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Engineering Problem Typology-based Reflection and Communication of Undergraduate Engineering Experiences: Professional Engineers' Evaluation of Students' Mock Interview Responses

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Abstract
Student consideration of technical and professional competencies often occur in disconnected contexts, leaving students underprepared for discussing their experiences. Development of technical competencies occurs in the context of the classroom while consideration of professional competencies is only attended to in preparation for career fairs and interviews. In this study, we explored the role of reflection on students' abilities to communicate their engineering experiences in professional terms. Students participated in formative reflection about specific professional competencies scaffolded around engineering problem typology (EPT). We conducted mock interviews (MI) pre-/post-PT based professional competency reflection with undergraduate engineering students. Analysis showed statistically significant improvement in MI evaluation scores. Through qualitative analysis of interview transcripts for the teamwork interview question we identify specific features of student responses that changed from pre to post mock interviews. The findings from this study demonstrate that there is significant value in getting students to consider both technical and professional competencies concurrently as they work through project-based experiences in academic settings. Importantly, this study shows that a little reflection can go a long way in improving student outcomes and supports an argument that professional competency reflection as a regular feature in the engineering curriculum.

1.0 Introduction

The motivation for this work stems from a need to help engineering undergraduates in the recognition and development of professional competencies. An important challenge for undergraduate programs is to provide students with experiences, inside and outside of the classroom, that give insight on what it means to be an engineer in practice. Programs across the country encourage and facilitate such experiential learning through a variety of mechanisms – e.g. student engineering clubs, internships, co-operative education, capstone design – that have been shown to help students in the transition from theory to practice [1]–[6]. However, for such experiences to be meaningful to professional formation, students must also be capable of internalizing and effectively communicating insights from these experiences later.

In the short-term, the ability to internalize and communicate experience and its relevance is important to producing students with the kinds of skills, dispositions, and attributes that are desirable to employers. While professional networks and career fairs can facilitate connections to professional opportunities, communication of professional competency (e.g. during interviews) is vital to successfully landing those opportunities. In the long-term, internalizing and communicating professional experiences is critical to being an effective lifelong learner, which is recognized as an important competency for engineers [7]–[9]. Developing an ability to reflect on day-to-day professional situations and recognize opportunities for self-improvement and adaptation is a first step in pursuing additional professional training (e.g. professional certifications, graduate course work, professional seminars).

Unfortunately, student engagement with technical and professional competencies often occur in disconnected contexts, leaving students underprepared for discussing their experiences.

Development of technical competencies occurs in the context of the classroom while consideration of professional competencies is attended to in preparation for career fairs and interviews. This runs counter to the reality of engineering practice where coordination of multiple competencies, technical and professional, are integral to technical project success [10].

Toward addressing this issue, we explored the role of integrated reflection on students' abilities to communicate their engineering experiences in professional terms. Students participated in formative reflection about specific professional competencies scaffolded around engineering problem typology. These reflection sessions occurred as students worked on a co-curricular group project team. Through a pre/post comparison of mock interview performance, we consider the impact of the reflection activities on students' ability to communicate their experiences through the lens of professional competencies. In this paper, we focus on the teamwork competency.

2.0 Literature Review

This research seeks to understand how engineering students internalize and communicate their relevant technical experience in terms of professional competencies. Specifically, we are interested in understanding how students communicate their experiences through non-pedagogical forms of communication, like mock interviews. Our approach is informed by the literature on engineering practice and professional formation, engineering problem typology, and reflection in support of educational objectives.

Engineering Practice and Professional Formation

Field studies have described the engineering workplace as involving a variety of activities that are not purely technical. Historically, there is an ideological view of engineers as rationally applying technical knowledge, but in reality integration of social and technical competence is necessary for project success [10], [11]. However, the educational experience of many students, with technical and professional competence being considered in disconnected contexts, may not bring this reality to the forefront.

Engineering education reforms of the past two decades, like cornerstone and capstone design, first year experiences, and more problem and project based learning, provide more team based experiences for students than may have been historically encountered [12]. However, without facilitation of explicit connections between technical and professional competencies, students may not develop an appreciation for the integrated nature of these competencies as they occur in the profession. For example, Trevelyan describes the idea of "technical coordination" among engineers as an inherently sociotechnical aspect of the workplace that is critical to technical work being done according to a schedule set outside of any authoritative structure [13]. Similarly, Passow and Passow identified eight "differentiating competencies" from the broader literature including competencies that are more often deemed professional competencies or "soft skills," like communicate effectively and coordinate efforts (i.e. teamwork). While a key finding of their meta-analysis is that "engineering practice requires coordinating multiple competencies to accomplish a goal" they also found that competencies important to practice are not aligned to the learning outcomes that engineering curricula are built around [10].

The lack of alignment between learning outcomes of the curriculum and the competencies necessary for practice are reflected in literature that graduates are underprepared for professional practice. Korte, Sheppard, and Jordan [14] suggested an expansion and emphasis on the professional competencies of critical thinking and communication through the problem solving process in the undergraduate engineering curriculum. Surveys of newly hired engineers found that critical thinking and communication were the most important competencies reflected in the problem solving stages of "organize, define, & understand the problem," and "gather, analyze, & interpret data." They also noted the importance of ill-structured real world problems that are "vastly more complex and organization-dependent," requiring deeper levels of thinking than the well-structured problems encountered in engineering classes.

