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# Student Experience for the Development of Professional Competencies in a Project-Based Learning Curriculum*

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In the calls for change in engineering education there is an increased emphasis for the student development of professional competencies. This paper looks at the student experience when the development of professional competencies is made to be an explicit learning outcome for students in a project-based learning (PBL) curriculum that is designed purposefully to develop them. This study builds on a previous quantitative study that indicated an increase in performance of the professional competencies by students who experienced the PBL curriculum. This qualitative study is focused on gaining an understanding of the student experience and also identifying which elements of the PBL curriculum affected the student professional competency development experience. Of equal interest, in the qualitative study, is to gain an understanding of the student experience in how they developed their importance for the professional competencies. The quantitative study indicates this was developed prior to upper division. The paper contributes to the literature on engineering education and serves to inform engineering education faculty and decision makers who are intent on transforming their respective engineering education systems through project based learning with the insights into the ways this PBL curriculum influenced the student development of professional competencies.

**Keywords:** project-based learning; professional competencies; reflection; and professional identity; outcome-based

## 1. Introduction

A significant step of the international community for addressing the gap between educational and industry expectations for engineering students commenced in 1989 with the professional organizations and institutions from Australia, Canada, Ireland, New Zealand, United Kingdom, and the U.S. forming what became the Washington Accord. It was later joined by several countries [1]. It sought to establish standards for professional competencies and develop attributes for engineering students graduating from an accredited institution. Specifically, it created a competency focus for engineering education and broadened the focus of engineering education to include preparation for professional practice. Lemaitre, et al. [2] confirm that the preparation "of students for professional competence has always been the ultimate goal of engineering curricula."

Within the U.S. engineering education community, ABET, the non-governmental accrediting body for engineering education in the U.S., introduced in 1996 a new set of engineering accreditation criteria, the ABET Engineering Criteria 2000. Of greatest significance to changing engineering education was the General Criterion 3 student outcomes, also known as the ABET Criteria. This set of outcomes reflected a movement in the U.S. towards a focus on the student development of their professional competencies. Of particular focus for this study is:

- an ability to function on multi-disciplinary teams (3.d);
- an understanding of professional and ethical responsibility (3.f); and
- an ability to communicate effectively (3.g).

Passow [3] identified these three as those found most important by engineers in the work place in a study of the ABET competencies. The same three competencies were also the characteristics identified as the missing skills of engineers as they transitioned from being an engineering student to being an engineer in the professional work environment [4].

Despite this movement and interest by universities and engineering faculty throughout the U.S., engineering education is still not providing graduates with these competencies identified as needed by industry [5]. In *Educating Engineers: Designing for the Future of the Field*, Sheppard's, et al., [6] study of engineering programs at several U.S. institutions, identified that not much had changed in the engineering education system regarding the design of the curriculum to meet the professional competency needs of the engineering profession. Engineering curricula are still heavily biased towards analysis to the detriment of professional skills development as well as other areas of engineering. Most educational experiences are still based on an assumption

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that the development of professional competencies can occur in a set of discrete finite episodes with a beginning and end [7]. This is despite the fact that students and employers, alike, expect a higher degree of synergy between what is learned in classroom and what is needed in the field [3].

It was in this context of the need for a new approach to engineering education that a new project-based learning (PBL) program was developed in the USA, Iron Range Engineering. Iron Range Engineering is an upper-division program that is a collaborative effort between Minnesota State University and a lower-division engineering program at Itasca Community College. Faculty members are dedicated to instructing only within the PBL program. The program has 90 graduates to date and has earned ABET-EAC accreditation.

One unique aspect of this program is its explicit and extensive curricular focus on professional competency development. The proposed learning process for professional development in the new PBL curriculum was specifically developed to address the alignment gap between the desired outcomes for engineering graduates and those attained by graduates of traditional engineering programs [8]. It focuses on the development of professional competencies through the development of the student professional identity.

Cajander, Daniels, and von Konsky [9], in their study of professional competency development in engineering education, identified the lack of a clear definition for professional competencies, which makes it difficult in setting development goals for them that move past the program level into the individual course level, where student learning takes place. A review of the literature regarding definitions of professional competencies yields several descriptions. They are described as more than just a set of knowledge and skills that an individual can acquire; they are the ability to implement this knowledge and these skills in complex systems [9–14]. For this study, professional competency will be defined as the potential that students have to use professional knowledge and skills to perform in the complexity of a real-life engineering situation. The student's self-conception and motives are considered an important foundation for these competencies.

Four core curricular foci were the focus of the IRE curricular approach for the student development of professional competencies, which emphasizes the role of professional identity development. The first curricular focus is the competency outcome-based nature necessary for professional development. This agrees with professional competency focus from the Washington Accord. It also provides a normative standard for students to position themselves. The second curricular focus is providing students with both individual and social dimensions to the development of their professional identity as an engineer. Third, a project-based learning (PBL) curriculum is the key aspect to supporting the first two foci through the learning of professional competencies and development of professional identity embedded in professional practice. The fourth is the role of student reflection in the development of professional identity and professional competencies.

### *1.1 Competency outcome-based education*

Harden, Crosby, and Davis in their study of outcome-based education in the medical profession identified the importance of a "clear and public statement of the learning outcomes" for an education program [15]. They note that outcomes exist in an educational program whether by design or not. They created an analogy between the competency outcomes of an educational model and the plans an architect develops for a building. The plan not only represents what has been proposed and agreed to, it also allows all interested external parties to see if it complies with governmental regulations, how it will impact the environment around it, opportunities for additional negotiation for changes. To internal partners, it communicates what materials are required, allows for planning of methods to construct, and a means with which to compare if the final product meets the original intent. So, a new engineering program needs to be clear as to its intent to develop the professional competencies as the outcome for the students, make these outcomes explicit to the students, and determine if the model delivers that intent. These competencies communicate to external partners and stakeholders what the program is focused on developing. Internally, these competencies guide the curriculum development and guide the learning focus for students.

### *1.2 Professional identity formation*

The process of developing professional competencies is about developing the competencies and ability to be successful in the professional workplace. Development of professional identity is an important factor in the student adaptation to the professional workplace [16] and has been identified for its potential in meeting the needs of the engineering profession [17, 18]. Dehing, Jochems, and Baartman [19] stated that professional identity formation should be the aim of curriculum and that the "curriculum process has to be redesigned, and recent studies suggest that a better connection between theory and practice within the context of the engineering profession and student identification with or the formation of professional identity

are important drivers for change.'' They cite several recent studies that suggest this [6, 20–23].

Professional identity is more than just knowing professional competencies; it is the ability to create a narrative that the individuals continue to construct, use and refine [24] in their educational and professional careers as students to better position themselves in relation to the profession [22]. Their identity is the base from which the students act out professional competencies. Dehing, Jochems, and Baartman, [19] found that the professional identity development process has both a social and individual dimension. These two dimensions directly connect back to Illeris's [25] dimensions of learning. The individual dimension directly connects back to the internal interactions of Illeris's content and incentive dimensions. The social dimension directly connects back to the external interactions of Illeris's social dimension. Eliot and Turns [26] identified that professional identity is developed through a social process where students are connecting expectations with their own needs, wants, and attitude. Wenger [7] identifies the identity development process taking place in the context of learning in a community of practice.

