Implementation of a Project-Based Learning Approach, Case Study of "Measurement and Evaluation Techniques in Industrial Engineering" Course

Dr. Behin Elahi, Indiana University Purdue University, Fort Wayne

Dr. Behin Elahi is an Assistant Professor in Industrial Engineering/Industrial Engineering Technology at Purdue University Fort Wayne (Fort Wayne, Indiana). Previously, she was fixed-term instructor at Michigan State University (East Lansing, MI) teaching courses such a manufacturing plan and control, supply chain modeling and management. She got her PhD in Industrial Engineering from the University of Toledo (Toledo, OH) in 2016. She has also a Master degree in industrial Engineering and was a consultant/ project manager of the Business Waste Reduction Assistance Program (BWRAP), a partnership between EPA, University of Toledo and Lucas County in Ohio from 2012-2016. She is a professional and an active member of the Society of Women Engineers, Society of Manufacturing Engineers, Institute for Industrial and System Engineering.

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Behin Elahi

Assistant Professor, Ph.D. in Industrial Engineering, Department of Manufacturing and Construction Engineering Technology

Purdue University Fort Wayne, 2101 East Coliseum Boulevard, Fort Wayne, Indiana 46805-1499, USA (belahi@purdue.edu)

Abstract

This paper focuses on the advantages of course-based research projects experience in an industrial engineering graduate course. Along with teaching the course materials, students were involved in two research projects. In the first project, they were asked to determine significant factors in a cold drawn process on the ultimate tensile strength of L-605 wire. They applied design of experiment (DOE) technique, identified critical factors and found the best setting for factor level which results in higher yield. In the second project, they were asked to determine a potential optimized structure of 3D-printed material to be used for future space suits. They designed different structures and analyzed the fabric strength versus fabric shape and structure using tensile test. The uniqueness of this project learning paper is the key findings from the study and the associated survey. They demonstrate that the project-based learning approach improves the students' attitudes towards engineering, results in higher-order cognitive learning, boosts their self-efficacy, enhances learning through high retention of the learning material and the subject matter, strengthens team working and communication skills. The results also indicated that the project encouraged group interdependence, active learning, and higher level thinking skills. Students viewed the project as a valuable and interesting experience.

Keywords: Project-Based Learning, Design of Experiment, Active Learning

Introduction

Project-based learning is an instructional approach planned to provide students with the opportunity to develop knowledge and skills through engaging projects set around the challenges

and problems they may tackle in the real world. It allows the learner to be involved in the analysis of a given project and the search for potential and feasible solutions (Van Den Bogaard and Saunders-Smits, 2007). Such a technique presents opportunities for deeper learning in-context and for the development of important skills tied to college and career readiness (Shaffer et al., 2014; Alves et al., 2012; Fleming 2010). Students' involvement in research projects is attracting more attention in the last decade (Shaffer et al., 2010; Harrison et al., 2011; Gavin 2011). The literature review indicates that project-based learning offer several advantages over traditional courses by enhancing self-efficacy and preparing a unique opportunity for students to put their knowledge into practice (Shaffer et al., 2014; Tamim and Grant 2013). Such experience allows students and instructors to collaboratively bridge the research and classroom and provide research experiences for students relative to traditional individual mentored research. Students who are engaged in research projects report cognitive gains such as a) learning to think and analyze, b) affective gains such as delight, c) psychosocial gains such as belonging to a team, identifying as an effective engineer, and d) behavioral gains such as motivations to pursue graduate education or careers in engineering (Downing et al., 2011; Amamou and Cheniti-Belcadhi 2018; O'Sullivan 2013).

This paper analyzes the students' attitude and performance after experiencing a real research projects in "Measurement and Evaluation Techniques in Industrial Engineering" course. Upon completion of the course, students showed increased confidence in using Measurement and Evaluation techniques.

