Case Study on the Two Individual Paradigms of Education in a Manufacturing Quality Course

By
Rustin Webster and Matthew Turner

ABSTRACT:

This article provides a review of two paradigms of education and the application of each in a manufacturing quality control course for engineering technology (ET) students. The most common paradigm of education used in quality-focused courses is teaching-centered. This traditional method has contributed to students' perception of quality (e.g., quality control, statistical process control, total quality management), as a dry subject to learn compared to other core and/or elective courses in their plans of study. This case study describes the creation and implementation of a manufacturing quality control curriculum that is learning-centered. Based on student feedback, this approach increased ET students' self-reported satisfaction of the course, lab, and instructor, as compared to a teaching-centered course. Additionally, the students' engagement and dynamic involvement in the learning activities increased, due in part to project-based learning. In order to enhance further adoption of student-centered instructional techniques in quality-focused courses, the authors have shared all project-based learning resources.

Keywords: Manufacturing Quality Control, Paradigms of Education, Active Learning, Project-Based Learning, Engineering Technology

INTRODUCTION

The use of lectures and problem sets as the default model of engineering and technology education is increasingly giving way to evidence-based instructional methods, primarily active learning. Instructors use active learning to engage students beyond passively sitting and listening to a lecture through activities such as peer teaching, team-based problem-based learning, project-based learning, or discussion-based learning. In general, active instructional techniques enhance learning compared to traditional lecture for most students (Freeman et al., 2014). However, Streveler and Menekse (2017) have recently argued that although active learning has been sufficiently proven, it is not a "blanket remedy for all instructional inadequacies" (p. 189) and significant work remains to determine the relationship between the different active learning strategies and their effect in and on different situations, disciplines, learning objectives, and students. This work responds to that call by presenting a case study of the application of two paradigms of education (i.e., teaching-centered and learning-centered) in a manufacturing quality control course for engineering technology (ET) students.

Definition

Although there are no universally accepted definitions for many of the terms used in this paper, the following list is representative of commonly accepted definitions as utilized in the published literature relating to higher education. The authors have provided them to enhance clarity and consistency among readers.

- Paradigm. A frame of reference that determines how we perceive, interpret, and make sense out of how we educate students (Johnson, Johnson, & Smith, 2006, McManus, 2001).
- Teaching-centered paradigm. The traditional paradigm of higher education with discussions generally centering on the use of passive learning instructional methods (e.g., lecturing), and a classroom environment where the instructor teaches the subject to the student and expects them to learn it (i.e., instructor is central) (McManus, 2001). *Has become engrained in higher education through widespread adoption.*
- Learning-centered paradigm. Discussions generally center on the use of active learning instructional methods (e.g., project-based learning), and a classroom environment where the instructor helps the students learn the subject (i.e., instructor and student are partners) (McManus, 2001). *Traditional instructional activities, such as homework, exams, quizzes, and lectures may also occur when the instructor is not acting as a coach or mentor.*

- Passive Learning. The use of teacher-centered methods favoring lectures presented by an instructor to an audience of students. (Menekse, Stump, Krause, & Chi, 2013). *Teaching is the emphasis.*

- Active Learning. Instructional methods that require students to do meaningful learning by participating in activities (Bonwell & Eison, 1991, Prince, 2004). *Learning is the emphasis and the core is student engagement and dynamic involvement in the learning activity.*

- Project-Based Learning (PBL). A form of active learning in which learning activities are context specific, students participate in the learning process, and goals are achieved through social interaction and the sharing of knowledge (Kokotsaki, Menzies, & Wiggins, 2016). Distinction from active learning may be made by the extended length of time students work to investigate and respond to a complex question, problem, or challenge (Donnelly & Fitzmaurice, 2005) and that the work produces a realistic product or presentation (Jones, 1997).

Literature Review

Educational fields, such as E , that contain well-defined content and skills to be learned are often teacher-centered, with an emphasis on the transmission of information. This perspective, often called the Engineering Conception, values teacher expertise, efficient content coverage, productive time management, and the development of instructional materials (Pratt, 1992). The act of teaching is therefore often a matter of presenting one's knowledge in a clear and accurate format, often utilizing educational media such as slide-based presentations (Kember & Gow, 1994). Although common in higher education, major deficiencies in the instructional techniques based in the Engineering Conception have been identified, including high drop-out rates due to poor-quality learning environments (Seymour & Hewitt, 2000), and an overall decline in the competitiveness of the American Science, Engineering and Math (SEM) workforce (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2007). These, and other, pressures have led to widespread support for changes to STEM education methods. For example, George (1996) recommended that better educational outcomes could be achieve via a shift in the paradigm of STEM education toward environments of engagement, using direct experience with real methods and processes to excite students to explore and discover the areas of science, technology, engineering and math.

In contrast to the Engineering Conception, "learning-centered" approaches are methods that place an emphasis on the relationship between the teacher and the learner, with the instructional process focused on the cognitive development and personal autonomy of students (Pratt, 1992). This learning facilitation perspective is often characterized by a focus on high-level aims such as problem-solving skills, critical thinking, and independent learning and a view that teaching is a facilitating, interactive, procedure of motivating students and creating environments where students really want to learn (Kember & Gow, 1994). Learning-centered teaching methods are typically characterized using in-class activities and include active learning, cooperative learning, and inductive teaching and learning (Prince & Felder, 2006). A wide variety of studies have found support for such methods, particularly active learning. For example, integration of challenge questions, physicist-like reasoning, and problem solving during class time were shown to increase student attendance, engagement, and learning in a large-enrollment physics class (Deslauriers, Schelew, & Wieman, 2011). A similar intervention in a chemical engineering course found effects related to both improved grade-point average and drop-out rates (Bullard, Felder, & Raubenheimer, 2008). Such findings are typically consistent across STEM education literature, and support increased engagement and content retention, as well as improved student attitudes and study habits (Prince, 2004).