In a survey of employers, Lang et al [15] also found that communication and critical thinking competencies were critical competencies that need more attention in the undergraduate engineering curricula. Communication, especially in the context of working with teams and others outside of business organizations, was lacking in new engineers, and they emphasized teamwork skills from capstone design projects to hold the most value. Survey results also found that critical thinking, seen in design skills for parts, processes, and systems were of utmost importance for success in the workplace.

Through a survey of Atlanta area construction engineers and managers, the highest emphasis was placed on competencies of "communication, ethics, professionalism, commitment to lifelong learning, and multi-disciplinary team collaboration." In comparing these industry preferences with undergraduate engineering programs, the study concluded that "engineering BS programs are not designed for team-based curriculum, even though team projects are paramount to engineering positions in the real world [16]."

Another study focused on the differences between behaviors/skills of senior engineering students and actual skill requirements that professionals desire in the field. Among the findings is a disconnect of course outcomes and the competencies of interest to professionals. Industry professionals were more interested in graduates that had fundamental skills -- like being willing to ask questions or say "I don't know," or being curious and open-minded to information and ideas -- rather than what the students were demonstrating in terms of technical accomplishment [17].

These disconnects between the professional competencies valued in practice and the educational outcomes attended in the classroom highlight a need to be more intentional in connecting professional and technical competencies during undergraduate education.

Teamwork and Collaboration as a Professional Competency

In this study we focus specifically on students' communication of their experiences as it relates to the competency of teamwork. Teamwork and collaboration is a well-covered topic in the literature inside and outside of engineering [18]–[20]. While teamwork and collaboration is recognized as an important aspect of engineering practice, it is also recognized that explicit training on teamwork is limited in most engineering curricula and requires more attention [21]–[25].

Teamwork has a variety of definitions and dimensions within the literature [10]. For example, Fruchter defines teamwork, in the context of (building) design, as a process - rather than a competency - of reaching a shared understanding of relevant knowledge domains, the object being designed and built, the design process itself, and the commitments it engenders [26]. Hirsch and

McKenna consider a variety of elements as part of teamwork, like conflict management, communication, leadership, and project management [21]. Teamwork is among the ABET learning outcomes for engineering programs and is defined as "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives." In this study, we have adopted professional competency definitions as developed by the National Association of Colleges and Employers (NACE), to align with the campus career services office, which supports engineering students at our institution. We also note that NACE's employer-based research regarding the most important attributes that employers seek from students [27] are well aligned with the research findings of a recent meta-analysis on the most important competencies for engineering undergraduates [10]. NACE defines teamwork as the ability to "build collaborative relationships with colleagues and customers representing diverse cultures, races, ages, genders, religions, lifestyles, and viewpoints. The individual is able to work within a team structure, and can negotiate and manage conflict."

Engineering Problem Typology
Jonassen argued that engineering undergraduates need more exposure to the ill-defined and ill-structured problems typical of the profession [28], [29]. He further argued that problem- and project-based learning (PBL) environments are important for exposing students to the range of problem complexity they will face as professionals, like varied solution strategies, distributed knowledge, multiple problem representations, and multiple conflicting success measures [28], [29]. Working through these types of complexities brings more opportunity for the connection between technical and professional competencies to be explored. Therefore, making explicit the connections between technical and professional competencies during PBL experiences is seen as a significant opportunity in this research. However, an instructional scaffold to facilitate those connections is necessary. In this work we use problem typology to derive a reflective framework for mapping problem type characteristics to underlying technical and professional competencies. Jonassen described 11 types of problems [28]–[30] and noted that the most common problem types encountered by professional engineers are: decision-making, troubleshooting, and design [29]. For example, design problems are often characterized by stages of problem definition, concept design, preliminary design, detailed design, and production design [31]–[33]. Each of these stages drives particular activities which are typically described in their technical context. However, this also provides an opportunity to consider the role of professional competencies in execution of those activities, especially those of a non-technical nature (e.g. communication with a client).

Reflective Practice
Reflection is generally recognized as an important part of practice, especially as described by Schön [34]. It is also a critical tool in educational settings for drawing out important learning and salient features that translate to practice, even while being difficult to assess. Reflection has been used to develop fundamental understanding of student conceptions of engineering and professional formation [35], [36], as well as to improve learning in engineering [37], and other professions like nursing [38]. Reflection frameworks have been established to facilitate career assessment and planning [39], [40] and as practical strategy to finding common perspectives on design [41]. Student reflections on project based experiences have also been used to study engineering students' understanding of specific profession competencies, like teamwork [42].

In this research, the role of reflection is toward helping students see that the project-based nature of engineering work inextricably ties technical competence with the broader range of professional competencies, like teamwork [10]. For most students, the focus on technical competence in engineering education leaves little room to develop a deep appreciation for the role of professional competencies in engineering practice. However, an important engineering education implication that we are investigating here is that the non-technical skills and competencies that are central to project success cannot be encountered separate from technical context where they are used [10]. That is, reflecting on professional competencies after the fact as part of preparing for a job fair or interview will lead students to having under-developed responses about their experiences. Developing strategies and methods to make these competencies explicit *as they are being operationalized* is critical to helping students to appreciate their role in professional practice [43].

