Evaluation of the Effectiveness of the Integration of a LITEE Case Study for a Freshman Level Mechanical Engineering Course at The University of Toledo

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Abstract

The purpose of this paper is to report the findings of the integration of a manufacturing case study to a freshman level mechanical engineering course at The University of Toledo. The approach to integrate this case study into the class was completed via weekly assignments analyzing the case, small group discussion, and weekly group discussion. The key findings from the study demonstrate that the integration of the case study into this course improved the students' attitudes towards engineering, higher-order cognitive learning, self-efficacy, ease of learning the subject matter, team working and communication skills. In addition, the retention rates in course improved by 4.5% and the final average grade improved by 3.3% over the previous year. The implications of these findings to educators are very positive. Based on student comments, the integration of the case study increased retention of the material and their satisfaction with the course and offered another mechanism for students to study and relate concepts of the course and understand its role in engineering and life. This, in turn, increased the students' confidence in engineering and should help to improve graduation rates. One key contribution from this study demonstrates that the case study method can effectively be applied engineering courses with positive results.

Keywords: case study approach, mechanical engineering

Introduction

The case study method is well established in management teaching, but not as heavily utilized in engineering [1]. This paper describes the application of a Laboratory for Innovative Technology and Engineering Education (LITEE) case study at The University of Toledo College of Engineering for the freshmen level Professional Development Course for Mechanical Engineers. One potential advantage of the case study method is that it may facilitate deep as opposed to surface learning [2] and enhance communication skills. As engineers are called upon to work in cross functional teams, the skills learned using this method will place them in a stronger position to be successful as they move into the workforce upon graduation. In this paper, the author draws upon his experience integrating the case study method into this course. This includes a literature review of potential benefits, methodologies applied, assessment results, and discussion. The justification and objective of this study is to demonstrate the benefits of the case study method to a freshmen level engineering course.

Literature Review

Limited studies have been conducted in the application of the case study method to science, technology, engineering, mathematics and medicine (STEMM) curricula. On the contrary, numerous studies have been conducted in the application of the case study method to management and education courses and regarding the STEMM curriculum as a whole. Some notable examples of the application of the case study method include a comprehensive study involving the case study method in entrepreneurial research [3] and the use of case studies in management training [1]. In terms of studying the STEMM curriculum, the *Journal of Science Education and Technology, New Directions for Teaching and Learning,* and the *Journal of STEM Education* have paved the way and published various articles related teaching/learning styles in STEMM [4, 5] and revisions in the STEMM curriculum [6, 7, 8, 9, 10]. In 2005, an interesting study related to the use of laptop computers during engineering classes was conducted [11]. This research applies to the integration of LITEE case studies because much of the information was downloaded using computers. Finally in 2000, Walls conducted a study involving the application of case studies to technology courses and in 2003, an international project studied the application of problem based learning in engineering courses [12, 13]. The insights offered by these previous studies demonstrate the effectiveness of the case study methods in management and engineering through enhanced learning and collaboration in the classroom. The research conducted for this study will help to bridge the gap between the application of the case study method and the STEMM curriculum by discussing a specific application at The University of Toledo College of Engineering. This includes complete analysis/quantification of the results and a discussion of the key findings for a freshman level course related to professional development for mechanical engineers with 140 students enrolled.

The need to include a LITEE case study in this course centers on enhancing the intent and value of the course for the students. The course itself, MIME 1010: Professional Development for Engineers, is a required course for all engineering students enrolled at the College of Engineering and prepares students for the workforce and The University of Toledo's mandatory engineering co-operative education program. In this course, social protocol and ethics in industry are reviewed. Resume writing and interview skills are developed and the course assists in preparing the students for the co-op experience in industry. The LITEE case study selected integrated into this course was the Lorn Manufacturing case that dealt with ethics, communication, and safety in the workplace. This case study helped to enhance these aspects through the development of diagnostic skills and the integration of subject and functional issues. The course and the integration of this case study creates and develops engineering leadership skills and attitudes through communication, teamwork, hands-on experience, and the ability to interpret large amounts of data from the case. In addition this case allowed the students to view issues from an interdisciplinary point of view.