Course Overview and Research Methodology

In this research, the course of Measurement and Evaluation Techniques in Industrial Engineering (IT 507 graduate level, 3 credit course) was assessed. The course description for the IT507 is: "This course covers applied statistical techniques and design of experiment in solving and analyzing industrial problems. It focuses on measurement and evaluation strategies in the industry."

This study was conducted across two semesters (each semester had 16 weeks, class size of 8 students) for the same course: in the spring of 2017 for a lecture-based classroom course and in the spring 2018 for a mix of lecture-based and problem-based classroom course. The faculty administering the courses in spring 2017 and 2018 was the same. The instructor has taught the course for two semesters before spring 2017 and 2018 (This can have learning effects in the

instructor as well, which are then transferred into the results of the classroom).

The grade distribution in spring 2017 and 2018 was as follows:

HW and Group assignment 25%, Midterm Exam 25 %, Final Exam 30%, Group Project (presentation and technical report) 20%. Assessment of project report and oral presentation were conducted using proper rubrics (see Appendix A and Appendix B). In spring 2017, faculty asked students to apply one of measurement techniques on a numerical example, as a course project while in the spring 2018 the faculty decided to engage students in a real research project to apply measurement techniques and solve an issue for industries. In spring 2018, students and the instructor had five on-site visits to tackle the defined project of industries. Every other week, student teams had a group meeting with their instructor and reported their progress in achieving objectives. The research projects provided an opportunity for the students to work in teams, enhance professionalism, and knowledge of contemporary issues – creating 'well rounded' and 'job market ready' engineers upon graduation. The research projects somehow improved students' understanding of measurement techniques, making over some other approach.

Summary of Conducted Research Projects

Two projects were defined based on industry's need clearly as follows and students were teamed up to work on them.

First Project: Cold drawing is widely used metal forming process with integral advantages such as closer dimensional tolerances, better surface finish and improved mechanical properties as compared to hot forming processes. A team planned to focus on improving the ultimate tensile strength of L-605 ® wire by determining significant factors. L-605 ® wire has a number of applications in the aerospace industry and medical industry due to the fact that it maintains moderately high strength even in high temperatures. The cold drawing process has many variables that should be controlled to produce consistent wire properties. Their research focused on evaluation of the effect of speed, tension, and lubrication temperature on the ultimate tensile strength of the cold drawn L-605® wire via the design of experiment technique. The data analysis verified that speed and tension factors, along with the interaction of speed and temperature, have significant effects on the ultimate tensile strength of the drawn L-605 wire.

