An innovative project-based learning approach to teach project management

Dr. Yi-hsiang Isaac Chang, Illinois State University

Dr. Yi-hsiang Chang is an assistant professor in the Department of Technology at Illinois State University. He received a MSME degree from Carnegie Mellon University, a MSIE degree and a PhD degree in Technology, both from Purdue University. Dr. Chang has worked with several international corporations including Boeing, DaimlerChrysler, and Dassualt Systemes, as well as multiple small to medium size companies in both US and Asia. His current field of focus is in product innovation, process improvement, and technology diffusion.

Dr. Dave Yearwood, University of North Dakota

Dave Yearwood, Ph.D., CSTM is Professor Emeritus in the School of Entrepreneurship. Yearwood was a Graduate Director in two disciplines and also the past chair of the Technology Department at the University of North Dakota. Dave has been teaching in higher education for 31 years at the undergraduate and graduate levels (Community College, Technology Department, and the Ph.D. program in Teaching and Learning). Yearwood's two research interests are: 1. Electronic Pedagogy—the purposeful use of technological tools in education to enhance teaching and learning; and 2. The study of control or semi-automatic systems for use in commercial and/or consumer settings.

Dr. Yearwood was presented with the outstanding teacher award in the College of Business and Public Administration (CoBPA) on two occasions, he also earned the coveted combined Teaching, Service, and Scholarship award (CoBPA), and was nominated at the university level for outstanding graduate and undergraduate teaching awards. In 2009 Dr. Yearwood was one of four professors recognized nationally by the Association of Technology, Management and Applied Engineering (ATMAE) as Outstanding Professor in the areas of Teaching, Research, and Service. Dr. Yearwood is a native of St. Vincent and the Grenadines—an island in the Caribbean. He is an avid cyclist (bicycle), rides his motorcycle even in the worse winter weather, and enjoys camping. Dave also served in the US Air Force. Dr. Yearwood continues to research and collaborate with colleagues. He can be reached at Yearwood@und.edu

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Abstract

Project-based learning often asks students to create a project plan for a real or imaginary client that is built upon what is learned in one or more courses. However, while the project-based learning pedagogical approach appears to be a useful candidate for providing students with hands-on experiences, how can we as educators create meaningful project planning activities that realistically reflect practices in the field? Successful plans are easily differentiated from deficient plans when input from subject matter experts is considered. Therefore, determining the scope of the project, creating a work breakdown structure, and identifying the critical path particularly with input from subject matter experts is crucial to facilitating learning-by-doing for real or pseudo projects in the planning stages.

In this paper we present an innovative project-based learning approach for teaching project management. By incorporating the design thinking strategy in the curriculum, student teams identify and define problems (or needs) by empathizing with the users, proposing design alternatives, and creating quick-and-dirty prototypes to gain quick feedback. Functional prototypes are built for benchmarking purposes while at the same time verifying whether the proposed solutions actually resolve the issue(s). Through the design-build-test process, it is expected that students would develop the knowledge and experience of the “subject matter experts”, and thus various activities at the project planning stage will become more meaningful. Using the test result(s) of functional prototypes, the team(s) will revise their solution(s) and develop a project plan to scale up their proposed solution(s), either with a product production line or a service model. The paper will conclude by discussing the outcome of this approach, identify possible limitations, and provide recommendations.

Introduction

The topic of project management (PM) as one of the boundary crossing competencies [1] has gained a lot of attention in higher education because PM creates opportunities for students to learn how to effectively collaborate and communicate across culture, manage time and resource, and develop leadership and risk management capabilities in addition to polishing critical thinking and problem solving skills. To ensure the competitiveness of future generation in a “flat world” [2], it is essential to equip students with PM-related knowledge and skills [3], [4]. Many undergraduate engineering, technology, and business programs have begun including PM or similar courses in their curriculum [5]. However, while this is a necessary first step, if program courses do not include substantial opportunities for hands-on practices, then the knowledge gained may be less than ideal. Student preparation for the project management professional (PMP) certification examination may have been the key objective of many PM courses, but a need also exists to ensure that authentic assessment—evaluation of student skillset and abilities on real-world projects—is conducted. The PM framework proposed by Project Management Institute in its book of Project Management Body of Knowledge (PMBOK) [6] largely focuses on discussing the project lifecycle—project initiation, project planning, project execution and control, and project closure. These topics are very important to address; however, educators need to ensure that course content driven largely by teaching the procedural knowledge of PM (e.g. best practices and how-to's) are not focused solely on rote memorization.

To address these concerns, PM educators have begun adopting different pedagogies for their course design. Kim, Jeon, and Kim [7] developed a web-based project management system utilizing the PMI's PM framework to assist the delivery of an Industrial Engineering Capstone course. Watson and Chileshe [8] at Sheffield Hallam University reported the use of a "unit guide learning outcomes framework" as a guideline to incorporate a PM curriculum into the education process of both undergraduate and postgraduate construction programs. Santos, Alexandre, and Rodrigues [9] described a problem-based learning pedagogy highlighting five project elements, namely problem, environment, content, human capital, and process, to teach software engineering. Mengel [10] at the University of New Brunswick reflected on his two-year experience of teaching project management in a leadership class and concluded that it is important to include the learning objective: being able to initiate, plan, execute, control, and close a project. Jaime et al. [11] discussed their use of spiral and project-based learning with peer assessment in a computer science project management course. Jewels and Bruce at Queensland University of Technology [12] studied whether using the cases-based learning pedagogy affected the PM learning of both undergraduate and graduate students. Liegel [13] argued that the project-based learning approach could improve student comprehension due to its student-centered approach and Sherwood [14] suggested using problem-based learning to enhance project management education.

Given the aforementioned potential benefits of PM, it would appear to PM educators that hands-on class project could provide some much-needed authentic experience, and thus reinforce student learning. A typical class project for PM is to create a project plan for a client so that different PM skills such as determining the scope, creating work breakdown structure, or identifying the critical path can be obtained. Nevertheless, due to the lack of subject matter experts' inputs, information such as task duration and associated costs, is not always available during the planning stage. Consequently, students may choose to guess and go through the motions, and the determination of project scope and the subsequent time and cost estimation could become less than meaningful.

In this paper, the first attempt at implementing a novel pedagogical approach for PM was reported. Instead of following conventional practices, the design thinking process [15] was introduced to help students better understand the project deliverable. Student teams started with identifying and defining problems or needs by empathizing with the users. Next, project teams proposed alternative solutions and created quick-and-dirty prototypes to gain quick feedback. Functional prototypes were then built for benchmarking purposes, and what was learned was then used to verify whether the proposed solution actually resolved the issue(s) of concern. With the test results of their functional prototypes, student teams then determined if revisions were necessary and what this rationale would be. At this point student teams, being the "subject matter experts" of this project, would be ready for a scale-up deployment of their solution, proposing a realistic project plan for constructing a production line or designing a service model.

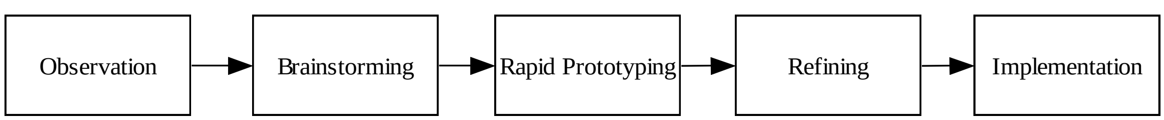
Design Thinking as the Foundation

This novel PM curriculum was designed and offered in a Midwest public university. It is worth noting that the students enrolled in the course came from different technology-related majors, including construction management; computer system technology; engineering technology; graphic communication; renewable energy; or engineering and technology education. At the beginning of the semester, students were assigned to project teams by the instructor instead of self-selection. Students were then asked to reflect on the interdisciplinary nature of real-world PM practices. One member of the team would take turns for a period of four weeks to serve as the project manager on duty, facilitating class discussion, coordinating project progress, and filing weekly project logs.

The first eight weeks of the course were dedicated to the design thinking activities. Figure 1 depicted the key stages of design thinking, namely observation, brainstorming, rapid prototyping, refining, and implementation, as being practiced at IDEO [16], an industrial design firm in San Francisco, USA. The process worked as follows:

- Students were grouped in teams of three or four. Each individual in the group would first propose two projects according to the criteria given.
- After conducting a SWOT analysis of him- or herself, student teams came together and scrutinized the proposed projects based on a follow-up group SWOT analysis that identified the team's strengths, weaknesses, opportunities, and threats.
- The list of six or eight proposals was further ranked by the student team using a SMART index (Specific, Measurable, Achievable, Realistic, and Timely).
- Once a potential project was identified, student teams were asked to develop a point of view (POV) statement and a plan of observation where they watched and talked to actual users to gain valuable insight about the project.
- After compiling the findings from the user interview, a cause-effect analysis was used to narrow down the project scope, and a project canvas was used to grant a Bird's-eye view.

Figure 1. IDEO's design thinking practice



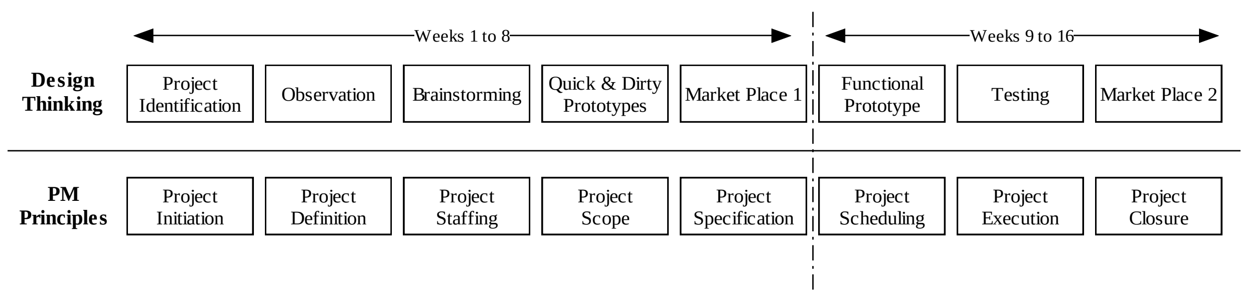
Alternative solutions that addressed the need or concern were developed through brainstorming, and student teams were asked to develop sketches or story boards to present their ideas to the rest of the class. To collect more substantive feedback on their solutions' feasibility, student teams were asked to revisit the users with their quick-and-dirty prototypes made of cardboard, glue, metal wires, and duck tapes. Proposed solutions were refined at least once according to the users' input. Since the purpose of the design thinking activities was to cultivate students into subject matter experts, the novelty of the proposed project—either product centered or process centered—was not evaluated. Nevertheless, the benchmark to compare the proposed solution with existing solutions for the same problem or need was required.

At the end of second refining, functional prototypes were built with proper—industrial or business— material. Student teams seemed inclined to utilize 3D printing for this purpose. However, this way of thinking was discouraged due to the fact that current development of additive manufacturing was not yet mature enough for mass production. The build experience using conventional prototyping methods was in fact a key ingredient for fostering knowledge of “subject matter experts”. Deliverable such as CAD models, blueprints, and product documents were required, along with prototypes eyed with a desired functionality instead of aesthetic or appearance. These prototypes were then tested by target users, based on the benchmark defined by the team. Both quantitative measures and qualitative comments were collected by student groups to determine the effectiveness of the proposed solutions.

Curriculum Layout

While student teams were experiencing different stages of design thinking, they also learned the basic of PM through mini lectures and class activities. Figure 2 illustrated the sequence of this PM course. Two tracks of content, namely *design thinking* and *PM principles*, were running simultaneously. Prior to coming to the class meetings, a weekly reading quiz was assigned to prompt students’ reading of identified material. Students therefore came prepared with basic understanding, and the instructor could refer to different in-class project examples to highlight relevant applications of PM techniques. Guided discussion among student teams was used to fortify their content comprehension thus motivating them to engage in deep learning given that they were stakeholders of the project.

Figure 2. The sequence of the project management curriculum



Two exhibitions of the projects were held in class, one at the end of week 8 and the other one during the final week. Titled as “Market Place”, these two events adopted the practice of business exhibitions: A booth was assigned to each team, and one student would take turn to stay at the booth and present the project. The other team members visited other boots and acted as potential buyers, learning about the projects, trying the prototypes, asking questions, and providing feedback in as shown in Figure 3. In addition, faculty members from the home department and representatives from other units on campus such as college deans’ office, business school’s entrepreneurship center, university office of research and sponsor program, and the center of teaching and learning were invited to interact with presenters and give feedback from an outsider’s viewpoint.

Every “buyer” was provided with a rubric of specific items to evaluate the presentation as well as the proposed solution, in Likert scale 1 to 10, where 1 was “worst/strongly disagree” and

10 was “best/strongly agree”. For each expo, items along with subitems were assessed by the “buyers”, as shown in Table 1. All the evaluation sheets would be returned to the team being evaluated at the end of the activity, and a best-of-the-show would be determined by votes at the end to recognize the most successful project at this point. The authors believed that such a presentation format would create positive peer pressure and expand students’ world view, while students also would be able to develop soft communication skills such as asking questions and providing constructive feedback.

Figure 3. The Market Place: Mid-semester project exhibition of quick-and-dirty prototypes

Table 1. Items assessed during the expositions

Exposition	Item and weighting	Subitems
Quick and Dirty Prototype Expo	Project overview (30%)	Root cause(s) and intended outcome
	Design alternatives (30%)	Variety and rationale
	Quick and dirty prototypes (30%)	Design intent and benchmark
	Project canvas (10%)	Connection between prototypes and project goal (holistic evaluation)
Functional Prototype Expo	Project overview (20%)	Root cause(s) and intended outcome
	Proposed solutions (40%)	Design features and build quality
	Test of functional prototypes (30%)	Test performed and test outcome analysis
	Supporting material (10%)	Artifacts to provide the project insight (holistic evaluation

To determine the effective of this pedagogical approach, students were asked to fill out an assessment of his or her growth of different PM skills, comparing between the beginning of the semester and the date of exhibition (the eighth week of the semester for the quick and dirty prototype expo, and the final week for the functional prototype expo). For each key skills A Likert scale of 1 to 5 was used, where 1 was the lowest and 5 the highest. The comparison covered the following skills:

- The knowledge of product research and development;
- The ability to define the problem or identify the need of the customer;
- The ability to determine whether the issue is product-related or process-related;
- The ability to properly estimate the scope of the project and the task duration/costs;
- The ability to articulate your thought in an effective way;
- The essential knowledge of project management (only for the second expo).

Results from the Fall 2019 Semester

In the fall semester of 2019, 40 junior or senior-level undergraduate students (36 male and 4 female) from five technology majors were enrolled in the 16-week class. Ten different projects were proposed with the instructor's approval. Table 2 depicts the project titles, the problem/need intended to address, and proposed solutions. All teams were able to complete their proposed projects by the deadline, yet the efforts and deliverable's craftsmanship varied. Figures 4 and 5 demonstrate the prototypes of eight project examples.

Table 2. Project titles, customer's problem/need to be addressed

	Project Title	Customer's Problem/Need	Proposed Solution
1	Safety sip	Fluid dripping from or drug added to the 16 oz beverage can	Plastic rotatable insert to cover the opening
2	Light rider	Bike riders lack a way to communicate or catch attention of the nearby car drivers	Handle attachable switch to signal riding directions
3	UAV cam holder	The camera attached to home-made UAV' bottom damages during landing	RC controlled fixture to carry the camera
4	Stuff bucket	Movie going families lack of a safe way to carry the purchased items into theater	Foldable bucket to carry drinks, chips, or popcorn
5	Elevation	Indoor rock climbers need a way to be motivated to use the same layout	A competing system through coin-collection
6	Call-me coaster	Restaurant owners want to increase the beverage sale	Controllable blinking coaster to catch waiter's attention
7	Car CO detector	Automaker lack a way to detect in-vehicle carbon monoxide level	Alarm device to detect the CO level
8	King ping	Decorators dislike the existing push-pin design (skin irritation, sore finger joints)	Redesigned profile to enhance user experience
9	Lock laces	Parents worry about kid's safety issue caused by loose shoelaces	Fabric-based enclosure to restrain shoelaces' movement
10	Pod storage	Phone users need a safe way to quickly store the plugged-in headsets	Cellphone case with a rabbit-ears structure for wrapping

Figure 4. Quick and dirty prototypes from selected project examples: From left to right, *UAV cam holder*, *light rider*, *stuff bucket*, and *safety sip*

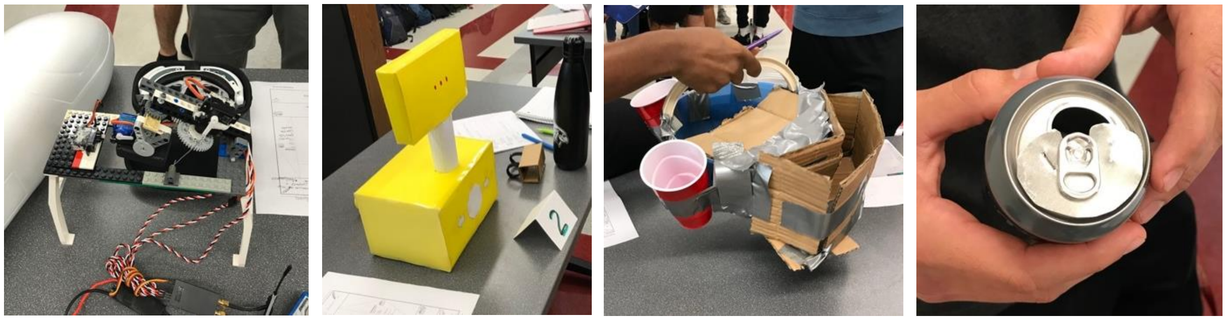


Figure 5. Functional prototypes (from left): *Pod storage*, *king pin*, *call-me coaster*, and *elevation*

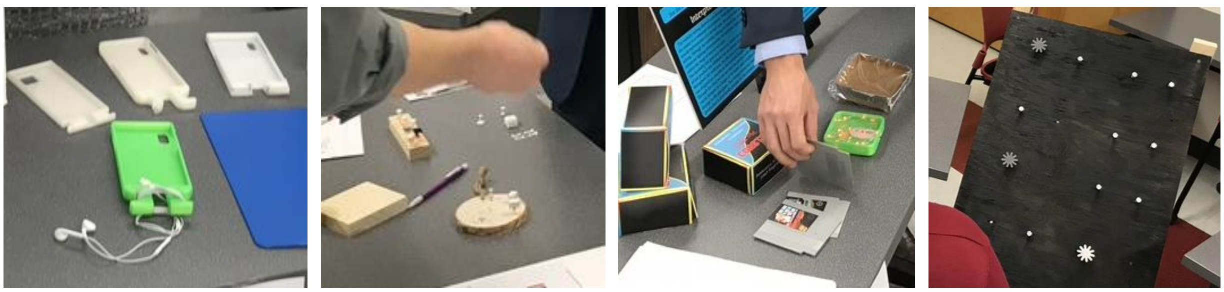


Figure 6. Individual growth in various PM skills from the beginning of the semester to the date of the quick-and-dirty prototype expo (left), and that to the functional prototype expo (right)

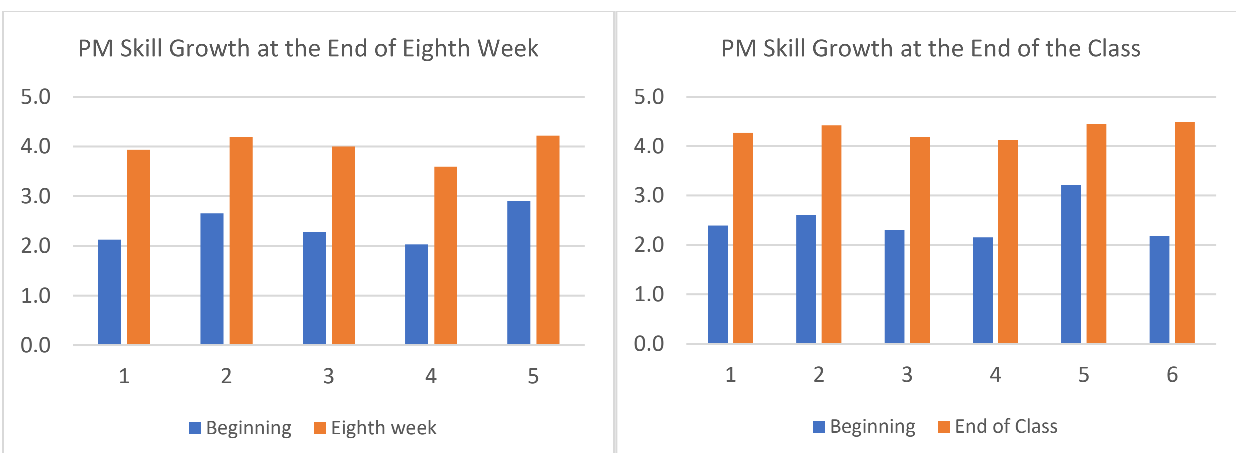


Figure 6 showed the results from two end-of-the-expo, self-reporting surveys on individuals' perceived growth of PM skills during the given periods of time. Both surveys carried no weight in the overall grade, but the respondents were coded in order to examine the correlation between student perception and his or her class performance. Table 3 listed out specific PM skills evaluated, corresponding averages, and growth percentages. The responding rates were 33 out of 40 and 34 out of 40 respectively. The average growth (e.g. change over the specified period) was presented in a relative percentage instead of an absolute value due to the fact that the respondents were not exactly the same in both surveys; even for the same respondents, they gave different values regarding his or her perceived PM skills at the beginning of the semester.

The average perceived level of different PM skills was not the same, probably due to the time of evaluation and individual difference. Nevertheless, the average change (e.g. skill growth) of different items might shed some light regarding the effectiveness of the design-thinking embedded pedagogy. For item 1, the increased skill growth of perceived R&D knowledge (detailed design-build-test instead of product conceptualization) might lead to a lower percentage of growth after students were exposed to different R&D activities. The higher percentage of growth in item 2 might come from the feedback from the quick-and-dirty prototype expo. The decreased growth of item 5 could simply because of different respondents' opinion or bias in self-reporting surveys.

Table 3. Result from self-assessed PM skill growth on the date of two prototype exhibitions

No.	Project Management Skill	Quick and Dirty			Functional		
		Wk0	Wk8	%	Wk0	Wk 17	%
1	Knowledge of product research and development	2.1	3.9	85.3	2.4	4.3	78.5
2	Define the problem or identify the need of the customer	2.7	4.2	57.6	2.6	4.4	69.8
3	Determine whether the issue is product-related or process-related	2.3	4.0	75.3	2.3	4.2	81.6
4	Properly estimate the scope of the project and the task duration/costs	2.0	3.6	76.9	2.2	4.1	91.5
5	Articulate your thought in an effective way	2.9	4.2	45.2	3.2	4.5	38.7
6	Essential knowledge of project management (holistic)	N/A	N/A	N/A	2.2	4.5	> 1

The average responses of items 3 and 4 might imply the positive impact on raising students as "subject matter experts". Item 3 evaluated individuals' understanding of their projects at the end of two expos, and item 4 asked individuals' confidence level in terms of giving a proper (or more precise) estimation on project's scope, time, and cost. Once one iteration of functional prototype was built and test, students appeared to know the amount of resource and effort needed in order to complete tasks required for project deliverable. While the increase might not be obvious (6.3% and 14.6% respectively), it was worth noting that the prototyping experience contributed substantially toward the changes.

Item 6 above was only assessed at the end of the semester, after students experienced all project lifecycle activities. The larger than 1 (105.6% to be exact) perceived growth in the area of project management, while being predictable, indicated the magnitude of students' perceived gain in PM knowledge through the hands-on experience.

Discussion and Lessons Learned

Multiple phenomenon emerged after adopting this pedagogical approach and this section was dedicated to the discussion of the possible causes of student behavior. The first phenomenon was related to student motivation and corresponding project outcome. All teams were able to complete their projects by the deadlines, yet the efforts and deliverable's craftsmanship varied. For those teams who were able to reach genuine consent in project topics at the front end, they generally treated the project seriously. Different manufacturing processes such as machining, 3D printing, thermal forming, and injection molding were used to create the functional prototypes. For others, their functional prototypes were mainly done by hands and were unimpressive. However, the quality of project outcome could also be the result of the team's hard skill, e.g. whether they knew how to operate certain tools and amount of time needed to deliver a better result. Besides, the budget for each project, if allocated by the instructor at the point of project kick-off, could also influence student teams' design alternatives and deliverable.

Another phenomenon observed was related to students' comprehension of course material. The instructor periodically collected formative feedback and the response from students spanned the gamut of two extremes. By using a coded system, the instructor was able to track students' comments to identify respondents with their responses. For those students who were excited about being able to select the hands-on projects, they took ownership and would go the 'extra mile' without any added incentive. These project teams were actively engaged in discussion and worked collaboratively. Their project deliverable(s) and presentation were therefore, more creative. Additionally, these same students claimed gaining valuable insights in learning the PM principles, by completing authentic projects. In contrast, some students felt lost and disorganized, easily frustrated and complained often. Subpar students' performance could also be affected by poor class attendance, not seeing the value of the project-based learning approach, personality issues, or generally poor overall GPAs. These students oftentimes chose not to participate in the non-incentivized surveys. For those who chose to participate in one of the surveys, their response to the questions was usually inflated: They considered their skill level a 4 (good) or 5 (excellent) while in reality, it was only at level 3 (average).

Three lessons were learned through the semester-long observation. Firstly, the instructor's intervention at the early stages of design thinking, especially during the stages of observation and brainstorming, was crucial. Even though this course was an upper-level class, students' demonstration of critical thinking could be still lacking, resulting in either a poorly defined project, or choosing an obvious solution instead of a well-thought out one. Rather than telling student teams what to do, the inquiry-based instruction (e.g. asking critical questions) would be a more suitable approach to take.

Secondly, just as the real project managers would do, the instructor should make the necessary arrangement/s for facility and equipment usage, instead of asking student teams to contact the equipment owners. As a department consisting of different technology majors, the equipment belonged to different academic areas and conflict of interest or shortage of resources was inevitable. In such situations, support from the administration level would have been essential, and constant communication with program coordinators would be equally important. In a sense, the instructor should serve as the head of a corporate’s project office, overseeing multiple projects simultaneously and closely following student project managers’ weekly logs.

Last but not the least, verbal encouragement to students and recognizing their efforts and problems in public were vital. Being afraid of uncertainty and reluctant to take risks, some project teams would just “play it safe”, even when they had the potential to come up with some “crazy” ideas and if failed, failed “gloriously”. The expectation of autonomy could be unrealistic; having ten to fifteen minutes’ chatting with each group frequently could help keep students to be more focused and on track.

Conclusion

The initial attempt of incorporating design thinking into a PM course was reported. The justification of this new pedagogical approach and the curriculum design rationale were presented. Project exhibition in the format of “Market Place” was described. The result of the first trial and the lessons learned were discussed. Judging from the student team’s deliverable, performance in course content, and self-reporting survey assessing perceived growth in PM skills, it seemed to the authors that this pedagogy was applicable and had the potential to create positive impact on student learning.

Clearly, there were multiple variables that might affect the practicality of the suggested teaching approach, for example, student readiness and preparation for this course, student maturity level, or the instructor’s ability in selecting appropriate project topics and providing feedback. Besides, the allotted length for class meeting time was critical. In the current setting, only two 75-minute class meetings were scheduled weekly. A major portion of work had to be done by student teams outside of the class. The instructor was not be able to fully observe the project’s progression and provide critical feedback in a timely manner. Some might suggest expanding this course to four credits in two consecutive semesters. However, changes like this would greatly impact the department’s course scheduling and team dynamic if one member left or was added to the team.

Due to its experimental nature, the self-reporting PM skill assessment was used. In the future, a more authentic and reliable assessment method to evaluate students’ learning will need to be fully developed. While three midterm examinations were used to assess students’ understanding of PM principles, and multiple instructor and peer evaluations were given toward the project itself, more efforts would still be required to help highlight the intertwined relationship between design thinking and the PM principles taught or required in this class.

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