Research Model and Hypotheses

The research model used for this study was adapted from previous research that suggested techniques for organizing and conducting the research successfully and draws upon this work and proposed six steps that could be used [14]:

1. Determine and define the hypotheses and outcomes
2. Select the cases and determine data gathering and analysis techniques
3. Prepare to collect the data
4. Collect data in the field
5. Evaluate and analyze the data
6. Prepare the report

The hypotheses tested for this research were "the application of a LITEE case study to the MIME 1010 Professional Development course at The University of Toledo will:

a) improve the students' attitude towards mechanical engineering,
b) enhance the students' understanding of the relevance of subject matter to life and society
c) improve the student's ability in decision making, problem solving skills, and applying concepts
d) improve the students' self-efficacy (like, easier, emotional, self-confidence, accomplishment, responsibility, inter-dis-ciplinary)
e) enhance ease of learning the subject matter for the students
f) enhance team working for the students
g) improve communication skills for the students
h) improve the students' understanding of the engineering code of ethics and the legal aspects of engineering,
i) improve retention rates for the course
j) improve the student's final grades for the course

These hypotheses were testing using the Kolmogorov-Smirnov normality test and z-tests for the pre and post learning outcome/assessment survey (these assessments are discussed in the Methodologies Section) given during the first week and last week of the course. The z-tests were used versus t-tests due to the large sample size for each response for 140 students in the class.

Z-tests at the 95% confidence level were conducted to examine if there was significant differences/improvements from the pre and post assessment survey results. The null hypothesis (Ho) states that there was no difference between the pre and post assessment survey results for each response. The alternate hypothesis (H1) states that there was a significance difference between the pre and post assessment survey results for each response. The z-tests were conducted as follows:

<u>Hypothesis Test</u>

$$H_0 : \mu_1 - \mu_2 = 0$$
$$H_1 : \mu_1 - \mu_2 \neq 0$$

<u>Decision Rule</u>

Reject Ho if z > 1.96 or t < -1.96

<u>Test statistic</u>

$$z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma_1^2}{n_1} - \frac{\sigma_2^2}{n_2}}}$$

Methodologies

The participants for this study included 140 freshmen mechanical engineering students enrolled in MIME 1010 Professional Development for Engineers for the Spring 2009 semester at The University of Toledo, the instructor, and one teaching assistant.

The LITEE case study that was chosen was the Lorn Manufacturing Case Study. This course covers social protocol and ethics in industry. In addition this course prepares mechanical and industrial engineering students for the required co-op experience with industry.

The case study was integrated into the class via weekly assignments analyzing the case, small group discussion, and weekly group discussion. The course was taught in our $2.5 million engineering auditorium that offers complete audiovisual equipment to aid in displaying and discussing the case. The Lorn Manufacturing Case Study added significant value to the class through its discussion of legal, ethical, and workplace issues and help prepare our students as qualified, knowledgeable, and ethical engineers in their co-op experience and full time positions.

The measures of learning as related to the integration of the case study for this course included:

- A pre and post learning outcome/assessment survey given during the first week and last week of the course
- Retention rates in the course versus the previous year
- The average final grade for the students versus the previous year
- Qualitative information gathered from the students during the last week of the course

Measure of Learning	Assessment Document
Improve the students' attitude towards mechanical engineering	LITEE pre and post learning outcome/assessment surveys
Enhance the students' understanding of the relevance of subject matter to life and society	LITEE pre and post learning outcome/assessment surveys
Improve the student's ability in decision making, problem solving skills, and applying concepts	LITEE pre and post learning outcome/assessment surveys
Improve the students' self-efficacy (like, easier, emotional, self-confidence, accomplishment, responsibility, interdisciplinary)	LITEE pre and post learning outcome/assessment surveys
Enhance ease of learning the subject matter for the students	LITEE pre and post learning outcome/assessment surveys
Enhance team working for the students	LITEE pre and post learning outcome/assessment surveys
Improve communication skills for the students	LITEE pre and post learning outcome/assessment surveys
Improve the students' understanding of the engineering code of ethics and the legal aspects of engineering	Multiple choice exam and weekly case assignments
Improve retention rates for the course	Retention rates in the course over the previous three years
Improve the student's final grades for the course	The average final grade for the students versus the previous year