The research methodology described in the next section is toward developing and understanding the impact of an instructional intervention that is focused on helping students to consider the role of professional competencies in technical problem solving.

3.0 Methodology

We conducted a mixed methods pre/post study in which student performance on mock interviews, as evaluated by engineering professionals, was the outcome measure. The research question of interest is: *What effect, if any, does professional competency reflection scaffolded around problem typology have on students' ability to synthesize and communicate their experiences?* While the mock interview comprises a total of five questions, we focus on the question related to the professional competency of teamwork in the qualitative analysis of this study.

3.1 Instructional Context

This research is conducted around a co-curricular project experience – Engineering Intramurals. The program brings together students from multiple departments to solve problems sourced from industry, community groups, and academic competitions over the course of a semester. Projects are typically a design problem or some form of case analysis problem. For example, one project had students developing an assistive device for a mobile phone that connects via Bluetooth (design) while another had students investigating the optimal use of road salt on campus (case analysis).

As part of the experience, students attend three reflection sessions. The sessions are a lecture style format, during which students are introduced to engineering problem typology. Students take part in instructor facilitated discussions that frame engineering as solving different types of problems [44], derived from the ideas put forth by Jonassen [29], [30]. At the conclusion of each reflection session, students work on an intermediate reflection form which they submit a few days later; these reflection forms were (approximately) submitted at the conclusion of the 5th, 8th, and 11th weeks of the 15 week project period. The reflection activity is focused on their intramural project. The form includes five pages, each associated with a specific professional competency, as defined by the National Association of Colleges and Employers (NACE) [45]. The competencies include professionalism/work ethic, problem solving/critical thinking, teamwork, communication, and leadership/initiative. These competencies are selected because they are among the most important competencies as reported in the literature [10] and as reflected in an annual survey of employers conducted by NACE [27].

A part of the reflection form is shown in the Appendix for the competency of teamwork. The form is structured around engineering problem typology; in the Appendix example, the problem type of design. The purpose of this structure is to force students to consider examples of the competency "in action" as it occurred with technical activities associated with the specific stage of the process (rows). The reason for this approach is to encourage students to critically evaluate their experience and identify multiple examples of the same professional competencies throughout the experience. In addition, students are guided to further breakdown examples of each competency in terms of the situation/task, actions they took, and results of their actions (columns). This format corresponds to the response format known as the STAR response format, which is the recommended approach for answering behavior based interview questions [46]. The STAR format encourages respondents to provide specific examples of their skills and experiences in a way that leads to more detailed responses to interview questions and better demonstrates their experience and understanding of a professional competency. The STAR format is a commonly referenced approach within university career services offices and on job posting sites, like Indeed. The combination of a problem typology and STAR reflection matrix represents the specific instructional scaffold intended to help students recognize important synergies between technical project activities and professional competencies that drive those activities effectively [10].

3.2 Data Collection

Prior to the pre and post mock interviews, students completed a summative reflection intended to help them recall and synthesize their experience in professionally relevant terms. For the pre, students were asked to consider a previous team-based experience; for example, some students choose their first-year project experience. For most students, the prior experience considered a class project based learning experience, like a design project or a lab experiment and report. A few students described a co-curricular project experience, like a voluntary undergraduate research experience. For the post, all students referenced their intramural experience. Table 1 summarizes the pre and post (intramural) project experiences of each student.

Within five days of completing the summative reflection, students participated in a mock interview conducted by a member of the research team. The mock interview comprised five behavior-based interviews questions taken from an interview preparation book [46]. Questions were selected for 1) project context and role (professionalism/work ethic), 2) critical thinking, 3) teamwork/collaboration, 4) written and verbal communication, and 5) leadership/initiative. A researcher conducted the interviews, which were video recorded.

Interviews were transcribed verbatim. Transcripts for three of the questions – project context, teamwork/collaboration, and written/verbal communication – were reviewed by professional engineers who have experience in the hiring process. The pre/post interview responses for 12 students were evaluated using a web-based survey, with each response evaluated by at least two evaluators. Evaluations were blind; evaluators did not know which students they were evaluating nor whether they were reviewing pre or post responses. However, we kept evaluators assigned to the same students toward consistency in scoring and to support comparison interpretation. The decision to have transcripts evaluated was to ensure that evaluators were focused on the content of the responses rather than other aspects of the respondent (e.g. tone, cadence, appearance) that could potentially bias their evaluation.

