Improving Retention through Implementation of "Toy Fun" Projects into Fundamental Engineering Classes

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Abstract

Low retention is one of the major common issues in engineering education. First two years retention rates of 30% to 45% are typical for many universities though it varies for specific programs. Increasing retention among first year engineering students is one of the major goals in engineering education. Evidences show learning experiences directly impact freshman retention. Among the many various factors in engineering learning and retention on which the educators may have influences are student engagement, interest, and academic success especially math performance. This paper studies the influences of implementing "TOY" projects into first year fundamental engineering courses on various learning indicators among engineering students and identifying methodologies to make improvements. Design and implementation procedures are also presented. Evaluation of the results using faculty perception, student perception, and the designed assessment rubrics were performed. It was found that the "TOY" project enhanced a first engineering experience course. The students showed great interest, active participation, and developed a positive aptitude in engineering learning through the project. It was observed that the students gained a better understanding of engineering ethics and concepts, and were more willing to acquire new knowledge independently. Students have significantly increased in the understanding of the field of study and showed increased confidence in learning engineering subjects. Positive impacts to freshman retention were also observed.

Keywords: Retention, Engineering Education, Student Engagement, STEM

1. Introduction

Learning and retention are among the major concerns in engineering education. Effective learning modules will help to promote retention. The retention used in the paper is defined as the rates of students who continue in engineering in the sophomore year after the first freshman year. First year freshman retention rates between 30% and 45% are typical for many universities though it varies for specific programs. Increasing retention among first year engineering students is one of the major issues in engineering education. Historically the statistical data among the commonwealth campuses at Penn State University shows that there are more than six hundred freshman students who declare engineering as the preferred major

every year. However, only about one-third remain in engineering, one-third pursue other STEM majors, and the last one-third drop out, after two years. The factors affecting the retention of engineering student vary. According to Penn State University College of Engineering, poor math performance is one of the major factors affecting retention. Only about 61% of engineering majors can pass the required pre-calculus courses (which are required for engineering majors) with C or better. Among underrepresented (African American, Native American or Hispanic) freshman students who declare engineering as a major, only about 13% remain in STEM fields [1]. Studies of this issue have been conducted by many educators and researchers on high school academics performance and SAT scores [2, 3, 4, 5], gender, ethnicity, citizenship status [6], and freshman year academic performance, especially the grades in math and science courses [7, 8]. Good test scores and academic standing in high school and college study are commonly used as indicators of success in engineering study. However, engineering students may leave the field of study due to perception differences of the institutional culture and career aspects instead of academic performance [9]. Self-efficacy and physical fitness are also reported as positive predictors of freshman retention. Inability to handle stress, mismatch between personal expectations and college reality, and lack of personal commitment to a college education are also given as reasons for freshman attrition [10]. Those studies are more focused on statistical data analysis and trying to establish correlations between the various factors and student academic behavior.

This paper presents the implementation of project strategies to actively change or impact students' attitude and behaviors (which are believed to be important influence factors to promote learning and the freshman engineering student retention) pertaining to student retention regardless of their background. Implementation of active, collaborative projects such as the TOY project in the First Year Experience (FYE) classes at Penn State University Park were effective in retaining women and underrepresented students in Mechanical Engineering. The FYE course involves designing toys with specific characteristics that engage students in science, mathematics, teamwork and communication skills in a fun, non-threatening environment. How does a "TOY" project work and play the roles among the engineering students in general? This paper describes the implementation effect of the "TOY" project at Penn State Hazleton. A first year engineering design experience course was chosen as the medium and toys were chosen as the "catalyst". Procedures are designed, evaluation techniques are developed, various indicators are implemented, the results and observations are obtained and evaluated.

2. "TOY" Project Implementation

Observations show that a freshman student who is comfortable in learning engineering topics and actively participates in learning activities is not likely to leave the field of study after the first year. First year engineering student retention can be affected by various complicated internal or external factors. Based on the experiences and observations obtained, it is believed that among the "controllable" ones, student engagement (I_1), learning interest (I_2), confidence in studying (I_3), knowledge and understanding in engineering topics (I_4) (represented as "Four-Element" indicator) will have a significant impact on learning engineering concepts and retaining first year engineering students. A mechanism which can

enhance the "Four-Element" indicator is expected to produce positive gains in retention. The following section will discuss the design, implementation and the effects of "TOY" projects in an introduction engineering course started in the Spring 2009.

