2006-982: FULL IMPLEMENTATION OF A NEW FORMAT FOR FRESHMAN ENGINEERING COURSE AT VIRGINIA TECH

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Full Implementation of a New Format for Freshmen Engineering Course

Abstract

This paper documents a continuing shift in one of the largest freshman engineering programs in the country. Fall 2005 implementation of a new format involving one 50-min lesson followed by a 90-min hands on workshop of a freshman engineering course "Engineering Exploration" at Virginia Tech is discussed. The implementation team consisted of seven faculty members and 21 students (graduate and undergraduate). About 1200 students were enrolled. The format was successfully piloted in spring 2005. Examples of new activities include introduction of a systems approach, hands-on engineering experiments for fitting empirical functions, students' presentations on contemporary issues, discussion of the attributes of "The Engineer of 2020," learning from seniors' study abroad experiences, and object oriented approaches for problem solving. In addition, a 5-week sustainable development design project was introduced. With the desire to increase student participation in the large classrooms and determine students' prior awareness, faculty adopted use of the eInstruction radio frequency response pads (clicker devices). A number of survey tools have been implemented to record students' experiences. Most of the new activities reflect the implementation of an NSF department level reform (DLR) project focused on a spiral curriculum approach.

Background

At Virginia Tech, all freshman engineering students enter as General Engineering (GE) students and are transferred to a degree-granting department when they have successfully completed a required set of courses. The GE program is conducted by the faculty in the Department of Engineering Education (EngE). The EngE faculty are also developing an active research program in the area of engineering education in collaboration with faculty members from other engineering departments and the School of Education .[1] One such collaborative effort, funded under the department-level reform (DLR) program of the NSF, (hereafter referred to as the DLR project) began in September 2004. The goal of DLR project is to reformulate the freshman engineering (i.e., GE program) within EngE and the bioprocess engineering option within the Biological Systems Engineering (BSE) program using a theme-based spiral curriculum approach. The twentieth century psychologist, Jerome Bruner, proposed the concept of the spiral curriculum. Bruner advocates a curriculum that revisits basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them.[2] In the proposed reformulation, a theme of sustainability has been selected to provide a contextual framework. The supporting principles of design, ethics, and a systems approach and cross-cutting skills of communication, teamwork, life-long learning, research experience, and lab experience will be woven throughout the curricula.

This paper mainly discusses the reformulation of a first semester freshman engineering course, called Engineering Exploration ENGE1024, in the GE program. In fact, over the past seven years, the first-year courses in the GE program have evolved from somewhat standard problem solving (including statics, electrical engineering, material balance concepts), graphics, and programming courses to a format that emphasizes early design and realization, collaborative learning, and highly interactive classroom environments[3,4,5,6]. Beginning in fall 2002, College of Engineering (COE) required all engineering freshmen to own laptop computers, which were immediately incorporated into the classroom environment. After considerable discussion in 2004, an improved ENGE1024 syllabus was designed to include general problem solving, engineering ethics, visualization of 3-D objects and also visualization of information, early design (including realization), graphing and simple analysis of graphs, and introduction to object-oriented programming (OOP) approaches for problem solving. This new course was offered for the first time in fall 2004.[7] Further, significant revisions to the course in light of the new DLR project were piloted in spring 2005 with ~210 students[8], and full implementation of these revisions were successfully executed for the entire freshman engineering class (~1200) of 2009 in fall 2005. It may be mentioned that in the past it was mainly EngE faculty who made revisions to the GE courses. However, as a result of the collaborative efforts like the DLR project, EngE faculty are now working with faculty members from other engineering departments like the BSE and Civil and Environmental Engineering (CEE) and experts on educational psychology and academic assessment to incorporate pedagogically sound changes into GE courses and assessing their effectiveness.

