Session 2653

kidslearn in Introduction to Engineering Design

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Abstract

EGR 101, Introduction to Engineering Design is a required, two semester hour, first year, multi-disciplinary engineering course offered at the University of Dayton (UD) through the school of engineering. In the winter semester of 2003, students enrolled in EGR 101participated in a service-learning project called *kidslearn*. The *kidslearn* service-learning project required the students to research a topic, develop a hands-on learning activity on one or more aspects of the topic and then facilitate this activity to at least one group of middle school or junior high students. Additionally, the students were required to choose a component that incorporated the basic principles addressed in their hands on activity and reverse engineer that component. Students wrote individual research papers summarizing the reverse engineering aspect of the project. Overall, the kidslearn *project* provided a mutually beneficial leaning experience to both the college age and school age students. Most importantly, this project helped the first year college students get excited about engineering and the school age students excited about science and engineering. Additionally, it provided the school age students with positive role models.

Introduction:

According to Census 2000, less than 25% of engineers were non-Caucasian.[1, 2] Many efforts to achieve a more diverse workforce in engineering include both recruitment and retention. Effective recruitment strategies include a variety of outreach programs that encourage elementary and high school age students from under-represented ethnic groups to become interested in science and math and to pursue that interest when making career choices. [3] This encouragement can come in many forms including mentorship, role models and teaching methods that make science and math exciting and fun while stimulating students to become more actively involved in their own learning. Some examples of successful outreach programs include various engineering summer camps and workshops for high school age students, science and technology exhibits, tours and field trips, and classroom exercises and experiments facilitated by engineering professionals, faculty and students. [4-9]

Increasing the retention rate of first year engineering students from underrepresented ethnic groups is also required to increase diversity in the field of engineering. Although the attrition rate among all engineering students is very high (approximately 50 – 60%) the attrition rate of engineering students from underrepresented ethnic groups is even higher (> 70%). [10-12] Many universities require their first year engineering students to take an introduction to engineering design or similar entry-level engineering course. This entry-level course can serve several very important functions that have been found to be helpful in retaining students in engineering. Among these functions include helping the students to develop an appreciation for engineering, introducing the students to various engineering disciplines and developing a community of engineering student by establishing relationships among the students and between students and faculty.[12] In most cases, this entry-level course will be the only engineering course that the students will take until they are sophomores or juniors since the first two years of most engineering curricula are taken up with calculus, humanities and basic science courses.

Many of the successful entry-level engineering courses include some form of experiential learning. Experiential learning has been identified as an effective way to help engineering students develop both technical skills and non-technical skills such as oral and written communication, project management, leadership, the ability to work on multi-disciplinary teams, a good understanding engineering ethics and understanding the societal impacts of engineering decisions. [13-17] Service-learning is a form of experiential learning that includes three basic components: course structure, community service and structured reflection which is designed to develop a sensitivity in the students to the impact of professional decisions on society, ethics in engineering and sound professional practice. [15]

Project Overview:

EGR 101, Introduction to Engineering Design, is a required, two-semester hour, first year, multi-disciplinary engineering course offered at the University of Dayton (UD) through the school of engineering. The overall goals of this course are to develop the problem solving and teamwork skills of the students, introduce the multi-disciplinary nature of engineering design, introduce structured programming and provide experiential learning. Additionally, this course is required to implement various first year experience (FYE) components. These FYE components include information literacy, introduction to the Catholic Marianist character of the university, career services offered at UD and computing ethics. EGR 101 is team taught by professors or graduate students from at least two different engineering disciplines.

There are two basic course formats for EGR 101 that are offered in various sections of the course. In most cases, students pick a section based on what is available and what will fit into their schedule. In one of these formats, students work on a single project that lasts the entire semester. In the second format, students participate in two separate modules, each of which lasts for half of the semester (approximately six weeks). These modules include a mechanical and electrical engineering module and a chemical and civil engineering module.