2.1 Course Identification

The goal of the project is to promote learning and freshman retention among engineering students through enhancing student engagement, interest, confidence and knowledge and understanding. There are a few fundamental introductory engineering courses for freshman students at Penn State. After carefully consideration, EDSGN100 was chosen as the course to implement the project. This course is a required course for all engineering students at Penn State Hazleton. This course provides students experiences in practicing fundamental engineering design process, data processing skills and ethics through hands-on creative team work. The objectives of this course are:

1) Conceptually design a system, component, product, service, or process to meet desired needs, and understand solutions and designs in context of overall systems;
2) Apply knowledge of basic science and mathematics to engineering;
3) Design and conduct basic experiments, as well as analyze and interpret data;
4) Participate effectively in small teams;
5) Identify, formulate, and solve engineering problems;
6) Communicate effectively using written and graphical forms and oral presentations;
7) Demonstrate professional and ethical responsibility;
8) Use software tools relevant to engineering practice.

This course influences all four aspects of the "Four-Element" indicator. "Toys" are identified as catalyst since everyone is familiar with them and it brings a "FUN" environment in learning. The project is implemented on a team basis. Budget for purchasing toys, tools, raw materials and project tutors are provided through the National Science Foundation (NSF) funded "Toys'N More" project with the objective of improving retention at Penn State.

2.2 Project Design and Learning Modules

The project was designed to meet the course educational objectives and enhance the "Four-Element" indicator. In order to meet the goals, the major activities and learning modules were carefully designed as shown in Table 1.

Table 1: Learning Modules and Objectives

	Objective Items	Learning Modules (Team Based)						
		Toy product examination (dissection, measurement, assembly…), new design concepts and solutions	Drawings and CAD modeling	Product fabrication (follow design processes)	Data processing	Design documentation	Presentation	Report writing
Course objectives	1)	■		■		■		
	2)	■		■	■			
	3)	■			■			
	4)	■	■	■	■	■	■	■
	5)	■		■	■			
	6)					■	■	■
	7)	■	■	■	■	■	■	■
	8)		■		■	■	■	■
Four-Element Indicator	I_1	■	■	■	■	■	■	■
	I_2	■	■	■			■	
	I_3	■	■	■			■	
	I_4	■	■	■	■	■	■	■

The concept of learning in a "FUN" environment was integrated into the course. The students were guided to complete the project to meet the goals while having fun following the procedure shown below. The learning modules were integrated in the activities.

1) Assign the "TOY" project to the class.
2) Form small groups (2 to 4 persons each) in the class.
3) Determine a toy of interest within a given budget (each group was free to choose their toy).
4) Discuss decision making strategy with the instructor to finalize the project idea.
5) Purchase "TOY" product and tools needed for each team.
6) Test and examine the product and its functions. Document work done and relevant findings.
7) Dissect the product with tools, study how different parts are assembled and how various functions are performed.
8) Conduct measurement with calipers and make working drawings.
9) Brainstorming for improvement and new product designs, document ideas with word expression and drawings, propose next stage work.

10) Give a presentation about their teamwork, product studying and proposal for next stage work in making improvement and fabrication.
11) Create CAD models (parts, assembly, and drawings) for the product to be done.
12) Fabrication (What do you mean by fabrication of activities?) and documentation of activities.
13) Testing of the new product, data collection, analysis and interpretation.
14) Write a final report describing the whole design process, the effort, the work done above including product benchmarking, marketing and financial justification)
15) New product demonstration and final presentation.
16) Survey and peer evaluation.

2. 3 Evaluation and Assessment

In order to evaluate the effectiveness in the enhancement of student engagement, learning interest, confidence built and knowledge/understanding gained, three assessment techniques (faculty perception, student perception and rubrics for quality work) and their relevant indicators were designed to make sure each outcome item could be evaluated sufficiently, "Four-Element" indicators were evaluated by each of the chosen three techniques to guarantee the effectiveness. The mapping of indicators and the items being evaluated are shown in Table 2. The rubrics for evaluating the written report and oral presentation are shown in Table 3 and 4.

Table 2. Mapping of evaluation indicators to the outcome of the project for promoting learning and retention

Evaluation Techniques		**Indicators Used in Evaluation**	**Outcomes/Objectives (Four-Element Indicator for Learning and Retention)**			
			Student Engagement	**Learning Interest**	**Confidence in Learning**	**Knowledge & Understanding**
1	Faculty perception	Attendance	■	■		
		Answer and ask question	■	■	■	■
		Teamwork	■	■		
		Attitude	■	■	■	
		Working skills			■	■
		Independent study	■	■		
2	Student perception *	Self evaluation/survey	■	■	■	■
		Peer evaluation on teamwork and contributions	■			■
3	Assessment Rubrics (for quality work)	Report	■			■
		Presentation	■	■	■	■

* Student surveys were conducted anonymously. The survey forms are attached in the Appendix section.