ENGE 1024 Course description and a New Teaching Format

The ENGE1024 course description is: "Introduction to the profession and the College of Engineering; foundation material in: problem definition, solution and presentation; design, including hands-on realization working in teams; modeling and visual representation of abstract and physical objects; scientific computation; algorithm development, computer implementation and application; documentation; ethics; professionalism".[9]

The course is a 2-credit course and all engineering freshmen are required to pass the course with a C- or better grade. Traditionally, this course was taught by EngE faculty using two 50-min lessons every week. In spring 2005, the first two authors took the lead in piloting a new format involving one 50-minute lesson, team taught by Lo and Lohani, in a 120-seat classroom followed by one 110-minute workshop, taught by graduate teaching assistants (GTAs), in a 30-seat classroom each week. The principal reasons for initiating this major change were to: i) allow additional time to students to become engaged in more hands-on activities during the workshop period, ii) create teaching opportunities for graduate students, iii) give students the opportunity to present and to become aware of contemporary engineering issues, and iv) collect/analyze data for conducting engineering education research as part of DLR project activities. This new format was by and large a successful experiment and was implemented for all 1200+ students in fall 2005. Lo and Lohani coordinated the course and co-taught two lecture sections (~160 students in each) of ENGE1024 in fall 2005. The next section discusses course management efforts.

Course management and training of GTAs

Seven faculty members including Lo and Lohani, 12 graduate teaching assistants (GTAs), and two senior undergraduate students were involved in the creation and/or teaching of the course. Seven undergraduates assisted in grading papers. Faculty and teaching assistants came from a range of engineering backgrounds and experiences. Lo and Lohani were responsible for coordinating the generation of common exams, development of lesson slides and assignments, creation and implementation of research/assessment instruments, management of involved faculty members and teaching assistants, and maintenance of a common website for student use. The common website contained common course documents, lessons, assignments, and announcements. A sub-group of DLR project investigators, led by a faculty member from the CEE department, created/reviewed DLR project related assignments in ENGE1024. One of the GTAs was assigned to be the lead GTA, with responsibilities of coordinating workshop activities and TA scheduling.

With an unprecedented number of GTAs who had never taught any EngE courses previously, a week of intensive training was organized a week before fall semester began. Training included instruction regarding teaching philosophy and style, information regarding the course syllabus and departmental policies, and demonstrations useful to conduct the first two weeks of workshops. A panel discussion on "teaching tips" by award-winning instructors at Virginia Tech was the concluding activity of this week long training. Throughout the semester, the course coordinators and lead teaching assistant led weekly meetings to discuss upcoming lessons and course related issues such as exams, review sessions, grading, etc. Several training workshops on course related software, i.e. Inventor, MATLAB, and Alice, were held on an as needed basis. Teaching assistants were asked to lead the coordination of activities that most closely related to their fields of training and/or research. For example, three teaching assistants from Civil Engineering generated the assignment and experimental apparatuses for the frustum tank experiment that let students observe a fluids flow phenomenon.

DLR project - Spiral curriculum activities

Fall 2005 offered more opportunity to strengthen the spiral curriculum activities in ENGE1024. The spiral philosophy, which involves revisiting material over time to reinforce concepts, was introduced into ENGE1024 though several means. Spirals were used on two levels: (1) within the course and the freshmen year (2) with the intention of continuing the spiral for those students who decide to pursue a degree in BSE. Assignments were specifically chosen to create linkages throughout the course. An example of a spiral within the course is presented in Table 1.

Spirals that will exist to the Bio-process curriculum within the BSE department include engineering ethics, design experiences, problem solving activities, exposure to an enzyme kinetics experiment, electronic portfolios, etc. For example, in fall 2005, freshmen watched the National Institute for Engineering Ethics' Incident at Morales[10], a video of a fictitious scenario which raises ethical issues such as lining bioponds and the effects of such contamination on groundwater. In addition, some of the team-based ethics project topics were BSE-related; for example, one topic discussed water and soil contamination in New Orleans following the aftermath of hurricane Katrina, which is related to the land and water resources track within the

BSE. Also, as part of an initiative under the DLR project, all freshmen created Virginia Tech electronic portfolios[11]. One of the e-portfolio assignments related to reflection on students' ethics projects and to think about what ethical and professional responsibility entails. BSE-bound students will continue to use electronic portfolios to document their learning experiences, including ones related to engineering ethics. In addition, BSE-bound students will study ethical issues related to bioprocesses by researching and discussing case studies[12].