Table 1. *Pre and post team-based experiences of student participants*

Student	Pre experience	Post (intramural) experience
Amelia	Concept design of fluorescent sensor to detect opioid levels in blood (course project)	Engineering testing of 3D printed prosthetics
Brody	Design of airduct car cooling system (undergrad research)	Autonomous snowblower design project
Charles	Design of adventure videogame (course project)	Autonomous snowblower design project
Cody	Concept design of automated breathing CPR device (course project)	Design of 3D printed “pre-prosthetic” device
Cora	Physics group experiment (lab course)	Local bridge hit frequency analysis
David	Design and build of a RC boat (course project)	Design of an IOT light switch
Kian	Concept design of biomedical device (course project)	Design of an IOT light switch
Madison	3D printer selection and commission (co-curricular project)	Compliant mechanism pump bottle design
Mike	Matlab computation project (course project)	Design of an IOT light switch
Rich	Design of membrane system (course project)	Road salt use analysis on campus
Sam	Design of biomedical device (course project)	Compliant mechanism pump bottle design
Will	Design of 3D printed car (co-curricular project)	Design of 3D printed “pre-prosthetic” device

We recruited evaluators who had prior experience with interviewing candidates for engineering positions. A total of 25 evaluators participated. They come from a variety of engineering disciplines but all had at least one degree from an engineering field. To quantify the interview experience of potential evaluators, during recruitment, we asked them to specify: 1) the number of interviews with entry-level engineers conducted over the prior five years (14 conducted 1-10 entry level interviews, six conducted 11-20, two 21-30, two more than 30, and one conducted 0 but indicated that they conducted more than 30 prior to retirement in 2013), and 2) their level of experience with behavior-based interviews (14 had conducted behavior based interviews, five were familiar but had not used, three were not familiar with it, and three did not report their experience level).

Evaluation was performed using Qualtrics. Evaluator training comprised two components. First, evaluators joined an orientation session that described the task, reviewed the evaluation system, and allowed evaluators to ask questions. Second, each evaluation survey contained written instructions of the evaluation task, criteria, and process, and a link to a two-minute video that described the evaluation task and criteria, and demonstrated use of the evaluation survey. The evaluation survey was set so that evaluators had to first read the transcript for one of the questions before being able to review and evaluate on a subsequent page. This was done to encourage evaluators to read through the entire transcript before starting the evaluation process.

Table 2 shows the three interview questions and the criteria used for evaluation, which were evaluated on a 1 (very poor) to 5 (very good) Likert scale. Two of the questions are evaluated on criterion of the STAR response format [46]. STAR is a response format for behavior-based interview questions covered in interview preparation texts [46] and taught to students by career services offices. It suggests that interview responses should describe a specific situation/task (ST) during a project, the actions (A) taken to resolve the situation/task, and the results (R) of those actions, whether positive or negative.

3.2 Quantitative Analysis

To test for difference in mock interview evaluation scores from pre to post, the evaluation scores were tested using Kruskal-Wallis one-way ANOVA [47] in Matlab [48]. The null hypothesis for the test is that the pre/post evaluations are from the same distribution. Statistical testing was applied to the overall score (i.e. sum of evaluation scores for all three interview questions), total score for each interview question, and the individual criterion scores for each question.

Table 2. *Mock interview questions and evaluation criteria*

Interview Question	Evaluation Criteria
Q1. Tell me about a project that you recently completed. What were the primary objectives? What was your role? Were you/your team successful in meeting the objectives?	1. Project overview - rate the degree to which the response describes the project and its primary objectives. 2. Student role – rate the degree to which the student's response describes the project and its primary objectives. 3. Project success – rate the degree to which the student describes the level of project success
Q2. How did your team perform throughout the project? Are there any specific positive or negative aspects of your team experience? What role did they play in the project outcome?	1. Situation/Task - rate the degree to which the student's response describes a specific situation and task. 2. Actions - rate the degree to which the student's response describes their action(s) relevant to the situation and task. 3. Results - rate the degree to which the student's response describes the results of their actions.
Q3. Were verbal and written communication important to the project? Why? Any specific examples where you used verbal communication to articulate an important point? Were you successful? Any specific examples where you used written communication to articulate and important point or communicate something important? Were you successful?	

3.2 Qualitative Analysis

Toward understanding the ways in which student mock interview responses may have changed from pre to post, we conducted a qualitative analysis of the interview transcripts using NVivo software. Given the well-structured nature of the interviews, we applied a structural coding approach [49], coding each question independently. In this study, we limit our qualitative analysis to considering the teamwork/collaboration competency (Q2 in Table 2). Qualitative analysis is comprised of two components; analysis of student responses in relation to the NACE definition for teamwork and analysis of responses in terms of their adherence with the STAR response format. Each of these is described in more detail.

Qualitative Analysis of the Teamwork/Collaboration Interview Question

The second mock interview question is intended to elicit a response related to teamwork and collaborative aspects of each students' project experience. We coded responses primarily based upon attributes of the NACE definition of teamwork, which is included in the literature review. Initial codes were developed for mentions of some form of collaborative relationships, team structure, and conflict. When student responses referenced one or more of those constructs explicitly, they were coded for that category. For example, Brody talks about the structure of his team in his post interview: "we initially started the Snowbot team with I think over a dozen members, over 12 people. But then transitioning from the fall semester to the spring semester, we lost about half of our project team."

