Engineering Students Learn ABET Professional Skills:

A Comparative Study of Project-Based-Learning (PBL) versus Traditional Students

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Abstract

This paper presents preliminary findings of a study that investigated the learning experiences of students who enrolled in two programs: a project-based learning (PBL) and a traditional engineering curriculum. The PBL students do not take classes; 100 percent of their learning is done in the context of industry projects to develop graduates with integrated technical and professional knowledge and competencies. The traditional curriculum involves classroom instruction, homework, and assessments. Using a qualitative research approach, the current study focused on students that completed two years of a new PBL program in a Midwest university, and compared their learning experiences to students that are graduating from a traditional program at a different university.

Initial results suggest positive outcomes are more pronounced for students associated with PBL as compared with students in traditional engineering curriculum, with regard to both Accreditation Board of Engineering and Technology (ABET) professional skills, outcomes, and future employment. For example, one immediate highlight of the PBL program is that a majority of PBL students ranked their program (i.e. instructors and project format) positively, and were more "encouraged" to work in teams to complete tasks for real clients in industry. The results of this study will provide insights into PBL as a model of learning engineering in the context of design and practice to support engineering programs aiming to establish project-based learning as well as academia in general.

The Need and Purpose of the Study

Project-Based Learning (PBL) Program Model v. Traditional Program Model

For the past two decades, there has been a call from the National Academy of Engineering, National Science Board, Industry Leaders, Engineering Education leaders and others for a new model of engineering education that will produce engineers who will meet current and future challenges to keep the United States competitive in an increasingly competitive global economy. One common realization is a consensus among engineering educators is that to better prepare engineering students, education models need to be improved, moving away from traditional ones to reflect the demands and challenges in work place.[2, 8] In response to the urgent needs in engineering education reform, a Midwest university is in partnership with a community college to create an entirely project-based learning (PBL) model where students are expected to combine learning of technical information with the execution of engineering design projects. The developers and proponents of the PBL strongly believe that an integrative program (PBL) can empower students to *develop* technical and professional *knowledge and competencies* in context of industry sponsored project-based learning and better prepare students to face challenges in an increasingly globalized technological world.[3,4] The traditional curriculum, on the other hand, involves classroom instruction, homework, and assessments.

ABET Professional Skills

For the past two decades, engineering programs and engineering educators across the nations have also observed the significance of the mastery of professional skills identified in *ABET* and *Engineering 2020* for the development of engineering students as emerging professionals. ABET professional skills combined with an ability to innovate will add value to U.S. engineering graduates. What are "ABET professional Skills?" They are (i) an ability to function on multi-disciplinary teams (3.d); (ii) an understanding of professional and ethical responsibility (3.f); (iii) an ability to communicate effectively (3.g); (iv) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (3.h); (v) a recognition of the need for, and an ability to engage in lifelong learning (3.i); and (vi) a knowledge of contemporary issues (3.j).[5, 7]

Assessing Student ABET Professional Skills in PBL

As part of the evaluation of the PBL program, the current study assesses the initial outcomes of students enrolled in the PBL program, particularly their ABET professional skills. Students who completed two years from the PBL program and students from a more traditional program were invited to participate in this study. They were interviewed by the researchers to investigate students' professional competency and motivation. Table 1 displays the interview protocol that the research team developed to measure students' knowledge and self-efficacy related to six professional ABET skills described above to determine the effectiveness of project-based learning (PBL) model in comparison to a traditional engineering education model. The PBL program is unique in several ways: a) it incorporates how people learn to empower students to take ownership of their education and gain their knowledge and competencies; b) it places special emphasis on professional competencies as articulated in *ABET a-k* and *Engineer 2020* and finally, c) it uses a context of learning engineering by practicing engineering side-by-side with engineers. Specifically, the paper will address two research questions:

(1) In what ways, does engineering pedagogical context influence the development of students ABET professional skills?
(2) What are the factors in PBL program, which contribute to effective learning of ABET professional skills?

Data Collection and Analyses

Project-Based Learning (PBL)

The PBL program is adapted from the Aalborg Model of PBL (Figure 1). Students combine learning of technical information with the execution of engineering design projects. The program model is 100% project based and does not include traditional courses. Entering students are community college graduates or transfer students from other universities who have all completed lower division requirements for a Bachelor of Science in Mechanical Engineering. The model has four semester upper division portion of a student's education. Graduates of the program earn a Bachelor's degree in Mechanical Engineering. Students must complete one or two industry-sponsored projects per semester.

Student Empowered Design and Monitoring is a guiding principal for the program model; students own responsibility for their learning. Students identify which outcomes will be addressed at the beginning of each new project, while working with faculty. Each project cycle includes two reports – a design report and a written report, and a final presentation. The final presentation is made to faculty and external clients, and includes an oral examination to assess student understanding of the knowledge and competencies required.

