The Role of an Introduction to Engineering Course on Retention

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Abstract – Introduction to Engineering is a course for freshmen engineering students at Armstrong Atlantic State University. The main objectives of this course are to excite students about engineering, cultivate problem-solving skills, encourage creativity in design, emphasize professionalism, team work and communication skills, and introduce essential mathematics and science skills. Currently, the course is a combination of lectures as well as project-based materials. While it does excite and motivate students about engineering, it is not clear if it prepares them adequately for the intense, mathematics and science based curriculum ahead. This paper presents an investigative study and analysis of retention rates with the objective to answer the following pertinent questions: What role do courses such as this play in influencing and motivating freshmen engineering students i.e. on their retention rates? What changes need to be made in this course to better prepare students for the rest of the engineering curriculum?

Keywords: Freshman engineering courses, retention rates, mathematical readiness

INTRODUCTION

Poor retention rates and student success is a significant and growing problem in all science, technology, engineering and mathematics (STEM) disciplines. There are several factors that influence retention in engineering including but not limited to [1]: (i) the level of mathematics and science preparation, (ii) the level of faculty-student interactions in and out of class, (iii) the efficacy of introductory engineering courses, (iv) the efficacy of advising, mentoring and student learning support systems and (v) the level of interest and motivation. In addition, factors such as the diversity (academic, ethnicity, gender, etc.) of the student body [1]-[4], availability of faculty resources [5], etc. also influence retention. While it is not always possible to perform a quantitative analysis to determine which one or more of the above factors play an important role on retention at a specific university, the ability to identify key factors that predict academic success can be an important tool in developing and implementing timely and focused interventions to improve retention rates [6].

Engineering faculty continue to develop and implement innovative programs that focus on improving student retention. One such program, called Teamwork, curriculum Integration and Design in Engineering (TIDE), was implemented at the University of Alabama with an emphasis on improving four areas of undergraduate engineering education [7]: (i) curriculum integration, (ii) team work and collaborative learning, (iii) technology in the classroom and (iv) continuous assessment and evaluation. The primary goal of this program was to improve student learning and towards this end, course topics were rearranged to achieve a better integration between chemistry, mathematics and physics and the students worked in same teams in all courses. A similar program, called Engaging Early Engineering Students (EEES), is being developed at Michigan State University with an objective to not only

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understand the factors contributing to retention, but also to use a structural equation model (SEM) to do so [8]. The program targets students in courses such as pre-calculus algebra and trigonometry, calculus I, physics I and computation based problem solving to prepare them for upper level engineering courses. A unique faculty development program, called Gaining Retention and Achievement for Students Program (GRASP), was developed at New Mexico State University based on the fundamental assumption that faculty are crucial to student retention [9]. This program focuses on incorporating faculty's teaching behaviors which are beneficial to student success to improve retention.

In addition to programs focused on improving retention, universities also have introductory engineering courses in their curriculum to better prepare entry level freshmen students for the rest of the engineering curriculum. Most of these courses have a two-fold objective: (i) to motivate students to continue in the engineering program and (ii) to increase the mathematical, analytical and soft skills such as team working, communication, etc. of these students. To this effect, faculty at the University of Wisconsin –Milwaukee have implemented a one-semester course involving engineering applications and experiments offered concurrently with college algebra and trigonometry [10]. The purpose of this course is to have potential engineering students use the mathematical skills they are currently learning and apply them to engineering problems with the objective to retain students who may otherwise become disenchanted with their delayed access to engineering courses as well as to improve information retention from these courses. A similar initiative at Wright State University introduced a freshmen engineering mathematics course taught by engineering faculty with lecture, laboratory and recitation components [11]. A long-term goal of this initiative is to shift the traditional emphasis on mathematics prerequisite requirements to an emphasis on engineering motivation for these mathematics requirements.