Like the broader category of active learning, a breadth of research supports the use of PBL in educational settings. Typically, these learning activities must meet five requirements: adds active participation by students (Cocco, 2006, Jones, 1997, Thomas, 2000), is realistic and context- specific content (Blumenfeld et al., 1991, Cocco, 2006, Thomas, 2000), produces a product or presentation (Blumenfeld et al., 1991, Helle, Tynjälä, & Olkinuora, 2006, Jones, 1997), is collaborative or team-based (Blumenfeld et al., 1991, Cocco, 2006, Helle et al., 2006), and lasts for extended periods of time (Jones, 1997). Instruction that uses methods meeting these criteria has been shown to improve student learning in a variety of ways. Primarily, PBL has been shown to increase student engagement and interest because of the cognitive challenges associated with the project (Wurdinger, Haar, Hugg, & Bezon, 2007) and the real-world problem solving (Lou, Shih, Ray Diez, & Tseng, 2011, Verma & Dickerson, 2011). In addition, it has been shown to promote the learning of conceptual knowledge (Barak & Asad, 2012), critical thinking skills (Shepard, 1998, Tretten & Zacharious, 1997), and educational resource utilization (Barron et al., 1998).

Additionally, a variety of design factors have been identified that influence P implementations. PBL must be accompanied by didactic instruction (Grant & Branch, 2005), and it is best utilized in a two-phase approach: phase 1 is to introduce the knowledge and technology concepts, and phase 2 is to implement the knowledge via independent design and production (Drain, 2010). Scaffolding techniques should be used to guide instruction by structuring tasks in ways the enable learners to focus primarily on the aspects of the task related to learning goals (Hmelo-Silver, Duncan, & Chinn, 2007). Finally, effective group dynamics must be encouraged, creating and environment of positive interdependence, individual accountability, and equal participation, such that both high and low achieving students can benefit from group processes (Cheng, Lam, & Chan, 2008).

Despite the evidence supporting PBL and the relative prevalence of quality-focused engineering and engineering technology courses (Callahan & Strong, 2004), little research has been done on the implementation of PBL in quality classrooms. There have been no studies comparing students' learning outcomes between teaching-centered and learning-centered approaches to the same course. The following paragraphs summarize the existing literature.

Researchers have reported on the use of a variety of active learning pedagogies (e.g. PBL, team-based learning, and problem-based learning) for quality education. One of the most common is the use of catapults, or commonly called statapults, to study statistics and design of experiments. Sun and Gao (2015), designed an experiment to simulate the manufacturing improvement process. The students viewed the action of shooting a projectile (i.e. tennis or golf ball) with a catapult as a production process with variation (i.e. shooting angle, location of tension springs, etc.) and the target as product specifications. After 100 shots, students analyzed the data by creating control charts and identifying assignable and unassignable causes of variation. The experiment continued with additional rounds of shooting but each time students used prior results to improve the process. Adams (2000), utilized a statapult in a similar manner for hands on projects in an Introduction to Statistical Quality Control course. In both instances, qualitative data collected from students and instructor observations were positive.

Wang (2004), created a role-playing game for a quality control class to help teach students the concepts of Total Quality Control (TQC). Various student teams manufactured maple leaf bookmarks and one team acted as a fictional custome . The instructor required students to role-play various positions (e.g. CEO, marketer, designer, engineer, and inspector) on each team, which demonstrated the dynamic relationships that can occur in competitive manufacturing environments. The researcher collected student attitudes on the game by a simple self-created survey. Based on the feedback and instructor observations the game approach to teaching TQC was effective in teaching abstract concepts and representing certain levels of real-world experiences.

THE CASE STUDY

MET 45100, Manufacturing Quality Control, is an elective typically offered in the Spring to ET students majoring in Mechanical Engineering Technology (MET), Mechatronic Engineering Technology (MHET), and Engineering Technology at Purdue Polytechnic New Albany. The majors are part of the School of Engineering Technology (SoET) at Purdue University. Students are encouraged to take the course in their junior or senior year and after passing STAT 30100, Statistics.

The purpose of the course is to engage students on past, present, and future issues pertaining to the management of quality in services and manufacturing, in international and domestic markets, as well as in the private and public sectors. Furthermore, the conceptual and analytical skills developed in this course should enable the student to provide leadership in managing for quality. The course objectives are as follows:

- Communicate on quality management theory, principles, and practices
- Recognize the need for continuous quality improvement
- Understand and communicate on various quality control philosophies and methodologies
- Quantify and control quality through statistical methods
- Employ several quality control tools for identifying quality problems and causes
- Analyze a company's quality culture and make recommendations for improvements

The following sections will review the past three offerings of MET 45100. The first was in the Spring of 2015 and the third and fourth were offered in the Fall of 2015 and Fall of 2016 respectively. Along with a change of instructor between the first and second, the educational paradigm for the course changed from teaching-centered to learning-centered.

Teaching-Centered Paradigm

Spring 2015, 12 MET students (11 seniors and 1 junior) enrolled in MET 45100 at the Purdue Polytechnic New Albany campus. The instructor of record was a senior continuing lecturer of eight years, who had previously taught the course five times. In course planning and preparation, he adopted the teaching-centered paradigm. Over the 15-week course, class time was approximately split 85 percent lecture and 15 percent lab. The course met twice a week and lasted two hours each meeting. Students were required to purchase a textbook (Evans & Lindsay, 2012), which was the main source of information for the instructor and the students. The instructor used a Learning Management System (LMS) (i.e. Blackboard) for course organization, file sharing, assignment submissions, grading, and testing.

The instructor's goal was to transfer information and for the students to accumulate knowledge. Course design included a combination of lectures, textbook readings, exams, and assignments (i.e. textbook chapter questions and lab exercises). The instructor used a weighted grading scale to assess students' performance (see Table 1).

Exams (20 percent each) and individual assignments (3.08 percent each) were equally weighted. The instructor allowed the students to

TABLE 1. Spring 2015 Course Assessments

Item	Frequency (count)	Total Points Possible	Overall Grade Weight (percent)	Points Possible	Team or Individual	Length (weeks)
Exams[1]	3	300	60		Individual	
Assignments:			40			
1. Chapter Questions[2]	9	700			Individual	
2. Lab Exercises:	4	310				
a. Gauge R&R				100	Team	1
b. Card Drop Shop				100	Individual	1
c. Personal Quality SPC				10	Individual	15[3]
d. PEX Fusion				100	Individual	2

Notes: [1]Unequal available points per individual exams; [2]Unequal available points per individual assignments; [3]Conducted outside of normal class time form each three-member team for the gauge R&R lab exercise. The instructor did not allow for peer reviews at the completion of the lab exercise, thus grade adjustments per teammembers did not occur. Only the personal quality lab required additional work time outside of normal class time. All exams were open book and open notes. See Table 2 for additional details on each lab exercise.