Table 3. *Codes for student responses about teamwork/collaboration*

Collaborative Relationships		The student mentions something related to building relationships during a project to progress it forward through utilizing skillsets and dividing up tasks
	With colleagues	Relationship building with anyone working congruently to the speaker on the project
	With customers	Relationship building with anyone that has some sort of recipient role to the project
	Negative reference to team mate relationship	The opposite of a collaborative relationship; the student mentions how another team member specifically negatively impacted a project's progress
Conflict		The student mentions an instance or time of contention within their group
	Resolved conflict	The conflict is resolved actively, is managed
	Unresolved conflict	The conflict does not come to a resolution or is left ambiguous
Team Structure		Speaker mentions or implies different roles that group members took, or mentions sub-teams within a single project
Team Communication		Speaker makes general comment about communication as a critical element of teamwork
	Written Communication	Speaker references using emails, texts/chats, or some internal document as a contribution to teamwork
	Oral Communication	Speaker references group meetings or spoken conversations as a contribution to teamwork
	Failed Team Communication/ Miscommunication	Speaker mentions instance where members of the team did not communicate effectively to where it affected progress
	Successful Team Communication	Speaker mentions instances when good communication was positively impacting teamwork for a project
Outcome Success		Speaker talks about succeeding, achieving, accomplishing, etc in relation to overall outcomes of teamwork on their project
	Project Success	Speaker's version of success relates directly to the project, such as getting a desired result, receiving a good grade, etc
	Team Success	Speaker's version of success relates to the team or group, such as team dynamic, gaining relationships, etc.
Reasons for success		Speaker attributes success to the team dynamic (why they were successful)
Teamwork Setbacks		Speaker mentions reasons why their team struggled at a given point, not related to communication

During the coding process, we noticed that some student responses did not obviously fit one of the three categories – collaborative relationship, team structure, conflict – derived from the NACE definition. That is coding of a particular response to one of those categories required additional inference on the part of the coder. To avoid such inference, additional codes were developed to capture other student sentiments and response categories closer to their descriptions. For example, responses often portrayed teamwork in terms of communication, which led to creation of several codes that reflect different elements of communication, like the quality (e.g. failed team communication) and type (e.g. written) of communication. The final codes for teamwork/collaboration are provided in Table 3.

STAR Format
Student interview responses were also coded in terms of the STAR format. Each response was coded independent of the NACE coding described above. The responses were coded to identify specific situations and associated tasks, actions that were taken to complete the tasks, and the results that arose from the actions. There were instances where interviewees would miss one aspect of the STAR format but still express the other aspects. For example, in his pre, Charles explains a problem that arose when one of his teammates used the software repository tool in a way that "broke" their code. The *situation*: "so I had one really strong member in terms of like coding ability, but he was just kinda like, 'I could do it later' cause, you know, he's a little overconfident, you could say... Um, and then there was one, you just kind of went like full on ghost for most of it. So, he kinda did his own stuff and then he's like, like, Oh, this should work. And pushed it into everybody else's branch that we've been working on, but he didn't check to make sure the logics matched up." Charles' *action* was "I figured out how to go to GitHub and get all repositories back... we caught it with enough time to fix it." The *result* was "So we just went back to the old branch."

Qualitative coding began as a group process among the research team until initial codes and definitions were developed for all three interview questions. Then members of the research group independently coded a subset of the student responses. To check for reliability in coding, members of the research team independently coded responses of two of the student participants and resolved any disagreement that stemmed from the coding definitions until inner-rater reliability exceeded 0.7 [50].

4.0 Results
We provide the quantitative results for the 12 students whose pre and post mock interviews were evaluated by industry professionals. As will be shown (Section 4.1), there was an overall improvement in students' mock interview performance from pre to post session as measured by evaluator scores. Toward understanding why evaluations improved from pre to post, we consider the qualitative results for five students (Section 4.2) for the teamwork/collaboration interview question.

4.1 Quantitative Results
A statistical analysis was conducted to test for any difference between the evaluation scores for the pre and the post mock interviews. The analysis consisted of 34 pre mock interview evaluator scores and 29 post mock interview evaluator scores for 12 students. A box plot for the total scores from the three evaluated interview questions is shown in Figure 1.