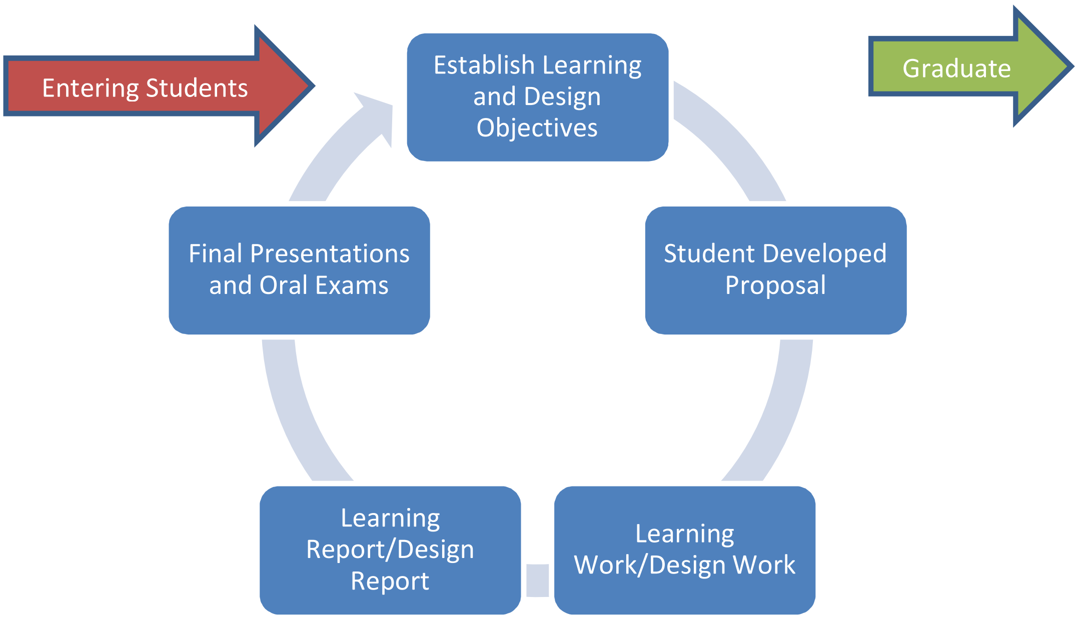

Figure 1. An adaptation of the Aalborg Model of PBL used in the Midwestern University PBL program

Table 1. *Project-Based Learning Interview Protocol of ABET Criterion 3: Professional Skills*

Interview Question	ABET Criterion 3: Skill Assessed
Why are you interested in becoming an engineer? Where do you see yourself in 5 years? 10 years?	*Warm up question*
What kinds of things do you plan to do to accomplish these goals?	*Lifelong Learning*
Tell me about a time when you had to expand your performance by seeking out resources and help in ways that support timely, quality performance?	*Teamwork* *Lifelong Learning* *Motivation*
How important is it to seek out mentors to support and challenge future growth and development?	*Lifelong Learning*
Name a big problem in the world and discuss how engineers and engineering might help with solving this problem	*Impact on Society* *Contemporary Issues*
Follow up: What are potential unintended negative consequences of this solution and who should they be mitigated?	*Impact on Society* *Contemporary Issues*
Where did you learn about teamwork?	*Teamwork*
Follow up: Did you learn any of this from your instructor?	
What challenges/benefits are there when working in a team?	*Teamwork*
What types of communication strategies do engineers have to employ when working with clients and other engineers?	*Communication*
What are the important aspects of communicating in these settings? In what ways has your education prepared you to communicate these ways?	*Communication*
What kinds of ethical considerations do engineers have to face and in what kinds of situations?	*Ethics and Professional Responsibilities*
Follow up: How has ethics in engineering been presented in your education?	*Ethics and Professional Responsibilities*

The Interview Protocol

Table 1 includes the interview protocol used to assess students' knowledge and competencies of six ABET professional skills. We follow the notion used by Shuman et. al (2005) and divide these ABET professional skills into two groups: *process skills* and *awareness skills*.[7] Process skills include communication, functioning on multi-disciplinary teams, understanding professional and ethical responsibilities. Awareness skills include the broad education to understand the impact of engineering solutions in a global and societal context, knowledge of contemporary issues, and recognition of the need for and the ability to engage in lifelong learning. Fourteen students in the traditional program and sixteen students in PBL were interviewed in late March and late April, respectively. Interview notes as well as transcribed recordings of interviews were used for further analyses.

The Coding Process

The research team used open coding at the beginning to identify emerging themes from one set of data. Following open coding, a matrix was created (Table 2) that summarizes the themes into more focused categories (i.e. Themes A-D described in detail below). Different colors were assigned to code each of the six ABET standards, and numbers from 1 to 5 to identify where the learning took place. For example, Teamwork [A3] (highlighted in yellow) is about students' knowledge of team dynamics gained from *current schooling*: "I think (teamwork) is important because especially here with the instructors at least I always go to them for advice on how to work with my team, or how to communicate with them." Another example, Ethics [B5], (highlighted in green) is about students' knowledge of general ethics gained from *"did not specify (DNS)*: "You could even affect the environment, like the BP oil spill. I'm not going to blame anyone because everyone makes mistakes, but eventually that lead back to an engineer who made the mistake at some point and it affected the environment and that was a huge deal." Varying numbers of themes (from two to four) were identified under each professional skill. For example, *Teamwork* had only two emerging themes: A- team dynamics and B- project management. The theme of team dynamics, A, included two subjects of interpersonal skills and relationships, whereas the theme of project management, B, consisted of four subjects: planning, team communication, time management and conflict resolution. Another professional skill with four emerging themes is *Impact on Society*: A-environmental, B-economic, C-societal, and D-globalization.

