, transformative learning, multidisciplinary

Introduction

If indeed education is the most vital of all resources (Schumacher, 1973) and sustainability is the key to innovation (Nidumolu et. al., 2009), then we will likely see more recognition of the true value of sustainability education going forward. Accordingly, sustainability has been a growing area of educational activity at Kansas State University. It is being incorporated into existing educational programs, departments, curricula, and courses. In this paper some creative educational programs and strategies to enrich and evaluate sustainability education at K-State are described. Recent innovative programmatic elements include: Sustainability Seminar, first offered in January 2008; Research Experiences for Undergraduates, focusing on sustainability, started in 2009; Dialogs on Sustainability, held each July in 2006-2009; and University wide sustainability conferences, held in 2009 and 2010. Additionally, the Natural Resources and Environmental Sciences Secondary Major has added sustainability courses and provides opportunities for students to expand their sustainability education. Furthermore, a Consortium for Environmental Stewardship and Sustainability (CESAS) has been organized to support and encourage communication related to sustainability both within the university system as well as more broadly with other private and public sector collaborators.

Sustainability has many dimensions, and there is often growth over time in comprehending the multidisciplinary aspects of sustainability. The social and political aspects of advancing sustainability are of great importance; however, the initial thinking of an engineer is often related

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to the science and technology that is needed to move toward sustainability. A perspective change is needed to recognize that the triple bottom line (environment, economic, and social) provides an excellent approach to decision making related to sustainability. There is also the need to see sustainability from the perspective of the person who is trying to sustain life and community in a developing country where people live on one to five dollars per day. Progress toward achieving the United Nations millennium development goals provides another perspective with respect to comprehending sustainability. In a sustainable world all should be able to have basic sanitation, public education and good drinking water. Water, renewable energy, land resources, and climate stability are crucial aspects of sustainability; however, population, health care programs and economic stability are also paramount. Adopting sustainable lifestyles and economies will require significant perspective shifts in many segments of the global population. Consideration of Transformative Learning Theory (TLT) (Mezirow and Associates, 2000) as a method of facilitating these perspective shifts and measuring the impact and efficacy of efforts to incorporate sustainability content in sustainability education is warranted.

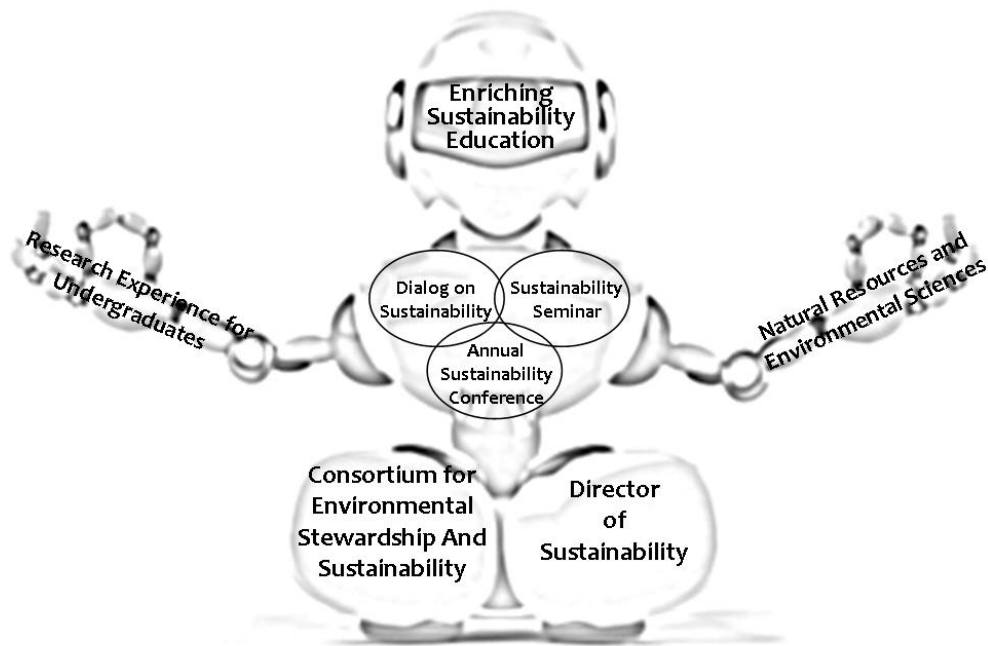
Many academic departments have taken significant steps to incorporate sustainability content into the core courses for their majors, while unique programs and partnerships are serving as complementary learning platforms and catalysts for transformation. These activities to enrich sustainability education are being described because readers may be interested in learning more about these positive experiences and how and why the activities were carried out. In addition to describing the programs offered at K-State that are nurturing sustainability education, this paper provides an example of how TLT was used to evaluate the outcomes of one of those programs. Evaluation results are reported for the 2009 10 week REU program, which included the Sustainability Seminar and the Dialog on Sustainability. The REU program is sufficiently long and focused to provide a good opportunity to evaluate the application of transformative learning theory to sustainability education. These results are preliminary because this is the first year of a three year program, and there will be further collections of data on the original 10 students in the future.

