Quality for Manufacturing: Integrating a Flipped Classroom Model with a Project Based Approach

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Abstract:

Too often instructors teach quality control courses from a strictly theoretical standpoint, omitting the opportunity for students to gain a deeper understanding of the concepts and mathematics through the integration of hands on projects. Therefore, this paper will present the audience with ways that instructors can utilize the flipped classroom model in a quality control course to provide students with a series of hands on learning activities that align with modern practices currently being used in industry. The authors will provide a brief review of literature about some of the suggested practices of incorporating both the flipped classroom model and active learning projects into an engineering technology curriculum and then discuss how they themselves have not only adopted these concepts to apply to quality control courses but worked with industry to assure the relevance of each project. The paper will provide details about the types of projects introduced to students, as well as the goals, objectives, and learned skills associated with each project. As continuous improvement plays a critical role in curriculum development, the authors will share some of the feedback collected from students about positive and negative experiences encountered throughout the projects, as well as comments from industry representatives about knowledge displayed during classroom presentations and recommendations as to content areas that may need further instruction for future projects. This knowledge is applicable for undergraduate and graduate level courses.

Introduction:

Project based learning or problem based learning (PBL) is one of the driving factors behind the movement to the flipped classroom. Lectures and reading outside of the classroom are intended to prepare students for more active learning in the classroom or lab space. This active learning is designed to closely replicate real world scenarios and experiences to prompt critical thinking and better prepare students for the workforce. Often times industrial partners that support university efforts in these endeavors by providing authentic projects or problems from functioning organizations. This unique out of classroom based experience becomes invaluable to students with respect to professional development, especially students that have not participated in internships or co-ops.

Literature review:

Recent, numerous changes to the Engineering Technology Curriculum are based on the Project Based Learning (PBL) approach. The main difference from traditional educational methods is a heavy reliance on hands-on activities, which allows students to participate in "real-life" projects. PBL might have different scenarios and applications, from university-industry partnership to more traditional laboratory-based student activities. In this paper, the authors will discuss the strategy, activities and documented outcomes of this method of experiential learning.

Trends in educational instructional approaches with respect to Engineering and Technology Education in the United States have changed drastically in the last decade. The practice of "teaching to the test," [4] especially in K-12 education in the areas of math and science, has created an overarching problem in educational practices. To some extent, it is possible to suggest a structural change in learning and teaching environments: instructors transform traditional lecturing to team-working and teaching by-doing techniques [4-6]. In that sense, doing is defined as: "A tactile/hands-on process of technological problem solving starting with human needs and wants that leads to the principles of innovation such as designing, making/building, producing, and evaluating" [4]. The notion of the hands-on learning approach and learning by doing is being praised in Engineering Technology departments across the country, as well as in various marketing materials and during on-campus visits. These trends corresponds with kinesthetic learning; the preferred learning style frequently identified by many students. This style involves both information perception (touching, tasting, smelling) and information processing (moving, relating, doing something active while learning) [7,8]. Higher level learning has increased with this experiential model.

Project Based Teaching methods, where students learn by doing "something real," participating in laboratory work, [9] or in actual industrial projects are suitable illustrations of the changing educational environment in recent years. Beginning in the 1960s this model became predominant in the study of medicine [10]. However, this was not the case in engineering and engineering technology. The drawback is the predominant model of engineering technology education is still considered "chalk and talk" and needs transition in many courses to more problem-based and project based educational approaches [10]. Despite its popularity, Project Based Learning (PBL) outcomes can vary radically depending on instructors' personalities, academic settings, project goals, team dynamics, and industrial partners commitment to participation. To make PBL more effective, these variable factors should be considered and managed. Carefully addressing these factors can decrease the gap between engineering technology courses and their linkage to the real industrial practice [10].

