First-Year Engineering Students' Environmental Awareness and Conceptual Understanding with Participatory Game Design as Knowledge Elicitation

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Abstract: The purpose of this paper was to investigate first-year undergraduate engineering students' awareness and conceptual understanding of environmental issues and to examine how effective a participatory game design strategy was to elicit their understanding. Respondents (n=1,394) completed baseline environmental awareness surveys and 24 respondents participated in the game design process consisting of four workshops and online activities. The game design component was focused on life cycle analysis (LCA) including environmental impacts of engineering design. Observations and artifacts were collected from workshops and interviews were conducted. Results showed that students had a general awareness about environmental issues but lacked awareness about LCA, pollution, and wetlands. Additionally, the participatory game design process showed that students struggled with applying the newly gained understandings of LCA in the game designs. The participatory game design provided a wealth of information on students' understanding and also served as an effective platform for knowledge elicitation.

Introduction

According to the Accreditation Board for Engineering and Technology (ABET) criteria for accrediting engineering programs, engineering graduates must have the "broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" (ABET, 2009; p. 2). One implication of this is that engineers need to be able to recognize the importance of environmental and ecological issues in engineering and to gain an understanding of what this means to them as an engineer. For example, life-cycle analysis (LCA) is a means by which to quantify the environmental impacts of a product (Blanchard & Reppe, 1998). The issues embedded within LCA are central to the design, manufacturing, use, and disposal of engineered products.

Sustainability issues play a role in all disciplines of engineering, from the consequences of the products' design to the manufacture and eventual use and disposal of the product. For this reason sustainability concepts need to be incorporated into all engineering disciplines (Boyle, 2004). Apart from programs in environmental engineering however, sustainability concepts are not well-integrated into the engineering curriculum (Crofton, 2000; Azapagic, Perdan, & Shallcross, 2005). There is also a lack of knowledge about how much first-year undergraduates in engineering programs actually know about environmental issues and how they obtained their knowledge.

The purpose of this study is to investigate first-year undergraduate engineering students' awareness of the concept of LCA and environmental issues, and examine how students' understanding can be understood within a participatory co-design of an educational game. Additionally, baseline data will provide information on (a) how influential previous educational and demographic factors are for students' environmental awareness, and (b) which environmental issues still need attention within the first year engineering undergraduate curriculum.

It is necessary that engineering students of all engineering disciplines be aware of environmental issues and that they understand the relevance of environmental issues in engineering design. For this reason, our study focused on the participatory design process as a means of increasing students' awareness and understanding of environmental issues particularly in regards to the engineering design process as well as the assessment of its effectiveness as a knowledge elicitation strategy.

Research questions

The core research was guided by the following questions:

- What is the environmental issues awareness of first-year engineering students?
- What are the predictors of students' environmental awareness?
- How does the game design process enhance students' awareness and understanding of life cycle assessment and sustainable engineering?

The secondary research was guided by the question: How effective is the participatory game design as a knowledge elicitation strategy to shed more light on students' understanding of environmental and sustainability issues with engineering?

Literature and Theoretical Framework

Participatory Design

Participatory design (PD) was deployed in this study as a design and knowledge elicitation feature. Rooted in the Scandinavian workplace movement, "participatory design of computer applications is about the direct participation of those who will be affected by the development of a particular computer application in the decision-making, design and/or development process" (Törpel, 2005, p. 177). PD is particularly focused on the exchange of skills, values and perspectives during the development on potential working settings (Greenbaum & Kyng, 1991; Kensing & Blomberg, 1998). In this study, students are collaborative co-designers of an educational game from which other students can both give feedback in the design and benefit from the process.

The concept of PD, used primarily in product design, has long roots in educational design (Strobel, 2006) and research practice as well: Jonassen, Wilson, Wang, & Grabinger (1993) reported that instructional designers learned far more by designing CAI (computer-assisted instruction) than the target audience will probably ever learn by using the designed CAI. Additionally, the rich teach-back literature (Johnson & Johnson, 1987) shows learners are especially successful when teaching newly acquired knowledge and skills to other learners. Nevertheless, there are few research studies and reports discussing how participatory design helps shape the educational process, benefiting students when engaged as designers and end-users. In addition, the authors are only aware of a few studies utilizing participatory design as a strategy for knowledge elicitation (e.g., Kafai, Franke, Ching, & Shih, 1998).

Environmental Education and Stewardship

Public education on environmental issues is essential, as public opinion plays a major role in the development and implementation of environmental policy. Popular perceptions and misconceptions surrounding environmental problems must be understood in order to make educational efforts most effective (Holl, Dailey, and Ehrlich 1995). According to Holl et al. (1999), educational effectiveness requires teaching the links between different issues, the relationship between individual actions and environmental quality, and tailoring the information on these environmental problems and solutions to a more local or individual context.

Ecological literacy and more broadly environmental literacy consists of three interrelated components: knowledge, affect, and behavior (Bruyere, 2008). That is, one must know about ecology, show concern for the natural environment, and act in a way that is consistent with this knowledge and concern. It follows then, that for students to have sustainable engineering literacy they must have knowledge about the subject, show concern for the natural environment, and show behavior consistent with this knowledge and concern, for example by developing technology with the ecological footprint in mind. Several studies on environmental behavior have found links between awareness, attitudes, and behavior or behavioral intentions, suggesting that as awareness about an issue increases, so will subsequent attitudes or behaviors (Cottrell, 2003).

Game Design as an Educational Tool

Computer games are an emerging and popular area of development (Danielsson & Wiberg, 2006) and seen as "an important teaching tool because they can provide a compelling context via interactive, engaging and immersive activities" (Gunter et al., 2008, p. 511). Despite the hype, whether games actually help learning remains a controversial topic (Gunter et al., 2008; Rieber, 2005; Shaffer, 2006). Becker (2007) observed that "design of games for learning is one of the biggest challenges that instructional designers have had to face" (p. 43). Other research studies have shown that few games have demonstrated that they can successfully teach academic content in a classroom teaching (Gunter et al., 2008; Rieber & Noah, 1997). Frietas (2008) reported that commercial games, which focus on fun and entertainment, often lacked the principles of good learning design. Educational games, which were created as collaborative efforts between educators and instructional designers, often resulted in boring play (Lim, 2008; Prensky, 2001). Other research studies, however, began to highlight the use of students as potential educational game designers and the positive effect this experience would have on student learning (Danielsson & Wiberg, 2006; Lim, 2008). Lim (2008) argued that students would be more likely to engage in the learning process, because they would be empowered to make decisions and take action by designing or co-designing their learning experience.

Methodology

Research Design and Data Analysis

In the study's research design, participants are asked to co-design an educational game with the researchers in a process called participatory design, with both quantitative and qualitative research methods employed. Quantitative methods were used to measure baseline data about participants' knowledge and understanding of environmental and ecological issues. The baseline survey was combined with academic data obtained from the University's Registrar Offices (i.e., semesters of high school math courses) and demographic data (permanent residence zip code). Students' permanent zip code data were matched to average household income data in the U.S. Census bureau from the most recent census year (2000). Qualitative methods were used as a formative measure of participants' changes in understanding through the game design process. To analyze qualitative data, two raters used the method of content and constant comparison analysis (Glaser & Strauss, 1967) to group common themes and reveal discrepancies among participants' responses.

Procedures and Project Implementation

Participants were 1,394 first-year engineering students who were enrolled in the ENGR100 course and who completed and returned the initial baseline survey. The sample consisted of 1,109 males and 285 females. Of those students, 1,250 were U.S. citizens and 144 were international students. The survey was administered in August 2008 and encompassed student demographic information, as students' initial understanding of ecological and environmental engineering (return rate = 82%).

For the game design component of the study, all of the ENGR100 students that participated in this survey were sent an email recruitment letter in October 2008. For the purpose of avoiding bias and increasing reliability and validity in the data collection process, participants were selected based on a stratified sampling strategy, so each participant team had a mix of demographic background. Twenty-four students participated in the game design component, developed by the research team and consisted of four workshops, an online wikispace environment, and two online activities (Figure 1). The game design workshops provided a venue in which study participants could interact amongst themselves and be observed by research team members, the wikispaces facilitated team member communication, and the online activities supplemented information presented in the workshops. Research team members also used the workshops to develop observation data, collect team artifacts, such as drawings, reflections, and provide teams with assistance when needed.

The themes of the workshops varied within the game design process. The first workshop lasted approximately one hour, and focused on Life Cycle Assessment (LCA) content knowledge, including introductions/assessment (10-15 minutes), a presentation by LCA content experts (30-40 m.), and a group activity (10-15 m.). The second workshop lasted approximately 70 minutes and consisted of a review of LCA (5-10 m.), a presentation of game design concepts (30-45 m.), and small group discussions (20-30 m.). The design of the third and fourth workshops were structured as "working sessions." Each team used their workshop time to develop game prototypes and provide one another with peer evaluation.
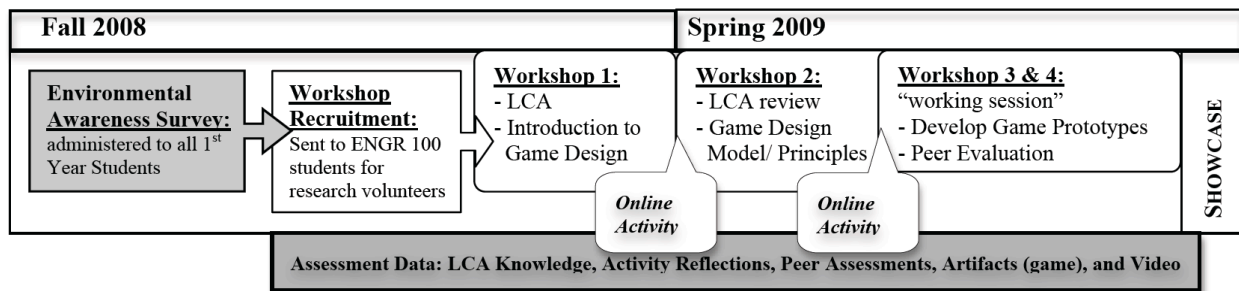

Figure 1. Workshop Activities and Timeline

Data Collection

Prior to the game design workshops, the research team administered a baseline survey, which consisted of several components: (a) demographic information, (b) an environmental survey (Azapagic et al., 2005) assessing students' level of awareness and understanding of sustainable development in general and about specific environmental topics, consisting of four subscales: environmental issues (14 items), environmental legislation, policy and standards (7 items), environmental tools, technologies and approaches (12 items), and sustainable development (13 items), (c) asking students to rate the importance of sustainable development, and (d) a survey about environmental knowledge from the National Environmental Education & Training Foundation (NEETF)/Roper Questions, 1997-2000 (Coyle, 2005).

Data collection for the game design process was centered on a series of game design workshops, which consisted of four face-to-face workshops and two online activities. Six teams of four students participated in the workshops and the following instruments were utilized to collect data and to triangulate the results of qualitative analyses.

- *Check-In Assessment:* Participants' reflection on their basic understanding of LCA concepts.
- *Activity Handouts:* Students reflected on activities, such as discussions and brainstorming that occurred during the workshop.
- *Artifacts:* The artifacts include the game prototypes and instructions.
- *Peer Assessments:* Each group evaluated the game paper prototypes developed by the other teams based upon a rubric developed by the research team.
- *Audio:* Includes discussion of workshop activities and final interview data.
- *Video Data:* These videos contain research team debriefing discussions held upon workshop completion.

Quantitative Results

In the results, we will first look at the findings of the baseline survey, describing specifics of the following: self reported perspectives concerning sustainable development and environmental awareness, cultural and previous research comparisons, and predictors of environmental knowledge. Then we will discuss the effects of the game design process on environmental and life cycle analysis understanding, and the way that students integrated environmental knowledge into the game design itself.

In the baseline survey, one of the questions asked students to rate the importance of sustainable development for themselves, as an engineer, for the country, for society, for population growth, and for future generations. The percentage of students who responded "important" or "very important" was calculated for each of the categories (Table 1).

Table 1: Percentage of students' ratings of the importance of sustainable development for each category

Category	Percentage of "Important" or "Very Important" Ratings
Future generations	68.5%
Your country	68.2%
Population growth	67.1%
You as an engineer	66.2%
The society world-wide	65.8%
You personally	61.8%

One finding was that that approximately 35% of students did not rate sustainable development as important for any category. This indicates that engineering students may not fully grasp the importance or applicability of sustainable development in engineering or the broader society.

Environmental Awareness

Within the baseline survey, 12 multiple-choice items were analyzed to determine students' awareness of environmental issues and to find any gaps that may need attention within the curriculum. Table 2 displays the percentage of students who responded correctly for each question. It appears that students are most familiar with the definition of biodiversity because 92.5% of students answered this item correctly. Five other items with percentages of correct responses in the 80-89% range indicates that students are mostly familiar with the concepts assessed in these items as well, which include electricity, renewable resources, ozone, household waste, and extinction. The item that students had the least knowledge about was "What is the most common cause of pollution for streams, rivers, and oceans," with only 30.3% of students answering correctly. In addition, only half of the students responded correctly for items asking about the source of carbon monoxide pollution and the benefit of wetlands (55.2% and 55.7%, respectively). It is puzzling that environmental knowledge is particularly low when it comes to the impact of everyday behavior of end users (question 2 and 4). This knowledge assessment indicates that although students may be familiar with or have a good understanding of some environmental concepts, that there are still some important concepts they have little knowledge about.

Table 2: Percentage of students responding correctly for each item

Item	Correct Response	% Correct Responses

1. There are many different kinds of animals and plants, and they live in many different types of environments. What is the word used to describe this idea?	Biodiversity	92.5%
2. Carbon monoxide is a major contributor to air pollution in the U.S. Which of the following is the biggest source of carbon monoxide?	Motor vehicles	55.2%
3. How is most of the electricity in the U.S. generated?	Burning oil, coal, and wood	80.9%
4. What is the most common cause of pollution of streams, rivers, and oceans?	Surface water running off yards, city streets, paved lots, and farm fields	30.3%
5. Which of the following is a renewable resource?	Trees	82.1%
6. Ozone forms a protective layer in the earth's upper atmosphere. What does ozone protect us from?	Harmful, cancer-causing sunlight	85.4%
7. Where does most of the garbage in the U.S. end up?	Landfills	78.4%
8. What is the name of the primary federal agency that works to protect the environment?	Environmental Protection Agency (the EPA)	79.9%
9. Which of the following household wastes is considered hazardous waste?	Batteries	84.1%
10. What is the most common reason that an animal species becomes extinct?	Their habitats are being destroyed by humans	82.7%
11. Scientists have not determined the best solution for disposing of nuclear waste. In the U.S., what is done with it now?	Stored and monitored	69.2%
12. What is the primary benefit of wetlands?	Help clean the water before it enters lakes, streams, rivers, or oceans	55.7%

Next, the self-reported levels of knowledge for four environmental subscales were analyzed. Students reported the highest level of knowledge on the Environmental Issues subscale (mean = 1.73). The Environmental Issues subscale consists of general environmental issues, such as global warming and air pollution. Students reported the lowest self-reported knowledge on the Environmental Legislation, Policy and Standards subscale (mean = 0.30); the subscale consists of specific policy and legislation questions. Finally, students still scored lower than average on the Environmental Tools, Technologies and Approaches subscale and the Sustainable Development subscale (mean = 1.16 and 1.07, respectively).

Comparison of Self-Report and Objective Knowledge

Previous research found that "most Americans believe they know more about the environment than they actually do" (Coyle, 2005; p. vi). To test this concept, Pearson's *r* correlation coefficient was calculated for the total awareness test score and the average self-reported awareness about environmental issues score (from environmental issues subscale questions). A significant ($p < .001$) correlation was found between the two variables. The higher a students' reported knowledge about environmental issues, the higher their actual knowledge as measured by a test of environmental issues; however the correlation was low to moderate ($r = 0.202$), indicating that strength of the correlation is weak.

Predictors of Environmental Knowledge

To determine what variables best predict the average awareness score of environmental sustainability, a regression analysis was performed. Standard multiple regression was considered the optimal method for answering the research question because (a) the independent variables (IVs) are correlated and there are unequal numbers of cases in cells and (b) regression can use several continuous and dichotomous IVs to represent the best prediction of the dependent variable (DV). Hypothesized variables thought to predict environmental knowledge included gender, income, previous environmental education, environmental issues subscale score, environmental policy/legislation subscale score, environmental tools/applications subscale score, sustainable development subscale score, number of semesters high school math, and number of semesters high school science.

Two variables were recoded into binary variables for better interpretation: income (low/high) and previous environmental education (none/some). The variable national/international students was omitted due to the low number of international students (*n*=144) as compared to national students (*n*=1,250). Additionally, the variable for income, although included in the model, only includes national students. Only four of the independent variables contributed significantly to prediction of environmental knowledge. These significant predictors are: (a) average self-reported knowledge of environmental issues (β=0.22, $p < .001$), (b) average self-reported knowledge of environmental tools/applications (β=0.14, $p < .01$), (c) gender (β=0.16, $p < .001$), and (d) number of semesters of HS math classes (β=0.08, $p < .01$), where β indicates the strength of the relationship between the dependent and independent variable.

Qualitative Results

Students' Environmental Understanding in the Context of Participatory Game Design

To determine what environmental awareness students gained while participating in the game design process, a content analysis was performed on the qualitative data, particularly the design artifacts, workshop observations, and follow-up interviews. The main finding that emerged was that all of the respondents (*n* = 14) appeared to have an understanding of what LCA is, the uses of LCA, and the types of factors to consider in LCA calculations when responding to open-ended questions. It appeared that students understood the complexity of LCA and that many variables must be considered in calculating the environmental impacts of a product. For example, the most common theme that was found in the analysis of open-ended questions was *consideration of the different factors involved in LCA*. For example, typical comments were, "Deciding which factors are most/least important" and "…they [LCAs] are multifaceted [and] there is not one factor alone that determines whether one product or method is better." In contrast, all of the observers noted that of the participant teams, little to no knowledge of LCA was demonstrated at the beginning of the workshop.

At the end of the workshop, participants were asked to provide their main understanding of LCA. Out of the ten respondents, all provided either a general descriptive definition or an explicit definition of LCA. The following are examples of the two types of descriptions that participants provided.

- *Explicit (n = 7)*. A definition was considered explicit if a student specifically defined LCA. An example of a participant's explicit definition is, "The effect manufacturing of products has on the environment, and how to change the environmental impact of products by redesigning them."
- *General descriptive (n = 3)*. A definition was considered general descriptive if a student described some uses of LCA but did not specifically define the term. An example of a participant's general descriptive definition is, "My main understanding is that it is to show how you can save energy by using and building more energy proficient items."

Integration of Environmental Information into the Game Design

Another focus of the qualitative analysis was to determine which teams embedded to what extent LCA information into the game design. The results show that only one of the three teams explicitly embedded LCA information into the game design while the other two games had a vague reference to "improving the environment."

For example, team 4 was one of the teams that did not integrate LCA information within the game. The only decision the player must make is whether to build/expand a business or take a mission card, which could possibly be a response to the LCA criteria embedded. The mission cards allow the players to help the environment. However, this is unclear; for this team, content dissemination in the game was not consistent with the comments made by the individual group members. For example, team members made comments regarding having the player choose different options that have different LCA emphases the game reflects more about luck than choices.

Another example of a team that did not integrate LCA into the game design is team 1. In this case, players are supposed to make choices for their character with the goal of "saving the environment" and "choosing the better option," yet there are only two statements regarding environmental issues: "Player will be presented with an option based on their role…the player has to choose between improving his/ her business or saving the environment. Each decision has pros and cons that the player must weigh before choosing the 'better' option." Because Team 1 does not have data regarding personal definitions of LCA it is not clear whether the situation is similar to that of team 4, where the method of content dissemination in the game does not match what the individuals in the team articulated. The incorporation of LCA into the game became difficult to assess, and should be kept in mind for future research.

In contrast, team 2 embedded the LCA thought process into the game while developing the game, merging the concepts well. Team 2 members discussed how the game would incorporate decisions that must be made regarding the raw materials found in the environment. Although participants used the vague term "eco-index" it appears that they were thinking about the principles of LCA, as they determined the process of the game by discussing how the player will need to make choices regarding the building of the community while considering the environmental impact such as raw materials and "eco- index."

One of the reasons that students may have refrained from adding LCA into their game design was because they found the complexity of the LCA process difficult to incorporate into a game. Although a major theme that emerged from the students' written responses was the importance of taking into account the wide variety of factors in calculating LCA, this also appeared to be one of the main difficulties that students expressed. For example, several students listed the most difficult knowledge of LCA as the need to take into account many different factors and environmental impacts. For example, typical student responses to an open-ended question asking about the most difficult aspects of LCA are: "Considering the wide range of impacts that a product can have," and "…[taking] into account all that affects the environment."

Conclusions and Implications

The purpose of this study was to investigate first-year engineering students' awareness of environmental issues and to examine how students' understanding of Life Cycle Analysis changed after participating in the process of co-designing an educational game. Results revealed that students show a lack of awareness about several aspects of environmental issues, and that all of the students who responded to the open-ended questions gained an understanding of LCA and the majority were able to define the term accurately and in detail.

Although participants responded correctly to the majority of environmental awareness questions, there were still some issues where students exhibited misunderstandings. For example, only 30% of students knew the most common cause of pollution of streams, rivers, and oceans. On a national survey, a majority of the sample of Americans also answered this question incorrectly (Coyle, 2005), indicating that there is a need to promote greater awareness about water pollution. Additional areas of concern are items relating to carbon monoxide pollution, benefits of wetlands, and nuclear waste disposal, as these issues might have implications for distributing or manufacturing certain products, and engineers should develop an awareness and understanding about these issues.

Additional results showed that there are four predictors of environmental awareness: (1) the level of awareness about environmental issues, (2) the level of awareness about environmental tools, technologies and approaches, (3) gender, and (4) the number of semesters of high school math courses. Not surprisingly, the largest predictor of environmental awareness is a students' self-reported awareness of environmental issues. Next, gender was the second largest predictor of environmental knowledge, followed by students' self-reported knowledge on the environmental tools, technologies and approaches subscale. Finally, the smallest predictor was the number of high school math courses taken, which was unexpected given that the number of semesters of high school science courses taken was not a significant predictor of environmental awareness. Thus, there may be a variable correlated with the number of semesters of high school math that was not measured and serves to predict students' environmental awareness. In addition, future research with non-U.S. citizens should use additional measures of environmental awareness because the survey used in this study may not be appropriate for international students. Lastly, students reported the lowest levels of awareness on the environmental legislation, policy and standards subscale especially as compared to the more general Environmental Issues subscale.

This study also examined how students' environmental awareness and understanding of the LCA concept changed following the game design process. Although individual participants demonstrated an understanding of the factors involved in LCA, they often did not fully incorporate their understanding into the game design. Only one of three teams explicitly embedded LCA information into the game design. Although participants showed an understanding of environmental issues as they pertain to engineering, they may have perceived LCA as too complex or lacked the time to successfully incorporate LCA into the game, indicating that additional planning time for game development is needed.

These results contribute to the research on first-year engineering students' environmental awareness. The participatory game design provided rich data about students' understanding of LCA and served as an effective platform for knowledge elicitation. It is apparent that first-year undergraduates in engineering lack awareness about many environmental issues. Because of the increased importance of sustainability in engineering, the need for engineers in all disciplines to understand sustainability issues in engineering is necessary. The game design process was a method that warrants additional research to determine the effects on students' understanding of LCA and the importance of sustainability in engineering. Future research is needed to focus more on the group processes within teams as well as how to moderate the game design process so as to better lead to participants' understanding of environmental issues in engineering and an educational game that can be used to teach others.

References

Accreditation Board for Engineering and Technology (ABET). (2007). *Criteria for accrediting engineering programs: Effective for evaluations during the 2009-10 accreditation cycle*. Retrieved Oct. 22, 2009, from http://www.abet.org/forms.shtml

Azapagic, A., Perdan, S., & Shallcross, D. (2005). How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum. *European Journal of Engineering Education, 30(1)*, 1-19.

Becker, K. (2007). Pedagogy in commercial video games. In D. Gibson, C., Aldrich, & M. Prensky (Eds.), *Games and simulations in online learning: Research and development frameworks* (pp. 21-47). Hershey, PA: Information Science Publishing.

Blanchard, S., & Reppe, P. (1998). *Life cycle analysis of a residential home in Michigan* (Rep. No. 1998-5). University of Michigan: Center for Sustainable Systems.

Boyle, C.A. (2004). Considerations on educating engineers in sustainability. *International Journal of Sustainability in Higher Education 5(2)*, 147-155.

Bruyere, B.L. (2008). The effect of environmental education on the ecological literacy of first-year college students. *Journal of Natural Resources and Life Sciences Education, 37*, 20-26.

Coyle, K. (2005). *Environmental literacy in America: What ten years of NEEFT/Roper research and related studies say about environmental literacy in the U.S.* The National Environmental Education & Training Foundation, Washington, DC.

Cottrell, S.P. (2003). Influence of sociodemographics and environmental attitudes on general responsible environmental behavior among recreational boaters. *Environment and Behavior, 35*, 347-375.

Crofton, F.S. (2000). Educating for sustainability: Opportunities in undergraduate engineering. *Journal of Cleaner Production, 8*, 397-405.

Danielsson, K., & Wiberg, C. (2006). Participatory design of learning media: Designing educational computer games with and for teenagers. *Interactive Technology & Smart Education, 3(4)*, 275-292.

Freitas, S.D. (2008). *Learning in immersive worlds: A review of game based learning*. Joint Information Systems Committee (JISC), London. Retrieved Oct. 27, 2009, from http://www.jisc.ac.uk/media/documents/programmes/elearning_innovation/

Glaser, B.G., & Strauss, A.L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine Publishing.

Greenbaum, J., & Kyng, M. (Eds.). (1991). *Design at work: Cooperative design of computer systems*. Hillsdale, NJ: Lawrence Erlbaum.

Greenbaum, J., & Stuedahl, D. (2000). *Deadlines and work practices in new media development*. Proceedings of IRIS 23, Laboratorium for Interaction Technology, University of Trollhattan Uddevalla, 2000.

Gunter, G.A., Kenny, R.F., & Vick, E.H. (2008). Taking educational games seriously: Using the RETAIN model to design endogemous fantasy into standalone educational games. *Education Technology Research and Development, 56*, 511-537.

Holl, K.D., Daily, G.C., Daily, S., & Ehrlich, P.R. (1999). Knowledge and attitudes toward population growth and the environment: University students in Costa Rica and the U.S. *Environmental Conservation, 26,* 66-74.

Holl, K.D., Daily, G.C., & Ehrlich, P.R. (1995). Knowledge and perceptions in Costa Rica regarding environment, population, and biodiversity issues. *Conservation Biology*, *9*, 1148-1558.

Johnson L. & Johnson N.E. (1987). Knowledge elicitation involving teachback interviewing. In A. Kidd (Ed.), *Knowledge elicitation for expert systems: A practical handbook* (pp. 91-108). New York: Plenum Press.

Jonassen, D.H., Wilson, B.G., Wang, S., & Grabinger, R.S. (1993). Constructivistic uses of expert systems to support learning. *Journal of Computer Based Instruction, 20*, 86-94.

Kafai, Y.B., Franke, M.L., Ching, C.C., & Shih, J.C. (1998). Game design as an interactive learning environment for fostering students' and teachers' mathematical inquiry. *International Journal of Computers for Mathematical Learning, 3*, 149-184.

Kensing, F., & Blomberg, J. (1998). Participatory design: Issues and concerns. *Computer Supported Cooperative Work, 7*, 167-185.

Lim, C. (2008). Spirit of the game: Empowering students as designers in schools? *British Journal of Educational Technology, 39*, 996-1003.

Rieber, L. (2005). Multimedia learning in games, simulations, and microworlds. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning*, (pp. 549-567). Cambridge: Cambridge University Press.

Rieber, L.P., & Noah, D. (1997). *Effect of gaming and graphical metaphors on reflective cognition within computer-based simulations*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Prensky, M. (2001). *Digital game-based learning*. New York: McGraw Hill.

Shaffer, D.W. (2006). *How computer games help children learn*. New York: Palgrave Macmillan.

Strobel, J. (2006) Participatory design strategies for eLearning: A design-based research approach in the field of Educational Technology. In J. Multisilta (Ed.). *Proceedings of the workshop on human centered technology*. Pori Publications, Tampere University of Technology.

Törpel, B. (2005). *Participatory design: A multi-voiced effort*. 4th Decennial Conference on Critical Computing: Between Sense and Sensibility, Proceedings, 21-25, Aarhus, Denmark, pp. 177-181.