Another approach involves the use of a multidisciplinary introductory course with a holistic approach in which all freshmen engineering students are exposed to different engineering disciplines though a combination of lectures, projects and seminars [12], [13]. Such courses are team taught by faculty from the different departments/disciplines. Similar Project Based Learning (PBL) approaches are also used by faculty at California Polytechnic State University to encourage creativity, collaboration and context in a first year engineering course [14]. This course is based on three tenets: (i) the course draws from and teaches about the interesting and relevant domain with which students are already familiar, (ii) encourages team work and collaboration and (iii) the student is actively responsible for their education. An advantage of such multidisciplinary, holistic approaches is that these courses can also prove beneficial to those students who decide to change majors from one engineering discipline to another or to a non-engineering major. A one-hour introduction to engineering course implemented at Mississippi State University was designed keeping this in mind [15]. The one hour format was chosen so as not to interfere with the other academic courses. The course material was divided into two categories: (i) general college success strategies applicable to any major and (ii) introducing the different engineering disciplines with an emphasis on helping students realize the magnitude of academic challenges they are undertaking with tentative graduation dates, etc.

Background and Motivation

The Engineering Studies Program at Armstrong Atlantic State University (AASU) offers three programs where students complete their freshmen and sophomore years of the engineering curriculum at AASU and transfer to the Georgia Institute of Technology (GT) to complete their degrees: (1) the Georgia Institute of Technology Regional Engineering Program (GTREP), (2) the Regional Engineering Transfer Program (RETP) and (3) the Georgia Institute of Technology Engineering Alliance (EA) Program. The EA program is relatively new and has been in effect since Fall 2008. It is a dual enrollment program in which engineering students accepted for admission to GT enroll and complete the first two years of the engineering curriculum at AASU. Over the past ten years, the Engineering Studies Program at AASU has grown significantly from about 185 students to 350 students. However, retention or successful transfer rates of students via the GTREP and RETP programs continue to be significantly low with an average of 35% of incoming freshmen engineering students successfully transferring to GT over the past nine years.

Introduction to Engineering (ENGR1100) is a multidisciplinary, freshmen engineering course at AASU in which students are introduced to the engineering process from problem formulation to the evolution of creative design. The only pre-requisite for ENGR1100 is College Algebra or a 550 mathematics score in the Scholastic Aptitude Test (SAT). In addition, most local high schools offer limited advanced placement (AP) mathematics and science classes. Hence, the majority of the students have limited or no calculus and/or science knowledge. Currently, the course is a combination of lectures as well as project-based materials. While the current structure and corresponding implementation appears to excite and motivate students about engineering, it is not clear if it prepares them adequately for the intense, mathematics and science based curriculum ahead (an objective of the course).

This paper presents an investigative study and analysis of retention rates of this program with the objective to answer the following pertinent questions:

- What are the primary factors that influence the student retention rates in the Engineering Studies Program at AASU?
- What role do courses such as ENGR1100 play in influencing and motivating freshmen engineering students to continue in the engineering discipline?
- What changes need to be made in ENGR1100 to better prepare students for the rest of the engineering curriculum?

The following sections present a description of the course under consideration, assessment data based on students' perspective of the course, assessment based on failure rates in freshmen and sophomore engineering courses – faculty's perspective of the course, and a few concluding remarks with an outline of future work.

COURSE DESCRIPTION: INTRODUCTION TO ENGINEERING

Introduction to Engineering (ENGR 1100) is a 3-credit hour course taken by all freshmen engineering students. In this course, students are introduced to the engineering process from problem formulation to the evolution of creative design. The current, specific objectives of this course are to

(1) excite students about engineering,
(2) cultivate problem-solving skills,
(3) encourage creativity,
(4) cultivate professionalism,
(5) emphasize the importance of team work and communication skills, and
(6) introduce essential mathematics and science skills.

An approach to objectives (1)-(5) is through the use of several 1-2 week projects implemented through the semester and a final 6-week engineering design project. Objective (2) is also met by assignments (in-class and homework) which are based on topics that are covered during class lectures. However, with the limited mathematical and science background of the students in this course, these topics are not covered in detail with the result that objective (6) is not being currently met adequately. Further details that support this are presented in the next section on assessment. In order to address this issue, the instructors are currently investigating other approaches that would better prepare the students for the intense, problem solving, mathematics and science based curriculum ahead.