Gaining this real world experience is important to students, faculty and employers. According to The Atlantic and the Business Insider, most employers of recent college graduates are looking for communication skills – verbal and written, the ability to work on a team, collegiality and overall integrity. Employers want to know if the new hire is going to be honest, dependable and represent the company well [12]. More explicitly the Chronicle of

Higher Education cites another expert Peter Cappelli to support his position and recent research:

> "When employers do hire from college, the evidence suggests that academic skills are not their primary concern," says Peter Cappelli, a Wharton professor and the author of a new paper on job skills. "Work experience is the crucial attribute that employers want even for students who have yet to work full-time."(2015)

Overview of course projects:

Purdue University - MET 451

In the fall of 2015, the author was tasked with redesigning the Quality for Manufacturing course in the Mechanical Engineering Technology program. This undergraduate course which is typically taken by approximately 40 seniors each academic term is meant to expose students to how quality plays a critical role throughout an organization. The goal of this transformation was to transition from predominantly lecture based meetings to more project based learning, utilizing various labs on campus and partnering with industry to give students a first hand experience with various aspects of quality. In order to do so, two major projects were introduced to the course.

The first project (2-3 weeks) involves having students work in groups of three to develop a weighted scorecard to compare quality, as defined by customers, between 3 like products, such as different safety glasses, each pair manufactured by different companies. Students start by selecting one brand for which they will be mock employees. They then utilize David Garvin's 8 dimensions of product quality to develop and define various measures and metrics for each. Once defined, students conduct a survey of a minimum of 40 individuals that would be included in the target audience for the selected products to determine appropriate weights for each quality dimension. Students then conduct a secondary survey and focus group of an additional 40 individuals that allow potential customers to interact with the products selected and provide a score to each brand of product. Students use these weights and scores to determine which product is ranked highest among potential customers. Once the data analysis is complete students present their finding to their peers and are encouraged to share their findings with the companies. Students are expected to dive deep into their analysis identifying how the raw scores and weighted scores can help each company, especially the one which they have chosen to be mock employees for, improve the product quality. Students were further tasked with developing a strategic plan for the company moving forward. This project allows students to better understand how various aspects of quality factor into a consumer’s decision-making process when poised with multiple version of the same desired item. This project concurrently provides students with a low level introduction to data collection methods, data analysis techniques, and how to utilize such data for continuous improvement objectives.

The second major project (4-5 weeks) infused into the course, became known as the "part inspection project". The instructor has teamed with two injection molding companies and one company that machines brass and aluminum air nozzles, each of which has provide several small samples (15-30 pieces) of different component parts for which the students must work to develop a production part approval process (PPAP) plan. The class is divided into three groups and told that they now work for one of the partnering companies. Students are provided the parts and associated mechanical drawings, and an outline of the goals and expectations for the project. Students must first select a team lead, which in addition to being on a subgroups, assures that all other subgroups complete and submit work in a timely manner. This person also acts as the primary contact with the companies if they need additional information about the various parts. Once divided into subgroups, each group must review the technical drawings, identifying critical dimensions and develop a plan for how one might measure these critical dimensions (caliper, micrometer, equipment in the metrology lab, pin/plug gauges, or go/no-go gauges). Each group is required to identify a minimum of 10 dimensions, 5 of which can be measured with go/no-go gauges. Students must then utilize their knowledge of Computer Aided Design and Drafting (CADD) software, technical standards that outline proper gauge design, and the various machining labs on campus to develop models and prototypes of the go/no-go gauges. The remaining 5 dimensions listed as critical must be measured using a Coordinate Measuring Machine (CMM), caliper, or micrometer. Each subgroup must conduct a repeatability and reproducibility study to ensure that all students are capable of using the measurement device selected. Students then proceed to measure the remaining critical dimensions on all parts and develop sample control charts with the data collected. Finally, students must develop a set of work instructions for their Pre-production Part Approval Plan (PPAP) and have another group walk through the process to confirm that the work instructions are comprehensive enough to avoid mistakes. Upon conclusion of this project, students present their work to the owners, manufacturing engineers, and quality engineers for the partnering companies.

The remainder of the term consists of smaller hands on projects including value stream mapping of a service industry, the walkthrough of a design of experiments project, and system reliability studies. From team dynamics to application of information presented in the textbook, each project allows the students to live the experience that they may encounter in future work environments. Being able to relate the reading material to real world examples, allows the students to be actively involved with the learning process and encourages them to ask questions during class meetings about how the book material relates to different aspects of their group projects. By the students asking the questions, they are more apt to retain the information when provided with additional information or examples from the instructor.