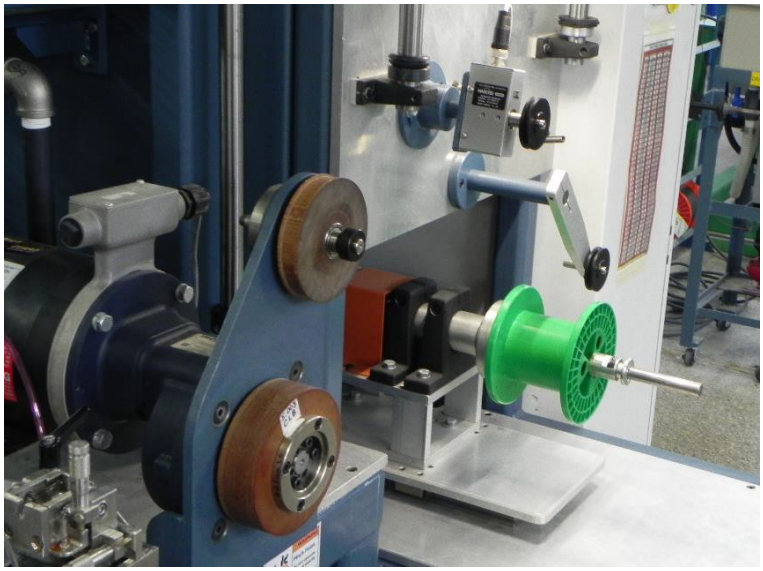

Figure 1. Schematic View of a Small Diameter Wire Drawing Equipment

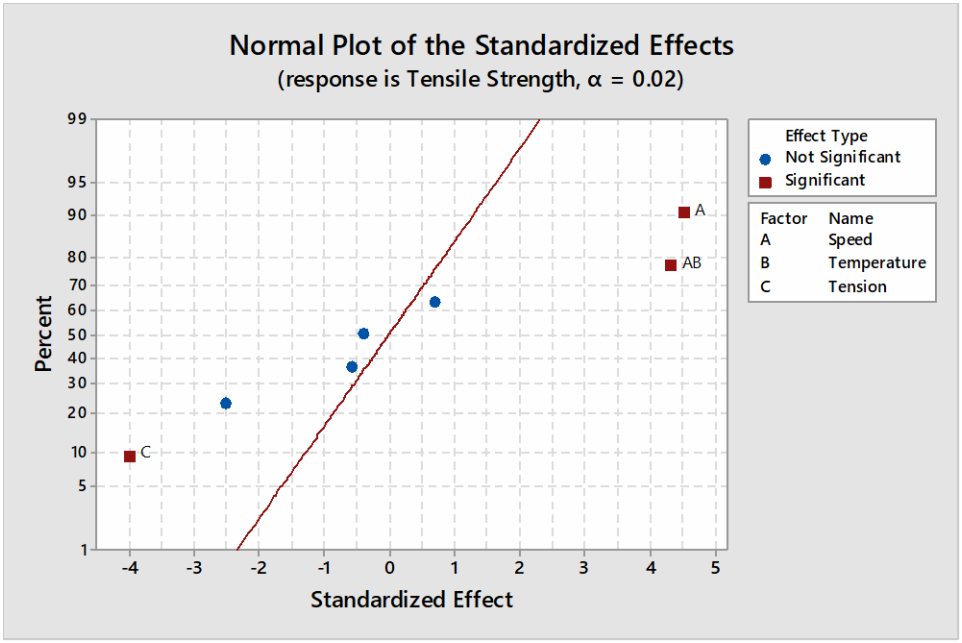

Figure 2. Significant factor effects in Cold drawing process

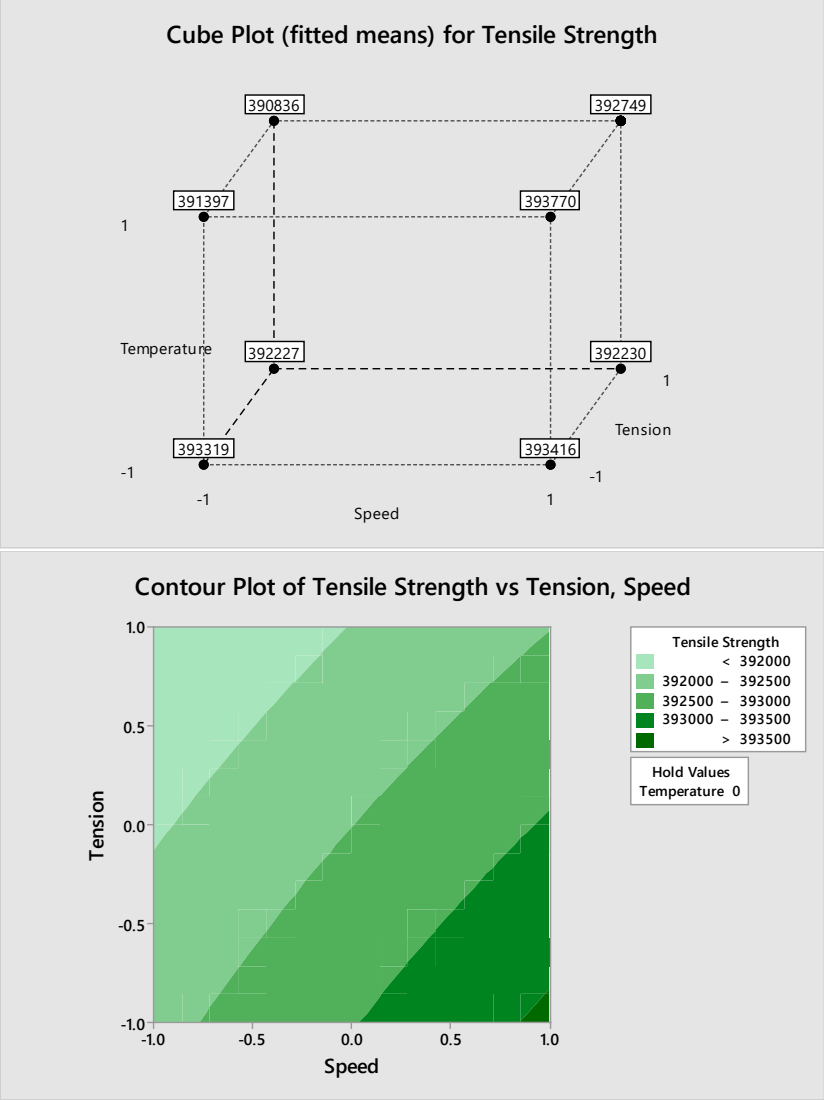

Figure 3. Using Measurement techniques (Contour plot and cubed plot) to analyze data.

Second Project: Students focused on an innovative idea to design, make, and test 3D printed fabrics to be used as a flexible skin for future spacecraft, spacesuits, or for deployable antennas.