The following questions were asked for the LITEE pre and post learning outcome/assessment surveys for each measure of learning:

General attitude toward subject matter:
1. Engineering is a subject learned quickly by most people
3. Engineering concepts are easy to understand
7. I understand how to apply analytical reasoning to engineering
11. Engineering is highly technical
13. I ***can*** learn engineering

Relevance of subject matter to life and society
4. Engineering is irrelevant to my life
14. Engineering skills will make me more employable
25. If I ever were to become a high ranking engineer in a company I would hire other engineers to help with decision making
34. I believe that an interdisciplinary focus is important in engineering.

Higher-Order Cognitive Domain of Learning (decision making, interrelate, alternatives, problem solving skills, relevant, applying concepts)
15. I learned how to identify engineering tools that will assist me in decision-making using the instructional materials

16. I learned how to inter-relate important topics and ideas using the instructional materials
17. I learned how to identify various alternatives/solutions to a problem using the instructional materials

18. I improved my problem solving skills using the instructional materials
19. I learned how to sort relevant from irrelevant facts using the instructional materials
33. My confidence in applying Engineering concepts to real situations improved as a result of this Engineering course

Self-Efficacy (like, easier, emotional, self-confidence, accomplishment, responsibility, interdisciplinary)
10. I like Engineering
20. The instructional materials, class activities, labs, and assignments were integrated in a way that made my learning easier
21. The instructional materials emotionally engaged me in learning the course topics
22. The instructional materials increased my self-confidence
23. I achieved a sense of accomplishment in learning by using the instructional materials
24. The instructional materials helped me assume a greater responsibility for personal learning

Ease of learning subject-matter (trouble, discipline, no idea, frustrated, stress, insecure)
2. I have trouble understanding engineering because of how I think
5. I get frustrated going over engineering tests in class
6. I am under stress during engineering classes
8. Learning Engineering requires a great deal of discipline
9. I have no idea of what's going on in engineering
12. I feel insecure when I have to do engineering homework

Impact on team working (interpersonal, listening to others, consensus, share ideas, interaction)
26. The instructional materials helped me improve my team-building and interpersonal skills
27. The instructional materials helped me and my classmates listen carefully to each other's statements and ideas
28. The instructional materials helped me and my classmates arrive at decisions based on consensus building
29. The instructional materials helped me and my classmates share ideas with each other
30. The instructional materials enhanced my interactions with my classmates

Communication skills (writing, presentation, informal communication)
31. My writing skills improved as a result of this Engineering course
32. My presentation skills improved as a result of this Engineering course
36. My informal communication skills improved as a result of this Engineering course

Results

Table 1 displays the results of the pre and post surveys. Each pre and post learning outcome/assessment survey response was validated for normality using the Kolmogorov-Smirnov test and all responses did not violate the normality assumption. Since the data set is consistent with the normal distribution, z-tests were used (equal sample sizes a) to compare pre and post survey results as displayed in Table 1.