Table 3. Report Evaluation Rubric

	1	2	3	4
Technique report key points in format	Does not follow the format well. Missed many key elements.	Followed the requirements, but missed or does not understand some of the elements.	Meet the requirements, only has a few minor problems.	Demonstrates a good understanding of all the format elements.
Visual quality	Very confusing. No clear sections. Plots and tables do not look good. Report appears "hasty" and "busy."	Have sections but random layout. Missing elements in plots and tables.	Content is arranged fine. Adjustments may be needed to sections as well as to the plots and tables.	Well presented, sections are clear, plots and tables are well arranged.
Delivery of the report	Poor spelling and grammar, many confusions.	Errors in spelling and grammar evidenced in the content but understandable.	Minor grammatical or spelling errors are noted in report.	Grammatically correct with only a few misspellings.
Content /Correctness	Content is not relevant. Mistakes, misunderstanding, misplacement of content.	Content is relevant but no logic between sections. Mistakes in the content.	Content is arranged well. Minor mistakes appear in the content.	Content is correct and presented well. Logic between sections and parts clearly shown.
Completeness	Only partially finished and missed most of the parts.	Incomplete section(s) or part(s) evidenced in report.	Minor missing content. More information needed. for clarity.	Complete with only a few missing elements. Content flows well.

Table 4. Oral Presentation Evaluation Rubric

	1	2	3	4
Format and organization	Chaos, no organization.	Has the common elements, but no clear logic in arrangement.	Has the common elements. Content is organized but adjustment for logical correctness.	Has the common elements for a professional tech. presentation. Content is logically arranged.
Content	Topic and content are not relevant with obvious mistakes.	Topic and content are relevant. Technical mistakes appear.	Topic and content are relevant with minor technical mistakes.	Topic and content are relevant with only a few technical mistakes.
PPT slides quality	Hard to read. Busy slides throughout.	Wordy but readable. "Flat" everywhere.	Readable, understandable. Used few visual aid techniques.	Readable, concise, understandable. Vivid with visual techniques.
Presentation	Does not meet the length requirement. Hard to hear. Poor teamwork. Do not understand the topic. Cannot answer question correctly.	Meets the length requirement. Voice ok. Teamwork ok. Misunderstanding the topic frequently .No confidence in answering questions.	Meets the length requirement. Voice ok. Good teamwork. Demonstrate knowledge on the topic. Misunderstanding the topic occasionally. Answers questions with less confidence.	Meets the length requirement. Good voice. Good teamwork. Demonstrate knowledge and understanding of the topic. Presents and answer questions with confidence.

3. Results and Discussions

The project was implemented in the EDSGN100 beginning with the 2009 Spring Semester. The retention rate in 2010 Fall Semester was 98%. The author attributes this record partially to the "TOY" project. The summary of the evaluated results and observations using the assessment techniques discussed in section 2.3 are presented in Table 5.

Table 5. Performance Results for Each Evaluation Indicator

Evaluation Techniques		Indicators	Results/Observations
1	**Faculty perception**	Attendance	The three semesters' overall class attendance is about 92% to 95% during the project period, 85% in the other class time.
		Answer and ask question	In the project time, the students were observed actively asking and answering questions. Although this indicator is common among all student groups, the type of questions were mostly technical ones and the students put more thought and effort in find their own answers before asking. When answering questions, they exhibited confidence about the knowledge learned and integrated this knowledge into their answers and the work done. Some times the students could use equations and drawings to express the idea in addition to oral expression.
		Teamwork	The students collaborated well and efficiently. The author s seldom heard complains. They worked together with responsibility and respect, and spent more time actively engaged in completing a quality project. Good time management and communication skills were observed. By the end of project, the students believed they could work in a team environment effectively.
		Attitude	Self centered, lower standard in doing the work, and unwilling to make corrections were observed among many students before the project. In the project, teamwork, peer pressure, strict standards, and attitudes changed significantly. The students were able to do a objective self evaluation, were willing to take advices and suggestions from the others and showed the willingness to learn.
		Working skills	The students showed confidence in what they were doing. They understood the design procedures and project requirements, and they could follow them well. They could design their own methods to conduct testing, collecting data and perform analysis with the aid of computer software, like Excel, as needed.
		Independent study	The students showed excellent independent study ability in the project. They followed the project guideline to acquire the knowledge needed to finish all the tasks. They were required to obtain their own solution(s) or answer(s) for each task or a technical problem before asking. It was observed that they did put a lot of effort in understanding theories and finding good solutions.
2	**Student perception**	Self evaluation /survey	Self evaluation was conducted by the end of the project. 94% of the students expressed that the project was interesting; It made the engineering design concepts straight forward and easy to understand It helped them to develop teamwork, write a report and make an effective presentation. This first experience helped them to develop knowledge and a better understanding in the field of study, involving engineering process, and ethics. It helped in building their confidence in studying. 95% of the students indicated that they will