Activity time/type	Spiraling activity
Week 2 Homework assignment	Compute the water drainage time from a conic frustum shaped tank by hand.
Week 5 Workshop Activity and Homework assignment	Conduct a water tower experiment, record the rate of water drainage from a conic frustum shaped tank, and fit an empirical function to relate water height with the drainage time.
Week 7 lesson	Demonstrate a systems model of the water tower experiment, done in week 5, using a systems model software (Berkeley Madonna) and demonstrate the effects of various parameters like height of water in tank, drain/orifice diameter, dimensions of tank, etc. on the behavior of the system (in this case, rate of change of water height in tank).
Week 12 and 13 lessons	Compute the volume of a conic frustum using an object-oriented algorithm implemented through a graphical programming language called Alice (www.alice.org). Create a new Cone class to implement new methods/functions by modifying an existing Cone class in Alice.

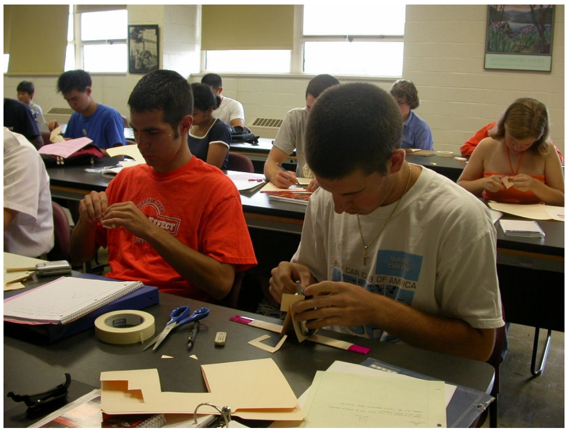
Table 1: Spiraling activity in ENGE1024 – fall 2005

Likewise, the elements of design and sustainability will continue as two major threads between the freshman and upperclassman years. While students worked on small-scale design projects lasting a few weeks to several weeks during the fall semester, many students will work on a semester-long design-build project in one of the follow-up spring courses. In the BSE track, students have the opportunity to work on more complex design-build projects and a capstone senior design project.

In the following sections, we present details of some new activities that were piloted/implemented in fall 2005.

Changes to hands on, collaborative learning activities

As stated earlier, considerable work has been done to implement active and discovery-based learning in EngE1024 over the past few years. Since a substantial part of the course involved group work, teamwork continued to be emphasized right from the first week of the semester. For example, students in the week 1 workshop began by watching a video regarding IDEO[13], which provided an excellent example of a collaborative and interdisciplinary approach for the design of a shopping cart, and then concluded with a team building activity of designing and building a cell phone holder using a folder, tape, scissors, and a ruler (Figure 1).



(1)

(2)

Figures 1 and 2. (1) Cell phone holder activity .(2) water tower experimental apparatus

Until fall 2005, students were taught graphing and analysis of data to fit empirical functions like linear, power, and exponential by giving them data to plot. This semester, lab exercises were created to allow students to generate their own data sets to analyze. As seen in table 1, during week 5 workshop students conducted a water tower experiment (see Figure 2) to determine the empirical relationship between water height and time. In addition, students determined the empirical relationship for an enzyme catalysis experiment. The main hands on and early design experience for the students involved a 5-week long sustainable development design project (SDDP), briefly described in the next section.

<u>Sustainable Development Design Project (SDDP)</u>

ENGE1024 instructors discussed the concepts of sustainability in the lecture part of the course and presented a number of well accepted definitions of sustainability including the one that states "*Sustainable development meets the needs of the present without compromising the ability of future generations to meet human needs and aspirations.*"[14] Further, in order to introduce the concept of sustainable design, real-world examples were discussed in the lecture and workshop parts of the course. After introducing relevant concepts related to sustainability, students were given a multi-page SDDP document that included: 1) a description of a village in a developing country that would serve as the "customer" 2) four main areas (education, agriculture, energy, and nutrition) that students could choose from and 3) project deliverables. Each student team received a bag of supplies which included a ziplock plastic bag, a bandana, ten bamboo skewers, 3 ft. of jute twine, 3 ft. of rope, and 4 oz. of terra cotta modeling clay. In addition, each team was allowed to use one soda can and one plastic water bottle in its final design, which the team was expected to provide. Project deliverables included individual assignments (short research paper of an existing design that exemplifies sustainable design, sketch, and engineer's log) and group assignments (proposal, prototype of a design that addresses one of the four areas, in-class demonstration, and report). Each workshop section voted for the best design, and these student-elected teams participated in a design fair that occurred in the first week of November 2005. During the design fair, students participated in a variety of sustainable design activities while judges chose three overall winning teams. Complete details of the SDDP are given in companion paper in the conference[15].