Enriching Educational Programs

Several programs have been developed at K-State to enrich sustainability educational programs and activities. These programs serve many audiences, including students, faculty, staff, as well as the surrounding community, industry, and government entities. They function as a web, connecting various stakeholders from multiple sectors and disciplines with each other in our common goal of advancing sustainable mindsets, practices, and policies both locally and across the globe.

The purpose in providing a description of these programs is twofold. First is to share information with other practitioners on the programs offered at K-State. The second is to provide a supporting context for the research on perspective transformation discussed later in the paper. While the research is focused on participants in one specific program, several of the programs described in this section provide support (directly and indirectly) to the program and make a valuable contribution to its effectiveness.

The programs described below are Sustainability Seminar, Dialog on Sustainability, Sustainability Conferences, the Consortium for Environmental Stewardship and Sustainability (CESAS), and the Natural Resources and Environmental Sciences Secondary Major (NRES). The first three visionary and symbiotic activities have provided opportunities for students, faculty, and community members to enrich their educational experiences related to sustainability without a major investment of time. There have been more than 1000 participants to date. Each program will be described in more detail below. Figure 1 illustrates the different elements of the sustainability effort.



Zenbot, the Sustainability Pal

Figure 1. A graphical illustration showing that the Dialog on Sustainability, Sustainability Seminar, and Sustainability Conference are core activities. This “Sustainability Pal” enriches education through credit and non-credit programs.

Sustainability Seminar

CHE 670 Sustainability Seminar has been a versatile platform for addressing many overarching and specialized topics within the field of sustainability. It was initially taught in January 2008 as an intensive 2 and 1/2 day Intersession event with the special topic "Renewable Energy, Food and Sustainability." In Fall 2008, it was offered in a weekly seminar format. In Summer 2009, it was offered as a weekly seminar as part of the new Research Experiences for Undergraduates program related to sustainable energy. In January 2010, it was offered as a rigorous 2 and 1/2 day Intersession event on the timely and relevant special topic "Greenhouse Gases, Carbon Taxes and Trading, and Carbon Sequestration."

The objectives of Sustainability Seminar are 1) to provide a high quality educational experience for those who participate; 2) to develop and offer an effective distance education course; 3) to

expose students to the leading edge of sustainability science from subject matter experts, practitioners, and policy-makers; 4) to create a collegial climate where professionals want to come, participate, network, and learn from one another; and 5) to have a streamlined learning and dissemination system that is easy to implement and use. Sustainability Seminar has two audiences: students enrolled for academic credit and professionals seeking to further develop their abilities in a non-credit program. To earn the hour of credit, students participate in the seminar program, prepare a written paper on a topic of their choice, make an oral presentation over the same topic, and prepare a top ten list of actions to make the world sustainable. Some experts from government, companies, and other universities are invited to help as speakers and panelists in order to develop a high quality offering. Professional development and continuing education hours are available for various certifications and credentials; important aspects that can support professional society educational activities.

In Sustainability Seminar, the learning objectives include 1) greater understanding of core sustainability principles and the various dimensions; 2) in depth study of one or more topics related to sustainability; 3) active learning by developing a manuscript and oral presentation on a topic of interest; and 4) the opportunity to address the global aspects of sustainability.

Information about the content of each of the four Sustainability Seminar offerings is available at <http://www.engg.ksu.edu/CHSR/sustainability/index.html#SpecialSeminars>. Both students and professionals are invited to participate in the distance education program; Sustainability Seminar is offered each semester as a distance education course.

Students have appreciated the dynamic dialog that results from having a mix of academic, government, and industrial professionals together asking questions and sharing information. The digitally linked classroom has advanced audio-visual capabilities, including Wi-Fi, video streaming, and embedded microphones located throughout the room for superior recording sound quality. Google video has been utilized to broadcast lectures via the World Wide Web.