To ensure inter-rater reliability the research team assigned one interview transcript to four researchers to code using a matrix shown in Table 2 for "coding training".[6] The coded results from different researchers were compared and differences in coding were discussed to minimize inconsistencies among coding. The data sets used for this study were coded by two researchers who went through "coding trainings". The coded interview results were later analyzed using "binary counting", i.e. "1" for "yes," and "0" for "no." These results were summarized in a figure similar to Figure 2 and Figure 3. Although some students' answers were more thorough and used detailed examples in interviews, our data analysis only reported whether or not students were able to respond to questions concerning the ABET standard ("1" for "yes," and "0"for "no"). Figure 2 and Figure 3 display the interview results of 14 students in traditional program. Our study focused on student' response that indicated learning occurred either in *current schooling* or *did not specify* because these data provided insightful information regarding how pedagogical context affected students' learning of professional skills.

Themes

The following section will provide a brief description of themes that emerged from the interview data:

Teamwork: Fidelity of teamwork implementation should include matching the conditions of the work environment as closely as possible; and involve factors such as time limits, deadlines; social context communication, coordination and conflict.[2] Two types of team work emerged: team dynamics and project management. Project management skills include planning, team communication, time management and conflict resolution. Team dynamics include interpersonal skills and relationships.

Ethics and Professional Responsibility: The goal of ethics in engineering education is to teach in context and make synthesis, evaluation, reflection and ethics part of every course; and suggested focusing concerns on how engineers perceive, articulate, and resolve ethical dilemma such as understanding rather than just demonstrating.[8] For example, ethics education should include decisions around moral dilemmas such as: moral reasoning (avoiding punishment); individualism (instrumental purpose and exchange); mutual interpersonal expectations, relationship and conformity, and fulfillment of duties to society. Finally, modeling desirable behavior as well as expose students to societal decision making also make up ethics education in engineering.[8]

Impact on Society: Three themes emerged: a) Environmental: local, regional, and global; b) Economic: local, regional, and global; c) Societal: local, regional, and global; and d) Globalization.

Contemporary Issues: Three themes emerged: a) Environmental: renewable resources, and global warming; b) Economic: renewable resources, and efficient use of resources; and c) Health and Safety: clean water and hunger.

Life Long Learning: Three themes emerged: a) Credentials: professional engineering license (PE) and professional development (PD); b) Career Path and Progression; and c) On the Job/Apprenticeship, or PD from employer.

Communication: Two types: a) Clients/Public (nontechnical audience); and b) Colleagues/Other Engineers (technical audience).

<u>Others:</u> The research team focused on two aspects of motivation: intrinsic and extrinsic. For example, the questions: *Why are you interested in becoming an engineer? Where do you see yourself in 5 years? 10 years?* (Warm up question) and *Tell me about a time when you had to expand your performance by seeking out resources and help in ways that support timely, quality performance?* A second theme: "other ABET skills" was used for responses not related to motivation or professional ABET skills

Table 2. *Coding Matrix for Interview Protocol of ABET Criterion 3: Professional Skills*

ABET Professional Standards	Theme A	Theme B	Theme C	Theme D
Teamwork	Team Dynamics: Interpersonal skills and relationships	Project management skills: planning, team communication, time management and conflict resolution		
Ethics and Professional Responsibility	Professional ethics: following license laws; i.e. carelessness	General ethics: knowledge of contemporary issues; i.e. environmental and health and safety		
Impact on Society	Environmental: local, regional and global	Economic local, regional and global	Societal local, regional and global	Globalization
Contemporary Issues	Environmental: renewable resources, global warming,	Economic: renewable resources, efficient use of resources	Health and Safety: clean water, hunger	
Lifelong Learning	Credentials (ie PE, PD, etc)	Career Path/Progression	On the job: apprenticeship or PD from employer	
Communication	Clients/Public (nontechnical audience)	Colleagues/Other Engineers (technical audience)		
Others	Motivation: Intrinsic v. Extrinsic	Other ABET skills		
Where learning takes place? **Code with numbers and with everything else [1]**	[1] Engr Internship/work experiences [5] did not say or N/A	[2] Previous schooling	[3] Current schooling	[4] Outside of engineering or school (K-12, sports, working (not engineering)

Findings

In this paper, we show interview results that were coded under *current schooling* and *did not specify (DNS)*, because some of our interview questions did not specifically ask students to identify where and when they learned these skills, Figures 2 and 3 include traditional students' interview results under *current schooling* and *did not specify*, respectively. PBL students' interview results under these two groups are displayed in Figures 4 and 5, respectively.

Results of Traditional Students: Current Schooling vs. Did Not Specify

The results based on *current schooling*, Figure 2 show that students at the end of the traditional program were not aware of contemporary issues, impact on society, ethics and professional responsibilities, and different ways to communicate with clients vs. colleagues. This is likely because the question did not specifically ask where and when the learning took place, however, almost all of students were able to discuss teamwork and skills related to team dynamics and project management, and talked about benefits and challenges. More than half could give specific examples of distinctive characteristics of communication with client vs. communication other engineers. It should be noted that for figures 2 to 5, the data sometimes total greater than 100%. This is because giving answer "a" does not preclude also answering "b." For example, students who answered a question about teamwork often gave examples of knowledge of Team Dynamics and Project Management from both current schooling and also did not specify.