General attitude toward subject matter	Pre Survey Results		Post Survey Results		z-test statistic	Null Hypothesis at the 95% Confidence Level
	Mean	Standard Deviation	Mean	Standard Deviation		
1. Engineering is a subject learned quickly by most people	2.61	0.95	2.13	0.81	10.44	Reject
3. Engineering concepts are easy to understand	3.15	0.98	2.86	0.92	5.38	Reject
7. I understand how to apply analytical reasoning to Engineering	2.91	1.01	3.53	0.94	-10.93	Reject
11. Engineering is highly technical	3.45	1.15	3.81	1.03	-5.09	Reject
13. I *can* learn Engineering	4.55	0.88	4.43	0.90	2.54	Reject

Relevance of subject matter to life and society	Pre Survey Results		Post Survey Results		z-test statistic	Null Hypothesis at the 95% Confidence Level
	Mean	Standard Deviation	Mean	Standard Deviation		
4. Engineering is irrelevant to my life	1.66	0.88	1.60	0.98	1.16	Do not reject
14 . Engineering skills will make me more employable	4.15	0.98	4.46	0.87	-6.08	Reject
25. If I ever were to become a high ranking engineer in a company I would hire other engineers to help with decision making	3.55	1.02	4.01	0.97	-7.78	Reject
34. I believe that an interdisciplinary focus is important in Engineering.	2.55	1.1	3.59	0.81	-19.53	Reject

Higher-Order Cognitive Domain of Learning (decision making, interrelate, alternatives, problem solving skills, relevant, applying concepts)	Pre Survey Results		Post Survey Results		z-test statistic	Null Hypothesis at the 95% Confidence Level
	Mean	Standard Deviation	Mean	Standard Deviation		
15. I learned how to identify engineering tools that will assist me in decision-making using the instructional materials	2.51	0.91	3.29	0.80	-17.93	Reject
16. I learned how to inter-relate important topics and ideas using the instructional materials	2.14	0.84	3.39	0.85	-29.29	Reject
17. I learned how to identify various alternatives/solutions to a problem using the instructional materials	3.01	0.86	3.41	0.88	-8.84	Reject
18. I improved my problem solving skills using the instructional materials	2.51	1.14	3.50	0.90	-16.15	Reject
19. I learned how to sort relevant from irrelevant facts using the instructional materials	2.15	0.84	3.43	0.79	-32.28	Reject
33. My confidence in applying Engineering concepts to real situations improved as a result of this Engineering course	3	1.14	3.55	0.76	-10.62	Reject

Self-Efficacy (like, easier, emotional, self-confidence, accomplishment, responsibility, interdisciplinary)	Pre Survey Results		Post Survey Results		z-test statistic	Null Hypothesis at the 95% Confidence Level
	Mean	Standard Deviation	Mean	Standard Deviation		
10. I like Engineering	4.01	0.94	4.17	0.99	-2.88	Reject
20. The instructional materials, class activities, labs, and assignments were integrated in a way that made my learning easier	3	0.98	3.43	0.85	-8.64	Reject
21. The instructional materials emotionally engaged me in learning the course topics	2.14	0.76	3.04	0.88	-22.52	Reject
22. The instructional materials increased my self-confidence	2.44	0.94	3.19	0.77	-17.34	Reject
23. I achieved a sense of accomplishment in learning by using the instructional materials	2.85	0.85	3.39	0.87	-12.22	Reject
24. The instructional materials helped me assume a greater responsibility for personal learning	2.98	0.94	3.40	0.92	-8.13	Reject

Ease of learning subject-matter (trouble, discipline, no idea, frustrated, stress, insecure)	Pre Survey Results		Post Survey Results		z-test statistic	Null Hypothesis at the 95% Confidence Level
	Mean	Standard Deviation	Mean	Standard Deviation		
2. I have trouble understanding Engineering because of how I think	2.18	0.89	2.15	0.90	0.63	Do not reject
5. I get frustrated going over Engineering tests in class	3.13	0.62	3.64	0.71	-19.39	Reject
6. I am under stress during Engineering classes	3.10	0.99	2.73	0.86	7.27	Reject
8. Learning Engineering requires a great deal of discipline	3.58	0.78	3.86	0.86	-6.98	Reject
9. I have no idea of what's going on in Engineering	2.14	1.4	1.96	0.93	2.31	Reject
12. I feel insecure when I have to do Engineering homework	2.14	0.88	2.46	0.84	-7.24	Reject

