AC 2007-558: IMPROVING RETENTION BY IMPLEMENTING OUTCOME BASED DESIGN EXPERIENCE IN A SOPHOMORE COURSE

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Outcome Based Design Experience in a Sophomore Course

ABSTRACT

The student retention in the private institutions is, in general, a difficult problem to handle and even more difficult to manage in the engineering programs. This study reports how the reorganization of a sophomore level thermodynamics course addresses these issues. The main objectives of this effort are to expand the boundaries of students' knowledge by engaging them with the *planning*, *design, build,* and *test* concepts. The process included the reorientation of theory taught in the class and required an active student participation in a special design project. The whole idea was to incorporate a hands-on design project and other pedagogical changes to transform the student's learning into a pleasant and fulfilling experience. The project was successfully completed for the first time in the spring of 2005. The students associated with this approach were divided into several groups, where each group was assigned to develop a Stirling engine based on their research and design. At the end of the semester the students participated in a design competition where they were graded on the basis of multiple of factors such as, simplicity of the design, application, cost, and creativity etc. This endeavor implemented an outcome-based, meaningful design experience early in the curriculum, with the intention of improving the retention efforts in the mechanical engineering program. The course assessment revealed that the students enjoyed the experience, generated a high level of interest and enthusiasm, and preliminary data indicate that the effort has helped in improving the student retention.

INTRODUCTION

In general, student retention in private colleges and universities is a difficult problem to reckon with, especially more so in engineering programs. It has been reported that, on average, forty percent of students leave engineering before graduation[1]**.** Unfortunately, the competition among admission representatives creates a "push-pull system", which often generates lower admission standards and as a result it worsens the retention problem further. There are many other reasons for student attrition which include, first and foremost, their own intention and commitment, the pedagogical support, high school preparation and the curriculum design. Students, who show persistence, determination, and devotion to accomplishing a clear career goal, tend to do better in the engineering program. After examining several engineering curricula, it was observed that the sophomore year course load often appeared more demanding than the course load of other years in the curriculum. This was noticeable in our curriculum as well, where students suffered from sharply decreased self-esteem and enthusiasm. It was also to some extent apparent from their course work and examination preparedness. Table 1 shows the Wilkes University's Mechanical Engineering curriculum. In this course structure the first truly relevant mechanical engineering course the students are exposed to is thermodynamics, which was also offered at the sophomore level. Previous outcome based analysis indicated that students struggled in this course and other math courses as they endured a high degree of difficulty and suffered from lack of interest. The students were unable to determine the purpose for taking these courses and they were uncertain how knowledge gained in these courses was inter-linked. These circumstances did not help in either improving the retention or increasing the recruitment. Although no conclusive evidence seemed to explain the reasons for these difficulties, the program did suffer from attrition problems. The program's attrition rate generally hovered around 31%. For a small program in a private institution this attrition rate is very high and must be improved. Regardless of the reasons therefore, it was imperative for the faculty to devise new approaches to improve upon retention without compromising on standards. The new approach described here provides students with more interesting, explorative, and enjoyable educational experience with intentions to improve upon their self-esteem. It is expected that similar approaches will be followed in other courses as well.

Table -1.Wilkes University Mechanical Engineering curriculum

First Semester			**Second Semester**		
Mth 111	Calculus I	4	EGR 200	Intro. to Materials Science	3
FYF 101	First-Year Foundations	3	Mth 112	Calculus II	4
ME 180	CADD Lab	1	EGR 140	Computer Utilization	3
Eng 101	Composition	4	Phy 202	General Physics II	4
PHY 201	General Physics I	4	Distribution Requirements		3
		16			**17**
Third Semester			**Fourth Semester**		
Chm 113	Elements and Compounds Lab	1	EGR 222	Mechatronics	3
Chm 115	Elements and Compounds	3	ME 232	Strength of Materials	3
Mth 211	Intro. To Differential Equations	4	ME 234	Statics & Dynamics II	3
EE 211	Electrical Circuits and Devices	3	ME 322	Egr. Thermodynamics	3
EE 283	Electrical Measurements Lab	1	EGR 214	Linear Systems	3
ME 231	Statics & Dynamics I	3	ME 175	Intro t Mfg/Machining	1
Distribution Requirements		3			
		18			**16**
Fifth Semester			**Sixth Semester**		
ME 321	Fluid Mechanics	3	EGR 399	Cooperative Education	6
			Or Technical Electives		6
ME 323	Fluid Mechanics Lab	1	EGR 201	Professionalism &Ethics	1
ME 215	Intro. to Manufactur. Processes	3	Distribution Requirements		6
ME 335	Engr. Modeling and Analy.	3	EGM 320	Engr. Project Analysis	3
ME 333	Machine Design I	3			
Distribution Requirements		3			
		16			**16**
Seventh Semester			**Eighth Semester**		
ME 324	Heat and Mass Transfer	3	Technical Elective		6
ME 326	Heat & Mass Transfer Lab	1	ME 392	Senior Projects II	2
ME 384	Mechanical Design Lab.	3	ME 332	Mechanics of Vibration	3
ME 391	Senior Projects I	1	Free Elective		3
EE 314	Control Systems	3			
Distribution Requirement		3			
Technical Elective		3			
		17			**14**