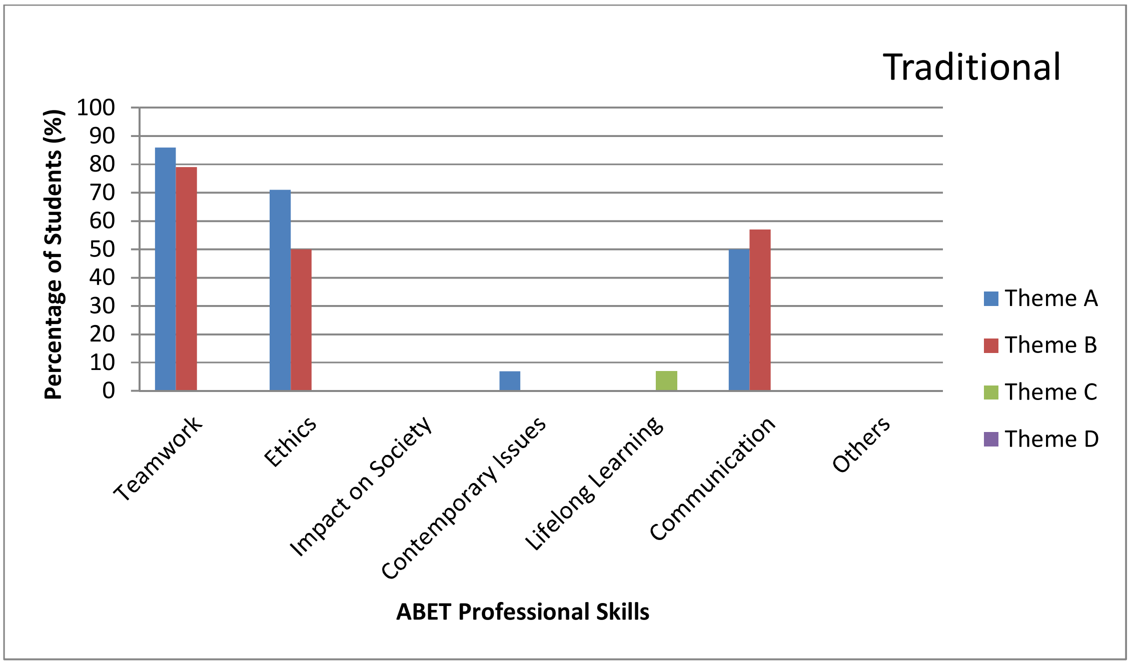

Figure 2. Traditional student interview responses learned from *current schooling (n=14).* The key for themes A-D can be found in Table 2

On the contrary, the results were dramatically different for four of six categories when responses were categorized under *did not specify (DNS)*. This is important to point out because the questions did not all hint to current schooling, but were asked as a general question. We report results under both *current schooling* and *did not specify* because these results show students' current understanding of professional skills. The major differences were observed in the following four categories: impact on society, contemporary issues, lifelong learning and others (motivation); for example: 79% percent of students were able to identify engineering solutions and potential negative impact on society, more than 60% were able to identify contemporary issues and shared lifelong learning goals, 86% demonstrated knowledge of communication skills with clients and 79% demonstrated knowledge of communication skills with other engineers/colleagues. Finally, 93% of students showed extrinsic/intrinsic motivations related to seeking mentors to expand their knowledge in a traditional setting when they responded to the questions of "*Tell me about a time when you had to expand your performance by seeking out resources and help in ways that support timely, quality performance?*"

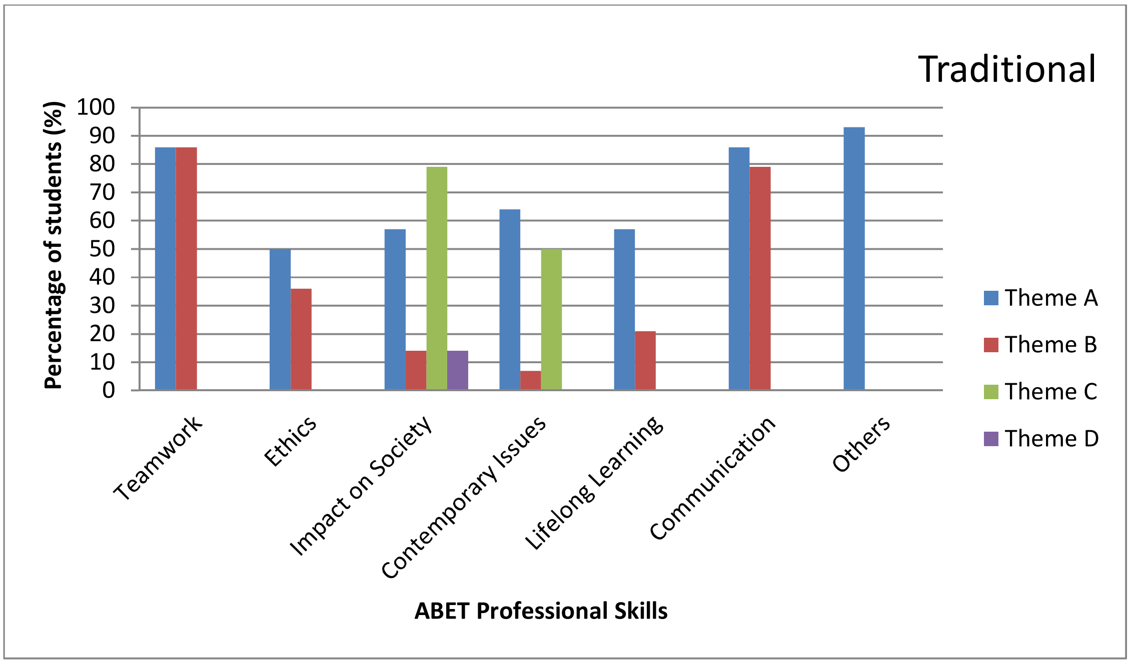

Figure *3.* Traditional student interview responses that *did not specify* the origin of their knowledge (n=14); the key for themes A-D can be found in Table 2