Dialog on Sustainability

Each year in July, starting in 2006, Kansas State University has hosted a Dialog on Sustainability in order to encourage meaningful exchange and engagement on educational, research, operations, and outreach topics. It has been organized as an open dialog without any registration fee. It includes oral presentations, panels, facilitated discussion, posters, and exhibits. Members of partner organizations of CESAS are invited to participate.

The goal of the event is to encourage communication, sharing of information, and direct interaction with facilitated discussion of germane topics. Notable features include the roundtable breakout sessions, guided by trained facilitators from the Institute for Civic Discourse and Democracy, and the green design and technology demonstrations. In addition to the university and extension network, online websites such as Greenopolis.com that focus on environmental sustainability have been used to disseminate event information. With strong support from university leadership, the new K-State president, Kirk Schulz was one of the featured speakers in 2009. Further information on these events is available at <http://www.engg.ksu.edu/CHSR/sustainability>.



Figure 2. Electric vehicle, President Kirk Schulz and Professor Noel Schulz, and REU student Tai-Wen Ko with solar lantern and poster.

Sustainability Conferences

The Director of Sustainability has provided leadership and coordination for the two sustainability conferences, "2009 Sustainability Conference: Leading Kansas in Sustainability" and "2010 Sustainability Conference: Kansas Going Green in Higher Education." A featured speaker, oral presentations, panels, posters, exhibits, and informal communication were included. In the 2009 conference, the emphasis was on leading Kansas in sustainability; that is, the challenge of making Kansas sustainable. Sustainable land use was the focus of one of the plenary sessions. The 2009 conference won "The Great Plains University Continuing Education Association Outstanding Non-credit Program Award." In the second conference, networking among colleges and universities in sustainability education was emphasized. For more information see <http://sustainability.ksu.edu/>. Furthermore, in 2006 and 2008 respectively, many K-State faculty and staff members, in cooperation with U.S. Environmental Protection Agency and others, led organizational efforts for successful Sustainable Agriculture and Sustainable Redevelopment conferences.

Consortium for Environmental Stewardship and Sustainability (CESAS)

The Consortium for Environmental Stewardship and Sustainability (CESAS) is a network of over 60 diverse partner organizations (academic, industrial, government, and nongovernment organizations) that are working cooperatively to advance sustainability. CESAS enriches sustainability education by pursuing forward-thinking initiatives and leveraging intellectual capital while also helping to support the planning and development aspects, publicity and offering of events such as those described above. CESAS representatives collaborate through regular monthly meetings with representatives from each partner organization, targeted working groups, and by putting together a calendar of activities related to sustainability for broad distribution. A simple voluntary dues process has provided sufficient financial support to allow the organization to cosponsor several events each year. CESAS was organized in part because sustainability impacts all educational programs, and open communication is needed to encourage cooperative efforts to enrich sustainability education. The CESAS Internet site is at <http://www.engg.ksu.edu/CHSR/sustainability>. The annual reports for CESAS are available there.

Natural Resources and Environmental Sciences (NRES)

The Natural Resource and Environmental Sciences Secondary Major, which requires 24 hours of courses including a 3 credit capstone course, provides another important option for undergraduates. This secondary major is available to all students in the university. It allows students to take several courses related to natural resources and sustainability and work on a sustainability project in a multidisciplinary team. Sustainability Seminar is one of the courses that can be taken.

The educational goal of the NRES program is to prepare undergraduate students to apply broadly-based scientific knowledge to the use, management, sustainability, and quality of soil, air, water, mineral, biological, and energy resources. The rationale for the program is that because resource and environmental issues are so broad and complex, they exceed the scope of any one discipline and are best addressed through an interdisciplinary secondary major. Consequently, the program was founded in 1991 and became an option for KSU students in 1992. To date, 521 students have graduated with the secondary major degree. Overall, the NRES Secondary Major stands today as one of the most successful and well-respected inter-disciplinary undergraduate programs at Kansas State University (NRES, 2009). It is an excellent educational program for students to enhance their knowledge of sustainability.

Research Experiences for Undergraduates (REU)

Sustainable energy is a critical area of importance nationally and internationally in terms of education and workforce development. To address this need, K-State created a Research Experiences for Undergraduate (REU) Program focused on sustainable energy with empirical data analysis, mentoring by faculty, and robust learning opportunities; this REU includes research, security, environmental stewardship (including climate change), policy, and economy topics as emphasized in the recent National Science Foundation, National Science Board report (NSF, 2009).