Alice Programming

Alice programming was introduced in the ENGE1024 in fall 2004 with an objective to expose engineering freshmen to some basic concepts in object oriented programming[16]. The Alice software, which is provided free of charge (www.alice.org) as a public service by Carnegie Mellon University (CMU), provides a completely new approach to learning programming concepts. Alice uses a 3D Interactive Graphics Programming Environment to teach the fundamental concepts of object-oriented programming. The course coordinators and teaching assistants continued to work in collaboration with Alice developers at Carnegie Mellon, St. Josephs, and Ithaca College to develop new Alice instruction material. In fall 2004 and spring 2005, it was noted that there were shortcomings with using Alice for a multi-week programming project[16]. Some students with significant computer experience were frustrated by the lack of one-on-one correlation between Alice and C/C++ and by software bugs encountered during completion of the programming project. Software bugs were regularly reported to the CMU team, and software bugs were significantly reduced in the fall 2005 version. Reacting to the exit survey responses from students in fall 2004 and spring 2005 and observations from faculty who taught ENGE1024 in fall 2004, the Alice coverage was reduced to 4 weeks for fall 2005 and the Alice programming project was eliminated. Because of the reduced coverage, no text was required for the Alice portion. Another significant change from previous semesters of Alice instruction included replacing storyboarding with flowcharting. The instructors felt that flowcharting was a more appropriate algorithm development tool due to the increasingly mathematical nature of the assigned Alice exercises and homework.

All of the Alice lessons necessitated the use of laptop computers by the students. Each classroom had a teaching assistant who was proficient in Alice programming. Weekly lessons of Alice involved two parts: (1) lecture containing new programming concept(s) with hands-on exercise (2) continuation of week's concept with hands-on exercise in the workshop and appropriate homework assignment. Weekly lessons covered the following topics: flowcharting, objects, classes, control structures including sequence, selection, and repetition, methods, and parameters. The first Alice assignment was based on geometry and trigonometry concepts. In subsequent assignments, students simulated a sine wave motion using an object of a Playball class in Alice, created circular motion of objects using Sphere class in Alice, and modifed an existing classes in Alice by adding new functions/methods. A pre-and post test was conducted to assess learning gains of OOP concepts.

Systems modeling

The National Academy of Engineering publication The Engineer of 2020[17] emphasizes the importance of developing a systems approach in engineering instruction. A systems approach involves placing as much emphasis on identifying and describing the connections between objects and events as on identifying and describing the objects and events themselves. A system, formally, is a set of components that interact with each other. If a change is introduced in one component, it leads to change in another component, which in turn induces change in a third component.[18] "Systems approach" is one of the spiraling themes in the DLR project. An attempt was made, for the first time, in ENGE1024 to introduce systems perspective by describing a systems model, simulated using Berkeley Madonna (BM), of the water tower experiment discussed earlier. The governing equations were programmed in the BM environment, and a plot of height of water versus time was generated that matched the experimental data of the water tower experiment. The instructors demonstrated the BM model of the water tower experiment showing relationships between height of water in tank, water discharge from orifice, and exit velocity of water from an orifice. Students did not use the BM software. Efforts to further improve the systems model are continuing at the time of this writing.

Introduction of attributes of future engineers and introduction of globalization practices in engineering

To increase the awareness of the future of engineering, students were introduced to concepts presented in the publication Engineer of 2020 during the lecture portion. While attributes of future engineers were briefly discussed, knowledge of contemporary issues and the internationalism of engineering were emphasized in several ways. Students were asked to work in pairs or trios to give a single 5-10 minute presentation on a contemporary engineering issue of their choice. Presentations by student teams occurred throughout the semester. In addition, as explained in greater detail in the next section of this paper, students were asked to reflect on an ethical aspect of one of a few recent (or impending) natural disasters. Five upperclassmen with study (or research) abroad experiences in France, Ireland, Spain, New Zealand, and South Africa were invited to give 20 minute presentations to students; these presentations highlighted the advantages of participating in an international experience. The sustainable development design project asked students to reflect on the needs of a developing country. The ethics video used mentioned implications with differences in international laws. In addition, students were encouraged to read Tom Friedman's best seller The World is Flat[19] during winter break.

Changes to teaching of engineering ethics

In previous semesters, the National Institute for Engineering Ethics' video Gilbane Gold[20] was used as a tool for introducing ethics. In fall 2005, the National Institute for Engineering Ethics' video Incident at Morales replaced Gilbane Gold. Reasons for changing videos were the age of the video and the inclusion of international issues. Students watched the video and then participated in a brief discussion led by their teaching assistant.

Students also gave a group ethics presentation[21], in which they had to work together to research and present an assigned topic related to the 2004 Asian tsunami, hurricane Katrina, earthquakes and San Francisco, or hurricane Rita. This presentation was meant to encourage teamwork, to allow students to reflect on a contemporary issue, to let students practice communication skills, and to better understand some ethical concepts.

Assessment for fall 2005 semester

For the first time, radio-frequency (RF) response pads (i.e., clickers) were used in the GE program to collect prior awareness data from students during lectures. The response pads definitely increased instructor-student interaction in the large lecture sections. Students were informed ahead of time that clickers were also being used to record their attendance. During each lecture, students were asked one or more clicker questions. Some questions asked students to give opinions on former course activities while others sought to gage students' prior experiences and current knowledge.

An example of a clicker question with the number of responses (in parentheses) is given below:

> *In terms of knowing what engineers in each field do, which discipline are you least familiar with?*
>
> 1. *Aerospace and Ocean (6 students)*
> 2. *Biological Systems Engineering (18 students)*
> 3. *Chemical Engineering (0 students)*
> 4. *Civil and Environmental (2 students)*
> 5. *Computer Science (5 students)*
> 6. *Electrical and Computer Engineering (2 students)*
> 7. *Engineering Science and Mechanics (12 students)*
> 8. *Industrial and Systems Engineering (21 students)*
> 9. *Materials Science and Engineering (17 students)*
> 10. *Mechanical Engineering (2 students)*
> 11. *Mining and Minerals Engineering (34 students)*

Interestingly, in the workshop part of the class later in the week included a slide presentation on "Mining and Minerals Engineering" department.

The clickers provided instantaneous feedback to the instructors and on a number of occasions the authors took advantage of this opportunity to know students' "prior knowledge" of various topics and address the misconceptions. For example, while discussing the concept of "independent" and "dependent" variables in the context of an engineering experiment, following clicker question was asked to determine "prior knowledge":

> *For the following phrase which quantity is the independent variable?*
> *Elapsed time for various piston sizes*
>
> A. *Time*
> B. *Piston Size*

Student responses in a class of about 150 students were:

A. 40%
B. 55%
C. Invalid response 5%

After reviewing the class response, the instructors gave a brief explanation of the associated concepts that an experimenter measures the response of a system (dependent variable) to some changes he/she introduces (independent variable) and another question on similar concept was asked as below:

For the following phrase which quantity is the independent variable?
Varied time and recorded distance

A. Time
B. Distance

Student responses to this question were:

A. 89%
B. 3%
C. Invalid responses 8%

Clearly, a significant number of students showed a better understanding of the concept. It may also be mentioned that the clicker questions did not take significant amount of class time. Typically, the whole process of asking a single question, recording response, and responding to the response histogram took less than 90 seconds.

In addition to using clickers to collect data, online surveys were used to determine students' prior experiences and opinions regarding the course. Over 900 responses were collected from an exit survey. Figure 3 shows a histogram of responses to an exit survey question that read: "Did your understanding of the engineering design process improve as a result of the hands-on design projects in ENGE 1024?"

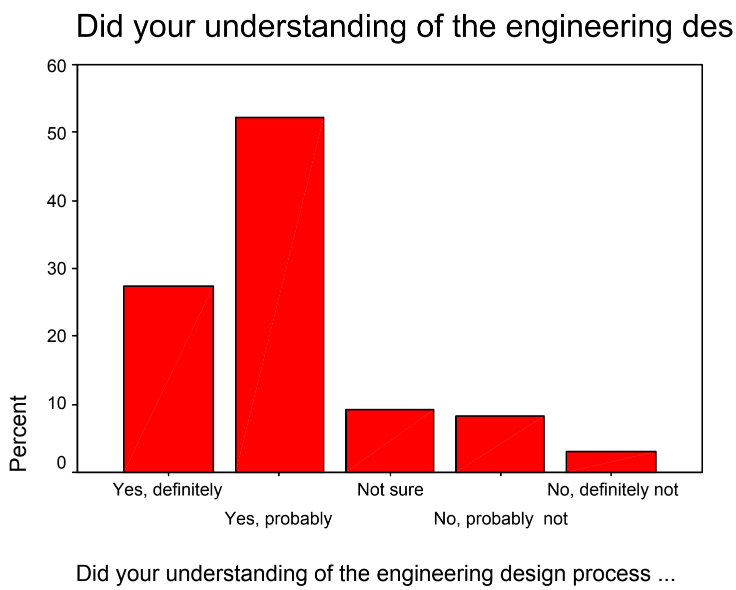


Figure 3: Exit Survey Response

It can be seen that more than 75% students seem to have learned from early design projects in the course. Also, the exit survey had a few free response questions like:

> *Question: What, if anything, did you learn in ENGE 1024 that you didn't expect at the beginning of the semester?*

Using a sample of 142 responses to the above survey question, commonly stated course topics are shown.

Ethics (27 responses)
Programming (22 responses)
Alice (20 responses)
Graphing (16 responses)
Nothing (13 responses)
Sustainable design (10 responses)
Object-Oriented Programming concepts (8 resposnes)
Engineering as a profession (6 reponses)
MATLAB (5 responses)
Teamwork (5 responses)

Sample responses from the aforementioend exit survey question are as follows. It may be noted that the responses are unedited statements by students.

- I learned a lot concerning ethics and sustainable design which I did not expect to be the primary focus of EngE 1024.
- In a word, Alice.
- I learned about professional, ethics, sustainable design, programming, etc. I basically did not know anything about the engineering profession until I took this class. I had also

never done any programming before, so it was interesting to do that. Therefore, I didn't know what to expect to learn in this class until I took it.

- The contemporary issues in engineering presentations were interesting.
- I did not expect to learn computer programming. I do not understand why engineers other than those in computer sciences need to know anything about it.
- Nothing at all, Class was by far the biggest waste of time and a pointless exerices, granted its a weed out class but at least tell us that upfront dont pretend to make this class something it isnt. This class has not even attempted to touch on any asecpts on Electrical Engingering, which is a shame. I think you should rename the class Busy Work 101 becuase that is what it is.
- The use computer programs such as MATLAB, Inventor, and Alice. I did not expect there to be so much focus on computer science-type things.
- graphing(loglog/semilog)
- That I would be this turned away from the engineering major. I feel pretty bad about how I did in this class.
- I'm not sure. Going into the class, I really didn't know what engineering really was and what it would be like or if I would even like if, so I didn't have any real expectations. But after taking the course, I feel more confident about what engineering is and I also know that I am very interested in it and I like it a lot.
- I definitely didn't expect to learn so much about the our connection as engineers to the world. We learned a lot about sustainability, cultural awareness, and professional responsibility and how it our job to make the right choices for the community.
- I did't know the huge relation that existed between ethics and engineering
- All the pointless stuff like graphing and MATLAB and all.
- I learned how to teach myself an entirely new subject because sometimes it wasn't explained in class. For example, flowcharting and MATLAB.
- How to apply my skills to a real life problem such as the water tower experiment and calculations.
- I really didn't have any expectations comming into this class, because orientation and description were not telling of what we would actually do. I was surprised at the breath of knowledge we were able to cover, I feel I was able to learn and retain a lot in this class. My study skills were also improved greatly.
- I didn't expect to be taught the proper sketching method or graphing on semi-log-y and log-log plots
- I didnt expect to learn about ethical issues such as those in New Orleans along with the contemporary issue projects. I found both of these very helpful in improving my presentation and teamwork skills.
- I thought that I would be studying this course with around 100 students, as in most of the classes it happens. But I was very lucky that I have gotten an opportunity to learn this course with few students. So our GTA or instructor can pay more attention tstudents.
- I feel like I can work with people better than I used to and can deal with juggling numerous tasks all at once.
- I didn't know that we would learn some basics of programming using Alice. We didn't actually program anything, but Alice was used to show how objects, methods, and functions work.
- I had never heard of sustainable design before. Also, working with Alice was fun.