Results of Graduating PBL Students: Current Schooling vs. Did Not Specify

The results based on *current schooling*, Figure 4 shows that students at the end of the PBL program were not aware of impact on society, contemporary issues or lifelong learning, and different ways to communicate with clients vs. colleagues. This is likely because the question did not specifically ask where and when the learning took place, however, almost all of students were able to discuss teamwork and skills related to team dynamics and project management, and talked about benefits and challenges. Less than half could give specific examples of distinctive characteristics of communication with client vs. communication other engineers.

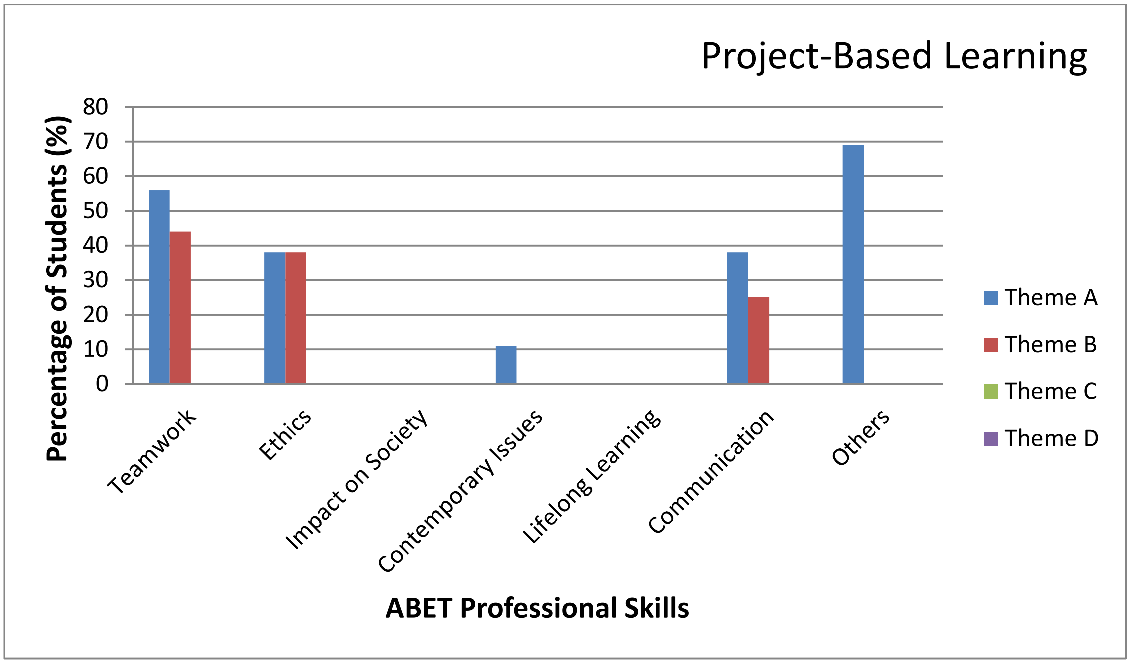

Figure 4. PBL student interview responses learned from *current schooling* (n = 16). The key for themes A-D can be found on Table 2

The results were dramatically different for four of six categories when responses were categorized under *did not specify*. Again, this is important to point out because the questions did not all hint to current schooling, but were asked as a general question. We report results under both *current schooling* and *did not specify* because these results show students' current understanding of professional skills. The major differences were observed in the following four categories: impact on society, contemporary issues, lifelong learning and others (motivation); for example: all students were able to speak about teamwork related to their program, 70% about team dynamics and project management; and majority of students were able to identify engineering solutions and potential negative impact on society on a variety of themes, and there were more variety of contemporary issues as well as shared lifelong learning goals in all themes from professional development to career advancement, about 80% demonstrated knowledge of communication skills with clients directly related to current schooling and over 60% demonstrated knowledge of communication skills with other engineers/colleagues. Finally, more students demonstrated a variety of motivation in this category; students showed extrinsic/intrinsic motivations related to seeking mentors to expand their knowledge in a traditional setting when they responded to the questions of *"Tell me about a time when you had to expand your performance by seeking out resources and help in ways that support timely, quality performance?"*