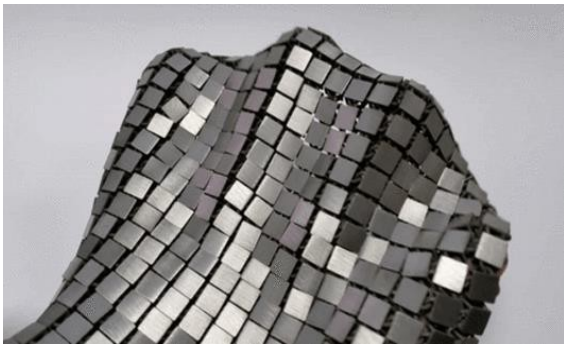

Figure 4. An innovative idea for making 3-D printed fabrics

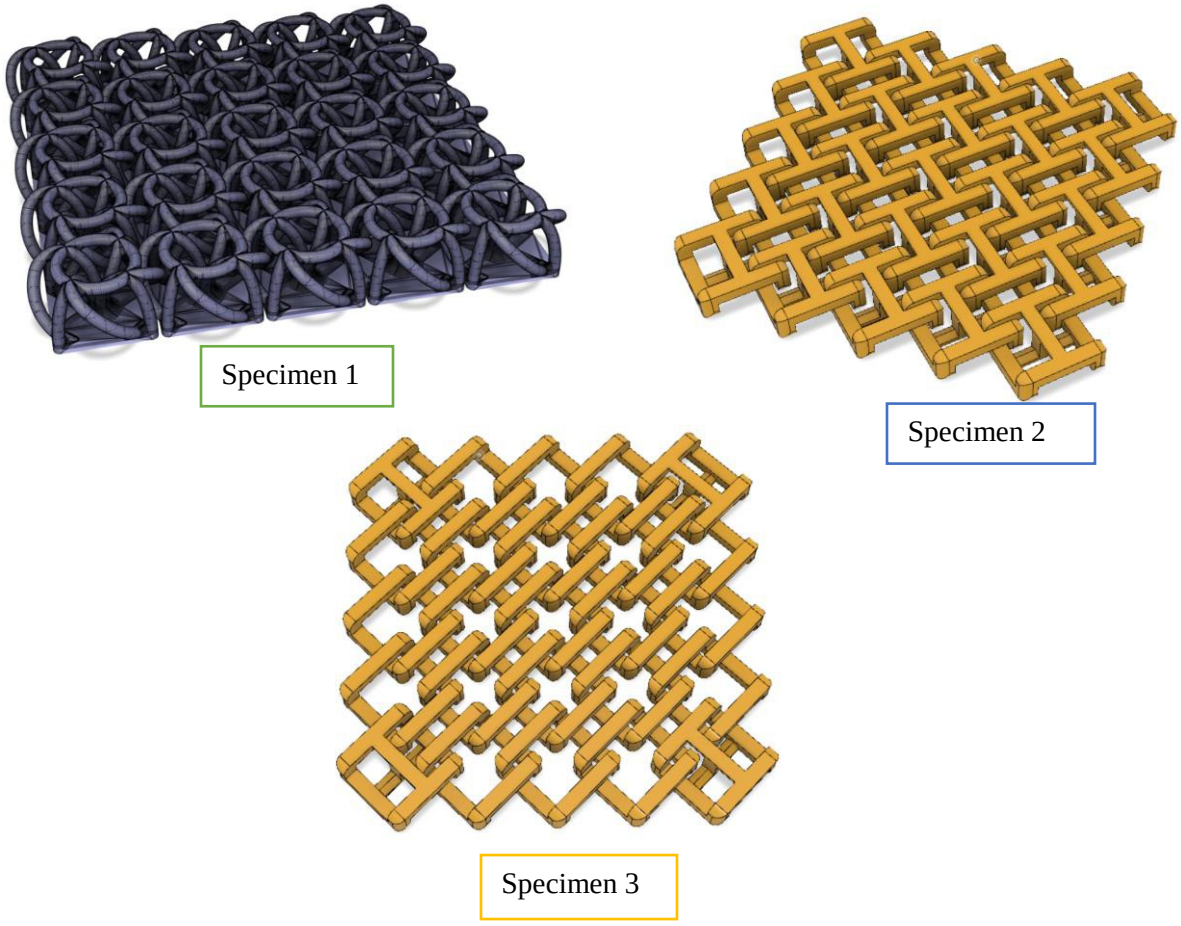

Figure 5. Proposed fabric structure

They used Polylactic Acid (PLA), a thermoplastic polymer and printed each structure. They analyzed the Tensile strength of each structure using statistical techniques learned in the related course.