Course Content

This course, which meets either as 3 x 50 minute sessions or as 2 x 75 minute sessions, is currently taught as a combination of several lecture modules interspaced with projects. A list of topics and projects covered are shown in Table 1.

Table 1: Topics and projects covered in ENGR1100

Topics (covered in lectures and assignments)	*Projects*
o Introduction to engineering: various engineering disciplines, career options, etc. o The engineering design process o Units and dimensions o Vectors o Newton's laws of motion o Mechanics: free body diagrams, etc. o Electrical circuits o Engineering ethics o Technical communications	o Research projects on select: engineering companies, historical engineering disasters/failures, famous engineers, and/or other engineering topics o Engineering graphics: SolidWorks, AutoCAD, and/or Google sketchup o Mechanical assembly/dissection of a product o Electrical circuits o Robotics: Lego Mindstorms or Boe-Bots o Engineering design project

The projects, which are primarily team projects, range from hands-on projects, computational projects using CAD and other software packages, to research based projects with end products such as written reports and/or oral presentations. The engineering design process is introduced in class lectures and then implemented in design projects. Student-teams are allowed to select topics for their final projects based on their personal and academic interests. The instructors (the authors) serve in an advisory role for the projects providing guidance as needed encouraging the student-lead teams to be creative and resourceful.

The topics covered in class lectures introduce students to fundamental engineering concepts with an emphasis on problem solving. These topics are typically suggested by most introductory engineering textbooks. However, based on the instructors' experience, students with limited mathematical and scientific backgrounds do not appear to grasp or retain these concepts beyond a superficial level that is ineffective as a foundation for later development.

Overall, students in ENGR1100 possess a broad range of academic backgrounds and a diverse set of interests, which has posed a challenge in developing a course content that engages all students concurrently. Currently, a customized textbook is used for the course consisting of selected chapter topics written by various authors, though the material in the textbook is only used as reference [16]. It is proposed that the authors develop a new customized course textbook to more closely address the varying skill levels of AASU's student population in ENGR1100, which would be beneficial and would help mitigate some of these issues.

Teaching Pedagogy

In ENGR1100, faculty have attempted to incorporate various modalities of delivering instruction consistent with modern teaching methods suggested by educational literature [17]. Students have access to a course website where class notes, lecture slides, projects, homework and other relevant and useful links are posted. The course has been delivered using traditional lecture slides, short videos, class discussions and hands-on activities. In addition to standard quizzes and exams, student performance measures have also included oral presentations and written reports, in-class projects, etc. Some projects have also incorporated the use of relatively new technologies such as developing YouTube videos (relevant to an engineering project), or Computer Aided Design with a 3D parametric modeler, while others have been designed to excite the students who enjoy working with their hands by requiring the construction of simple mechanical devices from common objects.

The course is graded on an A-F scale rather than a simple pass/fail in an effort to ensure that the students take the class seriously as it does contribute towards their overall Grade Point Average (GPA). It is also noted that the course is currently taught by tenured full-time engineering faculty so as to promote early faculty-student interaction.

ASSESSMENT: STUDENTS' PERSPECTIVE OF COURSE

One of the important factors in evaluating retention is the student's perspective [18]. This section presents the assessment of the effectiveness of ENGR1100 from this perspective. Surveys were given to students in other freshmen and sophomore engineering courses to complete and return anonymously. The survey consisted of the following five questions:

1. What are TWO important lessons/principles that you learnt from ENGR1100? Students were given six distinct choices (shown in Table 2) to select from.
2. What TWO topics did you enjoy most in ENGR1100? Students were given four choices (shown in Table 3) to select from with an additional option 'Not Applicable (N/A)' if projects were not used in class.
3. Would you say that ENGR1100 is relevant to current courses you are taking?
4. Would inclusion of more hands-on activities and projects have benefited you (better prepared you for current courses)?
5. Would inclusion of more material on basic mathematics and physics concepts have benefited you (better prepared you for current courses)?

Students were asked to provide written comments to justify their 'Yes or No' responses to questions 3-5.