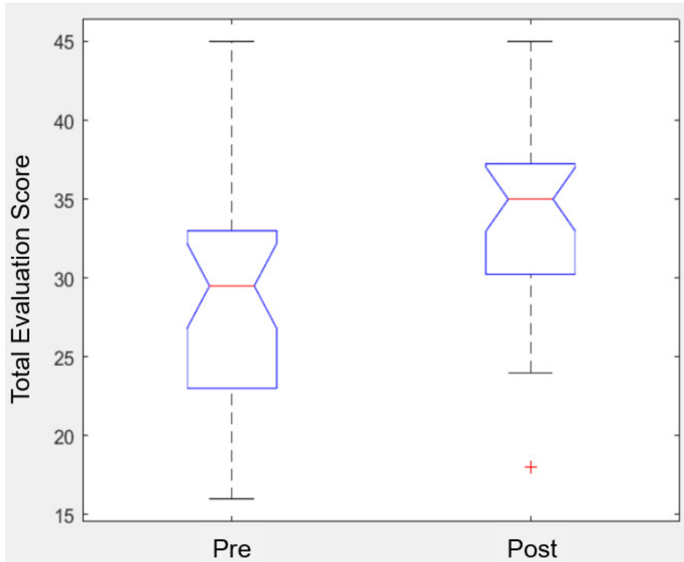

Figure 1. *Box plot of total evaluation scores*

As shown in the box plot, the first, median and third quartile evaluation scores all increased from pre to post interview. This was also the case for each interview question on an individual basis, as shown in Table 6 (only means are reported). The differences in evaluator score from pre to post were statistically significant (p-value < 0.05) for total score, as well as for the overall scores for question 1 (project context), and question 2 (teamwork/collaboration), but not for question 3 (communication). We also note that there were statistically significant differences for specific criterion for question 1 (role and success criteria) and all three of question 2 criteria (situation, actions, results). The evaluation results for each student from pre to post are shown in Table 5 for the Total evaluation score and for Q2 (teamwork/collaboration questions), which is the focus of the qualitative analysis in the next section. We have bolded the names for six students whose Q2 evaluation scores increased by at least three points from pre to post.

Table 4. *Means and significance test results for pre/post mock interview evaluations scores (*indicates statistically significant difference at 0.05 significance level)*

Question	Pre (mean)	Post (mean)	P-Value
Total score	28.97*	34.14	0.0049
Question 1 overall	9.74*	11.31	0.028
Q1: Objective	3.62	4.00	0.1273
Q1: Role	3.24*	3.83	0.0378
Q1: Success	2.88*	3.48	0.0301
Question 2 overall	9.00*	11.69	0.0008
Q2: Situation	3.09*	4.00	0.0013
Q2: Actions	2.97*	3.79	0.012
Q2: Results	2.94*	3.90	0.001
Question 3 overall	10.24	11.14	0.2179
Q3: Situation	3.44	3.79	0.241
Q3: Actions	3.38	3.83	0.065
Q3: Results	3.41	3.52	0.7158

Table 5. *Average scores for students overall and for teamwork/collaboration question*

	Pre		Post			Pre		Post	
	Total	Q2	Total	Q2		Total	Q2	Total	Q2
Amelia	23.67	6.67	28.67	9.33	**Kian**	21	6.5	34	11
Brody	38	12.5	37.5	13	Madison	29.67	8.67	34.67	10.33
Charles	38.5	12.5	38.67	15	**Mike**	34	9.5	38.5	14
Cody	34	10.5	31	9.5	**Rich**	20.75	6.5	33.67	11.67
Cora	21.5	7	39	11	Sam	27	10	24.5	9
David	26.25	7.75	32.33	12.67	**Will**	32	10	38.5	13.5

4.2 Qualitative Results for Teamwork Mock Interview Question

For qualitative analysis, we consider the mock interview responses for the teamwork/collaboration question in this paper. We compared the number of coded elements reflecting teamwork (Table 3) in student responses from pre to post (Figure 2). We saw a mix of results; most students (Amelia, Brody, Cody, Cora, Kian, Madison, Mike, and Will) included more elements of teamwork in their post response while some (Charles, David, Sam, and Rich) had fewer. The students who improved in evaluation scores most – the six with scores that improved by at least three points from pre to post – did not all increase in teamwork elements.

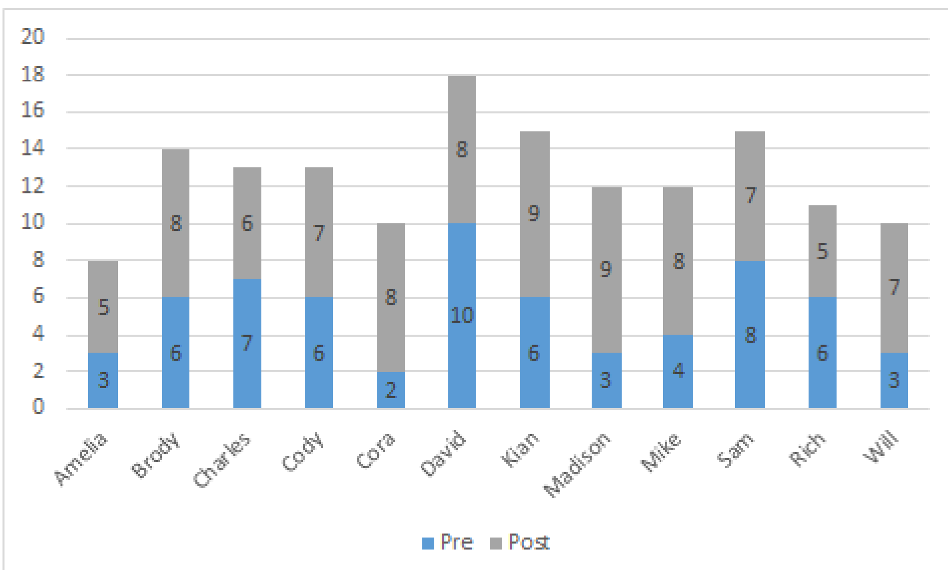

Figure 2. *Frequency of teamwork/collaboration attributes (Table 4) in pre and post by student*

After analyzing the frequency of coded elements for teamwork, we also considered the extent to which student responses matched the STAR response format. The breakdown of student responses that were described in ways that mapped to the STAR response format are shown in Figure 3. For the five of the six students with the largest improvement in evaluation scores (i.e. scores that increased by at least three points from pre to post) – Cora, David, Kian, Mike, and Rich – we found that a change from zero to multiple instances of responses that map to the STAR response format. We found that Charles' responses mapped to the STAR format in both pre and post. Sam's responses included elements of the STAR format for both pre and post but he failed to address results in his responses. That evaluation score increases track with increased use of STAR response format by students gives us confidence that the evaluators were reliable in their application of the evaluation criteria.