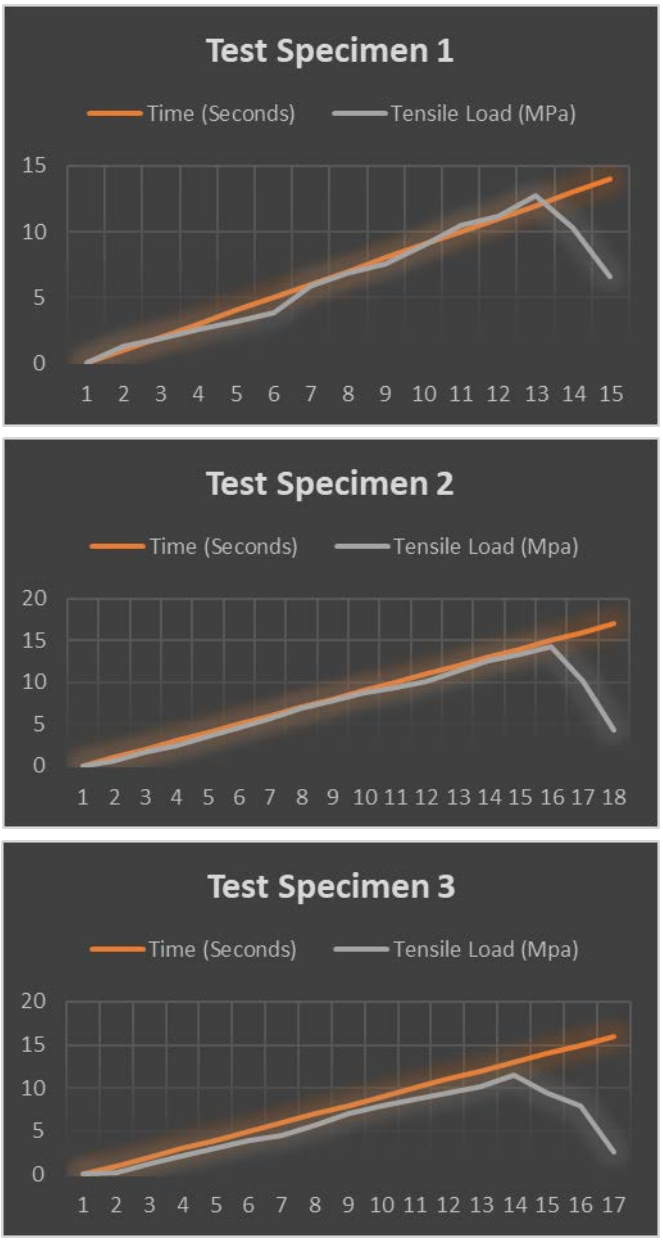

Figure 6. Using Measurement techniques (Tensile test and statistical analysis) to analyze data.

Data Analysis of Learning Outcomes

The hypotheses of this research defined in a way to evaluate whether "the application of a course-based research project for the "Measurement and Evaluation Techniques in Industrial Engineering" course will:

- Improve the students' attitude towards measurement techniques,
- Enhance the students' understanding of the relevance of subject matter to life and society

- Improve the student's ability in decision making, problem solving skills, and applying concepts
- Improve the students' self-efficacy (like self-confidence and responsibility)
- Enhance the ease of learning the subject matter for the students
- Enhance team working for the students
- Improve communication skills for the students
- Improve the student's final grades for the course

The hypotheses were tested using the Kolmogorov-Smirnov normality test and t-tests for comparing a) the pre surveys given during the first week of the course in Spring 2017 and Spring 2018, and b) the post surveys given during the last week of the course in Spring 2017 and Spring 2018.

The t-tests were used versus z-tests due to the sample size of 8 for each response, t-tests at the 95% confidence level were conducted to examine if there were significant differences/improvements from the pre and post assessment survey results in Spring 2017 and 2018 and the results were compared between years.

***Null Hypothesis* 1**:

H_0: *There was no difference between the pre and post assessment survey results for each response.*

***Alternative Hypothesis* 1**:

H_1: *There was a significance difference between the pre and post assessment survey results for each response.*

A comparison of the survey results for the two offerings of the course indicated very similar pre-survey results that were not statistically different at the 95% confidence level.

However, the comparison of the spring 2017 classroom versus the spring 2018 classroom post survey indicated statistically significant improvements at the 95% confidence level.

As displayed in Table 1, the students' mean scores in post survey responses for the spring 2018 classroom have significantly increased. These results indicate that the spring 2018 classroom approach provided better outcomes in terms of student attitudes and self-efficacy.

Table 1. Post Survey Comparison between Course Offerings (Scale Likert 4 points)

Question	Spring 2017		Spring 2018		t Test Statistic	Analysis of Null and Alternative Hypotheses #1 *at the 95% Confidence Level*
	Mean	Std. Dev.	Mean	Std. Dev.		
1. The instructional materials, class activities, labs, assignments, and the research projects were integrated in a way that made my learning easier	2.83	0.84	3.89	0.73	2.69	P-value=0.018 *H0 rejected and H1 Accepted*
2. The instructional materials and research project emotionally engaged me in learning the course topics	2.64	0.91	3.62	0.76	2.34	P-value=0.036 *H0 rejected and H1 Accepted*
3. The instructional materials and research project involvement increased my self-confidence	2.84	0.79	3.82	0.74	2.56	P-value=0.024 *H0 rejected and H1 Accepted*
4. I achieved a sense of accomplishment in learning by using the instructional materials and working on a research project with teams	2.86	0.74	3.69	0.72	2.27	P-value=0.041 *H0 rejected and H1 Accepted*
5. The instructional materials and involvement in a research project helped me assume a greater responsibility for personal learning	2.76	0.88	3.86	0.80	2.62	P-value=0.021 *H0 rejected and H1 Accepted*

Additionally, if it is assumed that comparing the average GPA of the students in spring 2017 and 2018 can be helpful, an analysis can be conducted on GPAs. The average final grades in the course increased by 6% (statistically significant at 95% confidence level, t Test statistic=2.60, p-value =0.022; n_1 and n_2=8.