Impact on team working (interpersonal, listening to others, consensus, share ideas, interaction)	Pre Survey Results		Post Survey Results		z-test statistic	Null Hypothesis at the 95% Confidence Level
	Mean	Standard Deviation	Mean	Standard Deviation		
26. The instructional materials helped me improve my team-building and interpersonal skills	3.00	0.80	3.43	0.80	-11.24	Reject
27. The instructional materials helped me and my classmates listen carefully to each other's statements and ideas	2.94	0.80	3.22	0.80	-7.32	Reject
28. The instructional materials helped me and my classmates arrive at decisions based on consensus building	2.55	0.74	3.31	0.72	-23.87	Reject
29. The instructional materials helped me and my classmates share ideas with each other	2.66	0.90	3.14	0.85	-10.50	Reject
30. The instructional materials enhanced my interactions with my classmates	2.44	0.87	3.10	0.92	-13.80	Reject

Communication skills (writing, presentation, informal communication)	Pre Survey Results		Post Survey Results		z-test statistic	Null Hypothesis at the 95% Confidence Level
	Mean	Standard Deviation	Mean	Standard Deviation		
31. My writing skills improved as a result of this Engineering course	2.63	0.92	3.74	0.80	-25.24	Reject
32. My presentation skills improved as a result of this Engineering course	3.01	1.01	3.88	0.65	-22.17	Reject
36. My informal communication skills improved as a result of this Engineering course	3.34	0.96	4.02	0.88	-13.47	Reject

General attitude toward subject matter	Pre Survey Results		Post Survey Results	
	Mean	Standard Deviation	Mean	Standard Deviation
1. Engineering is a subject learned quickly by most people	2.61	0.95	2.13	0.81
3. Engineering concepts are easy to understand	3.15	0.98	2.86	0.92
7. I understand how to apply analytical reasoning to Engineering	2.91	1.01	3.53	0.94
11. Engineering is highly technical	3.45	1.15	3.81	1.03
13. I *can* learn Engineering	4.45	0.88	4.43	0.90

Relevance of subject matter to life and society	Pre Survey Results		Post Survey Results	
	Mean	Standard Deviation	Mean	Standard Deviation
4. Engineering is irrelevant to my life	1.66	0.88	1.60	0.98
14. Engineering skills will make me more employable	4.15	0.98	4.46	0.87
25. If I ever were to become a high ranking engineer in a company I would hire other engineers to help with decision making	3.55	1.02	4.01	0.97
34. I believe that an interdisciplinary focus is important in Engineering.	2.55	1.1	3.59	0.81

Higher-Order Cognitive Domain of Learning (decision making, interrelate, alternatives, problem solving skills, relevant, applying concepts)	Pre Survey Results		Post Survey Results	
	Mean	Standard Deviation	Mean	Standard Deviation
15. I learned how to identify engineering tools that will assist me in decision-making using the instructional materials	2.51	0.91	3.29	0.80
16. I learned how to inter-relate important topics and ideas using the instructional materials	2.14	0.84	3.39	0.85
17. I learned how to identify various alternatives/solutions to a problem using the instructional materials	3.01	0.86	3.41	0.88
18. I improved my problem solving skills using the instructional materials	2.51	1.14	3.50	0.90
19. I learned how to sort relevant from irrelevant facts using the instructional materials	2.15	0.84	3.43	0.79
33. My confidence in applying engineering concepts to real situations improved as a result of this engineering course	2.69	1.14	3.85	0.76

Self-Efficacy (like, easier, emotional, self-confidence, accomplishment, responsibility, interdisciplinary)	Pre Survey Results		Post Survey Results	
	Mean	Standard Deviation	Mean	Standard Deviation
10. I like Engineering	4.01	0.94	4.17	0.99
20. The instructional materials, class activities, labs, and assignments were integrated in a way that made my learning easier	3.00	0.98	3.43	0.85
21. The instructional materials emotionally engaged me in learning the course topics	2.14	0.76	3.04	0.88
22. The instructional materials increased my self-confidence	2.44	0.94	3.19	0.77
23. I achieved a sense of accomplishment in learning by using the instructional materials	2.85	0.85	3.39	0.87
24. The instructional materials helped me assume a greater responsibility for personal learning	2.98	0.94	3.40	0.92