Learning-Centered Paradigm

Fall 2015, 11 MET students (11 seniors) enrolled in MET 45100 at the Purdue Polytechnic New Albany campus. The instructor of record was a visiting assistant professor in his first years. In course planning and preparation, he adopted the learning-centered paradigm. Over the 15-week course, class time was approximately split 15 percent lecture and 85 percent active learning. The course met twice a week and lasted two hours each meeting. No textbook was required for the course, however Evans and Lindsay (2012) was recommended. The instructor created all lectures and assignments. He used the same Learning Management System (LMS) (i.e. Blackboard) for course organization, file sharing, assignment submissions, grading, and testing.

Fall 2016, 8 MET students (8 seniors) enrolled in MET 45100. The instructor did not change; however, his title became assistant professor. The course design and curriculum remained unchanged from Fall 2015 offering.

The instructor's goal was to create a learning environment in which students could learn to lectures, guided/facilitated group discussions, restructure new information and prior knowledge into new knowledge about manufacturing quality control and to

TABLE 2. Lab Exercises Details

Lab Exercise	Overview	Topic(s)
Gauge R&R	Using provided measuring equipment (i.e. caliper and measuring stick), students measure the distance between two identical items on the provided handout sheet. Stu-dents record, analyze, and interpret the data using Excel.	1. Variation 2. Professional Competencies[4]
Card Drop Shop[1,2]	Using supplied materials (i.e. paper target, deck of play-ing cards, and paper clips), students drop individual cards above a target and measure resting distance to the target. Students repeat experiment while changing variables (e.g. drop method and card weight) and record, analyze (i.e. ANOVA), and interpret the data using Excel.	1. Design of Experiments (DOE) 2. Process Capability 3. Data Collection, Analysis, and Interpretation
Personal Quality SPC	Students collect data for an extended period on an item or process from their daily lives. Students record, analyze, and interpret the data with emphasize on using the seven QC tools.	1.Variability 2. Data Collection, Analysis, and Interpretation
PEX Fusion[3]	Students brainstorm factors that affect a PEX tube butt joint strength. After creating an experimental plan (i.e. screening design), students use the Taguchi method to optimize joint strength. Students record, analyze, and interpret the data using Minitab.	1. Design of Experiments (DOE) 2. Data Collection, Analysis, and Interpretation

Notes: [1]See Alloway (1994) for additional details; [2]See Arnold (2001) for revised/updated edition; [3]See Eckert (2001) for sample fusion method; [4]A combination of effective communications, problem solving, critical thinking, project management, teamwork, self-directed learning, cultural awareness, and innovation.

practice using it. Course design included a combination of mini/bridging, guest lectures, exams, assignments, field trips, and projects. The instructor used a weighted grading scale to assess students' performance (see Table 3).

The class took two field trips to local companies towards the end of the semester. The purpose of the field trips were to allow students to witness and discuss with company personnel, classroom covered quality topics and techniques(i.e. real-world application). The instructor also invited a local manufacturing engineering manager to deliver two guest lectures. The first included a mini/bridging lecture on 5S and lean manufacturing, followed by hands on activities (Sato, Trindade, & Boersema, 2011, SuperTeams, n.d.) to reinforce lecture material. The second was an informational presentation on the guest's recent international travels and involvement with international suppliers and contractors. The speaker emphasized worldwide manufacturing quality themes.

Exams (7.5 percent each), assignments (2.5 percent each), and individual projects (16.7 percent each) were equally weighted. The instructor randomly selected four (Fall '16) or five students (Fall '15) for each 5S team and two students for the Bozo Challenge and the Company Visit projects (i.e. different team members per project). At the completion of each project, students had the opportunity to submit a review of each team member. The instructor used the peer review input and self-observations to adjust individual student project grades as needed. All exams were open resource (e.g. books, internet, etc.) but students were restricted to individual test taking (i.e. no collaboration).

TABLE 3. Fall 2015/2016 Course Assessments

Item	Frequency (count)	Total Points Possible	Overall Grade Weight (percent)	Points Possible	Team or Individual	Length (weeks)
Participation and Attendance		10	5			
Exams[1]	3	340	22.5		Individual	
Assignments[2]	10	94	22.5		Individual	
Projects[3]:	3	39	50			
1. 5S				18	Team	4
2. Bozo Challenge				13	Team	2.5
3. Company Visit				8	Team	13[4]

Notes: [1]Unequal available points per individual exams; [2]Unequal available points per individual assignments; [3]Unequal available points per individual project; [4]Conducted outside of normal class time

See Table 4 for additional details on each project and Appendix for PBL resources (i.e. class project handouts).

OUTCOMES

Course Surveys

Students at the end of each semester anonymously took a University created course evaluation survey. Administration used the same survey and distribution mechanism for all three-course offerings presented in this paper. The survey contains demographic-based questions, University wide questions about course and instructor, course specific questions, and optional written comment sections. Based on the purpose of this paper, the authors have chosen to present the survey results for the university questions, a single course specific question, and a sample of written comments. On the two university questions students, self-reported on their satisfaction of the course and instructor by selecting a response on a five-point Likert scale (where 5 = extremely good, 4 = good, 3 = fair, 2 = poor, and 1 = very poor) that best reflected their perception (see Table 5). The course specific question also used a Likert scale (where 5 = strongly agree, 4 = agree, 3 = undecided, 2 = disagree, and 1 = strongly disagree) to survey student perception (see Table 5).

Additionally, students had the opportunity to leave written comments to two questions. The first question asked, "What is something/are some things that the instructor does well, e.g., something you hope that the instructor will continue to do in the class in the future?" The second question asked, "Make a suggestion(s) for improving the course (a criticism alone is not helpful; tell your instructor how you would fix any problem)." See Table 6 for comments that the authors believe relate to the purpose of this paper.