Since making curricular changes was difficult, a new pedagogical approach was conceived to resolve the issue described above. The students taking the Thermodynamics course were introduced with the concepts of Stirling engine very early in the semester. They were asked to work in a team to plan, design, build, and test their version of a Stirling engine. The project required students to begin from a concept and finish with a prototype within the given budget and specified time constraints. The scope of the project provided students ample opportunities to experience the research process, including concept generation, data collection and reduction, fabrication, application, and testing. In order to help students develop network and camaraderie, each group was also associated with a senior, who served as a mentor and guide.

The most critical parameter that must be considered before making a decision on its design and fabrication is the cost. The financial constraints are a reality that students must consider very seriously. Various voluntary class presentations were deliberately provided to explain students that many new businesses start by entrepreneurial efforts in which financial resources are scarce and that, on the same note, capital availability plays a critical role in the success or failure of any new venture. On the other hand, if product development costs are too high, competition will make a good product unmarketable. Students were asked to go over the economic concepts of supply and demand, breakeven costs, production and manufacturing costs, etc., reminding that resources are always limited. It was decided that total production cost must not exceed fifty dollars. Each group was asked to consider their team as a private company who was contracted to complete the project within a given budget. They were provided with full support of the engineering machine shop and other services at no cost. Finally, all groups were required to compete in public to explain their product and innovative designs in a poster session.

Four groups participated in this program for the first time. All groups were successful in the design and fabrication of the engine as shown in Figures 1 through 4. Two engines were of Alpha configuration and while the other two belonged to Beta configuration, for which all components were fabricated by the students in the Wilkes University machine shop. Out of these four groups, two were successful in the design and fabrication of a working Stirling engine within the given budget. The other two groups were not successful in developing a working engine. In these cases the students were asked to explain the reasons for their troubles. It was explicitly known to students that the grades were not dependent only on the successful design and testing of the prototype, but also on other parameters. One of the most important aspects was to demonstrate that the group had worked together as a team and tried their best to develop a working engine. Other aspects were; did they experience that the project was helpful in linking the knowledge and concepts learned in other courses? Did they enjoy and learn from working in a team setting? Were they willing to do it again if they were given another chance and what would they change? The answers to most of these questions were positive and the majority of students not only liked the format but also enjoyed the experience.

OBJECTIVES

Various events were designed to fuel interest and motivate active student participation through working on a real and applied project. The students were guided to learn from experience and appreciate how the knowledge gained in various courses is linked together. In summary, the Stirling project was designed to cater to the following objectives:

- Providing for hands on experience in a problem based learning environment
- Recognizing the importance of good design

- Realizing the impact of design on fabrication
- Appreciating the significance of working in a team setting
- Enhancing students' interest, imagination, and confidence
- Reducing attrition rate, particularly after sophomore year
- Improving graduation rates
- Developing students' ability to meet the educational standards required
- Identifying a knowledge-link between economics, thermodynamics, statics, mathematics, materials and manufacturing.