Tables 2 and 3 provide statistical data based on the various responses to questions 1 and 2 respectively and Figure 1 shows the responses to questions 3, 4 and 5 with a summary of written comments in Table 4. It is noted that only students who had completed ENGR1100 at AASU were asked to complete the survey (a sample size of 46 students).

It is observed from Table 2 that a total of 80.43% (from each of the combinations shown) of the students consider 'team working and communication skills' as one of the important lessons learnt in the course and a total of only 8.70% consider 'mathematical skills' as one of the important lessons learnt. It is also observed from Table 3 that a total of 76.09% of the students enjoyed the design project which introduces the engineering design process, teaches team work and communication skills and promotes creativity. Note that all the projects mentioned in Table 3 were not implemented in all the sections of the course. The engineering design project is however, implemented in all sections in different forms.

Table 2: Students' responses to question # 1

Q1: What are TWO important lessons/principles that you learnt from ENGR1100?(combinations selected by students from given choices A-F)		*# of students*	*% of students*
A: Basic mathematical skills	B: Fundamental concepts in physics	1	2.17%
A: Basic mathematical skills	C. Fundamentals of units and dimensions	2	4.35%
A: Basic mathematical skills	E: Team working and communication skills	1	2.17%
B: Fundamental concepts in physics	C. Fundamentals of units and dimensions	4	8.70%
B: Fundamental concepts in physics	E: Team working and communication skills	8	17.39%
C. Fundamentals of units and dimensions	D: Programming skills	1	2.17%
C. Fundamentals of units and dimensions	E: Team working and communication skills	13	28.26%
C. Fundamentals of units and dimensions	F: Time management skills	1	2.17%
D: Programming skills	E: Team working and communication skills	2	4.35%
E: Team working and communication skills	F: Time management skills	13	28.26%

Table 3: Students' responses to question # 2

Q2: What TWO topics did you enjoy most in ENGR1100? (combinations selected by students from given choices A-D).		*# of students*	*% of students*
A: Project Lego Mindstorms	N/A	1	2.17%
A: Project Lego Mindstorms	C. Project Mechanical Assembly of a Product	3	6.52%
A: Project Lego Mindstorms	D: Engineering Design Project	9	19.57%
B: Project Electrical Circuits	N/A	2	4.35%
B: Project Electrical Circuits	C. Project Mechanical Assembly of a Product	3	6.52%
B: Project Electrical Circuits	D: Engineering Design Project	9	19.57%
C. Project Mechanical Assembly of a Product	D: Engineering Design Project	14	30.43%
D: Engineering Design Project	N/A	3	6.52%
N/A		2	4.35%

The students' responses to questions 3-5 are shown in Figure 1. While the majority (76.09%) of the students agree that ENGR1100 is relevant to current courses, a similar majority also agree that the inclusion of more hands-on activities and projects as well as more material on mathematics and physics concepts would have been beneficial and better prepared them for current courses. These seemingly contradictory student responses actually suggest the need to develop hands-on activities and projects that better incorporate basic mathematics and physics concepts, especially those seen in latter courses and with clear engineering applications.

A summary of the written comments that students were asked to give to justify their responses to questions 3-5 are shown in Table 4. These comments provide further insight and understanding of the responses shown in Figure 1. It is apparent that the students benefited from the emphasis on team work and communication skills, units and dimensions and the overview of engineering disciplines. While certain projects such as the one of electrical circuits were considered beneficial, students would like to include projects with an emphasis on programming and CAD software. Here too, the lack of mathematical and science concepts is viewed by the students as a significant deficit (14 similar responses).