Kansas State University was awarded funding from the National Science Foundation to support undergraduate students for 10 weeks of sustainability research during the summers of 2009 - 2011. The "Earth, Wind, and Fire: Sustainable Energy for the 21st Century" REU program included research, Sustainability Seminar, the Dialog on Sustainability, student presentations, field trips, team projects, reflective journaling and social events. Evaluation by a team of professionals is part of the program. Ten students, 13 faculty and 3 staff participated in this program in 2009. The Graduate School also provided coordination with other REU and related programs for integrated activities. The focus of the Seminar component was on sustainable energy with presentations by faculty helping with the research program. On the final day of the 10 week program, the morning was devoted to a symposium with an invited speaker followed by poster presentations by the 10 students. The multidisciplinary summer program included chemistry, geology, grain science, and engineering (chemical, electrical, computer, biological, and agricultural engineering).

All of the students reported on their research twice during the summer in addition to their poster presentation at the end of program. Some of the student/faculty teams presented posters at the Dialog on Sustainability. All of the students submitted a written report as part of the requirements for the seminar.

Beyond the classroom and the laboratory, all students participated in one of two team projects. Six students created presentations on actions individuals can take to make their lifestyle more sustainable. A public meeting at the Manhattan Public Library was organized, and members of the public came to listen to the presentations. The other team prepared a white paper on solar energy and transportation planning. This team studied the benefits of shaded parking, energy production, and electrical connections for plug-in hybrid or electrical cars and the economics of the project. A program website was designed to foster information sharing, exchange, and knowledge base expansion (see <http://www.che.ksu.edu/reu/>).

Exploring real-world applications involved visits to local and regional industries and research sites. The field trips included trips to The Land Institute to discuss sustainability in agriculture, to a wind farm, a coal fired power plant, a nuclear reactor, NanoScale Corporation, and the Advanced Manufacturing Institute.

From the local to the global, one student worked on a project to develop a solar lantern for parts of the world that did not have electrical power. Some students realized for the first time that many people live without electrical power and simple light switches.

One of the challenges in the world is how to best move toward sustainability. A new perspective for some is the idea that we can best do this by making biofuels and wind and solar energy less expensive than energy and power from coal and petroleum. This is the motivation to support renewable energy research and for the REU students to help find better and less expensive power systems through their research projects.

Based on student feedback, most felt strongly that the REU would prove beneficial for their career. The growth in knowledge about sustainability has both personal and professional value. More details on the impacts and outcomes of this program are discussed in the next section.

Evaluation Framework

Transformative Learning Theory (TLT) was used along with other methods to evaluate some of the sustainability educational activities during the 2009 REU. TLT is the process by which the world views of individuals, groups, and organizations are changed as a result of the adult development process. TLT is focused on how we make meaning and "how we learn to negotiate and act on our own purposes, values, feelings, and meanings, rather than those uncritically assimilated from others to gain greater control of our lives as socially responsible, clear thinking, decision makers" (Mezirow and Associates, 2000, p.8). It is expected that these new or transformed perspectives or world views will be more complex than previously held ones and they will acknowledge a pluralistic view of reality.

According to TLT, the driving purpose or central goal of the human mind is to make meaning out of experience. TLT also recognizes that all meaning is embedded in the context of how we know it (Mezirow and Associates, 2000). TLT is intended as a "comprehensive, idealized, and universal model consisting of the generic structures, elements, and processes of adult learning. "Cultures and situations determine which of these structures, elements and processes will be acted upon and whose voice will be heard," (Mezirow, 1994, p.222).

While theorists and practitioners (Brookfield, 2000; Cranton, 1994) agree that transformative learning is not a neat, linear process, several key phases have been delineated. They are:

1. A disorienting dilemma;
2. Self-examination with feelings of shame or guilt;
3. A critical assessment of epistemological, sociocultural, or psychological assumptions;
4. Recognition that one's discontent and the process of transformation are shared and that others have negotiated a similar change;
5. Exploration of options for new roles, relationships, and actions;
6. Planning a course of action;
7. Acquisition of knowledge and skills for implementing one's plans;
8. Provisional trying of new roles;
9. Building of competence and self-confidence in new roles and relationships; and
10. A reintegration into one's life on the basis of conditions dictated by one's new perspective (Mezirow, 1991).