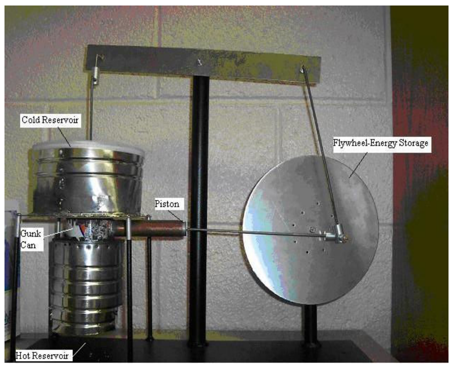

Figure 1. Engine 1

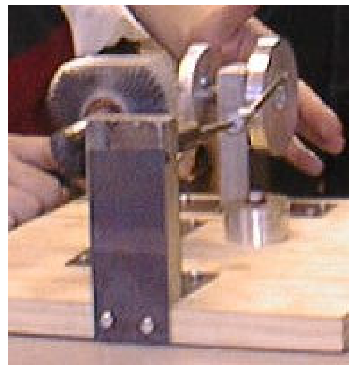

Figure 2. Engine 2

Figure 3. Engine 3

Figure 4. Engine 4

STIRLING ENGINE PROJECT

We will discuss only the Alpha configuration Sterling engine[5] shown in the Figure 1. The engine consists of a heat source, specifically an alcohol flame, a heat sink, specifically ambient air in an enclosed cylinder, a "heat piston", a "power piston", and a flywheel connected to the two pistons by a set of linkages. The heat transfer to the air in the enclosed cylinder is modulated by the position of the "heat piston". When the "heat piston" is located directly over the flame, the heat flow into the engine is at a minimum, while the heat flow out of the cylinder to the heat sink is at a maximum. Similarly, when the "heat piston" is at the location away from the heat source, the heat inflow is maximized and the heat outflow to the sink is minimized. During this state the alcohol flame heats up the volume of air enclosed in the cylinder behind the heat piston. When the heat piston moves towards the heat source, the thermal energy captured by the air is converted into mechanical motion by moving the power piston upward, which then, turns the flywheel. The flywheel stores this mechanical energy and uses it to power the heat piston to move left towards the heat source, after which the cycle repeats. The kinematics of the linkages determines the relationship between the motion of the “power piston” and the “heat piston”. In the starting position, the heat cylinder is positioned to maximize the heat inflow. Simultaneously, the power piston is positioned to maximize the output power.

The base (1), which is made of a 3/8″ steel plate, is attached to two supporting steel pipes (2) as shown in the figure 5. These pipes are used as a fulcrum and a support to facilitate smooth operation of the flywheel, the heat, and the power pistons. Four 1/8″ steel rods (3) support the main cylinder assembly. A Gunk aerosol can (4) was selected to act as the control volume. Placed inside of the Gunk can, a Coors Light can was used to act like a power piston inside the walls of the Gunk can. The two-can system was selected so that one can was able to slide into the other with minimal friction. Aluminum coffee cans (5) were used around the Gunk can as a heat sink. A good piston design, which is the heart of the engine, was essential for a successful engine. The difficulty with Stirling engines is that the pistons must remain dry since the high temperatures found within the engine would cause any oil used to carbonize and gum-up the cylinder walls. Additional to considering these factors and keeping it lightweight, the heat piston was fabricated from an aluminum stock.