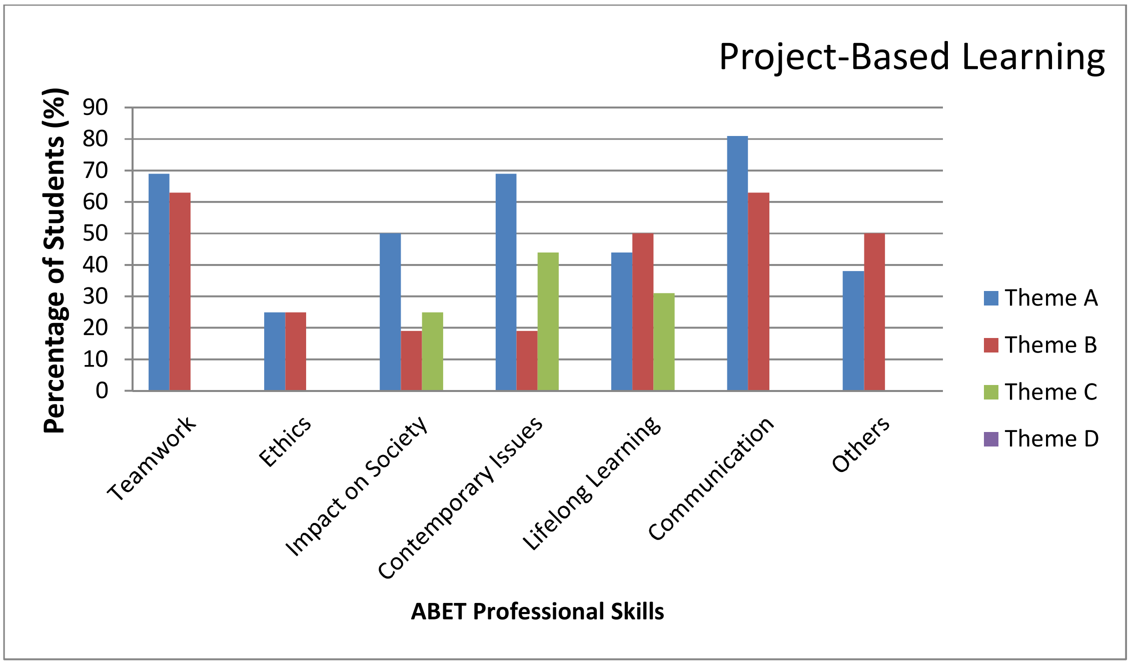

Figure 5. PBL student interview responses that *did not specify* the origin of their knowledge (n = 16). The key for themes A-D can be found on Table 2.

Discussions

Findings of this study show that engineering pedagogical context impacts learning of professional and technical skills related to the engineering profession. Just as all teaching in college, the fidelity and complexity of the curriculum influence students' learning outcomes. In particular, the fidelity and complexity of curricular activities influences student learning outcomes. Traditional and PBL programs offered students with different learning settings and opportunities. Therefore, students display various degrees of mastery of these skills.

Shown in Figure 1 above is an adaptation of the Aalborg Model of PBL used in the Midwestern university PBL program. PBL students spent 100% of learning in industrial project design and practice, a context provides them with multiple dimensions to perceive and develop their professional skills as expected.

For example, one project assigned to students is to design and implement a condenser performance test to be applied to the power generation condenser on a 400 MW power plant.

The performance test gives several indications of efficiency both before and after the condenser is retrofitted. The results of the testing will give the state power plant vital information on the cost savings and payback period. To perform the project, the student group learned cycle analysis, conduction heat transfer, convection heat transfer, heat exchanger design, engineering economics, evaluation theory, and studied the environmental implications all in the context of a real deliverable for a major client. Learning outcomes and assessments included several student publications of technical reports and oral presentations. A project like such clearly requires in-depth use of knowledge and skills in science, engineering, and technology. On top of this, students learned first-hand experiences and skills in teamwork, communication, and engineering professional responsibilities in a complete cycle: from inquiries of knowledge to completion of a deliverable. During the process, students were able to develop these professional skills, particularly process skills in multiple dimensions: personal, interpersonal, program management, and others. As expected, the current study illustrate that the PBL engineering program emphasizes the development of professional skills, and provides students authentic training in this respect. In the following table we provide detail discussions of the study results based on interview notes and transcriptions of recorded interviews for a qualitative comparison of traditional program graduates vs. PBL program graduates (students who completed two years of PBL).

Table 3 provides a summary of students' perceptions and understandings of the ABET professional skills. It includes interviewer's observations as well as highlights of students' responses to interview questions in both traditional and PBL engineering programs. The following are conclusions drawing on qualitative analyses.

- Both programs touch upon main topics and issues concerning the ABET professional skills and help students understand that the development of these professional skills are critical to prepare students to face real-world challenges. See results figures 2-5.
- As expected, PBL students were able to relate their development of the professional skills to their curriculum that enriched their learning experiences. They articulated their understanding through concrete examples and highly appreciated the program.
- While traditional students displayed progresses in developing the professional skills, they indicated that the curriculum was not able to provide them with hands-on experiences and wished the program could better prepare them to face the real-world challenges.

Table 3

Qualitative Summary of Findings from Student Interviews from Traditional and PBL Settings

Professional Skills	Traditional Students	Project-Based Learning Students
Teamwork	***Students understand:*** ***a) Challenges:*** Team dynamics, and Scheduling, and various skill sets and motivation of team members. ***b) Values:*** Dividing tasks and sharing various ideas to achieve a set goal**,** and support from a learning community "Teamwork is something you develop over time. You don't learn it in a class…it's just a skill you develop," "You can't really teach people how to interact, but you can learn that through experience." "Being able to work with different people even though they may not be your preferred choice is valuable part."	***Students appreciate:*** Teamwork: a) as instructive in handling interpersonal dynamics and for practicing project management skills; b) experience specifically with the PBL program; c) has more innovative solutions and lessening of work load; d) as a part of PBL education included: how to improve team work, design and review; talk about and take surveys. Faculty encourage teamwork and to use students as other resources. "In XXX everyone wanted to be there. In XXX's introduction to engineering class we switched teams often," "---each semester students go through team work evaluations both verbally and on paper. "I really like (PBL) format and team work, how to communicate effectively and how to deal with other engineers or critics…we learn to give and take constructive criticism