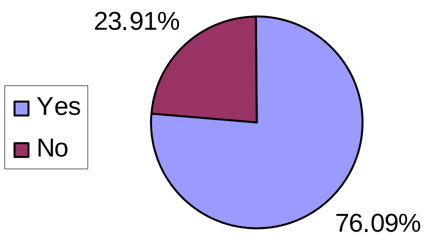	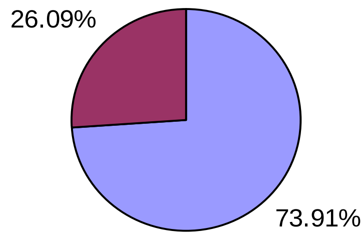	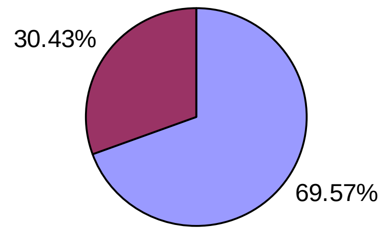
Q3: Would you say that ENGR1100 is relevant to current courses you are taking? **Figure 1 (a)**	*Q4: Would inclusion of more hands-on activities and projects have benefited you (better prepared you for current courses)?* **Figure 1 (b)**	*Q5: Would inclusion of more material on basic mathematics and physics concepts have benefited you (better prepared you for current courses)?* **Figure 1 (c)**

Figure 1: Students' responses to questions 3-5

Table 4: A summary of written comments from students on questions 3-5

Other comments:	*# of similar responses*
Comments in response to Q3: Would you say that ENGR1100 is relevant to current courses you are taking?	
o Good practices for teamwork and presentations, discussed uses of unit and conversions	10
o Good overview of lots of material covered in current courses	4
o It gives a good overview of the engineering field which allows us to make a better decision on our career field	5
o It was high school level physics class in engineering eyes. It might be useful for the person who has no idea in physics or engineering	3
o I do not feel as though I learned anything really useful from intro	3
o The entire class felt like an enormous college brochure. Each section and segment barely touched enough on the topic for one to really learn anything	
Comments in response to Q4: Would inclusion of more hands-on activities and projects benefited you (better prepared you for current courses)?	
o Include more programming and CAD software	3
o I thought it was a good mix of lessons and projects	5
o The sessions that include hands on work such as wiring the electrical circuits actually taught useful skills usable in physics courses	8
Comments in response to Q5: Would inclusion of more material on basic mathematics and physics concepts have benefited you (better prepared you for current courses)?	
o Being an introductory course, using more material that gave insight to the future math courses and science courses would be better to prepare students on what they should expect in the future.	14
o These are mostly learned in high school or other college courses	4

Discussion

Students were also asked to include information on their disciplines: mechanical engineering, civil engineering, computer and electrical engineering or other, programs of study: Pre-Engineering, GTREP, RETP or EA and their overall GPAs in these surveys. Additionally, it was observed that most of the students in the EA program (not including all the other programs) considered ENGR1100 not beneficial. This can be attributed to the fact that these students have an overall high academic standing - based on SAT scores, GPA (average GPA of 3.24) and levels of mathematics / science courses completed. In view of this, as of Spring 2010, ENGR1100 is not a required course for students in the EA program. These students take a GT 1-credit hour seminar course for their first three semesters.

Though these results present preliminary data, a couple of important observations can be made from them. First, the design and other projects are good tools to introduce several soft skills (team work, communication, etc.) as well as promote creativity. Secondly, the use of more project based material (hands-on, computational, research) that simultaneously incorporate the fundamental topics relevant to students in other mathematics and science based courses in an explicit and precise manner will most likely improve student performance and therefore improve retention.

ASSESSMENT: FACULTY'S PERSPECTIVE OF COURSE EFFECTIVES

This section presents the assessment of the effectiveness of ENGR1100 from the faculty's perspective. Overall grades were compiled for all sections of freshmen and sophomore level engineering courses taught from Fall 2005 to Spring 2009. A summary of results with the average DWF rates (% of students who did not successfully complete the course with a C grade or better) is presented in Figure 2.