If identity formation is both an individual and social process of students becoming professional engineers, the standard four-stage model of role acquisition can be used to develop a curriculum to create this process acquiring the value for professional competencies [17]. Thornton and Nardi [27] proposed that the identification within a professional role is a developmental process where the student goes from having an idealized perception of the professional role to a more personalized role that aligns with his or her own values and goals. They use the term ''role acquisition'' to describe the process for developing a professional identity through a four-stage process: (1) Anticipatory Stage, (2) Formal Stage, (3) Informal Stage, and (4) Personal Stage. It is the basis for the IRE PBL curriculum for professional competency development.

### *1.3 Project-based learning (PBL) curriculum*

Passow [3] identifies the need for utilizing the ''context of professional practice study of ABET competencies''. Sheppard, et al, [6], Educating Engineers, identifies the need for professional practice or a ''spine'' where students experience ''practice-like'' experiences as a central component to the educational process, thus enabling students to ''move from being passive viewers of engineering action to taking their places as active participants or creators within the field of engineering.'' Through this professional practice students will develop the professional identity of an engineer.

Felder and Brent [28] identify PBL as an instructional model that can be readily adapted to achieving the professional competency development desired in engineering students. Du [29] identifies that PBL goes far beyond just an instructional methodology; it develops an environment for facilitating the student professional identity development. Several other prevalent publications identify the use of PBL as a critical component of transforming engineering education: Beanland and Hadgraft, in their 2013 UNESCO Report: Engineering Education [1]; Sheppard, et al. [6] in Educating Engineering: Designing for the Future of the Field; Felder and Brent [28] in Designing and Teaching Courses to Satisfy the ABET Engineering Criteria; and Litzinger, et al. [30] in Engineering Education and the Development of Expertise. These publications identify the potential of a PBL curriculum in developing the necessary professional competencies and the identities of engineering students.

### *1.4 Reflection*

Schön [31] identifies the importance of reflection in professional practice. It is also an important part of the professional identity development process in the educational setting [26]. Eliot and Turns [26] acknowledge that one could expect that reflection would naturally be a part of the student learning process. Their study found students do not regularly participate in reflection activities unless it is made to be an explicit part of the curriculum. A critical part for the IRE PBL curriculum is making the reflection process explicit and frequent for students. The student ability to reflect in the complicated, ill-structured industry projects is an essential part or the process for them to achieve the intended professional competency outcomes of experiences. Moon's [32] suggestions for integrating reflection into higher education include the use of Professional Development Planning (PDP), Reflective Activities Within the Curricula, Learning Journals, and Work-related Learning with purposeful inclusion of reflection. All four are incorporated into the IRE PBL curriculum.

### *1.5 IRE professional competency cycle*

The incorporation of these curricular elements creates a curricular approach best described as a circular student development cycle. Ibarra [33] and Marcia [34] identified that professional identity development is, by its nature, a cyclical process of exploration and reflection. The proposed professional competency development cycle purposefully incorporates the four stages of the Thornton and Nardi [27] role acquisition model (Anticipatory Stage, Formal Stage, Informal Stage, and Personal Stage) and embeds them in a professional practice

spine of a four-semester design sequence. It is illustrated in Figure 1.

Each semester, students build upon the professional competency knowledge of the previous semester. The IRE professional competency development cycle starts directly with the anticipatory stage for each student at the beginning of every semester. Students develop a professional development plan in which they reflect upon and identify where they are in regards to their understanding of and ability to perform the professional role of an engineer. Through a faculty-guided professional development self-assessment process, each student identifies:

- Their current professional performance and abilities,
- What their professional growth goals are for the semester, and
- What planned activities they will participate in for the coming semester to achieve their professional development goals.

Throughout the semester, in the context of industry projects, students experience the formal and informal stages of their role acquisition. The formal stage is centered on the PBL program's weekly professional development seminars. The first day of the week starts with a session called "seminar" where all students and staff participate in a formal structured seminar on a relevant professional development topic. On Wednesdays, this topic is a structured part of the team's two-hour meeting with their project mentor. In this meeting, a discussion is conducted on the development of the project, but just as importantly the discussion also focuses on the professional development of the individuals in the team as it relates to that week's professional development topic. The week ends with each student reflecting in a journal on their development for the week, including their professional development. The entire week's professional development activities are about formalizing the expectations around a specific professional engineering competency and for the students to practice it in the PBL program.

The program's formal professional development seminar, the weekly reflection structure, and the team structure are all designed to set up the informal stage and guide students towards the intentional professional learning outcomes and avoid the accidental incompetencies. As students look to adapt

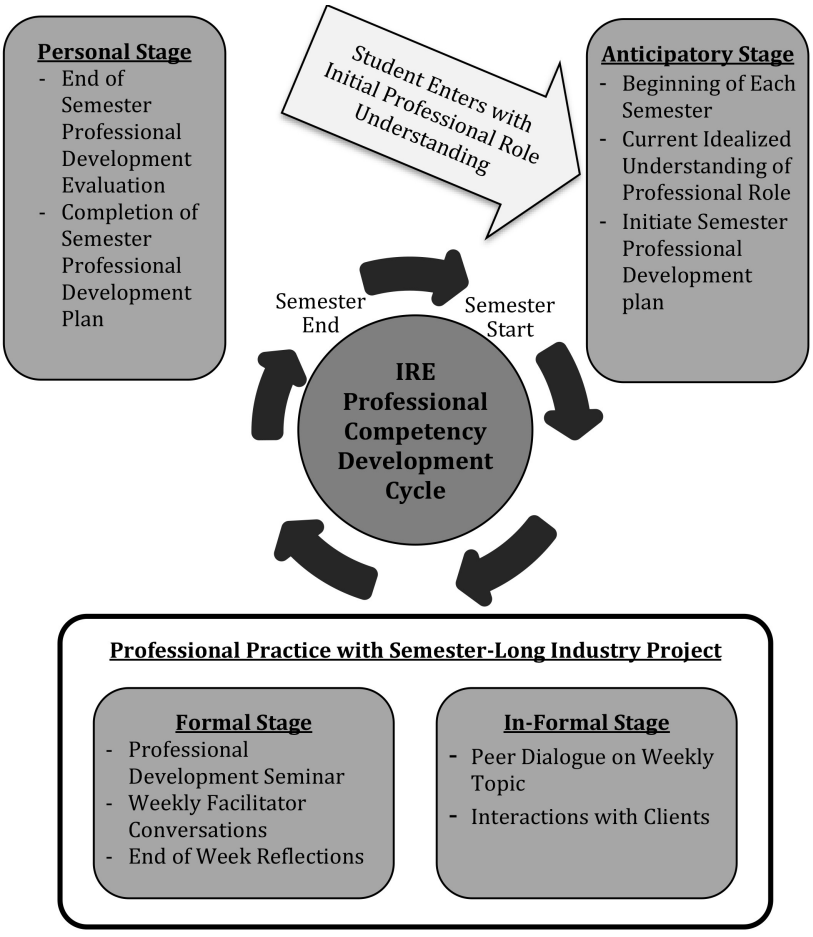


**Fig. 1.** IRE PBL Professional Competency Development Semester Cycle.

the expectations of that week's professional development seminar to fit their own individual perspectives, their peers have all heard the same message around professional competency. This is intended to provide guidance and common language for their informal conversations amongst themselves as peers. The mid-week meeting with their project mentor facilitates them in making this adaptation in a professionally supportive atmosphere. The difficulty of the adaptation is recognized and they are coached through the adaptation process. The end of the week reflection activity provides the opportunity and expectation for students to identify how they will accept that week's professional topic within their own professional identity.

For the informal stage, the vertically integrated teams provide for a professionally supportive collegial atmosphere. Students, at the beginning semesters of the program, benefit from peers on their teams that are further along in their professional development by providing them with a positive peer perspective on the value of the professional competencies. Thornton and Nardi [27] identify these types of interactions as ones on which students place the most value. In addition, the students who are further along in the curriculum benefit from having to guide the younger students. To do this, they must first reflect on their own understanding and experiences with a particular professional competency before they can guide the younger students in their development of that competency. The student interactions with their clients and faculty leaders also give them many venues to practice the use of their professional skills and get formative, non-graded feedback on how to improve.

At the end of the semester, the personal stage is an integrated part of the assessments and grades for each student. The student mentor evaluates her or his performance in all of the professionalism areas through a formal performance evaluation. It is meant to be similar to that which practicing engineers periodically undergo in the professional setting. The results of all of these experiences culminate in a chapter of the student's individualized personal development plan (PDP) for the semester. The PDP chapter starts with a summary of the learning activities during the semester, the level of attainment of the goals from the previous semester, and is then followed by a summary of the feedback the student has gotten during the performance evaluation. These inputs lead to the development of new goals for the next semester. Finally, the students create specific action plans detailing specific steps that can be taken to achieve the new goals. Critical to this process is the recognition that student competency development is facilitated based on reflection upon their development in conjunction with assessment from instructors. Cajander, Daniesl, and von Konsky [9] found this to be an essential part of their 2011 study of student professional development.

Students complete this four-stage cycle, which is repeated in each the four semesters of the upper-division program, with substantial progress toward the desired graduation level professional outcomes being the requirement. At the heart of this process is Cowan's [35] reflection model of "in—before—on—after reflection." The revisiting of the professional development topics with increasing level of sophistication each semester reflects the intent of the spiral configuration of the Networked Components Model proposed by Sheppard, et al. [6]. The cyclical model better reflects what is understood about learning and role acquisition than the more traditional linear "one-time" through from theory to application model. Professional competencies account for three credits of student work each semester. Their grade is solely dependent on the growth in these competency areas. The model is illustrated in Figure 1.

The student experience is further described through the perspectives of the student workweek schedule, progression of the semester, and progression of their four semesters. Atudents are registered for 15 credits per semester. Roughly, this translates to 45 hours of work on task each week. Of the 15 credits, seven are project related and involve design and professional competencies. The other eight are technical in nature. A goal is to have interplay between the technical credits and the nature of work on the industry projects.

From the technical learning perspective, each student spends eight structured hours per week in contact with faculty in "learning conversations" which are designed to use active learning techniques. They then spend an additional 16 hours per week in "non-faculty contact" learning. This time is spent acquiring new knowledge through reading or video viewing; creating conceptual models of understanding; performing "Deep learning activities" such as experiments or designs; and practicing retention activities, as well as doing some traditional problem sets. For design and professionalism, there are seven hours per week of structured contact, which takes place through professional development seminars, design instruction, and guided design reviews. The remaining 14 hours of non-structured time is spent working on the team project and in documenting professional growth through reflective writing.

The semester progression is 16 weeks. The industry project design process starts with an initial scoping meeting between the team and the client.

**Table 1.** Graduate Student Outcomes

| Technical Outcomes | Design Outcomes | Professional Outcomes |
|---|---|---|
| *Technical 1* An ability to apply knowledge of mathematics, science, and engineering. | *Design 1* An ability to design a system, component, or process to meet desired needs within realistic constraints. | *Professional 1* An understanding of professional and ethical responsibility. |
| *Technical 2* An ability to design and conduct experiments, as well as to analyze and interpret data. | *Design 2* An ability to function on multidisciplinary teams. | *Professional 2* An ability to communicate effectively. |
| *Technical 3* An ability to identify, formulate, and solve engineering problems. | *Design 3* An ability to lead, manage people and projects. | *Professional 3* An ability to work successfully in a diverse environment. |
| *Technical 4* A recognition of the need for, and an ability to engage in life-long learning. | *Design 4* An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. | *Professional 4* A knowledge of contemporary issues. |
| *Technical 5* An ability to engage in entrepreneurial activities. | *Design 5* The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. | |

From this meeting, the team creates the design goals, develops a scoping document, and presents a scoping presentation to the client. From the scoping phase, the team progresses through background research, ideation, options generation, testing, evaluation, and validation. Throughout this progression, the team creates thorough documentation in written form, defends their designs before faculty panels at three points in the semester, makes formal presentations to the student body, and informal update presentations to their clients. The semester culminates with a final design review through a final presentation and a major deliverable delivery to the industry client.

The student goes through this semester evolution four times with formative feedback on their personal development. It includes setting incremental goals for improvement, creating action plans for attending those goals, and monitoring their growth through the next semester. The teams are vertically integrated so that senior students mentor the junior students on the same team. The student graduates after four semesters of successful progression and completion of the 14 program outcomes listed in Table 1.

## 2. Research focus

This paper focuses on developing an understanding of how the students experienced the development of professional competencies in the PBL curriculum through the professional competency development cycle. The study focuses on the research question:

> ''In what ways does the Project-Based Learning (PBL) Curriculum Influence the Development of Professional Competencies?''

Answering this question will take place through bringing together the answers for the three research sub-questions:

1. What do students define as professional competencies?
2. What is the growth of the student professional competencies in a PBL curriculum?
3. What are the development experiences for professional competencies in the PBL curriculum?

The goal of this research is to better inform engineering education faculty and decision makers who are intent on transforming their respective engineering education systems through project-based learning with insights into the ways this PBL curriculum influenced the student development of professional competencies. The paper is focused on the qualitative results of a two-part mixed methods study. It was developed based upon the results of the initial quantitative study.

The quantitative study was conducted with a focus on the second sub-research question [36]. As part of the quantitative study, two instruments were developed to evaluate the professional competency growth of students in the PBL model as compared to students studying in a more traditional model. They were based on the internal (individual) interactions and external (team) interactions from Illeris's model [25] for learning. The first instrument focused on the individual professional competencies emphasizing the internal or individual interactions. The second instrument focused on the student professional competencies for external interactions, specifically in the team context. Both instruments were used pre- and post- with two groups. The first is the PBL group, students who experienced the two years of the PBL curriculum for their upper-division engineering education. The second is the non-PBL group, students who experienced a traditional (non-PBL) curriculum for the two years of their upper-division engineering experiences. Both instruments evaluated the students' self-reported growth in their (1) importance for and (2) perfor-

mance in their professional competencies. Growth was measured through a pre- and post-upper-division comparison.

The quantitative results reported growth in performance of the professional competencies by the PBL group, but not for the non-PBL group. This supports that the PBL curriculum and its explicit focus on professional competency development facilitated the student development of professional competencies. Neither group showed growth in their importance of the professional competencies. Scores started and stayed high. The only exception was the non-PBL growth showing a decrease in importance through the individual profession competency instrument.

Although the quantitative data indicated promising results for the PBL curriculum's influence on the student performance of professional competencies, it does not provide insight as to how the students experienced the curriculum and the development of the ability to perform. The qualitative study is focused on gaining an understanding of the student experience and to also identify which elements of the PBL curriculum affected the student professional competency development experience. Of equal interest, in the qualitative study, is to gain an understanding of the student experience in how they developed their importance for the professional competencies, as the quantitative study indicates that this was developed prior to upper division for both groups.

## 3. Research design

A phenomenological study was designed and conducted to develop an understanding of how the students experienced the PBL curriculum. This approach was selected to develop a deeper understanding of the participant experiences through a close examination of each individual's experience to "produce rich thematic descriptions that provide insight into the meaning of the lived experience" [37]. The results will produce a culminating experience as described by participants to depict the basic structure of the professional competency development experience. The study was developed with three aspects to align with the first and third research sub-questions.

The first aspect of the study is to identify how the students defined professional competencies. Understanding this is important in regards to how well the results of the students experience of the curriculum applies to their development of the intended professional competencies for the next two aspects of the study.

The second aspect of the qualitative study is developing an understanding of the collective student experiences as they relate to the self-conception of their importance for professional competencies. Of particular interest to the study is understanding when and where they experienced developing their importance. The third aspect of the qualitative study is to develop an understanding of the student experience to further explain the growth in the performance of professional competencies. It will focus on exploring in depth the last research sub-question through collectively identifying:

- How the students experience the development of professional competencies and
- Which curricular elements of PBL they identify as contributing to the probable growth in performance of professional abilities

The intent of the phenomenological study is to develop the collective student self-experience of the PBL curriculum. As the self-conception is ever changing for each individual and the student experience in the program itself changes, it is important to note that the collective student self-experience developed in this study is for the moment and time they experienced the PBL program.

### *3.1 Instrument development*

Central to creating this thematic description for the structure of the collective student experiences is the collection of data for analyzing the student experience. An interview is the primary phenomenology method for collecting this data [38, 39]. The interview protocol for this research study was developed with an introductory question [40] of "Which professional skills are important for an engineer?" and a planned follow-up probing question, "Why? [are they important]." The follow-up question was added to prompt additional insight [38] into not only what professional skills the student feels are important, but to understand how he or she came to that determination. The question not only served as an icebreaker [41] for getting participants to warm up to the interview process, it also developed a definition of professional competencies by the interviewee [38] for framing the later questions in the interview.

The second question was an experience question [38] focused on understanding the apparent development of the importance for professional competencies prior to the students starting the upper-division program: "When and where did you learn the importance of professional skills for an engineer?" The question was intended to confirm the findings of the quantitative study and to develop the collective student experience in the development of the importance.

An additional two questions were developed as a set of probing [38] secondary questions [40] as a

follow-up to the introductory question to provide students an additional opportunity to identify professional competencies.

- Which professional skills are your strongest? Why? Please give an example of each.
- Which professional skills do you need to keep developing? Why? Please give an example of each.

They approached the definition question from a different perspective and were intended to better prepare interviewees to answer the last two questions for explaining how they experienced their development of the professional competencies by having them further frame their definitions for professional competencies.

The last two questions are experience questions that specifically probe at how the interviewees experienced developing the ability to perform the professional competencies they had identified earlier in the interview. The first question is about identifying general themes for the student experience. The second question specifically focuses on the PBL curriculum experience and if the students identify the curricular elements intended for developing professional competencies. Both questions sought to determine if the development of the professional competencies was described in a way that confirmed the PBL curriculum's intended process of professional identity and competency development:

- Describe how you experienced the development of your ability to perform professional skills.
- Thinking back specifically on your experience in the PBL program, which elements of the PBL curriculum caused growth in your professional performance ability?

### *3.2 Methods*

Since the intent of the qualitative study is to further explain the results of the quantitative study, the participants were a subset of the original quantitative study participants [41]. Interviews were conducted with 18 total interviewees who were recent graduates or near the point of graduation from the PBL program in the spring of 2015. The lead researcher and a graduate student familiar with the project work conducted the interviews. An individual not associated with the study created verbatim transcriptions from audio recordings of the interview.

Analysis of the transcriptions followed the phenomenological process with the initial phenomenological reduction to identify and list the horizons: the key words, phrases, and expressions [38, 39]. The phenomenological reduction process used the node analysis feature of the software package NVivo for analyzing each student interview transcript. 122 nodes or potential units of meaning relevant to the research questions were identified. The frequency varied from being mentioned by one interviewee up to being mentioned by all 18 of the interviewees. These nodes were placed into initial categories of (1) professional competencies, (2) experiences for developing importance for professional competencies, (3) experiences for developing ability to perform competencies, and (4) PBL curricular elements that developed performance ability. These categories reflect the research questions and the interview protocol.

Eliminating overlapping, repetitive, and vague expressions within the categories reduced this to 102 core units of meaning, which formed the invariant constituents of the student experience. They were then "clustered" into central themes. This process included an iterative back-and-forth approach between the interview transcriptions and the non-redundant units of meaning [42]. Each interview transcription was reanalyzed with the central themes as new nodes as a validity check to determine if the essence of each interview was captured with the common themes. Through this second analysis, the central themes for each category were also separated into two groups:

- Common themes: central themes common to all or most of the interviews and
- Unique themes: central themes unique to single or a few interviews [42].

The phenomenological reduction was completed through organizing the themes into a coherent textual description of the experience for each of the four categories. The phenomenology reduction concluded with a synthesis of the thematic description of the essences and structures of the PBL curricular experience lived by the interviewees for each of the categories.

## 4. Presentation of results

Analysis of the data yielded qualitatively different characteristics of the student experience in the development of professional competency within each of the four categories:

(1) professional competencies,
(2) experiences for developing importance for professional competencies,
(3) experiences for developing ability to perform competencies, and
(4) PBL program elements that developed performance ability.

Each of the themes, within the categories, reflects a qualitatively different way of understanding the

student experience in the development of professional competencies. Students were not assigned to a theme, but their individual experiences are extracted to identify the themes.

### *4.1 Professional competencies*

Participants identified 27 different competencies as important to the profession of engineering. All 18 participants identified the professional competency of communication extensively. It was referenced 48 times in general, in verbal form, in written form, or in a presentation mode. In addition to communication, the common themes, mentioned by a majority of students, identified as professional competencies by the students are: Teamwork, Leadership, Professional Language and Behavior, Professional Dress, Interpersonal Skills, and Time Management. Creating a composite textual description for this category includes reflecting back on the professional competencies of focus in this study, these common themes can be placed within one of the three professional competencies for this study. In addition to the common themes, there were 8 unique themes mentioned by multiple interviewees. They are combined with the common themes to form Table 2.

*Synthesis of Professional Competencies*: The professional competency themes for the interviewees established that their composite description of professional competencies aligns with the professional competencies used in developing the study. It creates a reasonable expectation that as participants further discuss professional competencies, they are in a thematic sense referring to the same professional competencies used in the development of the study. Therefore, as the meanings and essences for participant experiences are developed in the remaining three categories, they will be considered applicable to the student professional competencies in a thematic sense.

### *4.2 Experiences for developing importance for professional competencies*

The interviewees identified a variety of experiences for when and where they learned the importance of professional skills for being an engineer. Experiences both in and out of the education setting were identified. The experiences were from all phases of life from early childhood up to, and including, the last semester of the PBL curriculum. The most common theme for the experiences, and thus the common experience identified by all interviewees, was that the experiences occurred prior to the PBL curriculum. This supports the findings from the prior quantitative study.

The most common sub-themes were the educational experiences in their undergraduate curriculum and experiences outside of the educational setting. The undergraduate curriculum theme centered on working in teams and project work in the team setting. Common themes for experiences outside of the educational system include: work, family, sports, observing others, and life-long experiences. The work experience included general jobs unrelated to engineering and jobs related to engineering such as co-ops or internships. A little more than half (ten) of the interviewees mention that the upper-division experience increased their importance for professional competency, but they primarily identified this as a continuation of the development process for importance.

*Synthesis of Developing Importance for Professional Competencies*: The essence for the experience of developing the importance for professional competencies can be characterized as being established over the entire student lifetime and academic career. The importance is primarily established prior to the start of the upper-division program. The importance is developed through experiences both within and outside of the educational process. The identified influence of an upper-division program is in the mode of either confirming or continuing to establish the importance that was already developed prior to starting the program. This affirms what was identified in the quantitative study.

### *4.3 Experiences for developing ability to perform professional competencies*

The descriptors of how the students experienced the PBL curriculum is not focused on the curricular elements, but instead it is focused on identifying the

**Table 2.** Professional Competency Themes

| | **An ability to function on multi-disciplinary teams** | **An understanding of professional and ethical responsibility** | **An ability to communicate effectively** |
|---|---|---|---|
| Common hemes | • Teamwork<br>• Leadership | • Professional Language and Behavior<br>• Dress Professionally<br>• Time Management | • Communication<br>• Interpersonal Skills |
| Unique Themes | • Situational Awareness | • Being Ethical<br>• Inclusiveness<br>• Organization<br>• Respect<br>• Safety | • Situational Awareness |

characteristics of the students' development process experience. Analysis of the interviews revealed four core common characteristics: (1) Reflective Process, (2) Self-Identifying Improvement Plan, (3) Cyclical—Continuous Improvement Process, and (4) Positioning One's Self in Professional Performance Expectations.

#### 4.3.1 Reflective process

Participants described their experience of development as a reflective process. The development of the student ability to perform professional competencies was described as occurring through their self-evaluation of their professional competency performance as they reflected back on an experience in the PBL curriculum. The reflective self-evaluation moments resulted from the completion of a project, a team experience, or from the feedback from a peer or staff member. The act of reflecting was a strong motivating force in their development process, "*reflecting on how you did and how you can improve, you're only going to get better*" [Participant O].

The repeated practice of reflection helped develop an important part of the growth process for the student and the next descriptor of Self-Identifying Improvement Plan, as students start to incorporate reflection into how they operate, as represented in the following quotes:

> "*I tend to just always think of the things that I can improve upon*" [Participant A]

and

> "*your own self-reflection and metacognition, taking the time to sit down and really think about what you're doing, how, how [sic] it has affected you, how effective you were at doing something, and then just deciding, or determining where the gap was or if there was a gap and then what you need to do to improve on that*" [Participant I].

#### 4.3.2 Self-identifying improvement plan

Students described the need to self-identify improvement areas as a way to build off of their reflection process for moving forward and engaging in learning activities that provide development in the professional competencies needing improvement. It is described as both the process of identifying competencies needing improvement and then developing a plan for opportunities for improvement. This is characterized in the following quotes:

> "*You can reflect on it, but if you don't implement what you reflect, it kind of just gets pushed away in the back part of your brain and you might look back someday and be like, hey yeah, I was going to do that*" [Participant Pilot].

> "*taking the time to sit down and really think about what you're doing, how, how it has affected you, how effective you were at doing something, and then just deciding, or determining where the gap was or if there was a gap and then what you need to do to improve on that*" [Participant I].

> "*one other thing I learned at IRE is, is the need to seek out opportunities. A couple of different types of opportunities I found is ones that are handed to you or set out in front of you, and other opportunities that you create yourself and really, with what you do you can generate a lot of your own opportunities for growth*" [Participant I].

Students express that a plan for improvement must be completed more than once for a competency. This repeating of the improvement process is the essence of the next descriptor, a Cyclical–Continuous Improvement Process, as represented by the following quote:

> "*To start out, you start by assessing where you are on a certain criteria and you're given examples of what, of each, you rate yourself, give some of your strengths and weaknesses, and then start developing an action plan to, to improve those weaknesses and then, then from there on after that first semester it's just a reiteration of did you improve on your weaknesses, what do you think might have worked or might have went wrong, um, and then just what can be improved for the next semester, and so on and so forth. Some good really comes out of it. Some of the students hate, myself included, sometimes hate doing the writing of it, but it's, I believe it's a good, um, process and. . .*" [Participant E].

#### 4.3.3 Cyclical—continuous improvement process

The students collectively identified the process of reflecting and identifying an improvement plan as part of a cyclical process of continuous improvement,

> "*Your first semester you get everything thrown at you, you just try and do it best you can, but then next semester you already know every, you already know it so then you're trying to improve on what you didn't do last semester. So now, you keep improving back and forth. Like I've been improving on what I did last semester so if, as long as you continuously improve, that right there is a good process to have*." [Participant N]

As students complete the program, the cyclical–continuous improvement process and the growth becomes more explicit to them as expressed by this student, in regards to leadership in a team:

> "*the first semester was just identifying what my weaknesses, what my weaknesses were within leadership and then the second semester I kind of looked for areas where there were good leaders so between different teams, maybe just see how they, how their team leaders were acting, maybe look or talk to a few people about what a good leader was versus a bad leader. Um, and then last semester is the one when I started taking on a little bit of leadership roles by leading conversations or idea generation sessions, um making myself more outspoken during conversations with teams, with our team I guess. And then, like I said, then the final step was actually take that leadership role and act as the leader overall and work on everything I'd seen through the last three semesters and make a good team leader*" [Participant F].

The Reflective Process, the Self-Identifying Improvement Plan, and the Cyclical–Continuous Improvement Process are the core common themes identified by the majority of participants. They represent what students all identified as part of the experience of developing professional competencies. There are also several other less common themes expressed by the participants. A group of these themes relates to the three common themes as they relate to students positioning themselves in regards to the expectations for professional competencies.

#### *4.3.4 Positioning oneself within professional performance expectations*

Analysis of the interviews revealed this group of themes, which individually do not create a core theme, but their collective presence is synthesized into a fourth common theme of Positioning Oneself within Professional Performance Expectations. They represent the collective experiences that the participants went through to position themselves relative to expectations for performing professional competencies such that they are able to reflect, identify a self-improvement plan, and complete the cyclical-continuous improvement process.

- *Experienced a Cultural of Professional Expectation*—the cultural expectation experienced by the participants causes them to genuinely become aware of their ability to perform professional competencies. It creates a base foundation for students' value in developing their ability to perform the competencies.
- *Comparison Process*—participants positioning themselves relative to others' professional competency through observation of their ability to perform the competencies and through their individual awareness of the overall expectations for professional competency performance.
- *Feedback on their performance*—the experience of feedback provided participants with an external perspective that aided them in positioning (calibrating) themselves.

*Synthesis of Experiences for Developing Ability to Perform Professional Competencies*: Synthesizing the four common themes together forms a thematic description of the participants' experience. As they progressed through the PBL curriculum, they experienced a cyclical process of continuous improvement for their ability to perform professional competencies. In this process, the individual abilities to perform these competencies were positioned relative to expectations of both the program and profession. As participants reflected on their position in their ability to perform, they expressed that growth came from self-identifying an improvement plan to improve their performance and completing the improvement work for the next project cycle of the program.

For some students, this was a gradual, continual process that was part of their experience from the beginning of the program. About half of the students identified that this process had a more abrupt start that began with a significant defining moment, which caused them to realize the need for developing their performance of professional competencies.

### *4.4 PBL program elements that developed performance ability*

This category continues to explore the student experience through identifying which of the elements of the PBL program generated this experience and developed their ability to perform professional competencies. Analysis of the interviews revealed three common characteristics of the student experience in their description of the PBL curricular elements: (1) Industry Projects, (2) Learning Activities, and (3) Program Culture.

#### *4.4.1 Industry projects*

Participants described the work related with the industry project was the most common theme of any influence in developing their ability to perform professional competencies. The aspect of working on a real industry project made the learning of the professional competencies that much more valuable to the participant. Three key sub-themes were identified for the industry project work:

- *Activities to Complete Project*—Participants identified the work associated with the completion of the industry projects as an experience that not only required them to use their professional competencies but also did so in a genuine fashion that made them real to them and their team members. This theme is represented in:

  "*I think the experiences that caused the most growth were actual projects. Um, it's one thing to sit in the workshop and be told you know, this is what good looks like, this is what we do, but then it's another to actually implement that and put it into practice*" [Participant D].

- *Interaction with Project Client*—a key sub-theme for the industry projects was the interaction with project client from the sponsoring industry. The credibility that the client had in regards to the value of being able to perform professional competencies was substantial. In the words of a few participants:

  "*the biggest one for me is the external clients, meeting with them, requires professional communication through email, uh, showing up to meetings, and meeting with them I guess involves professional skills, and then having that standard of these are companies in industry that you*

*might possibly work for in the future or use as a reference, really sets like a high standard for professionalism, which I guess gives you an idea of what's going to be expected when you're actually employed as an engineer so. It's, I'd say that's probably the most important aspect of professionalism at IRE is the external clients*" [Participant O].

- *Working on Teams*—When answering how they developed the ability to perform professional competencies, participants, as a common theme, would use the experience of working as one of the contact for one or more of their responses such as:

  "*makes you engaged, you know, just working with other team, other team members. You grow up, you're growing up in the skills communicating and the same time growing up in skills of working on a team, in a team at the same time um, you have your own weaknesses in the project you know. You're not perfect, but then just the fact that someone else can see um, your struggles and they will try to help you through the struggles, improve your skills of learning so it makes you more engaged and um, at the same time this really translate, the projects really translate to the real world*" [Participant H].

The industry projects serve as the integral part of the student experience.

"*They have you engaged throughout the whole semester, working on the project, working with other people, working with clients, you know it just teaches you a lot of professional (competencies).*" [Participant H]

It was the primary curricular experience identified as a core theme that students attributed to their development of professional competencies.

### *4.4.2 Learning activities*

In addition to the projects, participants listed other elements of the PBL curriculum that they identified as part of their experience in the development of the ability to perform professional competencies. Three key sub-themes emerged in the analysis of the interviews in regards to the program's learning activities:

- *Workshops and Seminars*—a signature experience of the PBL curriculum that students identify is the weekly professional development seminars and the periodic professional development workshops. Students identify that these two learning activities were where they became aware of how they could better perform professional competencies. They identified best practices for them. Other experiences in the curriculum allowed the students to practice the competency and grow in the ability to perform, but the workshops and seminars served as the starting point in this development process. As expressed by a few interview participants:

  "*I guess one of the big things would be, I mean we look at all the professional development seminars we did, you know, how to be a leader, how to, what it means to be a team member, but then also being able to apply that to your personal development*" [Participant D]

and

  "*(seminar) kind of sets the tone for the week. It makes you, you come back from, sometimes maybe a three day weekend and then you just don't really want to be there and then you go through your seminar and it's like, yep, I need to get back into my professional aspect. I was maybe a lazy bum all weekend. I went out partying or whatnot and then you get there Monday and you get your dose of reality again and it was just like, ok, it's time to collect myself and get back on task and think about and evaluate what was talked about so that I can keep moving ahead on through the week*" ]Participant L].

- *Student Presentations*—the role of extensive presenting in the curriculum was identified as curricular element of the program that developed students' professional competencies. Specifically, the repetition of the presentations served as a model for performing, reflecting, identifying improvement opportunities, and then practicing again. The sentiment of the student response, when asked what activities helped them to develop professionally, is summed up by Participant P's response, "*well, the presentations, obviously*!"

  In addition to the presentations themselves, the peer feedback process added value to the experience:

  "*So before I came to (PBL program) I had maybe done one or two presentations before coming there so I was not very outspoken. I didn't really want to do public speaking or anything like that. So the very first semester I kind of was just thrown in it and I didn't know what to do and I got some pretty bad reviews from people of what I did wrong and what I should be doing and I didn't come up with a very good plan of how to attack that right away so I just... The first semester, wrote down what I did bad, you know. I wasn't speaking clearly, I wasn't presenting clearly to clients or to faculty members for that, for that matter so I made a plan of I'm going to make sure I take notes as to what other presentations are doing because we had multiple presentations at (PBL program). So see what good presentations look like between the slides, between what their hand movements are, what their eye gestures are, how they're speaking, how enthusiastic they are. Attended a couple of seminars by (presenters) as to what's good presentation style, what you should do, what you shouldn't do. And then kept formulating that from there and now I've grown each semester as to refining my presenting style and I feel I'm a pretty effective presenter. Um, I have a pretty good pattern of just coming up with a basic slide deck, going through it a few times and then adding a little bit here and there and uh, presenting multiple times before actually presenting to either a client or (PBL program) or anyone like that so I'm pretty comfortable presenting to anyone now. I'm pretty outspoken with that, which I didn't think I'd do that before I came to (PBL program)*" [Participant F].

- *Professional Development Assessment*—students experienced the assessment of professional devel-

opment activity in multiple ways. Some was in the context of other activities like the feedback in the presentations. This feedback was mentioned as one of the core themes in their experiences. Participants identified two forms of professional development assessment as an important part of the curriculum in the feedback experience. One is the professional development plan (PDP) where students self-assess their ability to perform professional competencies and formulate a plan to develop the competencies most in need of growth. The second is the formal feedback from program facilitators on the same topics as the PDP. Example of each are found in appendix C. Participants referenced both of these:

"*by completing the (PDP) you're forced to gauge your performance in each of those areas, your personal view of where you're at, and I mean depending on how you perceive yourself you can see areas for improvement, you can . . . Um, if you have the desire to improve in those areas you tend to take it a little more seriously and develop a plan based on what you perceive of yourself to make it, make yourself better for the next uh, go-around*" [Participant F]

and

"*I do like getting the feedback um, because then it does help you to know where you're going and calibrate yourself in terms of, of that so like yellow sheets are useful. They don't always tell me stuff I didn't know, but um, it's still good and it pushes you to, to work on things you might not want to*" [Participant M].

The learning activities are a critical part of the formal PBL curriculum. Participants identified a wide variety of learning activities that were part of their developing the ability to perform professional competencies. The three common themes of Workshops and Seminars; Student Presentations; and Professional Develop Assessment are the activities that form the common core of the learning activities for the participants.

### *4.4.3 Program culture*

The experience of the projects and learning activities is strengthened by the overall program culture. Participants identified the cultural expectation for professionalism combined with the culture expectation for respectful feedback between students and staff to students resulted in a safe learning environment where they could practice and develop their professional competencies. The practice of professional competencies becomes part of how the students conduct themselves on an ongoing basis. Participant E described the overall cultural expectation for professionalism:

"*there's a few things that um, we do there that are just expected in the professional world of dress and timeliness, and to a sense I think they're good things to practice, but I don't know if dress is something, in my mind, that practice really makes perfect, it's not, anyone can dress, dress appropriately if they want to, but I think it really just sets the tone for a good professional sense in workplace and you're just kind of. . . In a whole, I treat my day like, like a workday, where I show up at, I show up at 7 and I leave usually around 4 or 5 o'clock. So it just puts you in that mind of being in that professional, professional world and treated like a professional and not really talked down to like you're, like you're a child so I think it's just kind of an all-around good, good ecosystem to kind of work and grow in. . ..the expectations are very high . . . just like they would in the workplace, and what you can expect. So I think the model really resembles, at least from what I know of industry of what's to be expected as, as you get there, timeliness and things in that matter that I guess I probably forgot to mention in the earlier part, but they're just so, I feel with the model, they're just so kind of ingrained in me that I often maybe even overlook them so....*"

A common theme for supporting this culture is the feedback to students from their peers, their facilitators, and program staff. Many experiences had the theme of the supportive nature of the feedback. The feedback is accepted due to the genuine belief that the feedback is coming to help and it can be trusted within a safe environment:

"*when you know people it's easier to receive feedback and to get good feedback. Like if you care about somebody and you give them feedback, a lot of times it's more, more useful than if it's. . . a stranger and this is what I think, you know, because you know more about them. You can, you can tailor your feedback to, to be more useful and maybe even say, well when you did this other thing that I saw you do and you were really good at that, try to do more like that. Then you know, but if it's somebody that you weren't that close to or you didn't really know you wouldn't be able to get that kind of connection and communication and those things I think are really useful. It's not just I guess we were saying failure is one of the things that makes you grow, but it also teaches you who has got your back and that can also be very useful in growth to have a system, a support system or people there to help you learn from your failure otherwise. . .*" [Participant M].

It is not only the receiving of feedback, but also the process of students giving feedback to their peers,

"*being asked to give feedback to others. So when, when somebody asks you for feedback and then you're critiquing them, it really thinks about how, how am I doing it, am I good at it or bad at it, am I a valid source of feedback and you start to think, when you're thinking about that, then you start to go back and develop yourself there further so you do feel credible*" [Participant I].

It is evident that there is a core theme for the participants that the program culture with its expectation for professionalism and an expectation for supportive feedback creates a rich environment for students to develop their professional competencies.

*Synthesis of PBL Program Elements that Developed Performance Ability:* The bringing together of

the three common themes of Industry Projects, Learning Activities, and Program Culture synthesizes a thematic description of the PBL program elements that collectively developed the participants' ability to perform professional competencies. As students experienced the PBL program, the industry projects formed the core program element that created genuine student value and appreciation for their ability to perform professional competencies. The "real world" aspect of the work and the interaction with the industry client caused students to generate a value for professional competencies that could not be created in the academic environment alone.

The learning activities created a structure that allowed students to develop in their ability to perform professional competencies. They guided students in identifying and understanding what good professional competency practices are, how to practice them, and then provided a guided process for developing them.

The program culture creates a learning environment that is supportive of the development process of the learning activities in such a way that students are practicing the competencies on a regular basis and not "just when they have to" for the industry projects and client interactions. The PBL Program elements create a continuous experience for the student development of professional competencies.

The overall essence of this experience is captured in:

> "*Having practiced it and then kind of ingrained that in you, that well everybody knows it's the right thing to do, but then how do you effectively execute that and having practiced it, working with professionals as peers, working with professionals as instructors, working with professionals in the real world from the projects, seeing what it's like, what you can expect and that it feels good and you can feel accomplished*" [Participant I].

## 5. Discussion

The qualitative study was designed to explain, develop an understanding, as to how the students experienced the PBL curriculum and how it led to developing their ability to perform professional competencies. Of equal interest is the development of the importance for the professional competencies. The discussion of the qualitative results from the phenomenological study will focus on the three sub-questions: (1) What do students define as professional competencies? (2) What is the growth of the student professional competencies in a PBL curriculum? and (3) What are the development experiences for professional competencies in the PBL curriculum? to answer the primary research question "In what ways does the Project-Based Learning (PBL) Curriculum Influence the Development of Professional Competencies?".

Student participants demonstrated the ability to verbalize professional competencies at a high level. Even though students were left to self-identify the professional competencies in the interview, they collectively verbalized common and unique themes that described the three professional competencies of focus in this study. Not only were students able to describe, or define, these competencies, they also demonstrated the consistent ability to self-evaluate their ability to perform them. They could articulate which were their strongest competencies and why, but they could also articulate the competencies that needed continued development and could articulate why they knew and how they would develop.

Looking back on the PBL model and the professional competency development cycle, the ability to verbalize the professional competencies results from the process of explicitly and repetitively using the language of these professional competencies and making them an explicit learning outcome of the program for students. The development of student understanding for the professional competencies takes place in the reflective process of the semester professional development cycle. An important influence in this process is the industry projects and the interactions with the project clients from industry.

Regarding the second sub-question, the qualitative analysis explains how they experienced the growth in importance for and performance of professional competencies. The synthesis of the participants' experiences in developing importance for professional competencies developed over their lifetime, primarily prior to upper-division. This helps support the high levels of importance for professional competencies for both groups in their pre- scores and no significant growth during their upper-division program. The PBL participants' experiences had the theme that the curriculum reinforced the importance that had been established in prior experiences.

In the growth of performance, qualitative study participants could identify common themes for their development. Overall the growth process was described as a cyclical process of continuous improvement. This is a direct reflection of the cyclical professional competency development cycle in the PBL model.

For the third sub-question, the synthesis of the student experience develops an understanding of how the PBL curriculum develops the professional competencies of students. It is the primary focus of the qualitative study. The common themes identified by the participants as their experience for developing the ability to perform professional competencies are:

- Reflective Process.
- Self-Identifying Improvement Plan.
- Cyclical—Continuous Improvement Process.
- Positioning Oneself in Professional Performance Expectations.
  - Experienced a Cultural of Professional Expectation.
  - Comparison Process.
  - Feedback on their performance.

Connecting this back to the IRE Professional Competency Development Cycle, the reflective process is a part of each stage and of the overall cycle. It is a purposeful part of the cycle that each stage has a reflective process as part of the curriculum. Self-identifying an improvement plan is a process of students identifying their growth areas for professional competencies. It is part of the development cycle in the anticipatory and personal stage. It is purposefully accomplished through the professional development plans, as well as through many informal opportunities.

The cyclical nature of the curriculum was identified in the study as being a cyclical-continuous improvement plan. It is a direct result of the intended PBL curriculum design to provide students with repeated exposure to developing the professional competency outcomes. Throughout these experiences students identified different ways that they experienced positioning themselves relative to professional competency performance expectations. Their developing awareness of the expectations for professional competency performance was supported by the expectations of the PBL curriculum culture. It was developed as they went through a comparison process of positioning themselves relative to the observed performance of other students, faculty, and project clients. What was observed was also reinforced by the feedback they received on their performance through structured activities in the program. Each of these themes is placed on the IRE Professional Competency Development Cycle in Figure 1.

The other category for answering the third sub-questions is the PBL program curricular elements that the participants identified as common themes for developing their professional competency performance ability. Students identified Industry Projects, Learning Activities, and the Program Culture, with their associated sub-themes in Table 3, as the curricular elements that developed the learning experiences they identified for developing their professional competency performance.

These elements connect the student themes back to the IRE Professional development cycle as they form the base structure that the cycle is based upon. The curricular elements not identified directly by the participants are the Role and Value Acquisition and the associated identity development process. However, their experiences can be directly mapped to the cycle that is based on this element. A future improvement in the IRE PBL curriculum is to make this element more visible to students.

A critical reflection on these results includes generalization of the results to project-based learning and the positions of the researchers. As mentioned earlier, the intent of the phenomenological study is to develop the collective student self-experience of the PBL curriculum and as the student self-conception is ever changing, and the program itself changes, the collective student self-experience developed in this study is only for the moment and time they experienced this PBL program. The researchers have an invested interest in the program. This creates strong familiarity for the program and the student experiences, but also introduces potential for bias. To reduce this, the lead researcher, who is not directly involved with instruction and leadership of the program, completed the phenomenological reduction process.

The reflection on both of these sets the stage for additional research work. The first is to have a researcher, who is completely separate from the work, repeat the interview process and phenomenological study with another group of students from the program. The second is to repeat this study with another group of PBL students to develop an understanding of the essence of their professional competency development and compare it to the results of this study. This would help to understand what is unique to this program and what is common to students in a project-based learning curriculum in regards to the development of their professional competencies.

## 6. Conclusions

The sub-question answers build the answer to the overall primary research question, "In what ways does the Project-Based Learning (PBL) Curriculum

**Table 3.** PBL Curricular Elements Identified

| Industry Projects | Learning Activities | Program Culture |
|---|---|---|
| • Activities to Complete Projects | • Workshops and Seminars | • Program Expectations for Professionalism |
| • Interaction with Project Client | • Student Presentations | • Feedback |
| • Working on Teams | • Professional Development Assessment | • Supportive Environment |

Influence the Development of Professional Competencies?'' The ways that the PBL curriculum influences the development of professional competencies begins with developing the students working definitions of the professional competencies. PBL participants are able to verbalize professional competencies at a high level and clearly describe their own professional development process. The PBL curriculum does not develop the importance for professional competencies, but it reinforces it such that students maintain a high level of importance. The comparative non-PBL group showed a decrease in their importance for individual professional competencies.

The PBL curriculum influences the development of performance of professional competencies through creating a cyclical process of exploration and reflection that develops the student professional identity and their ability to assess, thus increasing their performance ability of professional competencies. The curricular elements of team industry projects, professional competency learning activities, and a culture expectation for professionalism support this continuous improvement process over the course of the students' four semesters in the PBL program.

The results for this study demonstrate the ability of a PBL curriculum for developing professional competencies, specifically the ability to perform, when it is made to be an explicit and significant component of the curriculum. The study confirms that a PBL curriculum is a practice of promise for developing student professional competencies. The study identifies three curricular elements, which can transcend all PBL programs, was part of developing these student participants' professional competencies:

1. Projects (industry in this study) completed in a team environment with facilitators and clients that foster and reinforce the development of professional competencies.
2. Program cultural expectations for professional competency practice in all aspects of an engineering program.
3. The importance in embracing the role of defining moments for students in the development of professional competencies. The defining moments are most effective when tied to genuine engineering activities and participant-directed learning activities.

A practice for consideration, from the IRE PBL curriculum, for incorporation in other curriculums is the extensive learning activities that explicitly define the professional expectations for students and facilitates the student development of them. It is important to recognize the value of spending significant student and program time on these activities. Key program learning activities are the professional development plans, weekly professional seminars, extensive student presentation with peer feedback, and the structured team member peer feedback process.

A goal for this research was to inform engineering education faculty and decision makers who are intent on transforming their respective engineering education systems through project-based learning with the insights into the ways this PBL curriculum influenced the student development of professional competencies. Recognizing that many institutions with engineering education are exploring the best ways to develop the professional competencies, the results of this study are aimed at informing numerous decision makers at institutions with engineering education programs. The results of this study indicate that a project-based learning program, with an explicit focus on student achievement of professional competency outcomes, does influence their development of the desired professional competencies.

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