With respect to a planetary perspective, transformative learning theory "recognizes the interconnectedness among universe, planet, natural environment, human community, and personal world. Most significant of these is recognizing the individual not just from a social-political dimension but also from an ecological and planetary one" (Taylor, 2008, p. 9-10). A growing body of literature gives support for use of TLT as an appropriate vehicle for researching and facilitating perspective transformation related to environmental sustainability (Lange, 2004; Sims and Sinclair, 2008; Moore, 2005, O'Sullivan and Taylor, 2004). TLT is utilized in some of the programs described in this paper based on the view that making the shift to an environmentally sustainable world requires perspective transformation at individual and social levels. Mechanisms for facilitating transformative learning include critical questioning and reflection, shared experiences, experimenting with new roles and ideas, and planning for the future.

Evaluation methods

As part of the 10 week program, students were asked to maintain a journal where they reflected on their REU experience. In the first week, REU participants wrote about their initial

perspectives and attitudes toward sustainability, science and engineering, and research. Each week the students submitted written information on the theoretical and technical aspects of their research as well as reflections on the learning experiences for the week, with a focus on any perspective changes with respect to attitudes toward sustainability, science and engineering, and research. Journaling prompts normally included a short series of questions. For example, in Week 4 students were asked the following: Describe the group sustainability project you are working on. What is your role in the project? What will the benefits of this project be to you, the group, and to society at large? In week 9 of the program, students were asked the following: What are the obligations/responsibility of scientists and engineers to society? Has any experience during this program impacted your answer to the above question? Please see Appendix A for a copy of the journaling prompts and guidance used in the 2009 REU Program. The purpose of this part of the program was to develop students' ability to mindfully reflect on the learning experiences and write effectively about them. It also provided a rich source of evaluative data, which was collected unobtrusively.

The preliminary analysis represented 86 journal entries and the transcript from a focus group interview conducted with the participants during week 9 of the program. (See Appendix B for the focus group schedule.) Data from the student journals and focus group have been coded and managed using QSR NVivo 8 software to create a case study database. Data were coded using frameworks from Mezirow and Associates (2000) and The Cloud Institute for Sustainability Education (2009). Emergent themes were also included in the case study database. Data were analyzed using a keyword phrase search derived from the aforementioned frameworks. The case study database was utilized to conduct searches and to tabulate and manage search results. The results are termed a preliminary analysis as further data will be analyzed and incorporated, which may impact these results. These include observational data, student applications to the program, and follow up evaluation with students. Additional data will be collected from students in the subsequent years of the program and compiled with year one data.

Findings

Findings from this preliminary evaluation focused on four areas: career path, definition/concept of sustainability, role in sustainability, and habits of mind.

Career Path

Exploration of options is one of the stages of transformative learning theory (Mezirow and Associates, 2000). Summer 2009 REU students demonstrated their engagement in this stage through their comments about their career paths and future plans. Student comments about their future careers were related to refocusing their interests to renewable energy, deciding to pursue graduate degrees, expanding their perspectives related to sustainability and choosing research foci for future work. Examples of student comments are below.

“Before this, I was considering going toward petroleum. I think this overall experience has actually opened my eyes to maybe it’s not such a good idea to go into that field and maybe stick more to sustainable fields”. Student C, Focus Group

“As I continue to do more and more lab work and especially this first week of working in a lab full time, I find myself enjoying the work. I am a slow, methodical, and patient person who likes to do things precisely: a perfect fit for working in a lab atmosphere. I have been contemplating going to graduate school, and work like this has encouraged me more than anything to pursue my graduate school goals”. Student B, Journal Entry

Definition/Concept of Sustainability

Students’ concepts and definitions of sustainability underwent perspective transformation during the REU experience. Student comments related to their changing perspectives are representative of more than one of the stages in Mezirow’s framework: critical assessment of assumptions, acquisition of knowledge and skills, and planning a course of action. In the focus group and journals, students discussed their changing concepts of sustainability. Most notably, several students reported that prior to the program their concept of sustainability was limited to energy issues. As a result of the program, students’ perspectives were broadened to include a wider definition of sustainability issues, as well as options for solving problems. Examples of their comments are below.