***Null Hypothesis* 2**:

H_0: *there was no difference between the final grades in Spring* 2017 *and Spring* 2018

***Alternative Hypothesis* 2**:

H_1: *there was a significant difference between the final grades in Spring* 2017 *and Spring* 2018

As the p-value is less than the alpha (p-value< 0.05), then the null hypothesis is rejected, and we state the result is statistically significant.

Table 2. Final Grade Comparison

	Midterm Grade		Final Grade	
Year	Average	Standard Deviation	Average	Standard Deviation
Spring 2017	84.7	6.3	85.8	4.4
Spring 2018	89.6	5.2	91.2	3.9

Discussion on Validity

It is important to think about threats to validity. Here, the main focus is on internal and external validity as follows:

a) Threats to Internal Validity

Extraneous effects (history)

Are participants exposed to events, other than the treatments, whose effects on their behavior could obscure the effects of the independent variable?

Temporal effects (maturation; fatigue)

Do the participants change with the passage of time in ways unrelated to the effects of the independent variable?

Group composition effects (selection)

If different groups are used to compare the effects of treatments, could pre-existing differences among the groups obscure the effects of the independent variable?

Interaction of temporal and group composition effects

Could changes in the participants' behavior over time that are related to pre-existing differences among groups obscure the effects of the independent variable?

Selective sampling attrition (mortality)

Do participants drop-out of the groups during the study in a systematic or selective way? This could create differences among groups that would obscure the effects of the independent variable.

Statistical regression effects (regression to the mean)

Regression toward the mean: the tendency of extreme (very high or very low) scores to fall closer to the mean on re-testing. Could changes in participants' responses to the measures be caused by this?

b) Threats to External Validity

Non-representative sampling

Are the participants in the research study so unrepresentative of those people who need to be understood? This would preclude generalization of the research results from the former to the latter.

Non-representative research context

Is the context in which the research study was carried out so unrepresentative of contexts where the behavior in question takes place as to preclude generalization of the research results from the former to the latter?

Based on the conducted statistical analysis, the analysis of this paper is valid and can be generalized (There is a potentiality of generalization of this paper's idea regarding similar graduate courses) if it is tested for a larger sample size in different locations and institutions.

Conclusion

The application and implementation of the course-based research project and real case study to the "Measurement and Evaluation Techniques in Industrial Engineering" course proved to be a value-added addition and will be included in future offerings of the course. The approach enhanced the learning experience by improving the attitudes of the students toward the subject matter. Some limitations of the study include the location and sample size. A larger, more diverse sample would provide broader results.

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Appendix A

Assessment of Project Report

Max Score = 120

Reviewer's Initial:_____ Date: _____

Name of Student: _____

Title:_____

Writing Communication

(Decimal scores are allowed)

Performance Criteria	Weight	Total Score	Score	A	B	C	D	F
				4	3	2	1	0
Report writing is clear and concise.	2			Report is to the point, clear, and concise. Coverage is good.	Report sometimes deviates from the subject. Coverage is adequate.	Report deviates from the subject. Coverage is not adequate.	Report is vague. Coverage is poor.	Report not written
Report is well organized and easy to follow.	2			Good headings. Appropriate paragraphs. Followed formatting instructions.	Appropriate headings. Long paragraphs. Missed some instructions.	Few headings. Long paragraphs. Missed many instructions.	No headings. Long paragraph. Missed all instructions.	Report not written
Report is written in professional language and style.	3			Proper words used. Written in third person. Good Exceptional.	Some improper word used. Written in third person. Good.	Frequently improper words used. Written in first person. Fair.	Frequent improper words used. Written in first person. Needs improvement.	Report not written
Report free of typographical errors.	1			0 errors.	1 to 3 minor errors.	4 to 5 minor errors.	6 to 7minor errors.	8 or more errors
Use of appropriate technical literature.	2			Appropriate and current technical literature used.	Appropriate but older technical literature used.	Appropriate but outdated technical literature used.	Inappropriate technical literature used.	Not given in the report
Outcome *g1* score Max=40			Comments:					