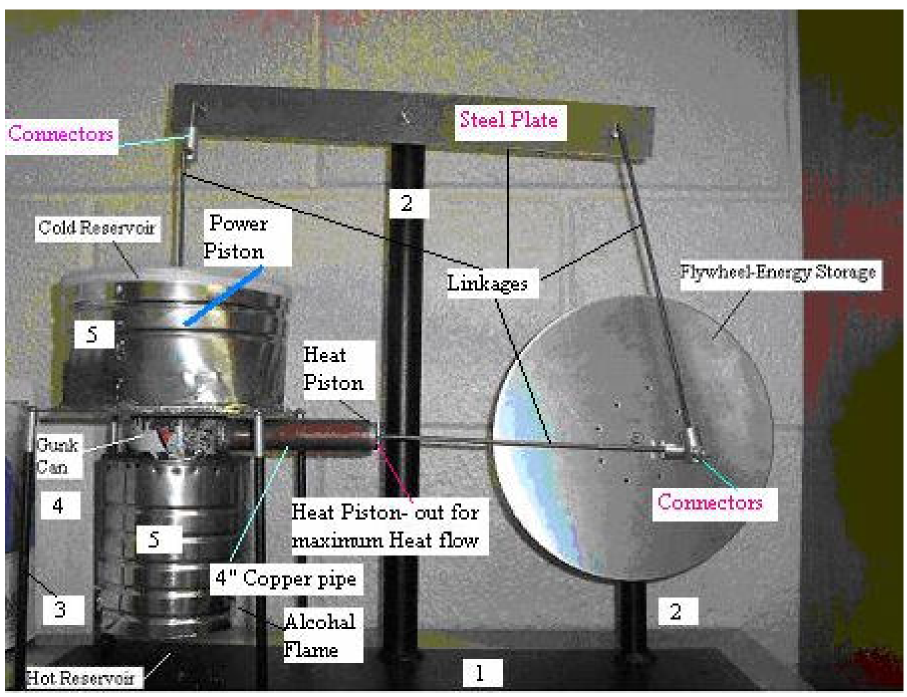

Figure 5 – Working Stirling Engine

A four-inch long copper pipe was attached to the Gunk can to facilitate reciprocating motion of the heat piston. The heat piston was connected to the flywheel via welding wire and self-machined connecters. This 1/8″ steel plate was attached to both the flywheel and the power piston using link rods. The connectors were turned on the lathes, then drilled and self-tapped, which allowed the rods to screw into them. The piston was also turned on the lathe and a slot was cut with the end mill, where another pivot point was established. At this point, a pressure fit pin was installed where the flywheel's connecting rod was attached. The purpose of this pressure pin was not only to facilitate the free motion of the connecting rod relative to the flywheel rotation, but also to maintain the linear motion of the piston in the cylinder relative to the angular motion of the flywheel. The heat piston was turned on to high finish so that it could slide into the inner side of the copper tube smoothly, which was necessary to ensure that the amount of hot air escaping the control volume were minimal. Finally, the heat piston's connecting arm was securely attached to the flywheel. The vertical piston was created by cutting the top of the beer can off, drilling hole in bottom of the can, and securely attaching it to the connecting rod. The other end of the connecting rod was attached to the steel plate, using thread couplers. It is remarked here that students not only interlinked but also applied the knowledge of statics, manufacturing, materials, engineering economics, thermodynamics, mathematics and CAD etc. Other groups also fabricated other engines using different materials and different sets of specifications in a similar fashion. The engines shown in Figure 1 and 2 worked well, but the other two engines, shown in the Figures 3 and 4, did not run smoothly, but were innovative in design.

The assignment of the hands-on project created ample interest, curiosity, and a competitive environment among students. The various activities seemed to improve the attention deficit students were facing previously. One student remarked, "Stirling engine project has allowed me to become interested in the application of thermodynamics and allowed me to understand how the knowledge of economics, thermal science, manufacturing, mathematics, and statics all linked together. I kind of understand what important role project management and teamwork play in the design and fabrication of a product." Another student wrote in his comments that, "In this project, working with a knowledgeable mentor has helped me invigorate the understanding of the principles of thermodynamics, and manufacturing and learned more about the support structure and interaction activities the school offers." It is evident that, while the classroom teaches engineering principles well, a project like the Stirling engine gives the same principles actuality and significance. Additionally, the program is experiencing a new phenomenon, which never occurred before, where students from different engineering majors are opting to enroll in this course as an elective. This paper explains the whole process and reports brief results. A number of engineering programs are also using various approaches and have reported that these measures have shown signs of improvement in their retention and recruitment efforts [2-4].

This is the second year that all sections of the thermodynamics course are implementing the outcome-based design process where students are in control. According to initial assessment, it appears that due to the modified pedagogical technique the program has witnessed some signs of improvement the past year. The retention ratio has increased as number of students dropping out of the program has sharply reduced this year compared to previous years. Preliminary results suggest that after the course was offered the attrition rate has decreased from 31% to 22%. Although the studies did show a good trend, it can not be claimed that the reasons for the improvement are solely the results of the curricular and pedagogical changes. The data gathered thus far is statistically insignificant since it has not been time tested. The future course of action is to continue the study for several years, during which data will be gathered and analyzed to eliminate unreliable conclusions, and report some tangible results at a later time.

ASSESMENT METHOD AND RESULTS

It is evident that offering the course only once can not yield realistic assessment data. The assessment studies are therefore continuing and it is intended to continue for a couple of years to provide tangible results. Nevertheless, the assessment studies were conducted from the available data to determine the impact of the Stirling project component of the course in establishing the multi-course linkages, boosting student interests and enthusiasm in mechanical engineering, in addition to gathering data on retention. There were two sections of the thermodynamics course: one section was assigned to include the Stirling project, while the other did not participate. The section in which the students did not participate were also assigned a design project, but they were not required to plan, design, build or test any product. They were assigned to design the project on paper and present their work to the class instead, as normally done in other courses. To assess above issues, student surveys were conducted. Both sections were asked to participate in the survey. This was intentional, so that the results from the two sets of data could be compared. The Stirling project section was populated with twenty students, while the other section had nineteen students. The responses were solicited for the following questions:

1. Did the various activities of the project require the use of the principles and concepts from other courses such as, Thermodynamics, Manufacturing, Strength of Materials, and Mathematics?
2. Did the project help you to understand the importance of teamwork?
3. Did the project help you to increase your manufacturing skills?
4. Was the amount of time spent on this project well worth it?
5. Did you enjoy the project and did you ask other students to join in?
6. Would you recommend assigning similar projects in all sections of the Thermodynamics course?
7. Was the information presented useful to you as an engineering student?
8. Was it a great idea to assign a senior student as mentor?
9. Did the project help in deciding whether you should continue with the Mechanical Engineering program?

Student responses were asked on 1-5 scale, with a score of 5 to *Strongly Agree*, 3 to *Neutral*, and 1 to *Strongly Disagree*. The survey results obtained from both sections are provided in Table -2 and plotted in the Figure 8. No response was offered to questions 1, 6 and 9 by the group of students who did not opt to take the course that included the Stirling project. They believed that the questions were not relevant in their case.

CONCLUSION

A new pedagogical approach was attempted in the Thermodynamics course in which an innovative project was assigned to a team of students who were asked to plan, design, build, and test their product. They were provided with financial support and other resources needed to complete the project. They were also aided by a senior engineering student who was attached with each group as a mentor. The course instructor also remained as additional resource and mentor. A comparative study was done on the basis of the feedback obtained from students of each section of the Thermodynamics class, in which one section participated in the Stirling engine project while the other did not. The results obtained from students feedback turned out to be very encouraging, on all accounts, such as students' morale, learning experiences, and retention etc. Preliminary analysis also indicates 9% improvement in the retention rates. In other words student who continued to enroll in the junior year has considerably increased in the past year compared to previous years. Although this is a significant step forward, it can not be claimed that the reasons for the improvement are solely the results of implementing the curricular and pedagogical changes. It warrants further study, which is continuing and will be reported in the future.

Table -2 - Survey Results

Question	Avg. Score Stirling Engine Project 20 Students	Avg. Score No Stirling Engine Project 18 students
1	4.1	No response
2	4.2	4.1
3	4.3	3.5
4	4.8	2.6
5	4.6	2.3
6	4.5	No response
7	3.7	2.4
8	4.7	1.5
9	3.8	No response

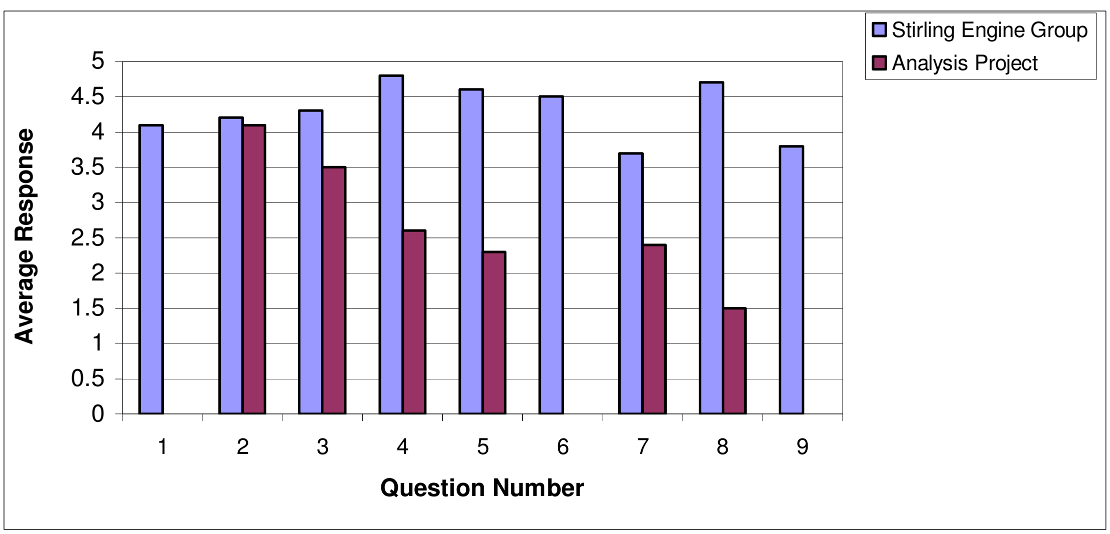

Figure 8. Student Survey Responses from Two Sections

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