“Throughout the events on sustainability, I have realized that every region has different sustainability issues and solutions, and it is less homogeneous than I once thought. Still, many of the broad challenges are the same, such as reducing the use of a finite resource, for example oil”. Student E, Journal Entry

“I would say it hasn’t really been challenged, but brought into perspective that we have to look at sustainability including water, and crops and basically everything has a certain level of sustainability and I always thought of sustainability as more as solar and wind. It’s interesting to see different aspects of it as well”. Student H, Focus Group

“The most compelling idea that I have learned in the program thus far is that there is not just one solution for making our world sustainable. We cannot depend solely on wind or solar energy, and we cannot just power our cars through biofuels, we also need to have them run on sustainable electricity. Sustainability is a much broader topic than most people tend to think about. Through this I think that sustainability is reaching across all of the sciences and bringing people together to come up with new ideas and new sustainable technologies”. Student I, Journal Entry

Role in Sustainability

Students were asked about their roles in sustainability and the role of engineers and scientists in sustainability. Student responses for this question were also related to the following TLT stages: exploration of options, planning for a course of action, critical assessment of assumptions, and building of competence and self-confidence. In discussing their individual roles, students saw

their roles as educating others and serving as role models for others in how to take actions that are more sustainable. With respect to the roles of engineers and scientists, students stated that scientists and engineers have significant roles in developing technologies and solutions related to sustainable issues. They also noted that scientists and engineers have problem solving roles, as well as have a role in educating the public about sustainability issues.

Examples of student comments related to roles in sustainability are below.

“The Dialog on Sustainability helped me some in this aspect. I think my role is to live a lifestyle that tends toward sustainability and show other people how to do it. Some of the people we were living with, the biology kids were great, some of the brothers at the frat don’t think about this stuff very much and you can influence everyone around you on steps they can take”. Student D, Focus Group

“Before I thought that as an engineer my job was simply to work to create the technologies that improved lives. Now I realize it is also my job to educate and teach others what I have learned. After last summer's REU (at another university) I had become a little concerned because it seemed like options for solving the energy crisis and becoming a sustainable society were running out, but this summer I have learned so many new ways to live sustainably and solve this challenge. It has renewed my hope for these things”. Student A, Journal Entry

“I attended the sustainability talk held last Thursday at the Manhattan Public Library, and that experience showed me that scientists, as technically inclined people, can also act as teachers to the community. The education that scientists receive put them in a position to learn about topics outside their field, and to explain them to less-technical people”. Student D, Journal Entry

Habits of Mind

Changes to existing habits of mind are essential to perspective transformation (Mezirow and Associates, 2000). The Cloud Institute for Sustainability Education has developed a rubric for assessing sustainable habits of mind, based on their sustainability education content standards (2009).

Table 1. Student rubric overview: The dimensions

Understanding of Systems as the Context for Decision Making	The extent to which one sees both the whole system and its parts as well as the extent to which an individual can place one's self within the system
Intergenerational Responsibility	The extent to which one takes responsibility for the effect(s) of her/his actions on future generations
Mindful of and Skillful with Implications and Consequences	The extent to which one consciously makes choices and plans actions to achieve positive systemic impact
Protecting and Enhancing the Commons	The extent to which one works to reconcile the conflicts between individual rights and the responsibilities of citizenship to tend the commons
Awareness of Driving Forces and Their Impact	The extent to which one recognizes and can act strategically and responsibly in the context of the driving forces that influence our lives
Assumption of Strategic Responsibility	The extent to which one assumes responsibility for one's self and others by designing, planning and acting with whole systems in mind
Paradigm Shifter	The extent to which one recognizes mental models and paradigms as guiding constructs that change over time with new knowledge and applied insight

(Cloud Institute for Sustainability Education, 2009)

Summer 2009 REU students' journal writings were analyzed in terms of the above rubric. All students had comments that were coded for one of the above dimensions. The dimensions with the most number of students' coded comments were understanding of systems as the context for decision making (80%), awareness of driving forces and their impact (60%), and assumption of strategic responsibility (60%). Figure 3 below shows the data for all dimensions.