- the enzyme kinetic lab that we did, and it's formulas that used to calculate the answers
- Nothing really, apart from a good practice on doing team works. Everything we covered was stated on the course outline and that was all I expected to cover.
- Computer Programming. I had no interest in this nor had I any experience in it. I learned how to make simple programs using software provided by the department. I have become more computer literate and friendly than I have been in the past.
- I didn't expect to learn programing, especially with respect to Alice. I don't understand the need for object-oriented programing in engineering.
- I learned about all of the different engineering disciplines which I may have not found out about by myself. I did not expect to start programming in this beginning course but I'm glad I did because I'm sure it will be really useful in the coming years.
- I learned how to manage my time better.
- I learned things about ethics and some other facts about the different fields of engineering that I had ignored to that point. I am happy that I took this class, because I feel that I am better prepared to answer question when someone asks why I want tobecome an engineer.
- I didnt expect to be able to program since i wasnt expecting to use alice. i also didnt expect to have to build a project from only certain materials, which i actually enjoyed alot. It made me think in a different way.

Although some student responses did include some insight into their feelings regarding topics covered in the course, many students only listed topics. Modifying the online surveys and conducting focus group interviews may provide more information regarding student perceptions of the course.

Summary and Future work

The ENGE 1024 course has undergone a number of changes in last 12 months. These changes are driven by pedagogy-based research, the need to introduce contemporary engineering issues including the concept of sustainability right from the freshman year, learning styles of students, and desire of EngE faculty to develop an enhanced engineering education research program. Data describing high school experiences, learning styles, computing skills, freshman year experiences, etc. are being collected, and it is planned to conduct longitudinal studies to assess the long term impacts of freshman year instruction. Some new hands-on activities emphasizing sustainability are planned for the spring 2006. For example, in spring 2006 a population related hands-on workshop has been piloted. Students worked in group of four to build 3D models using legos to represent the population of different countries on a map of the world. Each group examined geographic, literacy, population, environment, life expectancy, etc. related data of about 15 countries located throughout the world. These data were obtained from the CIA World Fact Book[22] . Students were then asked a few free response questions such as: *1)What are the most common "Environment Related Current Issues?" 2) What implication do these issues have for people living in these countries?*; their responses are being analyzed at the time of this writing. Another workshop on "mechatronics" will be piloted in spring 2006 which will involve building a robot and examination of sustainability concepts in mechanical/electrical/computer engineering disciplines.

The reformulation process of a course obviously takes a significant amount of faculty time and resources and students' perception is one key measure of the success. An example of an email about the course received by one of the authors of the paper on Feb. 27, 2006 is quoted below:

> *I felt that the field of engineering became much clearer after completion of Engineering Exploration. There are several valuable pieces of information that have been impressed upon me and that I will carry throughout my college/engineering career. The first being all of the opportunities available to engineers, especially at a research institution like Virginia Tech. Second, that the modern engineer must not only possess the power of knowledge, but maintain professional standards. Furthermore, I was taught how to use many tools such as the engineering design process, MatLab, the basics of Object-Oriented Programming, and how to effectively use graphing.*

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