TABLE 4. Project Details

Project	Overview	Topic(s)
5S	Teams add value and eliminate waste in a manufacturing lab by using the 5S technique. Teams are responsible for designing and implementing a 5S solution to an instructor identified problem area. Students report on project outcomes.	1. 5S: Sort, Straighten, Shine, Standardize, Sustain 2. Workplace Safety 3. Professional Competencies[2]
Bozo Challenge[1]	Using supplied materials (i.e. Xpult kit and Bozo Bucket Bonanza Grand Prize Game), students shot a projectile at buckets located a specified distance apart. Students design an experiment to optimize project success. Students record, analyze, and interpret the data using Excel.	1.Design of Experiments (DOE) 2. Variation 3. Data Collection, Analysis, and Interpretation 4. Professional Competencies[2]
Company Visit	Students arrange a tour of a local company after receiving instructor approval. Students meet quality personnel and analyze internal quality control methods/techniques. Students identify and recommend quality improvements and report on project outcomes.	1. Quality Control 2. Professional Competencies[2]

Notes: [1]See Peloton Systems LLC (n.d.) and Webster (2017) for additional details; [2]A combination of effective communications, problem solving, critical thinking, project management, teamwork, self-directed learning, cultural awareness, and innovation.

TABLE 5. Course Evaluations

Questions	Mean (Std. Deviation) Spring 15 n = 11/12	Fall 15 n = 11/11	Fall 16 n = 8/8
University Questions:			
1. Overall, I would rate this course as	3.90 (.96)	4.80 (.45)	4.80 (.43)
2. Overall, I would rate this instructor as	4.10 (.79)	4.80 (.45)	4.90 (.33)
Course Specific Question:			
1. The content of the lab is a worthwhile part of this course	4.10 (.67)	4.80 (.99)	4.70 (.99)

Notes: n = number of respondents/possible number of respondents

TABLE 6. Students' Comments

Questions	Spring 15	Fall 15	Fall 16
Question 1:	• "Tries to add videos and other media to make class more interesting"	• "The labs were great!" • "… made the course very interesting and engaging. Not a traditional environ-ment where he talked and we listened, but engaged us in conversation." • "He made what would normally be a dull class pretty interesting by having several active projects and taking field trips."	• "I really enjoyed the quality tours … Projects were also very fair and relevant to the course topic." • "Makes the class enjoyable by having interactive, group discussions and group pro-jects. This format also kept a rather dry subject to be fun to learn"
Question 2:	• "The class needs more labs …" • "The material of this course, yet useful, is also very dull. There needs to be more in class examples, group work, or labs to break up the lectures. This is nothing against the instructor, the material is just dull" • "More activities would make the topics a bit more interesting" • "Connecting material to student's workplace, such as a project or report"		• "The ping pong bozo thing was not what I'd consider a worthwhile project due to the disconnect between the concept and execution of that concept" • "Improve on having more projects …"

Project Examples

A goal of this paper is to share the PBL resources (see Appendix). To inspire future adoption by others, the authors have shared a sample of students' finished projects using the supplied handouts (see Figures 1-6 and table 7). Reference Webster (2017) for a live video of the Bozo Challenge competition day. The deliverables for the company visit project are unable to be shown in this paper due to submission formating and page length.