Ease of learning subject-matter (trouble, discipline, no idea, frustrated, stress, insecure)	Pre Survey Results		Post Survey Results	
	Mean	Standard Deviation	Mean	Standard Deviation
2. I have trouble understanding Engineering because of how I think	2.18	0.89	2.15	0.90
5. I get frustrated going over Engineering tests in class				
6. I am under stress during Engineering classes	3.10	0.99	2.73	0.86
8. Learning Engineering requires a great deal of discipline	3.58	0.78	3.86	0.86
9. I have no idea of what's going on in Engineering	2.14	1.40	1.96	0.93
12. I feel insecure when I have to do Engineering homework	2.14	0.88	2.46	0.84

Impact on team working (interpersonal, listening to others, consensus, share ideas, interaction)	Pre Survey Results		Post Survey Results	
	Mean	Standard Deviation	Mean	Standard Deviation
26. The instructional materials helped me improve my team-building and interpersonal skills	3.00	0.80	3.43	0.80
27. The instructional materials helped me and my classmates listen carefully to each other's statements and ideas	2.94	0.80	3.22	0.80
28. The instructional materials helped me and my classmates arrive at decisions based on consensus building	2.55	0.74	3.31	0.72
29. The instructional materials helped me and my classmates share ideas with each other	2.66	0.90	3.14	0.85
30. The instructional materials enhanced my interactions with my classmates	2.44	0.87	3.10	0.92

Communication skills (writing, presentation, informal communication)	Pre Survey Results		Post Survey Results	
	Mean	Standard Deviation	Mean	Standard Deviation
31. My writing skills improved as a result of this Engineering course	2.63	0.92	3.74	0.80
32. My presentation skills improved as a result of this Engineering course	3.01	1.01	3.88	0.65
36. My informal communication skills improved as a result of this Engineering course	3.34	0.96	4.02	0.88

To further analyze improvement results, the implementation year for the case study (2009) was compared to two control years (2007 and 2008). For the control years versus implementation year the following parameters were identified: 1) the same instructor was assigned for all three years 2) except for the case study, same curriculum was used each year, and 3) other then the case study, there were no significant difference in the course.

Mid-Term Ethics Exam

Year	Average	Standard Deviation
2007	82.4	7.1
2008	86.1	6.9
2009	92.0	5.5

Final Grade

Year	Average	Standard Deviation
2007	88.2	4.9
2008	90.1	4.2
2009	93.4	3.1

Retention

	Students Enrolled in Course	No. of Drops or Withdraws	Retention Rate
2007	136	9	93.4%
2008	135	8	94.1%
2009	140	2	98.6%

Discussion

The results from the application of the LITEE case study at The University of Toledo are very encouraging. All outcomes measured for this study indicated signs of improvement as validated by the t-test for the pre and post student surveys. Most dramatic were retention rates and the earned grades for the students for the midterm ethics exam and final grade for the course. The retention rate increased by 4.5% from 2008 and 5.2% from 2007 for the course based on the number of students enrolled versus the number of drops or withdraws. In addition, the average grade in the class for the ethics midterm exam increased by 5.9% from 2008 and the average final grade in the course increased by 3.3%. Based on comments provided from students for the midterm and final course evaluations, the students enjoyed the case study and felt that it added value for their understanding of the course. In addition, many students commented on how the case study made ethical issues 'come alive' and increased their interest and the material and study time outside of class. This is reflected in the higher course grades and ethics midterm exam grades. General comments also indicated that the students enjoyed and learned from the interaction with each other and the professor regarding controversial legal and ethical issues presented in the case. Perren and Ram found similar results when applying the case study method to small business and entrepreneurial research courses [3].

Results from the LITEE pre and post learning outcome/assessment surveys also indicated strong improvements in student perceptions of engineering. The students' general attitude toward engineering improved for all categories except the fact that the subject of engineering is learned quickly and easily understood by most people. Based on feedback from students, these categories decreased due to the difficult nature of the courses that the students were taking in addition to the MIME 1010 Professional Development course. Specifically, Engineering Physics I, Engineering Statics, and Calculus.

As a result of completing the course and the LITEE case study, the survey results indicated that the students' perception of the relevance of the course matter to life and society improved. Based on student feedback, the Lorn Manufacturing case that was used for this course was the driving force behind this improvement. The students were able to see, firsthand, the impact of engineering analysis and design from multiple perspectives and the dangers of poor product and process design.

Perceptions also improved in terms of cognitive higher order learning based on the pre and post survey. By applying engineering analysis concepts to the Lorn Manufacturing case, the students were able to better understand and evaluate the interrelatedness of various topics in addition to sorting out relevant information for the case. Most meaningful was the increase in the students' confidence in applying engineering concepts to real situations improved as a result of the engineering course. The mean response score increased by over 1 full point from 2.69 to 3.85 with a decrease in the standard deviation of responses. Rees and Porter reported similar improvements in the use of case studies in management training and development [1].

In terms of self-efficacy, the survey results indicated increases in the students' like for engineering and the instructional material. Based on student comments, this stemmed from the engaging nature, engineering focus, and teamwork involved in the case work. Ramasway conducted a study regarding student peer learning and found that students were able to effectively teach significant curricular content and improve presentation skills [8]. Ease of learning also indicated improvements in every survey category.

One of the great benefits of the application of this case study was the enhanced teamwork and communication during class and between students. All categories for these leaning outcomes indicated strong improvement. In the post evaluation, one student commented on how the interaction from the case allowed him to form strong relationships with several students in the class, including forming a study groups for other courses.

The implications of these findings to educators are very positive. Based on the results of the study, the application of the case study in this class increased retention and attendance. Based on student comments, the integration of the case study increased retention of the material and their satisfaction with the course. The case study offered another mechanism for students to study and relate concepts of the course and understand its role in engineering and life. This, in turn, increased the students' confidence in engineering and should help to improve graduation rates. The interaction and high level of communication that resulted from the application of this case fostered new relationships among students and faculty, relationships that will carry forward during the students' education at The University of Toledo. Based on the positive results of this case study, it may also be used as a recruitment tool to highlight the dynamic and interactive nature of engineering courses.

The limitations of this study center on the student population analyzed and the tracking timeframe regarding the results. The case study was applied to a freshman level course that was comprised of mostly 18-year-old Caucasian males. Few females or minorities were represented in the class, due to the Mechanical Engineering student population at The University of Toledo. Since the class was taught at the freshmen level, no upper class students were represented. Additional limitations include the degree of subjectivity associated with the pre and post survey as it gauged perceptions versus tested results. This was addressed by including a comparison to historical retention rates, exam grades, and final grades in the course. The final limitation was the short time for the study, which was a 16 week semester. Tracking the long term results and perceptions into fulltime employment would be more meaningful.

Suggested future studies include tracking the long term performance of the students involved in the class and including upper level courses. This would allow the research team to understand long term trends and benefits of the case study to various students groups. Also, the inclusion of minority and female students to enhance the diversity would be useful.

Conclusions

The application of the LITEE Lorn Manufacturing case to a freshman level mechanical engineering course proved to be a value added addition. The case enhanced the learning experience by improving the attitudes of the students toward the subject matter and highlighting the relevance to life society. In addition, students demonstrated improved communication skills and team working. In comparing the course to previous semesters without the inclusion of the LITEE case, retention rates, attendance, final grades improved. In conclusion, this addition of this case was very beneficial and will be included in future offerings of the course.

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