Ethics and Professional Responsibilities	a) Little diversity and in-depth understanding in the topic around ethics; and many mentioned, and b) not all students had educational classes "Being a good person and "not saving money to compromise safety types of issues. "Early on in the career in your freshman courses they outline the specific code of ethics for specific disciplines and those are reinforced in later classes." "We've never had an actual ethics class, so it has just been a few comments here and there in our design class."	Over half of students in this cohort were able to identify ethical considerations specific to practicing professionals, such as conflicts of interest and fair competition. Some did not specifically attribute this knowledge to their PBL experience in the interviews. For example: Safety is number one and also avoiding relationships with hidden agendas such as do not cut cost to compromise safety. The students that did attribute their knowledge to PBL mentioned weekly ethic review using both historical cases and contemporary cases with various perspectives. These included ethical presentations and a paper every semester as a big part of project.
Impact on Society	There was not a variety of topics. Examples include: Budget in transportation; exhaust byproduct (in renewed energy and clean water); cost/explore various solutions and maintenance (better materials); and pollution laws or lack of can impact amount of pollution	Students are aware of various issues from an engineer's perspective; and students shared how engineering could address contemporary issues and how engineering solutions might have unanticipated impacts to society: a) environmental hazard such as moving dirt around, b) sustaining much wildlife as possible; c) nuclear power by products; d) wind power has negative aspect since it takes up large footprint that could be used for agriculture; e) change weather pattern; and f) finally, clean water and where to put pollutants

Contemporary Issues	a) Although lack of diversity, students mentioned a few unique issues; and b) No in-depth discussions concerning global issues. Topics around nutritional epidemic and clean water around the world; roads and pipelines, and transportation safety was a common concern; degrading infrastructures as a contemporary issue; debris from natural disaster was another unique "big issue." For example, "Very poor understanding of economics" is a concern since the impact on society meant less spending on important transportation/safety concerns.	a) All students were able to identify contemporary issues related to engineering; b) Over two thirds identified environmental issues such as renewable resources, and environmental pollution. c) Traffic flow and city engineering that could be mitigated by shorter stop time and equal stop time; and sustainable energy and clean water
Lifelong Learning	Students mentioned a) earning their PE license, and the importance of continuing education, and b) earning an MA to starting their own firm. A majority mentioned lifelong learning was important around seeking out mentors being a very important aspect of growth as an engineer. For example: "You have to make yourself as valuable as possible to employers. You have to increase your skill sets…so I can get hired over someone else."	Most students associated lifelong learning simply as a career progress from technical to managerial work Less than half mentioned obtaining additional credentials such as a professional engineering license as part of their career plans. Sample student responses showed desires a) to lead projects (management), b) lead teams and projects; c) better their learning no matter what, take various classes and d) some shared specifics, manage a mine or a business.

Communication	a) Students answered the question literally and their answers included types of communication such as phone, email, face to face, etc. b) The group lacked depth understanding beyond “ways to communicate” such as instead of “strategies” that are unique to engineers. For example: use layman’s terms, use analogies, visual interpretations; technical writing; knowing audience. One student added the importance of people skills, “You listen to everything they’re looking for…transparency communication.” Another shared that it is “important to write down and sign for legal reasons” and direct documentation is also important part of communicating with clients and other engineers.	a) Almost all students recognized the need to adapt their communication strategies when working with non-technical audience, whether this be a client or general public. b) Approximately half of these students specifically associated this knowledge with their PBL experience. Use language that clients can understand to make your project much more valuable in their eyes; For example: bring a story into it since people remember stories; Students learned how to articulate stating what you need and who you are Listen to what clients want; you are working for clients, understand what they are asking for economically and ethically; and show you know your audience and understand their technical abilities: a) work together to get what they want and through an engineering perspective; b) speak less and listen; collaborate vs. shutting others down; be professional when presenting ideas; and c) technical writing course; oral final vs. written test (describe clearly, provide constant update
Others (Motivation)	a) Almost all of the students mentioned that it was important to “very important” regarding seeking out mentors, b) Many suggestions regarding reforms in lectures/curriculum: update lab manual, adding hands-on learning experiences (such as design courses in earlier years), and helping	a) Almost all the students showed <u>intrinsic motivation</u> to pursue engineering; b) Although all these motivations existed prior to or outside of their experience in the PBL program, but have been <u>enhanced by the program.</u> For example: love of problem solving or a desire to

	students think outside the box. "(In) engineering I think you need to have a proper balance. It can' all be sitting in a classroom and having a lecture…The application, I think, is where engineering really comes in." I wish labs across the four-year program – I feel like a lot of teachers started working here 20 years ago, wrote the lab manual, and never updated it." "Changing the manual and updating the labs we're supposed to do, but other teaches tend to use older manuals and don't reference books we use and are hard to decipher." "I feel like there's not much work put into them and can be updated. I really like the design programs in the junior/senior years. I think they should add a third one in the sophomore year to get you somewhat more involved earlier on. Not as in depth, but something you can do in your earlier years to make you feel like you're working toward something." "I tend to think that I could get a lot better education somewhere else. I think the organization of the engineering program is kind of set in its way. There is not a lot of thinking outside the box as far as what do our engineers need to learn and what would satisfy that. A few times they have filled that with somebody who wasn't adequate to teach… I was given a teacher that I didn't connect with and a lot of my peers didn't connect with."	help other people; only two students mentioned financial reward or career opportunities "Instructors sit down and talk to you about ideal job and where you want to work." "XXX is a great mentor and excellent instructor." Seeking mentors is "extremely important." One student already accepted a position two months as field engineer prior to graduation. Overall, related to mentors and motivation, many agree it was very important "to push you and keep you on track," and Mentors are "not always your best friends but have your best interest."