			continue in the field of study and plan to get the degree in engineering.
		Peer evaluation on teamwork and contributions	Peer evaluation of the project was given to students to evaluate the contribution and performance of the others in the group. Items of evaluation include: quality individual work, responsibility and dedication, participation in team activities, helpfulness, and ease to work with. The evaluations were all positive and did not include students who dropped the class. A few students drop class in each semester for various reasons).
3	**Assessment Rubrics (for quality work)**	Report	The final reports were evaluated using the assessment rubrics. It was observed that the students could follow the requirements and do quality work on the project. The reports were scored between 85% and 95%.
		Presentation	Twelve (max twenty) minute oral presentation was assigned to each group. The presentation was evaluated using the assessment rubrics. All the involved students could follow and meet the requirements, and more than 80% did better than what are required. Students could make PPT slides with good quality, show good presentation skills, demonstrate knowledge learned, discuss the work done and answer questions confidently.

4. Conclusion

A "TOY" design project has been incorporated into the existing first engineering design experience course. The design components introduced students to engineering ethics, design process and prototyping through a product type that everyone uses or used – toys. The students explored the design process through dissection and design or redesign, discussing and applying what appeals to the market (children of both genders), using drawing techniques and CAD technologies tools, prototyping of a new design, field-testing, teamwork, writing a technical report, and giving presentations. The project enhanced and added a new dimension to this first engineering design experience course. After the implementation in project year one the retention rate in the 2010 Fall Semester was 98%. The authors believe that this has the contribution of the project. The results show that the students learned through doing the hands-on work. They have shown high interest, active participation, and have developed a positive engineering aptitude in learning and doing their work on a team basis as a result of the project. It was observed that the students gained a better understanding of engineering ethics, the design process, technical report writing and oral presentation skills. It is exhibited that the students have increased understanding in the field of study, and increased confidence in learning engineering topics. The experiences showed that a freshman student with interest, confidence, good participation, performance in learning, and good understanding of the field of study is likely to continue in the study of their chosen field for the second year.

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Appendix: Student Survey

A) Toys Design Project Survey

	Items	Choices		
		Yes	Not Sure Yet	No
1	I feel I can work well in a team.			
2	I believe study in engineering is a right choice.			
3	I am confident that I can succeed in engineering study.			
4	I believe I will succeed in my first year engineering study and retain in engineering for the second year.			
5	I believe that I will retain in engineering and get an engineering degree successfully.			

* Survey given before and after the project

B) Toys Design Project Survey (General)

(1) Team Project

	Items	Choices		
		Yes	No	N/A
1	The project helped better understanding engineering concepts			
2	The project helped in increasing teamwork skills			
3	I am more comfortable with giving a presentation and more skilled			
4	I gained more knowledge in preparing report and document design activities.			
5	I feel more comfortable with working with people of different background			
6	The project helped increasing my interesting in studying			
7	The project helped increasing my participation			
8	I have increased expectation and confidence in learning advanced courses			
9	I have increased expectation for a good grade for this course			
10	I feel I have increased skill in managing my schedule			
11	The project is hard and I feel I cannot manage it			
12	The project is interesting and provides good engineering design experiences			
13	I feel more comfortable now to stay with engineering program through the project			
14	I am pretty confident that I can succeed in engineering. The project helped promoting my confidence			

(2) Teamwork – Teammate Contribution

	Contributions	Teammate Name							
		1.		2.		3.		4.	
		Yes	No	Yes	No	Yes	No	Yes	No
1	Take the responsibilities								
2	Quality work								
3	Participate team meeting								
4	Willing to offer help								
5	Easy to work with								

* Maybe give a percentage contribution when applicable instead of using Yes or No.

(3) Comments for Making Improvement

In your opinion, what can be done to make project or course better

* Survey given after the project.

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