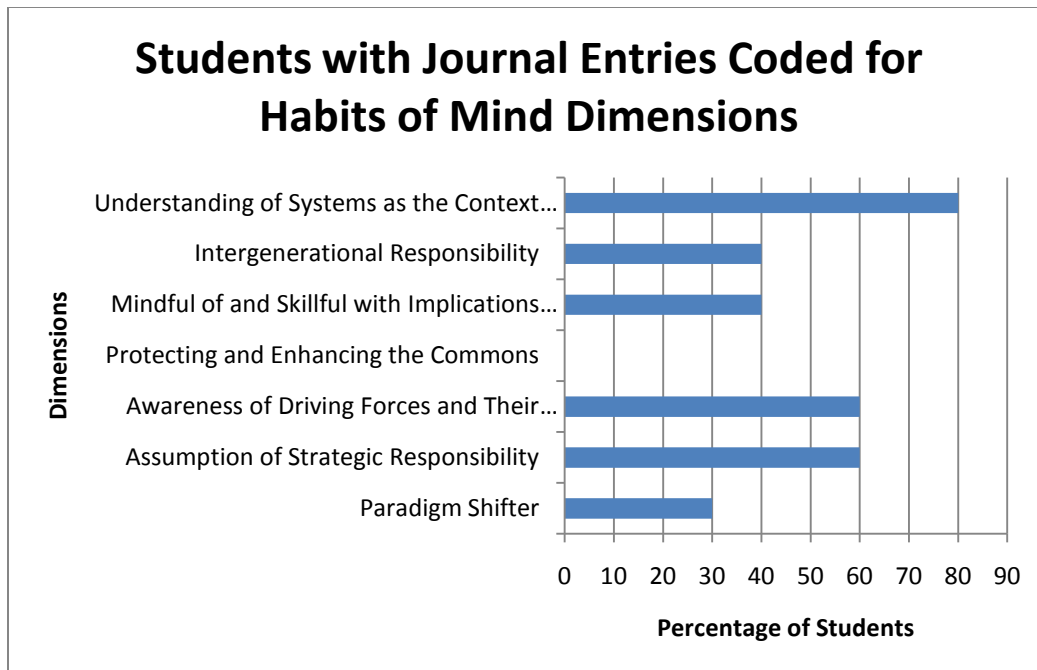


Figure 3. Percentage of students with at least one journal entry coded for individual habits of mind dimensions.

Understanding of systems as the context for decision making.

This dimension is related to the extent to which one sees both the whole system and its parts as well as the extent to which an individual can place one’s self within the system. Eight students had journal entries coded for this dimension, with a total of ten separate entries. Students’ discussions were related to the research process; synergy between demonstration projects, community education, and training engineers; global issues; complexity of energy systems, and elements of the triple bottom line. An example of a student comment related to this dimension is below.

“Visiting the wind farm was a great opportunity. I enjoyed seeing a new type of energy actually expanding. Everyone has known about wind power for quite a while now, but I never would have guessed the technology that actually goes into a turbine now. The wind farm does not tie directly into my project, but it does help lighten the load that bio-fuels have to fulfill. Assuming our energy consumption continues at its current rate, wind or bio-diesel alone cannot hope to fill the demand. Only by using all our available sustainable resources can we hope to be successful”. Student G, Journal Entry

Awareness of driving forces and their impact.

This dimension is related to the extent to which one recognizes and can act strategically and responsibly in the context of the driving forces that influence our lives. Six students had journal entries coded for this dimension, with a total of ten separate entries. Students’ discussions were

related to economic forces, social value, the importance of multiple perspectives, communication, community education, politics and leadership. An example of a student comment related to this dimension is below.

“The second stop at the wind farm was directly related to my project. I am working on a wind program for schools in the local Kansas area, so being able to see these massive turbines in real life was great. I also learned a little bit about where the power goes and how the wind energy is used and predicted on a day-to-day basis. It also gave me insight on some of the politics involved when installing turbines. You need landowners, grid power lines, and wind to all work in the same location. It sounds very difficult and hard to accomplish, but Horizon seems to be getting the job done”. Student F, Journal Entry

Assumption of strategic responsibility.

This dimension is related to the extent to which one assumes responsibility for one’s self and others by designing, planning and acting with whole systems in mind. Six students had journal entries coded for this dimension, with a total of eleven separate entries. Students’ discussions were related to their intentions to play active roles in sustainability problem solving by developing skills to prepare themselves for real world application. Discussions ranged from individual responsibilities to that of the engineering profession. An example of a student comment related to this dimension is below.

“I truly enjoyed visiting the wind farm at Concordia. As a Kansan, I appreciate the vast wind resource that this state has to offer. Kansas has the potential to be a wind power leader not for just this country but for the world, but unfortunately we do not have the leadership in this state to do that. This activity can be indirectly applied to my current project. Since wind is an intermittent energy source, large amounts of hydrogen could potentially be used to supply electricity when the wind is not blowing. That possibility, however, is a long way from becoming actuality. The fact that most sustainability projects are still in their early stages is somewhat troublesome for me. Research is a slow process, and even though many projects have promising ideas, the leap from theory to practicality to economic to becoming implemented is a long arduous progression. Someone has to work to make these leaps, and I certainly want to be a part of that process”. Student B, Journal Entry

Summary

Analysis of student journals and the focus group transcript provided a window into program impacts and benefits. This effort has demonstrated that many of the students had a very positive experience and they have a much better understanding of the dimensions of sustainability and the importance of it. Many of the students indicated an increase in their interest in pursuing a career in research and attending graduate school. They experienced perspective changes in their career paths, broadened their concepts of sustainability, and articulated their roles in creating a sustainable future. They also demonstrated their understandings of systems thinking, driving forces, and their willingness to play leadership roles in actions to promote sustainability.