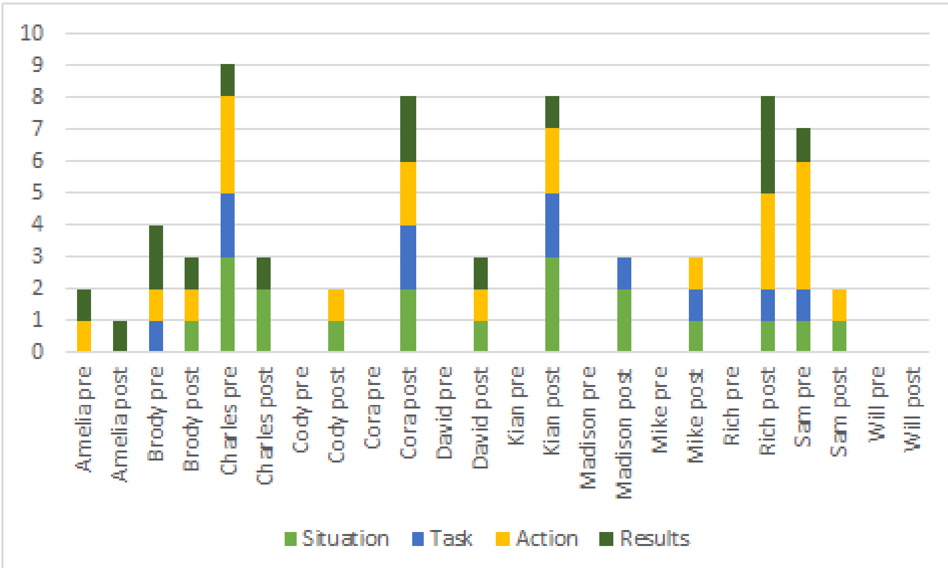

Figure 3. *Instances of STAR format for teamwork by student for pre and post*

5.0 Discussion and Implications

The purpose of this study was to investigate the potential for professional competency reflection scaffolded around problem typology to improve students' ability to synthesize and communicate their experiences in professionally relevant ways. We found that professional competency reflection integrated as part of a project based learning experience improved students mock interview responses as evaluated by engineering professionals. Through qualitative analysis of student responses for the teamwork mock interview question, we found that most student responses increased reference to a variety of elements about teamwork – i.e. students recognized more about the role of teamwork in the project and provided richer responses in the post mock interviews as compared to the pre.

For example, when responding to the teamwork question in the pre mock interview, Kian is non-specific in his response: "*I think we, we work together pretty well. Um, we were all pretty productive. We all did our, all the work that we need to. Um, but sometimes there was a little like, miscommunication on stuff, but like nothing that like stalled our progress or like, um, threw us off, totally.*" However, in the post he provides more specifics regarding actions the team took to be productive, especially as it relates to the evolution of team meetings to delegate tasks and eventually to serve as a group update: "*I think we, we, we were a pretty good team. I mean we, we met every week. We s- we started like the second, second or third week we s- we set the, that Tuesday four to six was going to be our weekly meeting for the whole team. And then, um, and then those meetings in the beginning were much longer because we were trying to figure out what the whole team was going to do. And then they showed that there- they turned into like update meetings where we come in and we would tell, tell what we did or what we need to do or what we need to collaborate with on then. Um, and then with our two other, like our two sub teams, we, um, we would make our, um, meetings, um, like week to week basically.*"

This change in response from Kian is representative of the change we saw in most students from pre to post, especially those with the largest improvement in scores. Student responses in the post provided more detail and evidence as to why they believed that their teams were more productive or effective during project work.

Additionally, we found that overall, students increased their use of the STAR interview response format from pre to post. Use of the STAR response format was important to increased evaluation scores. For example, Kian and Cora had a higher frequency of teamwork references than Rich in the post as compared to pre (Figure 3), but all three students had improved evaluation scores from pre to post. Instead, we see that increased use of the STAR format coincides with increased evaluation scores from pre to post mock interviews. Further, it seems that discussion of the results may be critical as shown by Sam, who failed to describe the results of his actions for the teamwork interview questions in both pre and post. These findings show that use of the structured intermediate reflection form, with the STAR format structure, helps students to synthesize and communicate aspects of their experience, even a few weeks later, and in a new communication mode - verbal instead of written.