In the winter semester of 2003, the mechanical and electrical engineering module was team taught by an instructor from the Mechanical and Aerospace Engineering department and a graduate student from the Electrical and Computer Engineering department. In this module, the students participated in a service-learning project called *kidslearn*. The *kidslearn* service-learning project required the students to research a topic, develop a hands-on learning activity on one or more aspects of the topic and then facilitate this activity to at least one group of middle school or junior high students. Additionally, the students were required to choose an electromechanical component that incorporated the basic principles addressed in their hands on activity and reverse engineer that component. Students wrote individual research papers summarizing the reverse engineering aspect of the project.

Project Objectives:

The educational objectives of the kidslearn service-learning project coupled with the reverse engineering research paper were:

- To expose the student to interdisciplinary engineering design;
- To help develop the student's ability to conduct internet and library research and apply the information gained from this research to solve engineering problems;
- To provide the student with the opportunity to use the computer to help solve engineering problems and communicate the results of their work;
- To provide the student with the opportunity to work in teams;
- To provide the student with an opportunity to enhance their written and oral communication skills;
- To increase the students ethical awareness as it pertains to engineering and provide the student with the tools for making good ethical decisions;
- To help the student understand how their chosen field can be used to help society;
- To get the students excited about being an engineer.

The ancillary objectives of the project were:

- To provide outreach to area elementary schools;
- To provide elementary school age children with the opportunity to interact with engineering students;
- To provide elementary school age children, including children from underrepresented ethnic groups, the opportunity to participate in fun, hands-on science and math activities;
- To get the children excited about math and science so that they might one day pursue a career in engineering.

Project Facilitation and Requirements:

For the second session electromechanical module of EGR 101(Winter 2003), the class was divided into six teams of three or four students each. Student teams were required to work together to develop and facilitate the hands-on learning activity and to do the research needed to accomplish the reverse engineering aspect of this project. A team leader was chosen by the team members based on the student's willingness to be team leader and the student's qualifications. The team leader received extra credit points for their efforts. The responsibilities of the team leader included:

- Maintaining the team room on the project Quickplace site (http://quickplace.udayton.edu/kidslearn);
- Overseeing all team activities;
- Coordinating the presentation to the school children;
- Delegating duties to team members;
- Scheduling out of class team meetings;
- Submitting a hard copy of the weekly progress reports to the graduate student instructor.

Students were required to review their teammates' performance. Peer review scores were averaged and a grade was issued based on the outcome of the peer review.

In the *kidslearn* service-learning project student teams developed and facilitated hands-on educational activities for middle and junior high school aged children that explained basic math and/or physics concepts. The hands-on, learning activities developed by the teams had to be interactive, to present basic math and/or science concepts and to include the scientific method, Figure 1.

Figure 1. EGR 101 students facilitate their hands-on learning module to a group of fourth grade students at Dayton Catholic Accelerated Academy.

Student teams were permitted to pick any topic they wanted for the hands-on learning activity and the associated reverse engineering project but they had to submit a proposal describing the hands-on, learning activity and a cost estimate for developing this activity as well as a description of the associated reverse engineering project. The proposals were reviewed and approved by the instructors. In most cases the proposals were accepted without revision. Reasons for rejecting a proposal included concept redundancy, lack of electromechanical aspect in the reverse engineering aspect, too expensive or not a reasonable project. Student teams were required to follow a specific format when writing their proposals. The student teams were also required to develop an advertisement for their proposed hands-on activity. This advertisement had to fully describe the hands-on activity so that it could be posted on the Quickplace site and sent to schools interested in participating in the *kidslearn* project. Guidance in selecting a topic for the hands-on activity was provided to student teams in the form of examples from the prior module's work, a field trip to Boonshoft Museum of Discovery to view the "How Things Work Exhibit", children's science books, information on curriculum obtained from the internet and general conversation with the two instructors and assistant, Figure 2. Students were encouraged to interact with upper level students in education or psychology during the brainstorming and development of their modules. The students were provided with contacts from the school of education and extra credit was offered to student teams that interacted with these upper level education or psychology students. Student teams were also encouraged to "try-out" their hands-on module on students that might have a good understanding of a middle school age child.

Figure 2. EGR 101 students take a field trip to Boonshoft Museum of Discovery to help them in the preparation of their hands-on learning modules.

In addition to developing the hands-on module, each team was required to research a component that used the math or physics principles presented in their hands-on learning activity. The students were then required to reverse engineering this component. The objective of the reverse engineering project was for the student to study the product and determine the rationale behind certain aspects of the component design. Students were required to write individual reports summarizing their findings from the reverse engineering research project. The students were required to follow a prescribed report format and the reports were graded for both technical content and technical writing.

To prepare for the reverse engineering activity, the students participated in several hands-on sessions during regular class time. In one of these sessions, the students were able to do library research using Ohiolink under the guidance of the librarian from the university library. In another session, student teams were given a hairdryer that they tore apart and examined. The teams were then required to respond to questions regarding the design of the component. Student teams summarized their findings in a team report. The goal of these two hands-on sessions was to provide the students with an understanding of reverse engineering and to provide the students with some tools that would be helpful to them in researching their component. In addition to these two sessions, representatives from the Rector's Office at UD came into the class and discussed the Marianist Character of the University. An attempt was made to relate the Marianist values of service to the service-learning component of the class.

Student teams were required to submit weekly progress reports which summarized what had been done on their project, what needed to be done to complete their project, identified action items, set an agenda for the week and assigned tasks to individual team members. Since the students were given a significant amount of class time to work on their research and project, these weekly reports were assigned in an effort to make sure that the students came to class prepared to work on their project and to verify that time in class was spent working on their project and not working on assignments from other classes.

Student teams were required to maintain team notebooks that included information on both the service-learning project and the reverse engineering research. The notebooks were required to be organized in the following manner:

1. Team Information
   a. Team roster;
   b. Team photo
2. Weekly Progress Reports
3. Research
   a. Bibliography
   b. Pages printed out from the internet
   c. Photocopied pages
   d. Notes
4. Reverse Design Information and work
5. Hands-on module
   a. Brain storming
   b. Proposal
   c. Advertisement
   d. Information regarding middle age students
   e. School contact information
   f. Module instructions
   g. List of needed materials
   h. Etc.

Participating Schools:

Student projects were facilitated at three urban schools, Patterson/Kennedy Elementary, Loos Elementary, and Dayton Catholic Accelerated Academy. Both Patterson/Kennedy and Loos Elementary Schools are part of the Dayton Public School System and serve children in grades K-6. The Dayton Public School System received a rating of "academic emergency", indicating that it failed to meet six or more of the 27 performance indicators. The enrollment at Patterson/Kennedy during the 2002-2003 school year was 641, with approximately 48% of the students being African American, 3 % of the students being multi-racial, 48% of the students being Caucasian and 94% of the students being from economically disadvantaged families. The enrollment at Loos elementary during the 2002-2003 school year was 440, with approximately 65% of the students being African American, 7 % of the students being multi-racial and 27% of the students being Caucasian.[18] Dayton Catholic Accelerated Elementary is a private urban school that serves children in grades K – 8. The enrollment in this school during the 2002-2003 school year was approximately 234. Although this school is affiliated with the Catholic Church, the majority of the students are not Catholic. This school serves a predominantly African American student body from an economically disadvantaged neighborhood in Dayton. The school is very small and provides a close and intimate learning environment. Several classrooms operate in a multi-grade level setting. Students in Catholic schools do not take proficiency tests, therefore the school rating is not available for this school. Information regarding the grade-levels and number of students that participated in the *kidslearn* program are summarized in Table 1.

Table 1. Participating Schools and Grade-Levels

School	Grade	Number of elementary school age students participating
Dayton Catholic	$4^{th} – 8^{th}$	
Loos	4^{th}	25
Patterson-Kennedy	4^{th}	21, 22

Student Assessment:
Student performance in this module was assessed based on the criteria shown in Table 2. The hands-on, learning activities were graded by the participating teacher. The teachers were asked to rank the team on a scale of one to five as indicated in Table 3. A score of five corresponded to "excellent" and a score of one corresponded to "horrible". Additionally, the teachers were asked to respond to three questions: (1) What did you like most about this hands-on learning activity? (2) What did you like least about this hands-on learning activity? (3) What could be done to improve this hands-on learning activity?

Table 2. Assessment of Student Performance

Item	Points	Weight
Peer Review	100	20 %
Individual report	100	20 %
Team project proposal	50	10%
Reverse Engineering Ex.	50	10%
Hands-on Activity	100	20%
Weekly Progress Report	100	20%

Table 3. Form used by Teachers to Evaluate Student Teams

	5 Excellent	4 Good	3 OK	2 Poor	1 Horrible
Students showed up on time for presentation					
Students were respectful and courteous to teacher.					
Students were respectful and courteous to the children.					
Students behaved in a mature and responsible manner.					
Students were dressed appropriately for the presentation.					
Students showed enthusiasm while presenting module and working with the children.					
Module was effective at meeting the educational goals established by the student team.					
Module was hands-on and required participation of every child.					
Module clearly demonstrated the use of the scientific method.					
Students communicated effectively with children and teacher.					
Students were well prepared for their module.					
Children enjoyed interacting with students.					
Children enjoyed the module					
Children appeared to learn a lot from the module.					
Overall, how would you rate this module.					
How likely would you be to ask students in the future to come into your class to facilitate this or another module.					

With the exception of one student team, scores provided by the teachers were in the "A" (93- 100) range. The teacher that scored the one student team low (72%) commented, "This was a fantastic project and had all of the indications of a sensational hands-on experiment but the UD team arrived late and could only stay 40 minutes which was not long enough to present the entire module. The student teams should have practiced the presentation so it ran smoothly and completely." Comments provided by the remaining teachers indicated that the projects were "fantastic," the students were well prepared and enthusiastic and the children had a lot of fun and learned a lot. A few teachers specifically commented that they liked the fact that the activities were team based. All of the teachers indicated that they would like UD students to return to their classroom for presentations in the future.

Project Assessment:

An effort was made to assess the effectiveness of the *kidslearn* service-learning project at meeting particular educational goals through an end of the semester survey. Students were asked to fill out an evaluation form at the end of the module that consisted of sixteen statements that summarized the educational objectives of this project. The students were asked to respond to each statement by providing a score from one to five indicating how effective the service-learning project was at meeting a specific educational objective. A score of five indicated that the project did an excellent job at meeting the specified goal, whereas a score of one indicated that the project did not meet the specified goal. The students were also asked to provide written responses to three questions: (1) What did you like most about this project; (2) What did you like least about this project; (3) What are your suggestions for improving this type of project? Results of the end of the module survey are provided in Table 4.

All of the students that responded to the survey indicated that what they liked most about the project was developing the hands-on activity and presenting it to the children. Some of the aspects of the project that the students did not like were insufficient time at the schools, weekly reports, the reverse engineering paper, timing of presentations, not enough organization and structure, lack of guidance and low level of technical knowledge gained from developing the hands-on activities. Some suggestions provided by the students for improving the project included providing more guidance, providing a better explanation of reverse engineering, more direction and less openendedness, provide a better explanation of the criteria and requirements for each part of the course and develop a set project where students are graded according to how well they perform.

Table 4. Results of Student Assessment of *kidslearn* Service-Learning Project

	5 Excellent	4 Good	3 OK	2 Poor	1 Horrible	Average Score
This project was an asset to reverse engineering research project.	0	10	6	2	2	**3.20**
This project provided me with technical knowledge related to engineering and design..	1	6	11	1	0	**3.37**
This project helped develop my ability to use the library for research (Ohiolink, etc).	0	4	6	9	1	**2.65**
This project helped develop my ability to use the internet for research.	2	6	7	5	0	**3.25**
This project helped to develop my ability to manage a project and helped develop business awareness and skills.	3	12	3	2	0	**3.80**
This project helped me to develop my written communication skills.	0	10	9	1	0	**3.45**
This project helped to develop my oral communication skills.	2	15	3	0	0	**3.95**
This project helped me to develop my teamwork skills	8	11	1	0	0	**4.35**
This project helped me to understand others (classmates, engineers, professors, "client")	5	12	3	0	0	**4.10**
This project helped to develop my interpersonal skills.	1	12	6	1	0	**3.65**
This project helped to develop my leadership skills.	5	10	5	0	0	**4.00**
This project aided in preparing me for the workplace.	0	9	9	2	0	**3.35**
This project helped me to understand or to reinforced my understanding of community and/or public service.	3	12	5	0	0	**3.90**
This project made me aware or reinforced my awareness of environmental responsibility.	0	3	10	5	2	**2.70**
This project helped to increase my sense of ethics and moral knowledge.	0	4	12	4	0	**3.00**
This project was enjoyable and made me excited about being an engineer.	5	12	1	2	0	**4.00**
						3.54

Conclusions and Recommendations:

The *kidslearn* project was fairly successful at meeting a majority of the educational goals of the EGR 101 electromechancial module. In particular, the project did a very good job (score of > 4.00) at helping the students develop their teamwork and interpersonal skills, helping the students to understand others and making the students excited about engineering. Surprisingly, the students did not feel that this project helped them to develop their ability to use the library for research. Although the students were asked to address environmental issues associated with the manufacture, use and disposal of the product they reverse engineered, they were not required to address environmental issues in the hands-on learning activity they developed and facilitated. Because of this the student provided a low score (2.70) in response to the question: "This project made me aware or reinforced my awareness of environmental responsibility." Also scoring low (3.00) was the effectiveness of this project at increasing the students' sense of ethics and moral knowledge. Ethics was not specifically addressed in this module.

Teacher response to having the students come into their classroom and facilitate the hands-on learning modules was very positive. For the most part, the teachers felt that the students did a terrific job and having the students in the classroom was an asset to the children. All of the teachers would like to have the UD students return to their classrooms to facilitate hands-on learning next school year.

Although teaching this course was a lot of fun for both instructors, organizing the service-learning project was very time consuming. Since the instructors had the opportunity to facilitate this modules two times in the Winter 2003 semester, they incorporated many lessons they learned from the first half of the semester into the second half of the semester. Among these lessons included having one of the instructors serve as the point of contact for the teachers instead of going through the service-learning coordinator and arranging presentation dates early on in the semester. The service learning coordinator was extremely helpful in identifying schools that might be interested in and benefit from interaction with the UD students, but it was easier if the instructors scheduled the presentations since they had a better idea of the students' availability. Another lesson learned from the first module was to make the teams small in number so that everyone had enough work to do. One of the lessons learned from the second module was that a small class size (fewer, smaller teams) is preferable to larger class sizes for this type of project. The reason that a smaller class size is preferred is that transporting the teams to stores to purchase the materials needed to build and/or facilitate their hands-on activities was difficult when there were six teams. Additionally, with the larger class size it was difficult to keep track of the students and make sure that each student was participating in the team activities during class time. In the first half of the semester, education majors were brought in as guest lecturers to describe how to effectively interact with school age children. In the second half of the semester, the students were only given the names and contact information for education majors that could be consulted, but were not provided with a formal lecture on this topic. Having the education majors come in to speak with the EGR 101 class was important as it established contact between the two groups and provided the engineering students with information regarding effective teaching methods. Because of this, the formal lecture from the education majors should not have been abandoned in the second session module. Although both instructors felt that the students were given guidance and formal instruction on both the reverse engineering project and service-learning project, the level of the students required that these instructions be continually reiterated throughout the session and that the students be closely monitored for progress in their research. It is recommended that a better effort be made to reiterate the requirements and monitor the students' progress.

Although the *kidslearn* project has room for improvement, overall it provided a mutually beneficial leaning experience to both the college age and school age students. Most importantly, this project helped the first year college students get excited about engineering and the school age students to get excited about science and engineering. The engineering students were able to start thinking like an engineer and to also see how they might be able to use their skills as an engineer to help children learn about science and math. The school age children were exposed to positive role models and were given an opportunity to experience fun hands-on math and science related activities. Although there is no data regarding the effectiveness of this project in retaining first year engineering students, the inclusion of some form of experiential learning in entry-level engineering courses has been found to help with retention. [13-17] Similarly, there is no data regarding the effectiveness of this project in encouraging children, especially those from underrepresented ethnic groups, to pursue their interest in science in math. However, previous outreach programs that involve hands-on learning and interaction with engineering students, faculty or professionals have been found to be an effective recruitment strategy. [3] Therefore, it is anticipated that the *kidslearn* project will aid in encouraging children to pursue their interest in science, math and engineering and retaining first year engineering students.

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