Results and Conclusions

Our modern society is facing very complex issues which demand sustainable and pragmatic solutions. This is complicated by today's increased economic, ecological, and geopolitical uncertainty. Addressing these complex issues requires global citizens and leaders who are capable of perspective transformation and are equipped with habits of mind that reflect sustainability concepts. As institutions charged with producing future generations of scientists, engineers, teachers, and policy makers (to name a few), higher education has a need to develop methods of both facilitating transformative learning in our communities as well as ways to measure its successes (and failures). Transformative learning theory offers a set of solutions to address both of these needs.

For some of the students in the 2009 REU, this summer program was a transformational experience. They gained the perspective that sustainability will impact their professional career and increase in importance during their lifetimes. The group assignment to present their ideas to the public required them to formulate these ideas. There was significant personal growth associated with the information gathering, group discussions, and evaluation of ideas on how to change personal behavior to advance sustainability

While sustainability education can be included in many classes, there is also a need to enrich sustainability education by adding seminars, dialogs, special programs, and conferences which can enhance the experiential value, professional exposure, and engaged training for students and faculty. Our experiences with several of these have been described. Evaluations of these activities have demonstrated that many participants have had positive experiences and have developed richer understandings of sustainability and options for action and involvement. Transformational learning is often one of the outcomes of these activities. The perspectives of many college students are changed because of their participation in active learning processes such as dialogs, field trips, developing reports, reflective journaling, making oral presentations, and real world group projects.

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Appendix A Reflective Journaling Topics

Please review the questions and/or guiding statements below. In 20-30 minutes, write a response to the appropriate week's topic. We are asking you to write a reflection on your experiences and how they are affecting you as a scientist, a learner, and as a person. Do not be overly concerned with crafting a perfectly written document. Instead, just relax and let your responses emerge.

Week 1

1. Describe the project you are working on this summer.
2. What are your goals for the summer research program?

Week 2

Choose an activity from the week and answer the following questions:

1. Describe the activity and why it was significant to you.
2. How can this activity be applied to your current project?

Week 3

1. What is the most compelling idea/concept you have learned about in the program so far?
2. Describe your understanding of this concept.
3. Why do you find it compelling?

Week 4

1. Describe the group sustainability project you are working on.
2. What is your role in the project?
3. What will the benefits of this project be to you, the group, and to society at large?

Week 5

Choose an activity from the week and answer the following questions:

1. Describe the activity and why it was significant to you.
2. How can this activity be applied to your current project?

Week 6

Reflect on the research project you are working on.

1. Describe your role in the project and your contributions.
2. What have you learned during this work that is significant? Why is it significant?
3. What problems will this project help solve?

Week 7

1. What is the most compelling idea/concept you have learned about in the program so far?
2. Describe your understanding of this concept.
3. Why do you find it compelling?

Week 8

Reflect on the Dialog on Sustainability that you attended on July 23.

1. What surprised you?
2. Was there anything you didn't agree with? Please describe why or why not.
3. What do you think are the benefits of these kinds of activities? Who does it benefit?

Week 9

1. What are the obligations/responsibility of scientists and engineers to society?
2. Has any experience during this program impacted your answer to the above question?

Week 10

Review your previous entries.

1. What have you learned this summer?
2. Have your perspectives and beliefs changed?
3. How will you use this experience in the future?

Appendix B NSF REU Summer 2009 Focus Group Schedule

- 1) Has your definition/understanding of sustainability been challenged or changed? In what specific ways?
- 2) Have you met your original goals? What helped you meet them and what barriers or challenges did you meet?
- 3) What elements of the program have been particularly good and useful? What haven't been so good and useful? (program elements - field trips, individual projects, group projects, seminars, brown bags, dialog on sustainability, journaling)
- 4) Do you have any recommendations for next year's program?
- 5) What are your future goals? How has this summer affected your future plans?
- 6) What is your role in developing a sustainable future? How has this summer affected your ideas about that role?
- 7) Is there anything else you'd like to add to the discussion?