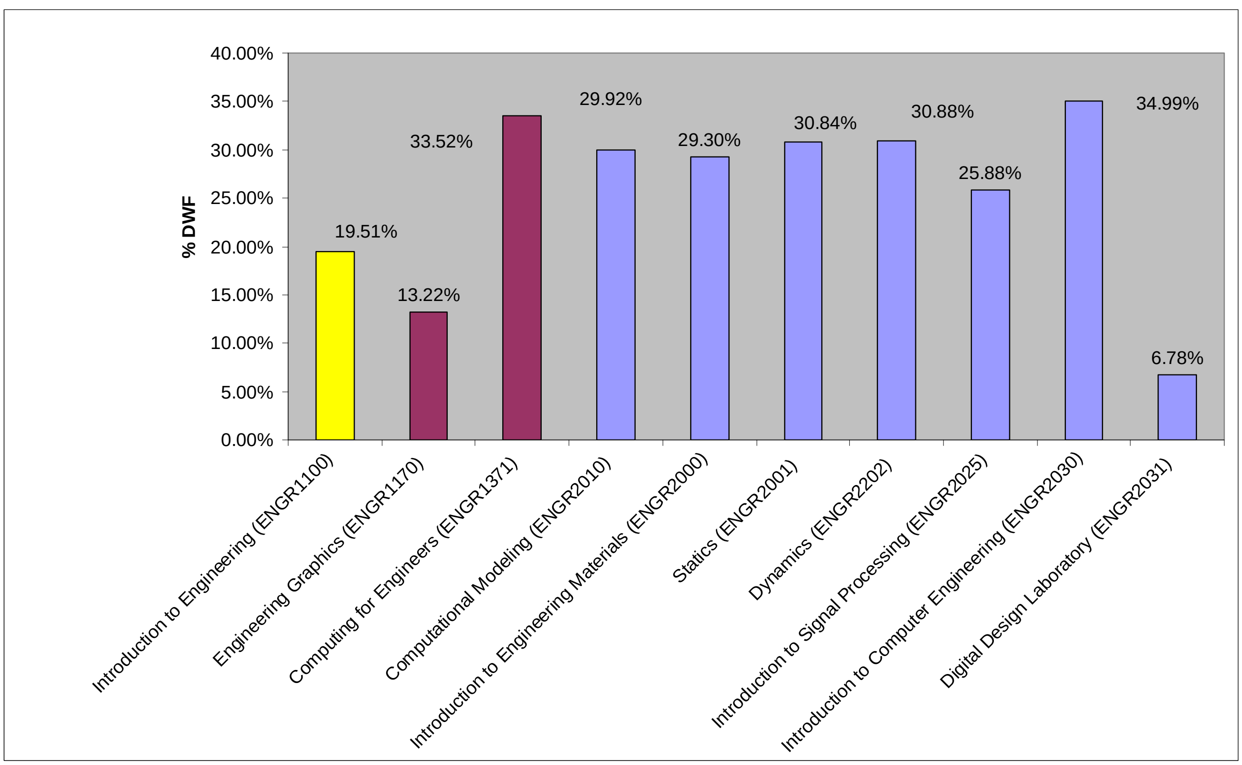

Figure 2: Average DWF rates for freshmen and sophomore engineering courses (Fall 2005 to Spring 2009)

Note that the average DWF rate for ENGR1100 is 19.51%, which is relatively low, however, the DWF rates increase significantly as students' progress toward the freshmen programming course - Computing for Engineers (ENGR1371) and the sophomore engineering courses. For example, if we consider a hypothetical group of 100 students enrolled in ENGR1100, with a DWF rate of 19.51%, about 80 of the 100 students will complete the course and then take Computing for Engineers (ENGR1371). With a DWF rate for ENGR1371 of 33.52%, about 53 of the 80 students will complete this course and move to Computational Modeling (ENGR2010) of whom only 37 will be successful (29.92% DWF rate). Thus, only 37% of our entry level freshmen engineering students are successfully completing ENGR2010 – a required course for all mechanical engineering students. A similar analysis shows a 38% success rate for entry level freshmen engineering students who successfully complete Dynamics (ENGR2202) – a required course for all mechanical and civil engineering students and a 48% success rate for entry level freshmen engineering students who successfully complete Digital Design Laboratory (ENGR2031) – a required 2-credit hour course for all computer and electrical engineering students. Note that this preliminary analysis does not consider the DWF rates in the mathematics (Calculus I and II) and science (Physics I and Chemistry I) courses which are pre-requisites for the sophomore engineering courses. In addition, several transfer and non-traditional students who enter the program as sophomores are not required to take ENGR1100.