Professional Development

Performance Criteria	Wt.	Total Score	Score	A	B	C	D	F
				4	3	2	1	0
Use external sources in course/project work	5			Reliable external sources used.	External sources used.	Some external sources used.	Internal sources only used.	No sources used at all.
Outcome *h* score Max=20			Comments:					

References

Performance Criteria	Wt.	Total Score	Score	A	B	C	D	F
				4	3	2	1	0
All references cited in the written work	5			All references cited clearly in the text.	Most references cited in the text.	Some references cited in the text.	Few references cited in the text.	None cited.
Outcome i_1 score Max=20			Comments:					

Creativity in Design

Performance Criteria	Wt.	Total Score	Score	A	B	C	D	F
				4	3	2	1	0
Select a well-defined problem for project.	4			Project description is clearly defined and explained.	Project description is clear but needs explanation.	Project description not clear and needs explanation.	Project description is not clear at all.	Project not done.
Design using proper knowledge and skills.	4			All knowledge and skills were used.	Some relevant knowledge and skills were not used.	Important knowledge and skills were not used.	Irrelevant knowledge and skills were used.	Project not done.
Design creatively and accurately.	2			Very creative in design.	Reasonable creativity is shown in the design.	Little creativity is shown in the design.	Textbook application in the project design.	Project not done.
Outcome *d* score Max=40			Comments:					

Overall Project Score Max=120		Overall Comments:

Appendix B

Assessment of Student Presentation
Max Score = 40

Name of Student:_____ Date: _____

Start time:_____Finish time: _____

(Decimal scores are allowed)

Performance Criteria	Weight	Total Score	Score	A	B	C	D	F
				4	3	2	1	0
The presentation includes introduction, body, conclusions, and references.	2			They are given very clearly. Time spent on each was adequate.	They are fairly clear. Time spent on one was short.	They are just clear. Time spent on two or more was short.	They are barely clear. Time spent on all three was short.	Not done.
The student communicates clearly.	3			Communicates very clearly. Eye contact is good.	Clear but some "ums". Eye contact is ok.	Sometimes hard to hear. Read from script.	Mumbled most of the time. Often had back to audience.	Not done.
The student has well-prepared audiovisual materials.	2			Slides well prepared. All slides were clear.	Slides well prepared. Few slides not clear.	Slides were ok. Most slides not clear.	Poor slides. Hand drawn sketches.	Not done.
The student responds effectively to questions & comments.	2			Most questions answered correctly and confidently.	Most questions answered, but lacked confidence.	Answers were weak or not in sync with questions.	Could not answer questions. No time for Q&A	Not done.
The student dresses appropriately.	1			The dress was appropriate for technical presentation. Exuded confidence.	The dress was acceptable for technical presentation. Confidence was adequate.	The dress was casual. Confidence was weak.	Dress was very casual. Did not take the subject seriously.	Not done.
Overall Score			Comments:					

Appendix C

Post-Survey

Please indicate how strongly you agree or disagree with the following statements:	Strongly Disagree	Disagree	Agree	Strongly agree
The instructional materials, class activities, labs, assignments, and the research projects were integrated in a way that made my learning easier	O	O	O	O
The instructional materials and research project emotionally engaged me in learning the course topics	O	O	O	O
The instructional materials and research project involvement increased my self-confidence	O	O	O	O
I achieved a sense of accomplishment in learning by using the instructional materials and working on a research project with teams	O	O	O	O
I achieved a sense of accomplishment in learning by using the instructional materials and working on a research project with teams	O	O	O	O