The University of Texas at Tyler - TECH 5310

A Lean Six Sigma Quality Course is taught in a similar manner for graduate students at The University of Texas at Tyler. The two institutions are over a thousand miles apart geographically but the theoretical framework that support the course structures are almost identical. The learner population at the east Texas institution is comprised of fulltime and part time graduate students seeking to improve their skill set while acquiring additional credentials for career advancement. The course is taught in the evening and is comprised of working professionals and traditional graduate students. A typical class consists of approximately 50 people.

This course seeks to deliver an understanding and application of the basic concepts of modern manufacturing process management systems, with regards to quality, just-in-time, lean manufacturing and six sigma. This three credit hour graduate course presents techniques for the planning, measuring, and implementation of Six Sigma Quality efforts. Key elements for company-wide strategic quality planning such as identifying customers and their needs, designing quality services, establishing optimal quality goals, statistical based improvement methods, and implementing six sigma tools to include DMAIC. Instead of two smaller projects like an undergraduate course, this course has one larger project with rigor commensurate with graduate studies. The experiential learning illustrated for this writing was conducted via a 5S project with grocery store chain warehouse. The grocery store chain has locations in Texas, Louisiana and Arkansas. Two of the major warehouses are within 15 miles of the UT Tyler campus. Hence student and industry engagement was convenient.

Five S projects are defined as process improvement initiatives. As a popular lean tool 5S is defined as "sort, straighten, shine, standardize, sustain" [14]. 5S sounds like a simple concept to implement – and it is.

> A 5S initiative can fall broadly into one of two categories: 1) department-specific wherein each department manages the 5S initiatives specific to the department, or 2) corporate-wide wherein designated teams independent of the departments deploy and manage the 5S initiatives. A successful 5S deployment path is one that is aligned with a company's strategic plan and priorities, optimizing resources to add value [14]. page 354

The specific project was described as follows:
"Case Height Flow Sections: Identify high volume areas to re-slot for case height order selector efficiency with the Brookshire's Perishable Foods Warehouse", Teams were assigned the task to review and develop a resolution regarding the issues for order selector efficiency within this warehouse. Students were placed on teams of four assigned actual projects with an industry partner. The project directions are shown in Figure 1.

Deliverables for The Grocery Store 5S projects

- Formal written report
- Oral presentation
- Feedback from sponsors
- Completed project analysis form (each individual)
- Assessment by your team members

Background work:

Understand the industry group or segment that this company belongs to. Quality systems, standards and procedures are often determined by an industry group or governing body for an industry segment. Knowledge of the higher level industry requirements provides important background as you consider the following key points:

1. The systems they use to track costs and the COQ
2. Plans for quality education of the work force
3. The company's system/procedure for problem solving, forming and using teams, and for recognition of employees.
4. The systems for communication with customers related to complaints.
5. The company's definition of quality and how this definition is communicated throughout the organization.
6. Does the company follow one of the "Gurus" of Quality such as Deming, Crosby, etc.? If so, how is it going? Are they satisfied? Have they had to modify the plans from the experts to make it fit with their organization?
7. What is the company's level of success with quality improvement? How long have they been working on quality as a management issue? How do they feel about their progress?
8. Is a demonstrated commitment to quality improvement from management at all levels of the organization evident?

Execute the project:
Write the project charter with a full description of work to be done.
Develop a project plan, timeline and work breakdown structure.
Assign tasks to individuals on the team.
Coordinate team meetings and follow up meeting(s) with the sponsor.
List the requirements as outlined by the sponsor.
Complete each requirement
Document the starting and ending conditions.

Develop recommendations:
Support your findings with diagrams and examples. When it makes sense, document the flow of data and information with a "flow chart" diagram. If possible, include samples of the forms the company uses, and obtain samples of representative reports, procedures and policies.

Figure 1: Project Direction

Sample of one team's report

Purposes:

In order to improve the efficiency of the order selectors, review of time study revealed that the average time for an order selector to travel up one aisle picking products for a shipment is approximately 5 minutes and 26 seconds. Taking this time into consideration which is to pick product from the candy vault then moving to the excess candy vault, considerable time is wasted just to pick a candy order for shipment and with the candy products being stored in different locations, the possibility of missing or overlooking a product on the order for a shipment exist.

Methods:

We utilized the team brainstorming approach and created a Cause and Effect diagram to visually display all possible causes for our specific problem. What is Fishbone diagram?? Fishbone diagram is a tool that can help you perform a cause and effect analysis for a problem you are trying to solve. This type of analysis enables you to discover the root cause of a problem. This diagram is also called as Cause and Effect diagram and Ishikawa.

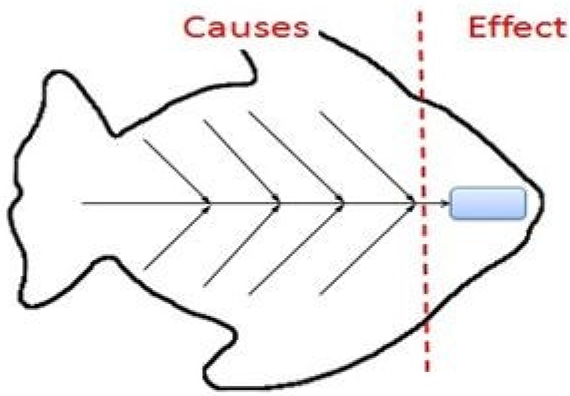

Figure 2: Cause and Effect Diagram

The problem or effect is displayed at the head or mouth of the fish. Possible contributing causes are listed on the smaller “bones” under various cause categories.

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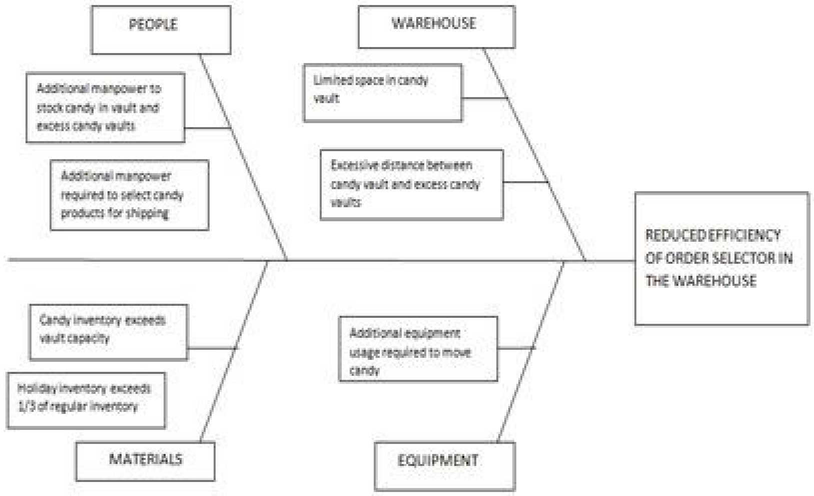

Figure 3: Fishbone Diagram

The mouth of the fish shows that the problem is reduced efficiency of order selector in the warehouse. The cause and reason for that problem are:

- In *warehouse*, due to limited space in candy vault and excessive distance between candy vault and excess candy vaults.
- Due to *people*, as more manpower is needed to stock candy in vault and excess candy vault and also more manpower to select candy products for shipping which increases the labor expenses in the warehouse.
- Due to *material* over inflow to the warehouse, that is candy inventory exceeds vault capacity and this needs large amount of space to store your inventory and costs more to maintain the excess inventory.
- Due to *equipment* because lot of equipment is used to move candy from the candy vault and excess candy vault to the shipping area which creates traffic in the warehouse and costs a lot for the equipment maintenance.

Results from both courses:

Industry partner feedback:

Purdue-

As part of the "part inspection project", students present their work to industry representatives from each company. To aid in the continuous improvement of the course and ensure that students are leaving the course with the knowledge and skills needed in industry, the instructor asks each representative to provide critical feedback about the information presented and indicate areas that may need further instruction. In general, the company representatives were pleased with the students ability to analyze the mechanical drawings and select critical dimensions as well as conduct repeatability and reproducibility studies. Additionally, the representatives were impressed with the students understanding of process capability, understanding of and ability to develop control charts, and the development of work instructions that utilized graphics rather than strictly text. One the other hand, representatives felt that students should spend time investigating the industry for which each component is being manufactured for and align the go/no-go gauges with industry standards. Representatives also suggested that students needed to dive deeper into their data analysis, especially when anomalies occurred and they are not able to provide any clear explanation. Finally, student presentation skills need to be refined such that they are able to better communicate the process they undertook and the technical information involved in the completion of the project.

UT Tyler-

Representatives from the grocery store chain attended the class session for the final presentations of the project results. The representatives were provided with rubrics to render feedback and given the opportunity to ask questions of each student team. (See Appendix A) The industry partner was more than satisfied with the results garnered from the twelve groups working on the projects and chose to implement several of the recommendations.

> Continuous flow rack system:
> In order to handle huge volume of products generally discrete manufacturing companies use such methods. This is a continuous racking system with the product of same kind and within weight limits. …………
> If the product is of same kind and weights fall within the limits then this method would be more effective, but we have products of different kind in each section and they are in different sizes and a continuous flow will not make them available in time so they cannot be used in vegetable and candy section…….
> We have the possibility to implement this method ……….

A month later, the instructor received an email from the company liaison requesting the project deliverables.
"Dr. Donaldson, we are looking to move forward with some of the projects we had last semester. If you could please send me the projects ASAP so I can provide them to my team before any decisions are made.
Thanks, Brendon"

Student Feedback:

Purdue -
As a result of integrating project based learning into the quality for manufacturing course, students have indicated that compared to a traditional lecture based class, the project based

learning style was very effective in helping them learn the material. In addition, students indicated a significant increase in their knowledge and understanding of the following topics: creating a balanced scorecard, gauge design, conducting repeatability and reproducibility studies, developing control charts, and statistical process control. As most of the students have had some form of industrial experience, there was also indication that the students felt as though the projects did an excellent job at relating the material to current industry practices. Finally, several students indicated that they utilized these projects as discussion points during interviews.

UT Tyler -

The students reported learning more from conducting the project and having interaction with industry experts than they ever visualized from the traditional textbook activities. The instructor, consequently many students worked with students they would have never chosen for teammates, assigned teams. Initially there was some resistance. The end of the course had formed new friendships. Students expressed appreciation for being partnered with people they did not know. Ultimately the students reported understanding the value of being uncomfortable in a work setting. They realized that they will not be able to choose all of their coworkers in the real world.

Conclusion:

Employers are seeking talent with results. These results are garnered most quickly when new hires come into an organization with real world experience. Experience can be acquired via class projects, service learning, internships, or volunteer assignments. The GPA is ranked as the second to least important factor, followed only by reputation of the university. Internships were enumerated at the top of the list as most important. Working during college was the second most important attribute being sought. Extracurricular activities and community service is valued as well. In essence the "experienced person and complete individual who is well rounded" is being sought.

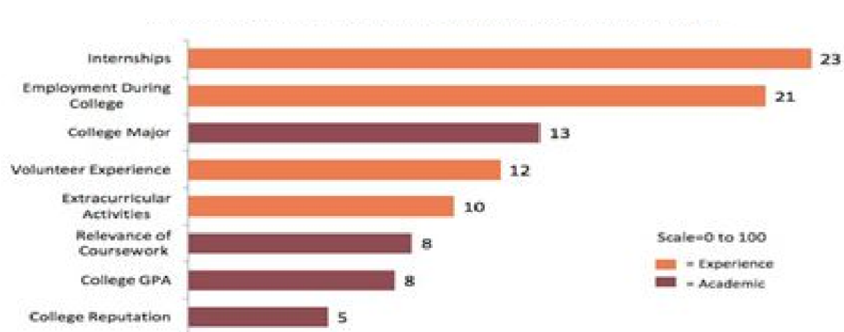

Figure 4: Relative Importance of Attributes in Evaluating Graduates for Hire [11]

While the projects introduced to these courses help align students skills and knowledge with industry demand, the feedback from students and industry partners alike will help in the continuous improvement efforts of the instructors. The critical feedback will translate into more refined projects and the inclusion of additional information that better prepares students for their professional careers.

Plans for Future Research

A collaborative project is being developed for students at both Purdue and UT Tyler. The professors from both institutions will facilitate a broad scale project with an industry partner which operates nationally or globally. This scenario will give students an opportunity to further problem solve in an environment with real world challenges. Quality issues maybe further complicated by communication barriers, time zone differences, logistical requirements and cultural norms.

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Biographies:

E. Shirl Donaldson, PhD PMP

E. Shirl Donaldson earned a doctorate of philosophy in Industrial Technology from Purdue University in December 2012. Upon receiving her Ph.D. she completed a strategic post-doctoral appointment focused on diversity, entrepreneurship, project management, and supply chain management. In July 2013, Dr. Donaldson was certified as a Project Management Professional (PMP). This credential was subsequently leveraged in the classroom. As a clinical assistant professor she taught project management and engineering technology courses while providing mentorship on senior capstone projects. Dr. Donaldson was selected to become an Entrepreneurial Leadership Academy (ELA) Fellow in 2015. The ELA is a resource support program for faculty who have entrepreneurial interests. Ten faculty members are competitively selected annually to participate in the Entrepreneurial Leadership Academy and receive $5,000 in seed funding for a project.

Today Dr. Donaldson is an Assistant Professor at the University of Texas at Tyler in the College of Business and Technology. Her commitment to intellectual growth is driven by her life experience. Dr. Donaldson's research interests include project management, technology management, quality systems, entrepreneurship, and diversity in STEM fields. She examines how academic and industrial environments enable effective learning, discovery, and realization of new and transferred knowledge.

Paul McPherson

Paul McPherson currently serves as a Visiting Assistant Professor in the School of Engineering Technology at Purdue University teaching design and quality for manufacturing courses. Prior to Purdue, Paul was an Assistant Professor at Berea College in Berea Kentucky where he taught design, manufacturing, and quality control courses. At both institutions he has strived to implement a flipped classroom model that provides students with real world, hands on experiences. He holds a M.S. of Engineering Technology from Purdue University and a B.S. in Technology and Industrial Technology Management. Prior to entering academia, he worked as an application engineer for Tri C Company designing jigs and fixtures for the machining and assembly operations at the Caterpillar Marine Engine facility. **Appendix A - Rubric for grading presentations**

Team Oral Presentation Rubric
45 Points Possible for Presentation Individual

Message	**Fair**	**Superior**	**Excellent**
1. Did the presentation give a good overview of the project?	1	2	3
2. Were the ideas adequately developed?	1	2	3
3. Was the conclusion or transition to next speaker appropriate?	1	2	3
4. Was the essential message clear?	1	2	3
Language, Voice, Physical Communication			
5. Were dictation and grammar correct?	1	2	3
6. Was there proper vocal volume, tone, and variety?	1	2	3
7. Were gestures appropriate?	1	2	3
8. Was eye contact sufficient?	1	2	3
9. Was the pace appropriate?	1	2	3
Presentation			
10. Were visuals well prepared and well handled?	1	2	3
11. Did all team members contribute equally to the presentation?	1	2	3
12. Dressed in business casual attire?	1	2	3
13. Overall evaluation of the presentation?	1	2	3

14. Was the time limit of 8-10 minutes met? 1 2 3

15. Something Lean Six Sigma related? 1 2 3

Team Final Product Rubric
55 Points Possible for Final Product

	Exemplary = 5	**Average = 3**	**Unsatisfactory = 1**
Engagement in Creative Process · Evidence of Original Thinking and/or Creative Process involving Synthesis or problem saving	Student shows demonstrated evidence of original thinking and creative design	Student often demonstrated evidence of original thinking and creative design	Student rarely demonstrated evidence of original thinking and creative design
Expressive & Innovative Product/Outcome · Finished Project shows personalization, resourcefulness and originality	Finished product demonstrates extraordinary resourcefulness, originality and personalization	Finished product demonstrates adequate resourcefulness, originality and personalization	Finished product demonstrates limited resourcefulness, originality and personalization
Technical Proficiency · Knowledge of subject and process	Project demonstrates exceptional knowledge of key supply chain issues	Project demonstrates adequate knowledge of key supply chain issues	Project demonstrates limited knowledge of key supply chain issues
Established Criteria · Fulfills requirements of the assignment	Students project fulfills all the requirements of the project	Students project fulfills most of the requirements of the project	Students project does not adequately meet all the requirements of the project

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WOW factor · Project shows exceptional interactive capability	You did it!	Almost there!	Not close enough!

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