Figure 1. 5S Project Example 1 – Before

Figure 2. 5S Project Example 1 – After

Figure 3. 5S Project Example 2 – Before

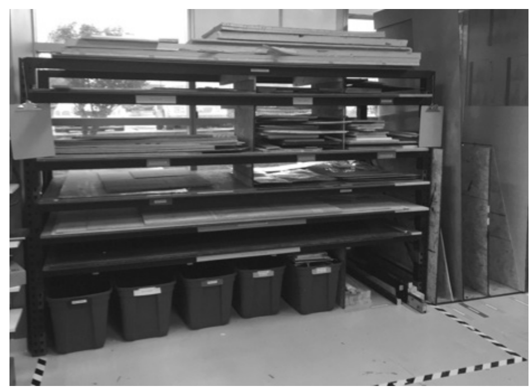

Figure 4. 5S Project Example 2 – After

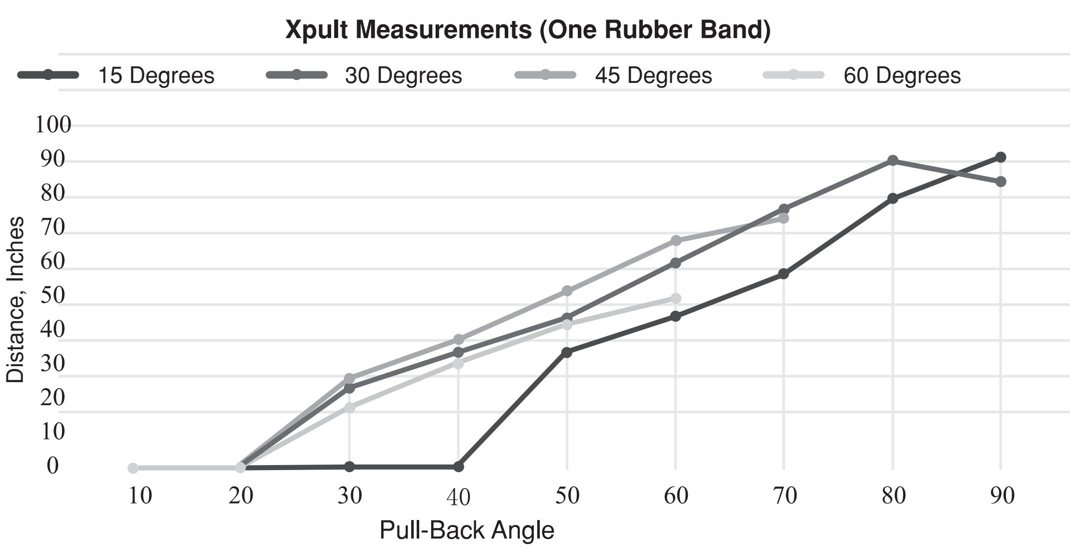

Figure 5. Bozo Challenge DOE Chart Example 1

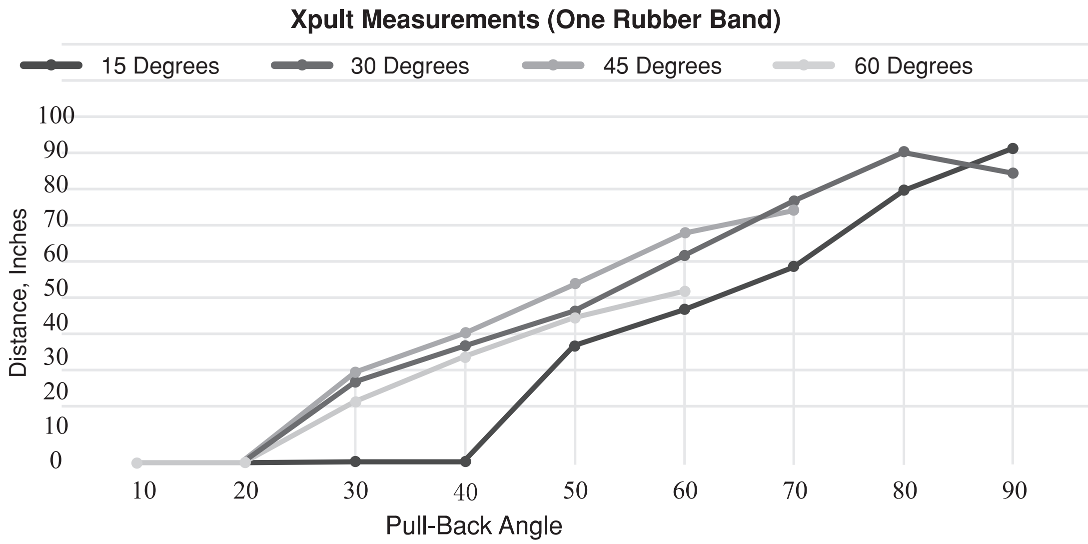

Figure 5. Bozo Challenge DOE Chart Example 1

TABLE 7. Bozo Challenge DOE Spreadsheet Example

Start Angle	Launch Angle	Rubberband Configuration #					
		1	2	3	4	5	6
0	20	X	X	X	X	X	X
	40	X	X	X	X	X	X
	60	X	X	X	X	X	X
	80	X	X	X	X	X	X
	100	X	X	X	X	X	X
	120	X	X	X	X	X	X
15	20	X	X	X	X	X	X
	40	X	X	X	X	X	X
	60	X	X	X	X	X	X
	80	X	X	X	X	X	X
	100	X	X	X	X	X	X
	120	X	X	X	X	X	X
30	30	X	1	X	X	X	X
	40	X	2	X	X	X	X
	50	X	3	X	X	X	X
	55	X	4	X	X	X	X
	60	X	X	X	X	X	X
	80	X	X	X	X	X	X
45	20	X	X	X	X	X	X
	40	X	X	X	X	X	X
	52.5	X	5	X	X	X	X
	60	X	6	X	X	X	X
	80	X	X	X	X	X	X
	120	X	X	X	X	X	X
60	22.5	X	1	X	X	X	X
	32.5	X	2	X	X	X	X
	40	X	3	X	X	X	X
	47.5	X	4	X	X	X	X
	53.5	X	5	X	X	X	X
	60	X	6	X	X	X	X
75	20	X	X	X	X	X	X
	40	X	X	X	X	X	X
	60	X	X	X	X	X	X
	80	X	X	X	X	X	X
	100	X	X	X	X	X	X
	120	X	X	X	X	X	X

DISCUSSION

Published literature whose authors studied quality-focused courses and the instructional techniques and/or methods used in the classroom is limited. However, the importance of educating ET students in quality control theory and application is of great importance because all industries must control the quality of their services or goods. In no other industry is this more relevant than in manufacturing, where effective quality control can be a cornerstone to success. The transformation of MET 45100 to a student-centered learning environment is a direct response to improve Purdue Polytechnic New Albany quality control curriculum so it may better align with the needs of graduating students and industry.

> "Businesses clearly need socially well-adapted, communicative employees who are eager to learn, involved and willing to work actively toward a permanent improvement of their organizations more than they needs theoretically trained quality technicians" (Kemenade & Garre, 2000, p. 35).

The idea that active learning and PBL can strengthen students' knowledge and skills is not a new concept. Even decades old quality related literature recommends combining theoretical knowledge with practical situations (Kemenade & Garre, 2000), and that "applied quality concepts should be added to basic quality control curricula at the college level" (Callahan & Strong, 2004, p. 45). However, there remains a need for comparison studies investigating the implementation of teaching-centered and learning-centered paradigms in quality courses. A similar request is made by Callahan and Strong (2004):

> A comparison of student skills after completing a more traditional lecture-based course versus a more applied course as suggested by this study would be of interest. This information could help determine the potential for improving quality control skills by revising course content and structure (p. 53).

The resources supplied and the data revealed in this paper offer a starting point to such a request. However, the authors advise caution with the course metrics and students' comments. The mean scores for course and instructor satisfaction increased by 23.08 percent and 17.07 percent respectively, and students' perception that lab content was worthwhile part of the course increased by 17.07 percent. The given sample of student comments also suggest that students' perception of quality is a dry subject to study and that active learning can have a positive impact. The data suggests a learning-centered paradigm as the more popular and satisfying approach to quality-focused courses; however, bias is most likely present in the data.

A more formal evaluation should take place. Researchers need to sustain course topics, objectives, and assessment points (e.g., written exams, practical exams) consistent across both educational paradigms. Measuring students' quality knowledge and skill level with common quality tools/techniques (e.g., DOE, statistical process control) at the beginning and end of the course would also need to take place. Thus, researchers would need to create a valid and reliable instrument to do so, as the authors did not locate one during their review of the literature.

Limitations

"The results of this study are limited in many ways. Generalization of findings to other colleges and universities should be approached with caution, as … students participating in the study were not random" (Cabrera, Colbeck, & Terenzini, 2001, p. 341). The sample size for all three offerings was small so generalizability should be limited; however, the authors strongly believe that the project success and student satisfaction achieved are repeatable at other institutions of higher education. Statistical analysis between the groups (i.e., three course offerings) did not take place due to a variety of reasons. First, the creation and use of a valid and reliable measurement instrument(s) would need to occur.

Second, the authors did not plan a controlled research study prior to the first course offering. There is also only one data point for the teaching-centered paradigm approach. Either a third instructor taught MET 45100 prior to Spring 2015 or data was no longer available to analyze.

Finally, if statistical analysis of the groups is to occur, it is often more favorable to use a more objective measurement than student self-reporting (i.e., course evaluations). However, research suggests that self-report measures of learning can be used as valid objective measures (Cabrera et al., 2001). Hayek, Carini, O'Day, and Kuh (2002), stated that generally five conditions need to be present:

1. The information requested is known to respondents
2. The questions are phrased clearly
3. The questions refer to recent activities
4. The respondents think the questions merit a serious and thoughtful response
5. Answering the questions does not threaten, embarrass, or violate the privacy of the respondent or encourage the respondent to respond in socially desirable ways

CONCLUSION

In conclusion, this paper provides a review of two paradigms of education, and the transition of a manufacturing quality control for ET students from teaching-centered to learning-centered. In writing this case study, the authors had no scientific pretensions but above all wanted to increase awareness and access to teaching materials. The given sample outputs from the course offerings support the general assumption that students consider quality, as a dry subject to learn and that they prefer a more student-centered approach (e.g., PBL) to a manufacturing quality control course. In hopes of further adoption of student-centered instructional techniques in quality-focused courses, the authors have shared all PBL resources. Finally, there is much opportunity for further studies investigating the impacts of different paradigms of education used in quality courses.

Dr. Rustin Webster *is an Assistant Professor of Mechanical Engineering Technology at Purdue University, New Albany, where he specializes in mechanical engineering and computer graphics technology.*

Dr. Matthew Turner *is an Assistant Professor of Electrical and Computer Engineering Technology at Purdue University, New Albany, where he specializes in the areas of power systems and controls.*

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APPENDIX

MET 451: MANUFACTURING QUALITY CONTROL

5S Project

I. 5S Overview
This semester you will embark on 5S classroom, lab, and workplace organization as part of a lean implementation (i.e. creating value and eliminating waste). 5S is a five-step proces in which each step is a prerequisite for the next. The following table provides a quick reference description of each *S*, including the actual meaning of the Japanese *S* as well as the anglicized version.

II. Project Overview
This task will be a group-based project, where each individual team member is expected to contribute equally. To ensure equal workload, each group member will complete a peer evaluation survey at completion. Group assignment was randomized.

This task will take place in the Paul W. Ogle Foundation Mechanical Engineering Technology Advanced Manufacturing Lab, room N1363. Two different *bubbles* have been identified for 5S application and each will be assigned to a group. The *bubbles* are as follows:

B1. Flat stock (large)

B2. Flat stock (small) and round stock

During each *S* step, the group is responsible to involve and coordinate with the required faculty and/or staff, as needed, for step completion.

It is expected that during certain steps that materials will need to be purchased. It is the group's responsibility to provide a detailed and professional bill of materials (BOM), including at a minimum part numbers, quantities, preferred source of supply, SKUs, and unit and total pricing (including shipping) to the instructor. Each group has an initial budget of $250.00. If additional funds are needed it is the group's responsibility to submit the request to the instructor and provide justification in a timely fashion. It is encouraged that local supply sources be used, such as, Harbor Freight, Home Depot, and Lowes. If online suppliers are targeted, such as, McMaster-Carr or Amazon Prime, please beware of shipping times and it is the group's responsibility to complete the project on time.

All purchases must be made directly by the instructor, no reembursments allowed

III. Deliverables

1. Proposal including BOM
   - Group submission
   - Proposal should be no more than one page (not including BOM)
   - Must use statewide letterhead (Blackboard-Projects Folder)

Japanese "S"	Japanese Meaning	Anglicized Version
Seiri	Remove all items from the workplace that are not immediately needed for the work.	Sort
Seiton	Place needed items (material, information, tools) in a location that supports the worker.	Straighten (set in order)
Seiso	Make the workplace spotless, free of contaminants, dirt and foreign material	Shine (scrub and sweep)
Seiketsu	Create a standard means for keeping the workplace clean and orderly	Standardize
Shitsuke	Make a commitment to order and cleanliness.	Sustain

- Includes details for each S step implementation, including but NOT limited to strategies, fund usage, and faculty/staff point of contacts (POC).
- It is encouraged to deliver as much detail as possible for project success.

2. Team presentation
   - Group submission
   - Given during class time
   - Slides submitted to Blackboard
   - 30 minutes max, including 5-10 minutes of Q&A
   - Must use Polytechnic-Slide Templates (Blackboard-Projects Folder)
   - Includes *preliminary* before and after images and/or videos for each *S* step, budget breakdown, and project summary, which could include but NOT limited to strategies used, lessons learned, 5S tips, inputs and outputs, outcomes, and faculty/staff POCs.

Criteria	Levels of Achievement			
	Exceeds Expectations	Good	Lacking	Seriously Deficient
Graphical Presentation	2.7 to 3 points Demonstrates high level of organization, balance, and audience engagement. The visual aids greatly enhance the presentation and never contain misspellings and grammatical errors. Presentation length was within the given time limits and a question/answer session was held. The correct PowerPoint template was used. Exceeds or meets project requirements for presentation.	2.4 to 2.7 points Demonstrates moderate level of organization, balance, and audience engagement. The visual aids somewhat enhance the presentation and rarely contain misspellings and grammatical errors. Presentation length was within the given time limits and a question/answer session was held. The correct PowerPoint template was used. Meets project requirements for presentation.	2.1 to 2.4 points Demonstrates low level of organization, balance, and audience engagement. The visual aids very little enhance the presentation and sometimes contain misspellings and grammatical errors. Presentation length was not within the given time limits and a question/answer session was not held. The incorrect PowerPoint template was used. Does no meet all project requirements for presentation.	0 to 2.1 points Demonstrates no level of organization, balance, and audience engagement. The visual aids do not at all enhance the presentation and often contain misspellings and grammatical errors. Presentation length was not within the given time limits and a question/answer session was not held. The incorrect PowerPoint template was used. Does no meet project requirements for presentation.
5S Solution	2.7 to 3 points 5S solution is complete, functional, and contains high levels of value-added for the Paul W. Ogle Foundation Mechanical Engineering Technology Advanced Manufacturing Lab, room N1363. Exceeds or meets project requirements for 5S solution.	2.4 to 2.7 points 5S solution is complete, functional, and contains moderate levels of value-added for the Paul W. Ogle Foundation Mechanical Engineering Technology Advanced Manufacturing Lab, room N1363. Meets project requirements for 5S solution.	2.1 to 2.4 points 5S solution is incomplete, nonfunctional, and contains no levels of value-added for the Paul W. Ogle Foundation Mechanical Engineering Technology Advanced Manufacturing Lab, room N1363. Does not meet project requirements for 5S solution.	0 to 2.1 points 5S solution is incomplete, nonfunctional, and contains low levels of value-added for the Paul W. Ogle Foundation Mechanical Engineering Technology Advanced Manufacturing Lab, room N1363. Does not meet all project requirements for 5S solution.

5S Steps	2.7 to 3 points Demonstrates high level of knowledge of the 5S process. All five steps (i.e. sort, straighten, shine, standardize, sustain) of the 5S process and safety are included in the graphical presentation and lab solution. Exceeds or meets project requirements for each 5S step.	2.4 to 2.7 points Demonstrates moderate level of knowledge of the 5S process. Many of the five steps (i.e. sort, straighten, shine, standardize, sustain) of the 5S process and safety are included in the graphical presentation and lab solution. Meets project requirements for each 5S step.	2.1 to 2.4 points Demonstrates low level of knowledge of the 5S process. A few of the five steps (i.e. sort, straighten, shine, standardize, sustain) of the 5S process and safety are included in the graphical presentation and lab solution. Does not meet all project requirements for each 5S step.	0 to 2.1 points Demonstrates no level of knowledge of the 5S process. None of the five steps (i.e. sort, straighten, shine, standardize, sustain) of the 5S process and safety are included in the graphical presentation and lab solution. Does not meet project requirements for each 5S step.
Final Report	2.7 to 3 points Demonstrates high level of organization, focus, sentence fluency, and writing conventions. The paper contains no errors in capitalization or punctuation. The paper is exceptionally easy to read. The correct Word template was used. Exceeds or meets project requirements for the final report.	2.4 to 2.7 points Demonstrates moderate level of organization, focus, sentence fluency, and writing conventions. The paper contains a few errors in capitalization or punctuation. The paper is easy to read. The correct Word template was used. Exceeds or meets project requirements for the final report.	2.1 to 2.4 points Demonstrates low level of organization, focus, sentence fluency, and writing conventions. The paper contains some errors in capitalization or punctuation. The paper is difficult to read. The correct Word template was not used. Does not meet all project requirements for the final report.	0 to 2.1 points Demonstrates no level of organization, focus, sentence fluency, and writing conventions. The paper contains many errors in capitalization or punctuation. The paper is difficult to read. The correct Word template was not used. Does not meet project requirements for the final report.

- Team presentation slides should be visual and treated like an executive summary

3. Final report
    - Group submission
    - No page limit
    - Must use statewide letterhead (Blackboard-Projects Folder)
    - .pdf submitted to Blackboard
    - Includes *final* before and after images for each *S* step, budget breakdown, and project summary, which should include but NOT limited to strategies used, lessons learned, 5S tips, inputs and outputs, outcomes, and faculty/staff POCs.
    - Report should contain **greater details, exploration, and discussion** than team presentation slides
4. Peer evaluation
    - Individual Blackboard submission

IV. Due Dates

1. Proposal including BOM: 9:30 am, Wednesday, 14th September 2016
2. Team presentations: 9:30 am, Wednesday, 28th September 2016
3. Final report: 11:59 pm, Monday, 3rd October 2016
4. Peer evaluation: 11:59 pm, Monday, 3rd October 2016

V. Assessment

1. Proposal will be based on 0 to 5 points.
2. Peer evaluation will be based on 0 to 1 point.
3. 5S project will be based on 0 to 12 points and use the above rubric

MET 451: MANUFACTURING QUALITY CONTROL

Bozo Challenge Project

I. Project Overview

This task will be a group-based project, where each individual team member is expected to contribute equally. To ensure equal workload, each group member will complete a peer evaluation survey at completion. Group assignment was randomized.

Teams will be given two full classroom periods (4 hours) to work on the project but it is anticipated that a minimal of 10-20 additional hours will be needed to satisfy project requirements and instructor expectations.

The objective of the project is to provide students an active and enjoyable opportunity to study design of experiments (DOE), statistics, variation, process capability, etc.

Teams shall fully complete the experiments in the three Xpult instructional documents (i.e. basic, highered, and advanced). Not doing so will result in poor results during the challenge.

II. Bozo Challenge Rules

1. Shall only use equipment provided in Xpult kits and by instructor besides the following:
   - Teams may design and rapid prototype part(s) to control variability in the connection between the Xpult arm and Xpult base
   - Teams may design and rapid prototype part(s) to control variability in the connection between the buckets and red connection strip (i.e. button snaps)
   - Shall only use 3D printers and lasers in the Paul W. Ogle Foundation Mechanical Engineering Technology Advanced Manufacturing Lab, room N1363
   - Once a team makes their first attemp during the Bozo Challenge they may not move, remove, and/or modify the designed/rapid prototyped part(s)
2. No modifications allowed to Xpult ki components/parts
3. Can use either ball type
4. Can use any combination of variables (i.e. pull back angle, number of rubber bands, Xpult starting position, etc.)
5. Ball must be launched by Xpult (i.e. no human assistance besides setup and the act of pulling arm back)
6. Ball may not hit any object other than current target bucket to be counted as a made basket (i.e. no bounce in or ricochet)
7. All parts of the Xpult must be behind the launch line during the challenge
8. Buckets and launch line will be placed on the top side of the tables in N1136
9. Table tops will be 28.50" from the floor an 91.50" from the ceiling
10. Only one make per bucket counts towards grading
11. Using official Bozo Bucket Bonanza Gran Prize Game equipment
12. Using official Bozo Bucket Bonanza Gran Prize Game instructions besides the following exceptions:
    - Replacing the human thrower with an Xpult
    - Team gets three shots at each bucket in order, starting with the firs
    - If ball is shot into the target bucket and bounces out it is recorded as a made bucket

III. Bozo Challenge Measurements

1. Launch line to center of first bucket = 18.75
2. 1st bucket to 2nd bucket = 11.75"
3. 1st bucket to 3rd bucket = 23.50"
4. 1st bucket to 4th bucket = 34.875"
5. 1st bucket to 5th bucket = 46.50"
6. 1st bucket to 6th bucket = 58.00"
7. Launch line to center of grand prize cup = 120"
8. Official Bozo Bucket diameter = 5.875
9. Official Bozo Bucket height = 6.437
10. Grand Prize Cup diameter = 9.4375"
11. Grand Prize Cup height = 7.00"

IV. Deliverables

1. Bozo Challenge
   - Team competition (all members present)
   - Conducted during class time
   - Upload all DOE resources (i.e. spreadsheets) and CAD files t Blackboard
2. Peer evaluation
   - Individual Blackboard submission

V. Due Dates

1. Bozo Challenge: 9:30 am, Wednesday, 2nd November 2016
2. Peer evaluation: 11:59 pm, Wednesday, 9th November 2016

VI. Assessment

1. Peer evaluation will be based on 0 to 1 point.
2. Bozo Challenge project will be based on 0 to 12 points and use the following rubric:
   - 100% = 6 buckets made
   - 90% = 5 buckets made
   - 80% = 4 buckets made
   - 70% = 3 buckets made
   - 60% = <3 buckets made
3. Grand prize
   - The Grand Prize Cup will be in line with the Official Bozo Buckets. If a team akes it 5 consecutive times in the grand prize cup I will buy them lunch (<$7 per person).

MET 451: MANUFACTURING QUALITY CONTROL

Company Visit Project

I. Project Overview

As part of the company visit project, Company Visit Teams (CVT) will be formed. CVTs will apply their knowledge of quality to analyze a company's quality culture and make recommendations to improve upon the design of the quality systems they have observed. CVTs must also describe how their recommendations will impact quality improvement at the particular facility.

This task will be a group-based project, where each individual team member is expected to contribute equally. To ensure equal workload, each group member will complete a peer evaluation survey at completion. Group assignment was randomized.

This task will take place outside of the classroom and outside of our normal meeting time. CVTs shall propose two potential companies to visit. After instructor approval is given, CVTs shall coordinate a tour/visit. The CVTs shall target the quality department and/or personnel during the tour. CVTs shall learn as much as possible about the company's quality culture, policies, procedures, qualifications, tools, etc. Request to take photos and/or videos during the tour.

The objective of the project is to gain enough knowledge to analyze and then make recommendations concerned with quality management.

II. Deliverables

1. Proposal
   - Group submission
   - Company Visit Proposal submitted to Blackboard
2. Team presentation
   - Group submission
   - Given during class time
   - Slides submitted to Blackboard
   - 15 minutes max, including 5-10 minutes of Q&A
   - Must use Polytechnic-Slide Templates (Blackboard-Projects Folder)
   - Team presentation slides should be visual and treated like an executive summary
3. Peer evaluation survey
   - Individual Blackboard submission

III. Due Dates

1. Proposal: 9:30 am, Monday, 3rd October 2016
2. Team presentations: 9:30 am, Wednesday, 30th November 2016
3. Peer evaluation: 11:59 pm, Friday, 9th December 2016

IV. Suggested Slide Outline

A. Title
B. Company
   a. Name
   b. Location
   c. Executive statement (who they are and what they do)
   d. Logo included somewhere on the slide
C. Point of Contact (POC)
   a. Name
   b. Title
   c. Executive statement (who they are and what they do)
D. Observations
E. Observations Cont.
F. …
G. Recommendations
H. Recommendations Cont.
I. …
J. Conclusion

Note: shall include justifications for each recommendation

V. Assessment

1. Proposal will be based on 0 to 1 point.
2. Peer evaluation will be based on 0 to 1 point.
3. CVT project will be based on 0 to 6 points and use the following rubric:

Criteria	Levels of Achievement			
	Exceeds Expectations	**Good**	**Lacking**	**Seriously Deficient**
Graphical Presentation	2.7 to 3 points Demonstrates high level of organization, balance, and audience engagement. The visual aids greatly enhance the presentation and never contain misspellings and grammatical errors. Presentation length was within the given time limits and a question/answer session was held. The correct PowerPoint template was used. Exceeds or meets project requirements for presentation.	2.4 to 2.7 points Demonstrates moderate level of organization, balance, and audience engagement. The visual aids somewhat enhance the presentation and rarely contain misspellings and grammatical errors. Presentation length was within the given time limits and a question/answer session was held. The correct PowerPoint template was used. Meets project requirements for presentation.	2.1 to 2.4 points Demonstrates low level of organization, balance, and audience engagement. The visual aids very little enhance the presentation and sometimes contain misspellings and grammatical errors. Presentation length was not within the given time limits and a question/answer session was not held. The incorrect PowerPoint template was used. Does no meet all project requirements for presentation.	0 to 2.1 points Demonstrates no level of organization, balance, and audience engagement. The visual aids do not at all enhance the presentation and often contain misspellings and grammatical errors. Presentation length was not within the given time limits and a question/answer session was not held. The incorrect PowerPoint template was used. Does no meet project requirements for presentation.
Observations/ Recommend.	2.7 to 3 points Demonstrates high level of knowledge of quality management Many recommendations for improvement are presented from observations during site visit All recommendations are accompanied by justification. Exceeds or meets project requirements for CVT project	2.4 to 2.7 points Demonstrates moderate level of knowledge of quality management Some recommendations for improvement are presented from observations during site visit Some recommendations are accompanied by justification. Meets project requirements for CVT project	2.1 to 2.4 points Demonstrates low level of knowledge of quality management Few recommendations for improvement are presented from observations during site visit Few recommendations are accompanied by justification. Does not meet project requirements for CVT project	0 to 2.1 points Demonstrates no level of knowledge of quality management No recommendations for improvement are presented from observations during site visit No recommendations are accompanied by justification. Does not meet project requirements for CVT project