In Figure 6 we compare coding results of student interview responses under two groups *current schooling* and *did not specify (DNS)* for both traditional and PBL programs. Uncertainties, possibly arising from individual interviewers who conducted interviews somewhat differently are included as estimated 15% error bars are also shown in this figure. The data shown in this figure support the conclusion that both traditional and PBL programs taught students basic concepts and ideas of the ABET professional skills. However, the coding results are not able to reflect students' learning experiences and in-depth understanding of their education if the ABET professional skills. It reveals some limitations of this study. We believe that there are several issues that need to be carefully addressed for future study:

(I) Make changes in interview protocol:

- Add follow-up questions to clarify interview questions and answers when needed;
- Provide researchers with training in conducting interviews

(II) Create rubric to quantify results

- Using a scale of 1-3 to evaluate the depth of interview responses

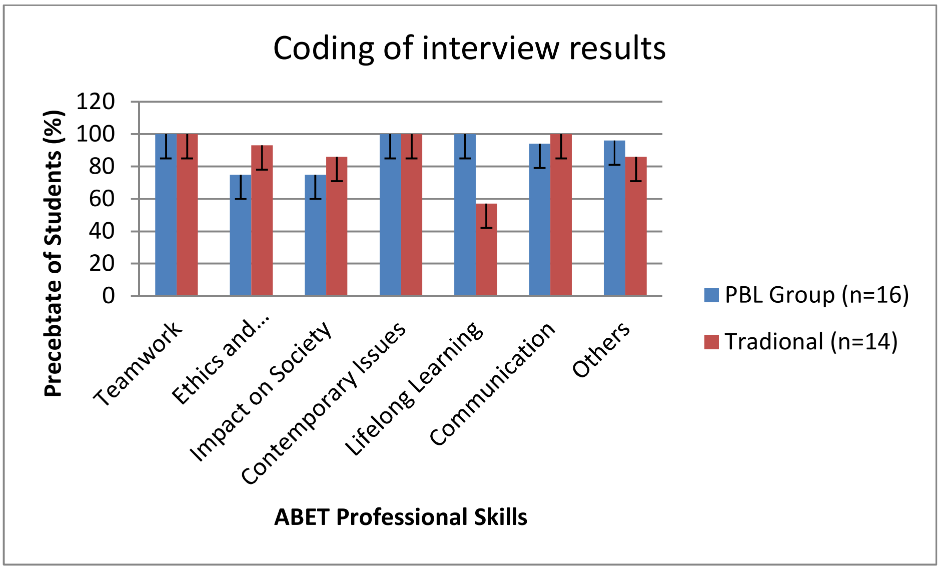

Figure 6. Summary of student interview responses coding including both *current schooling* and *did not specify* the origin of their knowledge for both programs. The key for themes A-D can be found on Table 2. Error bars (~15%) to take into account the inconsistencies arising from different interviewers are shown

Conclusion

Findings from the interview protocol to assess ABET professional skills of PBL and traditional student groups need to be combined with other measures to assess engineering programs to gain a more complete picture of student mastery of the professional skills. The interview can be (and will be) employed longitudinally to help students and faculty assess their program strengths and weaknesses. Faculty and university curriculum designers can use the information from this study to improve current practice and start discussions about pros and cons of each skill being assessed for their program and the benefits of exposing students to real working environments.

Future interviews will be more focused on current schooling and how current schooling is contributing to student understanding of the six competencies; and whether or not improvements can be made. Future interviewers and users of this interview protocol may include professionals in the field, faculty, clients, and students in order to check for student readiness to enter the field, or if more instruction is needed in PBL settings. The preliminary findings of this study will provide insight of student learning experiences in two programs, and eventually support engineering programs aiming to establish project-based learning, as well as to academia in general as a model of learning engineering design and practice in context

Finally, the most significant finding is that students who were asked to comment on their PBL experience all identified positive feelings involved with peer interactions and the value of teamwork to complete projects. A majority of both PBL and traditional students mentioned the importance of seeking mentors; but more PBL students mentioned having several opportunities to seek outside support to complete their goals, and many shared the willingness of instructors outside of office hours to help. Overall, the PBL experience better prepares students to work in industry, especially when discussing a variety “unintended negative consequences” of engineering. The research team hopes that our findings will support engineering educators and curriculum developers.

In conclusion, we believe that traditional programs are able to teach students professional skills to a certain degree, but will need to add training settings to help students develop these professional skills that will empower students to face real challenges. In contrast, PBL programs provide natural and authentic settings to help students develop professional skills while learning innovative skills. Several factors that are unique in PBL programs, for example, working in a real-world engineering setting, working with a real engineering problem, working side-by-side with engineers, working from the design proposal to the completion of a product, and etc. contribute to the effective learning of ABET professional skills.

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