Not shown in Figure 2 is the data for Creative Decisions and Design (ENGR2110), a sophomore course for mechanical engineering students in which the students are introduced to standard design tools and fabrication through hands-on projects [19]. Each week, students attend two 1-hour lectures and a 3-hour lab. This course has a 100% success rate (students who pass the course with a C grade or better). This high success rate may be attributed to the fact that the course is primarily project based. The outcomes for this course seek to improve students' communication skills, students' ability to work in teams, students' knowledge of and hands-on ability to fabricate machine components and integrate electrical and mechanical systems. While quizzes are given relevant to the lecture modules, eighty percent of the course grade is derived from student performances in a variety of projects (e.g. functional decomposition, newspaper or spaghetti structure design, writing assembly instructions to be read and utilized by other groups, robotics). Student motivation may also play a role in the fact that the course has a 100% success rate, as this is their first engineering design course that allows them to think independently and convert their ideas to actual devices. The majority of the students report that this aspect of the course makes it most enjoyable.

These data further support the conclusions brought forth in the previous section on assessment based on students' perspective of the course ENGR1100. The course does instill soft skills and promotes creativity in engineering design (based on the relatively good student performance in ENGR2110). However, while students fail to withdraw from course for a myriad of reasons, the fact that many students are able to do well in ENGR1100, and yet they end up failing or withdrawing from latter engineering courses corroborates the conclusion that the introductory course, as currently taught, did not provide them with adequate preparation for their subsequent engineering courses.

CONCLUDING REMARKS AND FUTURE WORK

This paper presents an investigative study and analysis of an introductory engineering course: ENGR1100 taught at AASU. Assessment data based on student surveys, student comments and student performance in this and other engineering courses have been used to identify primary factors that influence student retention rates in the Engineering Studies Program at AASU and to propose pertinent changes in ENGR1100 to improve these rates.

It has been observed that the retention rates in the program are primarily impacted by the difficulties faced by students in the mathematics, science, and programming courses taken after ENGR 1100. While ENGR1100 has served well in motivating and exciting students about engineering, students' perceptions and the faculty's observation of academic performance in subsequent courses suggests that more can and should be done in the course to better engage and prepare them for these mathematics, science and programming courses.

Several changes can be made to ENGR1100 to affect these deficiencies. These changes include:

(1) The implementation of more programming activities that incorporate mathematical skills and model physical phenomena studied in subsequent mathematics, physics and engineering courses. The greater programming emphasis can bolster students' critical thinking and problem solving skills while engaging them with hands-on activities. For example, this can be facilitated with the expanded use of the Lego Mindstorms platform using various sensors (temperature, rotation, light, etc) with the built-in data logging

features. Students can then use these data to compare with their hand calculations based on analytical models.

(2) The expanded use of team project-based activities. Student perspectives of the course strongly support these activities as they promote team work and communication skills. Furthermore, team work and communication skills are ubiquitous ABET educational outcomes, and thus should be promoted as early and often as possible in our engineering curriculum.

(3) Partnering with the mathematics and physics instructors to identify student deficiencies and potential project ideas for ENGR1100. For example, these projects could cover physics concepts in an abridged from while stressing the engineering related implications and applications. These discussions will also help in the development of the content of the customized ENGR1100 textbook mentioned in (3).

The above mentioned changes correspond to a more rigorous and engaging introductory engineering course. It is noted that the implementation of these changes may negatively impact the DWF rates in ENGR1100. However, with the completion of the proposed ENGR1100 with a grade of C or better, students will be better prepared and motivated for subsequent courses in the engineering curriculum. Thus, these changes would be expected to decrease DWF rates in these latter courses and increase overall retention rates and student performance.

Introduction to Engineering (ENGR1100) is taught every semester in 1-2 sections with an average enrollment of about 75 students per year. It is proposed that these changes will be implemented in these sections over a course of time. Future assessment will examine the projected impact of these changes in ENGR1100 on student perceptions of the course as well as their performance in ENGR1100 and the subsequent freshmen and sophomore engineering courses.

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