Based on these findings, we consider a few implications for pedagogical practice. First, is the importance of helping students to recognize the form and function of professional competencies in technical work. While students participate in a variety of team-based project and problem solving experiences in the classroom, especially with the growth of PBL implementation [12], [51], it is clear that they are not always recognizing specific dimensions and lessons about teamwork. This is evidenced in the pre mock interview responses of students in our study. A primary implication of our findings and the integration of professional competency reflection in PBL experiences is the potential to help students improve their ability to identify specific dimensions and lessons of teamwork/collaboration and their impact on project outcomes. This is particularly important for engineering students based in helping them to appreciate that the coordination of multiple professional and technical competencies is critical to project success [10]. However, it is important that such integrated reflection become a regular feature across the curriculum if we expect to see growth among students. Sporadic integration is not likely to allow students to see the full range of dimensions and lessons and is less likely to "stick" with students when they need to communicate those experiences later, like in job interviews. In addition to helping students in more substantive ways, cross-curriculum integration of professional competency reflection offers a relatively simple way improve the connectivity engineering curricula [52] by regularly highlighting examples of professional competencies for students.

A second implication is tied to the challenges of getting participation from all team members in student project teams [21], [53]. Identifying ways to reduce instances of students' shirking and to improve the accuracy of summative assessment is an ongoing challenge. For instance, Marin-Garcia and Lloret introduced a teacher-driven observation tool and reported overall improvements [53]. Similarly, self and peer assessment tools have been found to improve student engagement and satisfaction [54]–[56]. But these methods still require assessment of student contribution by others (teacher or other students). Further, student participation in team projects is a complex topic that includes motivation. We see the integration of a professional competency focused reflection as an approach that can be part of an assessment toolkit. Such reflection requires students to highlight *their* specific roles within project activities through professional competencies and thus may support an assessment function. Because the focus of the reflection activity is to get students thinking about communicating their experiences in ways that are relevant to their future (e.g. for successful job interviews), this may improve students motivation, particularly as it relates to utility value [57], [58]. There is a need for research that captures more granular data related to student team experiences and to see the impact on student contribution and motivation.

A third implication has to do with the design and facilitation of PBL experiences themselves. In thinking about the types of teamwork elements we want students to experience firsthand, three questions arise: 1) how do we ensure that team-based experiences engender specific dimensions of teamwork/collaboration so that students are likely to encounter them?; 2) how do we ensure that project work is divided in ways that will necessitate relationship building and potential for conflict?; and 3) do students have and spend sufficient time on project tasks for these issues to arise? As Fruchter noted [26], teamwork can be thought of as a process wherein understanding emerges over time as each team member develops an understanding of their own role in the project and provides information and outputs that support the progress of others. The process involves communication, negotiation, and team learning, and like any process, it takes time for understanding and interaction to emerge. Considering how this process might evolve for students should be an important consideration in the design of team-based project experiences.

Related to the design of the experience, a final implication is consideration of formal training on professional competencies, like teamwork, that may be required. As noted in the literature review, there is little evidence that teamwork is explicitly taught in most engineering curricula [21]–[24]. Instead, it is often expected that students will learn about teamwork as an emergent aspect of team-based experiences. Existing training curriculum for teamwork have been developed and investigated with positive gains demonstrated for undergraduates [23], [24]. Based on the study results and with consideration of these implications, the co-curricular program where this study was conducted, we have made program changes to adopt a longer project timeline (moving from one semester to a year-long experience) and integrating specific training on professional competencies as a complement to the reflection practices already implemented.

Conclusion and Study Limitations

The core quantitative findings – i.e. practice improves interview outcomes – supports a recommendation of greater integration of professional competency focused reflection activities as a regular part of engineering projects, inside and outside of the classroom. For students, this has a clear pragmatic benefit in that it better prepares them for discussing their experiences in professional contexts, like interviews. It also raises student awareness of the impact of professional competencies on technical success and provides greater opportunity for discussing those synergies throughout their undergraduate career. This is important because it can help in raising the perceived value of team-based project opportunities that they encounter in class. Opportunities that are, at times, only superficially engaged.

We recognize important limitations of this study. Notably, the quantitative data is limited in terms of the number of student participants and the number of evaluators. Developing a larger and more robust data set, both student participants and evaluators, is an area for future work. Another limitation of this study is the fact that all student participants voluntarily worked on co-curricular projects and participated in the research. Such students may be more invested and engaged, benefitting more from the experience than students in a classroom setting might. Despite these limitations, we feel that there are important implications for engineering education and opportunities for additional research.

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Appendix

Portion of intermediate reflection form for design projects

Design Problem – Intermediate Reflection

3. Communication (Oral/Written)

[Definition: **Articulate thoughts and ideas clearly and effectively in written and oral forms** to persons **inside and outside of the organization.** The individual has public speaking skills; is able to express ideas to others; and can write/edit memos, letters, and complex technical reports clearly and effectively.]

	[SITUATIONS/TASKS] Who are you communicating with in each stage? Why?	**[ACTIONS]** How are you communicating – written, verbal, both? What tools are you using to communicate – email, text, presentations, etc.?	**[RESULT]** Is the communication effective? How do you know? Why or why not?
Understand the Problem			
Define Requirements			
Concept Development			
Preliminary Design			
Detailed Design			

Additional thoughts related to this professional competency: