Enhancement and Assessment of a Non-Traditional Engineering Design Course

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Abstract – At Northern Arizona University, an interdisciplinary sophomore design course – EGR 286 – has undergone a fundamental shift in its innovative and award-winning course structure. This shift is part of a Hewlett Foundation-supported development effort to encourage recruitment and retention of engineering students, with an emphasis on under-represented student populations. The course revitalization is centered upon enabling more direct student participation in design projects. It begins with two-person design teams that design, build and test weekly projects involving LEGO® parts, sensors, and the Robotic Command eXplorer (RCX). Control of the automated systems requires programming in both RoboLab (a LabView™ derivative) and in the "Not Quite C" (NQC) environments. The course develops in the semester to finally encompass larger design teams of fourteen students, with each team designing a complex, autonomous, robotic-styled system. An important part of this course development is the integration of assessment procedures that record the students' perception of learning and enthusiasm. We present an overview of the course enhancements and objectives. Assessment categories include the students' self-efficacy in their ability to design/build/test electro-mechanical devices, as well as their level of enthusiasm and motivation towards engineering as a chosen career. The assessments are accomplished before and after the course revisions for comparison.

Index Terms –Student retention, design education, engineering education, Legos, Mindstorms.

Introduction

The College of Engineering and Natural Sciences (CENS) at Northern Arizona University (NAU) is renovating the way it recruits, educates and graduates engineering students. With the aid of the William and Flora Hewlett Foundation, CENS is actively assessing its regional recruitment resources for incoming freshmen, as well as restructuring its courses to excite and encourage currently-enrolled students to stay in engineering. NAU is the smallest of three Arizona universities offering undergraduate engineering education programs. While the larger University of Arizona and Arizona State University (ASU) enrollments have increased since 1998, NAU CENS enrollments in engineering has remained flat.[1]

Enrollment must increase in order for the CENS to maintain a vital engineering education program and to increase CENS's availability to students from under-represented populations in the four-corners region of the Southwest. We subsequently applied for and received a five-year grant under the William and Flora Hewlett Foundation Engineering Schools of the West Initiative to aid in increasing ongoing enrollment. There are basically two ways to increase enrollment (and thereby inferred, graduations) of engineering students: 1) increase the numbers of entering freshmen and transfer students, and 2) increase retention of currently-enrolled students. The topic of this paper is primarily associated with retention of sophomore engineering students.

The “Design4Practice,” or “D4P,” curriculum is a series of innovative undergraduate classes which involve active learning laboratories for the students in each of their freshman, sophomore, junior and senior years. This program received the 1999 Boeing Outstanding Educator Award, in recognition of its quality and effectiveness in providing a well-rounded engineering design education.

Each D4P course builds on the previous design course with the threading of topical design content from course to course. The courses are team-taught by faculty and/or local engineering practitioners who are experienced in engineering design. The sophomore design course, EGR 286, is the course where students fully integrate their current level of engineering education with a semester-long, team-based design activity. EGR 286 was and is the cornerstone of the Engineering undergraduate design curriculum; its revision is the primary activity discussed in this research.

In the three-credit-hour EGR 286 course, under the old format, students experience the process of engineering design by actively learning and practicing design within a simulated corporate environment – an organization which develops and builds electro-mechanical systems for various external clients; the clients in some semesters may be actual external partners, or may be fictitious clients created by the faculty. These ‘robots’ are guided vehicles with integrated electrical and mechanical systems controlled by users via a software interface. The old format consisted of having large teams with mixed disciplines assigned to a single design project for the entire 15-week semester. The design teams were about 20-25 students in size, each comprised of Electrical, Mechanical, Civil, Environmental and Computer Engineering students. The proportion of these students varied with each semester, but typically the largest proportion of students were Mechanical Engineering students, followed by any number of combinations of the remaining disciplines.

The basis for mechanical prototyping is Legos®

Legos were used in both the old and new course format for a very simple reason: These literal building blocks allow for physical prototyping without the student needing to have great mechanical skills. Another equally important reason: The educational institution does not need extensive manufacturing facilities for constructing prototypes if Legos are the primary mechanical prototyping media. It should be noted here that, in the old course format, some limited custom parts were allowed to be fabricated. Typically, student teams preferred to stretch the ‘limited’ definition, constructing much of the robotic system out of fabricated parts (Figure 1); such preferences typically earned them unknown difficulties during the design process.

Using Legos for physical prototyping is very prominent in undergraduate engineering education. [2, 3, 4]. The use of Legos to allow a design process to culminate in a physical product for even the earliest of undergraduate classes. Many freshman engineering courses use Legos in this manner. [5, 6] Legos can also be used at higher levels with the use of the robotic controller, Mindstorms® RCX. [7, 8] Based upon these prior success cases, the EGR 286 revision incorporated the RCX as a controller and eliminated the use of custom circuit prototyping, interfaced with a PC and C++ custom software. Custom circuitry was a frequent source of serious difficulty for the course, due to a frequent imbalance of enrolled students with basic circuits education for any given semester.

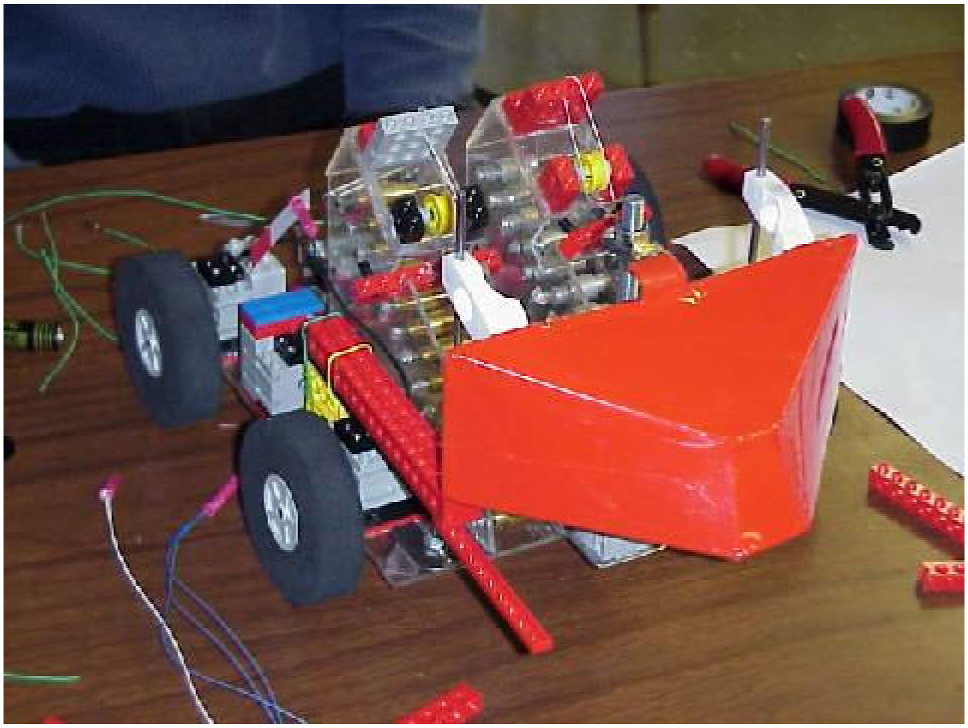

Figure 1. EGR 286 design, Fall 2001. A 'search-and-rescue' robot, conprised of a mixture of Legos and fabricated parts.

The EGR 286 course format was changed for a variety of reasons; the basic reasons include attempting to increase retention of sophomores into their junior year, increasing individual student participation in team design, using a modular project structure for recruitment purposes, and providing more timely technical knowledge to the students for the projects.[9] The purpose of presenting this paper is to illustrate the assessment process integrated in the course and to publish the preliminary assessment results from the first offering of the new course revision. Nevertheless, a brief summary of the course revisions are in order, such that the assessed results from the first offering can be discussed properly.

Overview of Course Enhancements

The course was changed to accommodate several objectives:

1. Encourage continued enrollment in the engineering program.
2. Incorporate a small team design format.
3. Technical knowledge is transferred to students in an active-learning format.
4. The technical knowledge provided to the students directly supports the large team project.
5. Continue oral presentations required of all students.
6. Continue written design report requirements.
7. Incorporate project management issues, but not as the top priority in the class.
8. Allow for student teaching assistants (TAs) to assist in the active learning process.

In support of the above objectives, the overall course progression was designed as is schematically shown in Figure 2. The first nine to ten weeks of the semester would involve teams of two students each. The small teams would work on *weekly* projects which address specific technical issues of the larger project to come (the last short projects were 2 weeks in length). Each weekly project started on a Monday and ended on a Friday with a demonstration of their robot. The robot was built mostly during the class hours, though the teams were allowed to take the materials home with them for additional work time. Instructors and student TAs are available to assist the students with problems they may have during this process during a 'recitation period;' two were offered each week. After a demonstration, each small team turns in a 2-page design summary report.

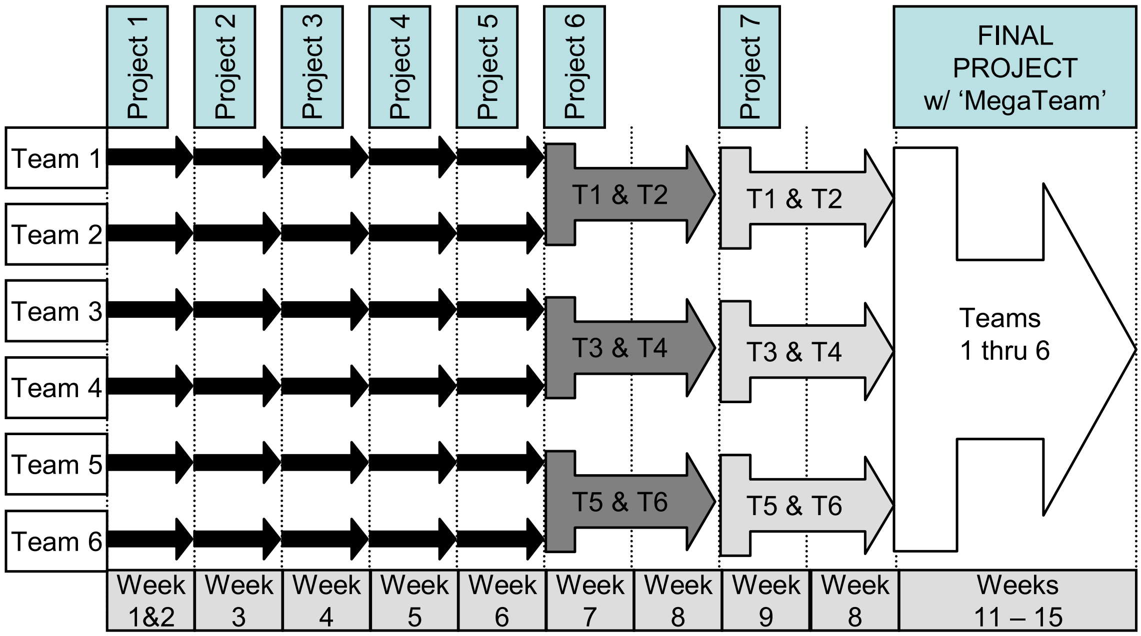

Figure 2. Course Progression. Note: Typically, 12 or more teams are in one class.

The course would culminate in a complex robotic project, requiring the efforts of roughly 12 to 15 students in a single "megateam." This "large project" (also known as the "final design project") would only be addressed in the last five to six weeks of the semester. At least one oral presentation was required of each student during the final project phase as part of one of three weekly megateam presentations. This presentation was accomplished in the context of a three-stage design process: Conceptual, detailed, and final design phases. With larger numbers of students working together, an anonymous peer review evaluation process was in effect within each megateam for the remainder of the semester, to assist the instructors in assigning individual grades.

By working in smaller teams at the start of the semester, individuals would gain immediate ownership of the technical knowledge required to tackle the larger, complex final project. The smaller teams also begin to work in larger groups by being paired with other teams for projects 6 and 7; this procedure allows for a 'growing' of teamwork and planning in intermediate-sized groups of four students, before being finally organized into a single, large megateam for the final project.

The class would still use Legos as the basis for mechanical design, though in this course *no custom fabricated parts were allowed*. As presented earlier, RCX programming module would be the controller for the robotic designs (previously, all software was PC-based). *All* students would be required to learn both RoboLab and NQC in the small projects as well as the large project. Each small team would have an RCX as the core controller for their project, and the final design project would incorporate at least one (typically, more than one) RCX in its controlling system.

The practices of planning, resource allocation, and scheduling were a major component of the former EGR 286 course format, throughout the entire semester. However, with the emphasis on providing more complete technical information to the students in the new format, the project management issues were de-emphasized during the first nine to ten weeks for the small projects. This topic was addressed in the final project, but not as in-depth as with the old course format.

In the past, student TAs were never allocated to this course, even though up to seventy students could be in a single classroom for active learning sessions. The new course format insisted upon inclusion of such assistance; the Hewlett Foundation funds, plus other local undergraduate research funds, allowed for a trial of using student TAs. In addition to being available to the enrolled students during recitation sessions, the student TAs set aside regular office hours for assisting enrolled students outside of class and recitation hours.

Assessment Approach

There are several assessment instruments used to guide the development of the EGR 286 course changes. These instruments are:

- Course-specific assessment surveys
- Student interviews
- Student Skills/aptitude self-assessment surveys

Course-specific Assessment Survey

A twenty-two item survey was designed to assess how well the revised course was meeting its primary instructional objectives as well as to assess student perceptions of the learning environment and course structure. The survey was administered in Spring 2004 to the EGR 286 class, taught under the 'old format.' That same survey was subsequently administered to students in the revised EGR 286 in Fall 2004. This procedure allowed for a pre- and post-revision comparison. Survey items included questions related to students' self-confidence in their abilities to take a project from the design phase through building and testing, attitudes toward the way the course was structured, and the relationship of the course to both their studies and the real work world.

Student and Teaching Assistant Interviews

Two sets of focus group interviews were conducted at the end of the revised EGR 286 course: one with students taking the course and one with the teaching assistants helping in course delivery. To allow for a freer discussion, the course instructors were not present during the interviews. The interviewer is a member of the College of Education who specializes in assessment and evaluation; as such, she was unknown to the students and had no influence on student grades for the course.

EGR 286 students were interviewed as a group at the end of a class period in the 14^{th} week of the semester. The number of students (approximately 45-50) was larger than ordinarily desired for interviewing purposes. The majority of students participated in the discussions which centered on course content, structure and delivery.

The four student TAs for the course were interviewed together, separately from the class-enrolled students. All four TAs were junior or senior engineering majors who had taken the course in previous years before it had been revised, giving them a unique insight into the revised format for the course.

Student Skills/aptitude Self-assessment

The course format includes a skills/aptitude assessment survey given to the students on the first day of class. The surveys query the students to assess their view of their own capabilities in various areas, specifically in the areas of

a) Computer skills,
b) Writing skills and knowledge,
c) Verbal skills,
d) Teaming attitudes, skills, and knowledge,
e) Other skills and abilities.

There were three levels for these questions that the students could assess: None, Low, Medium or High, scored as 0, 1, 2, and 3, respectively. For example, a student might self-assess a 'none' skill level for a particular category or question at the start of the semester, and a value of 'high' at the end of the semester. As such, their change in skill would be a +3. Thus, the maximum and minimum change expected for any student would be +3 and –3, respectively.

These surveys were *not* anonymous, for they were used for two purposes:

1) To put the students in initial 2-person agile design teams.
2) To compare with another set of surveys given to the students at the end of the semester.

The instructors used the student skills/aptitude self-evaluations as a rough guide to put students with weak skills (primarily in computer skills) with those having stronger skills. This method allowed for no team to be overly disadvantaged; however, most students had little computer programming skills at this stage in their education, given that the Computer Science department had opted out of requiring the EGR 286 course in the past several semesters. Another category considered at a lesser level was in the "Other skills" area: A "knowledge of machines" question was addressed if neither team mate showed great or small confidence in computers.

This self-assessment survey was again given to the students at the end of the semester; as the first survey documents were not handed back to the students. The students did not use them for referencing their second set of answers, after the course was essentially finished. Once the students filled out the second, identical self-assessment skills/aptitude survey, they were handed back their original surveys for comparison. They were required (as part of a final exam assignment) to compare their two survey results and comment about any changes they found from the comparison. They were told explicitly that those changes in *either* direction of increased or decreased skills/aptitude assessments were considered as acceptable by the instructors. Their results were turned in and graded solely upon their writing ability; however, their changes were tabulated for purposes of assessment for this course.

Results

Course survey and student interviews

Six items on the course survey revealed differences between students in the class prior to the revision and students in the revised course that were statistically significant (Table 1).
Four of the six items involved students rating their confidence levels with respect to skills that were gained during the course, with a rating of 1 being "no confidence" to a rating of 5 being "very confident". The final two items were rated on a scale of 1 to 5, with 1 being "strongly disagree" and 5 being "strongly agree.

In the revised course format, students rated themselves significantly more confident in their understanding of simple sensors and simple motor control. They also rated themselves more confident in their ability to program a control system for a simple robot and in designing systems to meet desired needs and specifications. These results support the course revision efforts to increase technical content in the course. We also believe the students gained confidence in the latter category due to requiring their small teams to reflect on their designs in their short design summary reports for each project.

Students in the revised class were in stronger agreement that team sizes fostered greater participation (Table 1). Survey results and interview discussions indicate that students believed the initial small team sizes were effective in many ways. Small team sizes guaranteed the participation of all students rather than a few. When the course was taught in the old format, using large teams of fifteen or more students for the entire semester, a frequent criticism was that a few students in the group did the majority of the work while others did little.

Students in the revised course also enjoyed the small team sizes because it gave them an opportunity to work at all aspects of the project. In the old format, much of the workload was assigned by the instructors to discipline-specific students: Circuit design/construction to Electrical Engineering, programming to Computer Engineering, and mechanical design/construction to Mechanical, Civil and Environmental Engineering students. In the new format, the custom creation of circuits, software, and mechanical parts were minimized by restricting all designs to the use of Legos, the RCX, and either RoboLab or NQC. Thus, *all* students were expected to contribute in technical design to all portions of their creations.

The student TAs saw small, interdisciplinary teams as providing students a view into engineering disciplines other than their own declared majors, which allowed them to "learn a little of the other engineering languages" and "to create an environment where everyone can learn what others know". TAs for the course commented that the smaller team sizes also allowed for greater student-instructor contact, and fostered more personal interaction between the students in a team.

A final pre-post revision comparison on the survey involved motivating students to continue in engineering as a profession. This item was actually rated higher by students in the course prior to revision (Table 1) where they expressed stronger agreement with the statement "This course has motivated me to continue in engineering as a profession". As one of the primary objectives for the course revision is to increase student retention in engineering, this result is of great concern to the instructors. However, there is some indication that many of the student criticisms related to this issue reflected issues that arise when a course is being taught for the first time.

As an example: There was a philosophy of the instructors not to give the students all of the information on some projects at the start, so that the students would be forced to discuss the project with their teammate(s), analyze the problem, note any information they needed, request it and then receive that information at the next class period. This procedure was instituted on several of the short projects because of the instructors' observation that students were going directly from the design problem definition to "fiddling" with Legos, without laying out a reasoned design approach and plan of construction. However, the students in post-class interviews believed that in these design projects, the instructors changed the design requirements late in the week (or late in the design phase, for the final project). Their perceptions lead to them being discouraged in this course to some extent, as noted above.

Table 1. ratings for outcomes of the revised EGR 286 course.

	N	Mean	SD
I understand the basics of simple sensors.			
Spring 2004	27	3.11	1.423
Fall 2004	50	4.48**	.677
I understand simple motor control.			
Spring 2004	27	4.07	.917
Fall 2004	49	4.55*	.614
I feel capable of programming a control system for a simple robot.			
Spring 2004	27	2.19	1.272
Fall 2004	50	3.72**	.904
I am able to design a system, component or process to meet desired needs.			
Spring 2004	27	3.96	.706
Fall 2004	49	4.31*	.652
When working on design projects, the size of the teams was small enough to make it easy for all students to actively participate.			
Spring 2004	27	2.96	1.224
Fall 2004	50	3.94**	.978
This class motivated me to continue in engineering as a profession.	27	4.30*	.775
Spring 2004	48	3.81	.960
Fall 2004			

* significant at p<.05
** significant at p<.01

When interviewed, students suggested that the course *was* motivating to them in a variety of ways. They commented that the frequency of the projects gave more them more repeated exposure to the design process, allowed them to work on every part of the project, including programming, and set them up to work on a greater variety of projects which kept the course and content more interesting to them.

Teaching assistants offered a different view of the course design as a motivating factor. When they took the course under the old format, they felt that the greatest excitement came at the end of the semester when they were actually building their single design project prototype. They viewed the more numerous short projects in the revised course offering as positive; students experienced the excitement of the design, build and test process during nearly every week of the semester. They commented on the positive energy in the classroom and high level of student engagement, when each small project was demonstrated during the course of the semester.

The TAs themselves thought it was an invaluable experience. They felt that they had more opportunities to learn communication skills in working with students. They learned a lot with respect to programming. The experience gave them a lot of opportunities to problem solve in working things through with students and in "thinking on the fly". They also saw it as gaining a bit of managerial experience.

Student Skills/aptitude Self-assessment

The skills/aptitude self-assessment survey was an ad-hoc instrument used for several years by the EGR 286 faculty as an open-loop control to guide them in evaluating their instruction. As such, a central database of these surveys were not retained past a semester; much of the data from previous years were lost. Nevertheless, data from Fall 2001 (old format) was recovered. This data, plus Fall 2004 (new format) were available and will be discussed in the results section.

The skills/aptitude survey had 50 skills/aptitude category questions; all will not be individually covered here. However, of particular interest is the students' average assessment of their improvement (or degradation) the skills/aptitude after the course was over. The average change in the student population's skill assessment must range between –3 and +3. Thus, small values near 0 are considered to be essentially neutral changes.

For both the old and new formats, all 50 categories showed the students on average either improved their skills/aptitude or remained neutral. The average improvement scored by the two class sessions (Fall 2001 and Fall 2004) were, on average, significantly different within the student scoring: In Fall 2001, the average improvements for the entire 50 categories were 0.52, and in Fall 2004, 0.31. As the survey is subjective, we look at the top five categories of change for each of the courses separately, as shown in Table 2. As the emphasis was in increasing technical content in the revised course, it is natural to see the students perceiving an increase in technical skills for Fall 2004. The old format emphasized project management; as such, scheduling and presentation writing was in the top categories, though robotics understanding was also considered improved as well.

One category of concern was "Understanding design and what design engineers do." This question was badly worded, since two concepts were rated in a single question. Nevertheless, in the old course format, students rated this category as improved. In the new revision, it was scored an average of 0.18, virtually a non-improvement. The course developers are sensitive to the de-emphasis of the design process in the first revision, due to the compressed 5-week final design project. They consider it an indicator of improving the topical content of the course materials in future revisions. It is also possible that the students did not gain an increased appreciation for the engineering profession (due to the double topic wording). This problem is highlighted in the Course survey and student interviews section, above.

Table 2. Top five average student self-improvements from Fall 2001 and Fall 2004.

Category	Average score	Class offering
A systems Understanding of Robotics	1.03	Fall 2004
Computer Programming	0.97	Fall 2004
Knowledge of Technical Report Writing	0.68	Fall 2004
Circuits Analysis Software	0.63	Fall 2004
Presentation Software	0.63	Fall 2004
Presentation Software	1.53	Fall 2001
A systems Understanding of Robotics	1.53	Fall 2001
Scheduling Software	1.06	Fall 2001
Understanding design and what design engineers do	0.94	Fall 2001
Knowledge of Technical Report Writing	0.88	Fall 2001

Conclusions

The revised course format will be further revised in the coming semester. Using small teams at the start and improving technical content have shown positive results from the formal and ad-hoc survey instruments, plus the student interviews. However, due to less positive results in imparting the design process to the students under the new course format, the instructors will improve the emphasis of the design process during the semester. This process, simply put, is to 1) designing an engineered product, 2) building the product according to the design, and 3) testing the product to measure against the specifications first set forth in the first stage. This emphasis will be imparted in the long final project, where the students have more time to break their time down into three distinct phases of engineering development.

The instructors will also include more "engineering as a profession" content in the next course offering, such that the students will gain increased professional knowledge and motivation to stay in engineering. The instructors will incorporate examples of engineering design accomplishments; for example, the Boeing 777 development process.[10] These examples will be related to the student design activities of the EGR 286 course, in order to give the students an improved appreciation towards their chosen profession.

There will be some consideration in the method of withholding some information for certain projects, in order to require the students to deeply analyze the project before attempting to build with Legos. When undertaking this procedure, the instructors will make clear to the students that information is vague on specific topics, so that they will understand clearly that they must analyze the design problem in order to provide feedback to the instructors at the next class session. Nevertheless, the second offering of the revised course will also allow the instructors to polish the design problems for better delivery to the students.

In closing, there were two particular examples of students from the revised course which give heart to the researchers in this course revision. Two students enrolled in the new course revision after having failed the course under the old format. They provided comments in their "final exam," which was an essay of their experiences, knowledge and skills gained (or not) from the course.

The first student had taken EGR 286 before, but had difficulty contributing in a large team (20-25 students) under the old format; his difficulty likely stemmed from his permanent physical disabilities, resulting from a severe automobile accident. A quote:

> "As a student who was in another EGR 286 class under the old format, I would say that this format is 100% better than the old. I think it is mainly due to …having weekly projects with tangible results."

The second student, of Native American descent, noted his improvements in verbal communication. He had particularly valuable comments for the researchers, relative to his underrepresented population in engineering:

> "...I have also improved on my ability to effectively communicate in both formal and informal presentations. For myself, there has always been a kind of cross-cultural gap in my communication. In my upbringing, it is considered extremely rude to interrupt when someone is talking. However, among the larger population, this is an aspect of normal conversation. Working in teams helped me to assert and present my ideas to others."

He also states (in bold is authors' clarification),

> "Overall, I felt that this was a very good course. I have the perspective of taking the course previously in the fall of 2002. In that course, the teams were huge in comparison. The entire semester culminated in a final project. Early on, it was easy to fall back in the shadows. This new method **of teaching** allowed for much greater individual participation. In the old course, the work load was not evenly distributed among the team members. …I felt this **current teaching** arrangement allowed every student to get a taste in all aspects of project development. Beginning with the smaller teams on multiple projects is the most important improvement made to the course."

Acknowledgements

This research was accomplished under a grant by the William and Flora Hewlett Foundation, as part of the Engineering Schools of the West initiative. The NAU Hooper Undergraduate Research Assistantship Program also contributed to this research effort.

Bibliography

[1] ASEE Profiles for Engineering Colleges – **http://www.asee.org/publications/colleges**
[2]Jolley, W., Rencis, J., Cobb, E. and Hagglund, R. "Incorporating a LEGO fourbar mechanism project in undergraduate dynamics" Proceedings, 32nd ASEE/IEEE Frontiers in Education Conference, Boston, MA, November 2002.
[3] Flikkema, P. "Learning Embedded and Real-time systems via low-cost mobile robots," Proceedings, ASEE Annual conference and exhibition, session 1332, 2001.

[4] Wang, E. L., LaCombe, J., and Rogers, C., "Using LEGO® Bricks to Conduct Engineering Experiments," Proceedings, ASEE Annual conference and exhibition, session 2756, 2004.
[5] Goff, M. and Vernon, M. "Using LEGO RCX bricks as the platform for interdisciplinary design projects"proceedings of the ASEE Annual conference and exhibition, session 3425, 2001.
[6] Shih, A. and Hudspeth, M. "Using the LEGO robotics kit as a teaching tool in a project-based freshmen course" proceedings of the ASEE Annual conference and exhibition, session 1353, 2001.
[7] . Campbell, M.I. "Teaching machine design through product emulation" proceedings of the ASEE Annual conference and exhibition, session 2366, 2002.
[8] Moor, S.S., Piergivanni, P., and Keyser, D. "Design-build-test: flexible process control kits for the classroom," Proceedings, ASEE Annual conference and exhibition, session 1526, 2003.
[9] Tester, J. T., Hatfield, J., The Design4Practice Sophomore Design Course: Adapting to a Changing Academic Environment, Proceedings, American Society for Engineering Education (ASEE) Annual Conference and Exposition, Session 3430, 2005
[10] Sharma, K.J.; Bowonder, B., "The making of boeing 777: A case study in concurrent engineering," International Journal of Manufacturing Technology and Management, v 6, n4, p 254-264, 2004.

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