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Understanding Expert Perceptions of PBL Integration in Introductory Aerospace Engineering Courses: Thematic Analysis of Focus Groups with PBL and Aerospace Engineering Instructors

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Abstract
Problem-based learning (PBL) is gaining momentum in engineering education as a student-centered teaching approach that engages students in problems that mirror realities of practice. While the goal of this pedagogical approach is to more authentically prepare and train students for success in the field, it can be both challenging and frustrating for faculty to effectively implement. In this research paper, the opinions of faculty experts from aerospace engineering and PBL are considered. Data were collected through two structured focus groups to identify areas deemed critical for the transition of an introductory, second-year aerospace engineering course to PBL at an R1 university on the East Coast of the United States. Four different dimensions of PBL integration were considered: design, learning objectives, implementation/facilitation, and assessment. Through a thematic analysis of focus group transcripts, results showed that while the experts identified many areas that were critical to consider during this transition, there are important areas of divergence among the expert groups. In fact, areas of distinct opposition were exposed. This study highlights the importance of considering feedback from both content/technical experts and pedagogical design experts during the development and integration of PBL and lays the groundwork for further exploration of if and how consensus between these two groups can be found to support improved curriculum development.

Introduction
An increasingly strong body of educational research suggests that Problem-Based Learning (PBL) is a highly effective way of training students for success in the workforce [1]-[3]. Specifically, research shows that engineering students benefit from the “real world” elements of PBL teaching methods more than the traditional teaching strategies often found in collegiate engineering programs [1]-[3]. However, while many engineering faculty are experts within their field, they are often not experts in pedagogy and may not have the expertise needed to successfully navigate a transition from traditional teaching practices to PBL [4], [5].

Managing a successful transition to a PBL environment requires an understanding of the role that problem design, problem facilitation, assessment, and learning objectives play in this process. It is critical, then, to elicit feedback from experts within the PBL field to capture the nuances of this teaching style. Eliciting feedback from content area experts is also critical so that the course content is appropriately aligned. In this paper, we describe feedback from engineering faculty (content area experts) and PBL experts that reflect what each group feels should be prioritized during this transition. Specifically, we discuss feedback from a group of aerospace engineering faculty and PBL-in-engineering researchers about critical elements of problem design, facilitation, assessment, and learning objectives for an introductory aerospace engineering course.

A Delphi-study, by nature, attempts to find convergence on a topic (or series of topics) through consecutive rounds of feedback from experts where their ideas are anonymously shared within the group to help reach a consensus. This study highlights the results from two focus groups that became the basis for a Delphi study (whose results will be published separately) and aims to answer the following research question: *What are the critical considerations for transitioning an introductory Aerospace Engineering course to PBL, as defined by PBL application and Aerospace engineering education experts?*

Perspectives from Literature and Theory

Pure PBL is a student-centered teaching method in which students learn by working through realistic problems under the guidance of an instructor [6]. Based on social constructivism, PBL attempts to create a learning environment in which student learning occurs through their interactions with others. Unlike traditional lecture-based teaching methods, PBL requires students to take personal responsibility for the learning process for success [7]. Whereas in traditional teacher-centered teaching methods a teacher acts as the source for knowledge transfer, instructors utilizing PBL act as a guide for students as they work through problems self-directed. Initially developed as a method to authentically train students in the medical field, PBL was developed to introduce technical content through students' exploration of clinical problems. Over time, different aspects of PBL have been reconsidered and refined and its application has expanded outside of the medical field to fields like engineering [6].

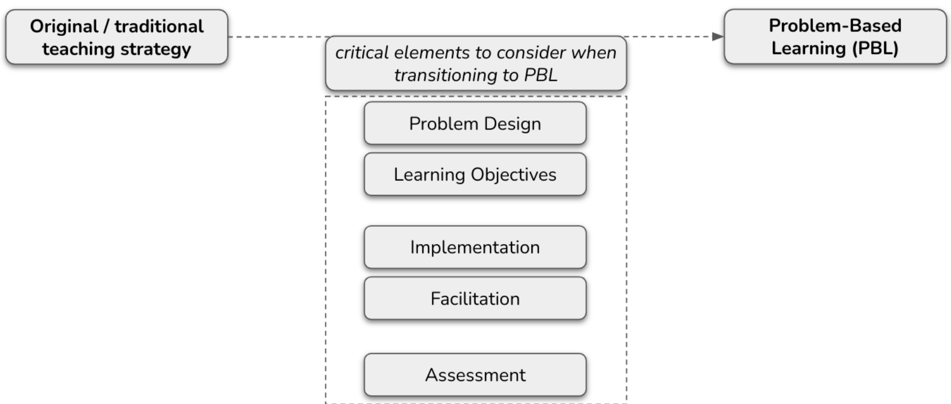
Framework

As previously noted, problem-based learning, in *theory*, challenges students to develop experiential problem-solving skills as they work through curricular content. As idealistic as this approach may seem, it is critical that the curricular approach to this learning strategy be thoroughly considered before a course is transitioned into a PBL model. The Wiley Handbook of Problem-Based Learning [8] identifies several key elements of instructional design that were considered in this study, including: problem design (and learning objectives), facilitation (and implementation), and assessment (Figure 1). These key elements of instructional design will be discussed in detail in the subsequent sections.

Design and Learning Objectives

Research suggests that it is critical to carefully consider the specific objectives and type of problem that best fit each topic when using PBL to execute an engineering curriculum. De Graaf & Kolmos [1] suggest considering a series of questions when determining the objectives for work in PBL, including (but not limited to): where will the problem lead, what goals does it fulfill, and what should students learn? These questions should help the PBL designer identify key student learning outcomes that should be highlighted in both the implementation and assessment of the project. Once objectives have been considered, the type of problem used to meet that objective can be selected. Pasadin [9] identified four types of engineering problems for use with PBL, including (1) simple problems that reflect specific concepts, (2) complex yet structured problems with sufficient information for students to resolve, (3) complete but ill-structured problems with insufficient information given (requiring students to search for information in order to solve the problem), and (4) complex, ill-structured problems that also require analysis to determine a solution. These problems reflect a progression/range of difficulty and complexity levels that students could be asked to solve.

Figure 1. *Critical Areas of Consideration when Transitioning to PBL*



Recognizing that a progression of familiarity, comfort, and expanding knowledge exists and allowing students time to ramp into PBL work and increase their familiarity with the process over time has been recommended by existing studies as a way to counteract the uneasiness some students feel with this often-new style of learning [10], [5]. Additionally, a mixed-methods approach that balances traditional lecture-based coursework with PBL projects has been shown to be a successful way to approach PBL in an engineering curriculum [10], [11] as it addresses this uneasiness on both the part of the student and teacher [5]. Perrenet et al. [11] noted the value of this gradual phase-in for PBL in engineering specifically, noting "In engineering some topics are characterized by an hierarchic knowledge structure and complex problem-solving. These topics cannot be approached without risk in a PBL-setting. Therefore, separate direct instruction and supervised practice are needed: direct instruction of outlines, demonstration of expert problem solving, teacher-guided discussions, and problem-solving tutorials with specially structured group work" (p. 9).

Implementation and Facilitation

While the potential benefits of PBL are hard to refute [1] - [3], successful execution of experiences that can feel very open-ended and ill-structured can be a struggle for both faculty and students [4], [5]. An example of this struggle for students was raised in the work of Nepal [12] who compared the experiences of engineering students in both a PBL and traditionally (lecture/tutorial) taught course. He found that despite the fact that students performed better and even believed that they learned better in the PBL version of the course, they ultimately gave worse feedback about the PBL course than the traditionally taught version. One possible explanation for this result is that “unfamiliarity and a lack of prior experience with PBL delivery where the requirements, processes, and outcomes are not fixed may be feared by some engineering students who prefer structured approaches to achieving solutions” [12]. This same lack of familiarity and ill-structuredness has been shown to be responsible for resistance on the engineering faculty side as well [5]. Therefore, it is important to incorporate the ideology of those with PBL experience when developing a new PBL curriculum in engineering.

While the previously discussed phase-in or mixed methods approach can be utilized to address the lack of familiarity students and faculty may feel with PBL work , the ill-structuredness is not addressed within these strategies. To address this ill-structuredness, Schmidt’s 7-step process (Table 1) can be utilized as a baseline from which to build and standardize PBL implementation. Though this framework was developed in the 1970s for the medical field, it has been applied and analyzed in engineering coursework as well [7].

Research has shown that engineering students often struggle in the middle of this 7-step progression (during steps 3 and 4) and that they do not sufficiently analyze and/or inventory the problem [7], [13]. While strategies to counteract this insufficiency and help students improve their work in this area (such as utilizing concept maps) have been explored [7], more work needs to be done to improve the implementation of these steps for engineering students. One suggestion for improving PBL implementation noted by multiple studies is to have instructors/facilitators specifically trained in PBL [3], [11].

Table 1 *Schmidt’s 7-step process for PBL implementation [2]*

Step 1	Clarify terms and concepts not readily comprehensible
Step 2	Define the problem
Step 3	Analyze the problem (and brainstorm solutions)
Step 4	Draw a systematic inventory of the explanations inferred from Step 3
Step 5	Formulate learning objectives (i.e., solutions to Step 4)
Step 6	Collect additional information outside of the group (independently)
Step 7	Synthesize and test newly acquired information

Assessment

Assessing ill-structured student problems or projects has been a notorious problem for engineering faculty and is even more challenging when implementing PBL in engineering courses [14]. Because of the inherent goals and learning objectives of PBL (i.e., creating professionally situated, student-directed independent and group work aimed at solving ill-structured problems that can sometimes have distinctly different outcomes), paper-and-pencil style unit tests generally do not accurately capture student performance [14]. In other words, the problem-solving and professional skills students use during PBL are not captured with a traditional testing approach. Identifying what should be assessed and understanding what strategies have been successfully utilized to assess students in those areas is critical to developing a PBL curriculum. Since PBL is meant to help engineering students grow in both technical competencies and professional skills (including teamwork, communication, and problem-solving skills) [3], it is important that a PBL curriculum assesses students in all of these areas and is not limited to only one subset of these skills.

Non-traditional methods of assessment, such as compiling portfolios or completing self, peer, and/or instructor-based student assessments have been shown to have some promise for improving assessments in PBL by capturing both the technical and problem-solving/professional elements [15], [16]. One example of this alternative assessment method is to numerically evaluate student performance in the following 5 areas [16]: 1) contribution to the analysis of the problem and to the statement of the learning goals; 2) keeping one's agreement to the group/team; 3) contribution to the discussion concerning the collected data; 4) fulfilling a leadership role in a group session; and 5) contribution to the promotion of the group process.

While these considerations have value as a solid starting point for future work, there are some concern areas for broad application. For example, this assessment approach has been shown to yield higher scores for those who speak the most in the group [16].
Research focused in the engineering field offers further analysis of assessment during PBL. As discussed previously, professional skills (including the impact of group dynamics) have been shown to be a struggle to assess due to the many variations groups can have [17]. Regarding technical skills, a study by Mitchell and Delaney [18] showed that students did feel they effectively learned technical content through PBL coursework, but also showed that student perception of their learning was lower than that of their facilitators. This could suggest that there is a mismatch between what students perceive the objectives to be and what facilitators intend for students to learn. DeGraaf & Kolmos [1] echo this concept in their work, suggesting the importance of ensuring that the assessment methods are specifically aligned to the objectives of the PBL projects (i.e. assessing an individual's technical competence as opposed to testing for isolated technical knowledge). Waters and McCracken did suggest that intertwining independent reflective activities for students at each phase of project completion has promise for more authentically assessing PBL in engineering [17]. It is important to note that while design, implementation, and assessment have been discussed separately in this literature review, a successful PBL curriculum will ensure that these parts all align with one another.

A widely accepted benchmark for quality assessment for PBL in engineering has yet to be developed, despite several attempts discussed in the literature [17], [18]. Moreover, research focused specifically on applying PBL in an aerospace context is very limited. It is therefore critical to understand the feedback from both aerospace and PBL experts to identify critical components of assessment before attempting to transition to a PBL course structure.

Methodology

This multi-case study considers two distinct systems: (1) PBL in engineering experts and (2) aerospace engineering faculty experts. Consistent with the definition of case study research, multiple data sources were used (through two distinct focus groups and three rounds of continued data collection via Delphi survey responses) to deeply understand the ideology of each system [19]. This paper examines the results of the first phase of data collection: the focus groups. The first focus group, PBL in engineering experts, consisted of researchers who had published multiple papers on PBL in engineering. The second focus group consisted of practicing aerospace engineering faculty. Because there is extremely limited research on the use of PBL in aerospace engineering and because many aerospace engineering faculty do not have significant experience implementing PBL, both groups were critical in order to capture the expert know-how from both groups. IRB approval was exempted for the expert testimony in this study because the research gathers the opinions of the experts as a way to shape the research and is not about the experts themselves.

Participant Selection

PBL in engineering experts. A Google scholar search of "PBL" and "engineering" was initially utilized to compile a list of potential experts. Authors of these papers were then searched independently to explore their body of work. Experts with multiple papers about both PBL and engineering (n = 12) were contacted by email and asked (1) to participate in the study, and (2) to recommend any other experts they think would add value to the study. Of the initial list of twelve, four did not respond and three declined, though two of these experts did offer referrals for other participants. The remaining six participants agreed to participate, with several offering additional referrals. Two additional experts were secured through the recommendation process. Information regarding these experts is summarized in Table 2.

Table 2 *PBL in Engineering Expert Panelists*

	Institution Type/Location	Experience
Expert #1 (he/him)	Research Institution/Southeastern US	Retired research scientist and PBL researcher
Expert #2 (he/him)	Research Institution/UK	Professor of communications systems engineering and PBL researcher
Expert #3 (she/her)	Research Institution/Southeastern US	Director of learning sciences research in the college of engineering, PBL researcher
Expert #4 (she/her)	Research Institution/Denmark	Professor of engineering education and PBL researcher
Expert #5 (he/him)	Research Institution/Southeastern US	Engineering department chair, PBL researcher
Expert #6 (he/him)	Research Institution/Denmark	Teaching faculty and PBL researcher
Expert #7 (he/him)	Research Institution/Australia	Teaching faculty and PBL researcher

The eight experts who agreed to participate in the study were polled to find a convenient date and time for a synchronous initial focus group, which was challenging due to the experts being located across the world. Based on the results of that poll, the focus group was held in April 2022 and seven expert participants were able to attend and participate.

Aerospace engineering faculty experts. The planned transition to a PBL environment being implemented by the authors occurred within an introductory aerospace engineering course. Instructors of a similar class at ABET-accredited universities were identified from class offerings listed online. Aerospace faculty within the authors' networks who had demonstrated interest in pedagogical practice in aerospace engineering were also identified. Like the PBL experts, these faculty were contacted by email and asked (1) to participate in the study, and (2) to recommend any other faculty they think would add value to the study. Seven experts agreed to participate in the study, and after a date was set, two participants were unable to attend. Information regarding these experts is summarized in Table 3. The focus group was held in May 2022.

Table 3 *Aerospace Engineering Faculty Expert Panelists*

	Institution/Location	Experience
Expert #1 (he/him)	Research Institution/North Midwest US	Retired aerospace engineering teaching faculty
Expert #2 (he/him)	Research Institution/Southwestern US	Aerospace engineering faculty, industry experience
Expert #3 (she/her)	Research Institution/Southeastern US	Aerospace engineering faculty
Expert #4 (he/him)	Research Institution/Southeastern US	Retired teaching faculty
Expert #5 (he/him)	Undergraduate Institution/Northeastern US	Teaching faculty, consultant

Positionality of the research team

The research team that performed this study consists of four members, as described in Table 4 below. Their shared experiences as STEM educators and unique experiences as researchers create a rich foundation through which to collect and interpret the data.

Table 4 *Research team participants*

	Current Titles / Roles
Team member #1 (he/him)	Engineering Education Faculty (University)
Team member #2 (he/him)	Aerospace Engineering Education Faculty (University)
Team member #3 (she/her)	Engineering Education Faculty (High School); PhD candidate in curriculum, instruction, and the science of learning
Team member #4 (she/her)	Educational Programs Representative (National Lab); PhD candidate in curriculum, instruction, and the science of learning

Data Collection and Analysis

Data for this study was collected through two different 1-hour focus groups. One focus group contained only the aerospace engineering faculty experts and the other contained the PBL in engineering experts. Both focus groups were conducted by the same moderator (team member

#1) and the associated script for each focus group is included in Appendix A. These scripts, developed collaboratively by the research team, were designed with the goal of facilitating a dialogue among the experts that would yield insights into their perspectives on problem design, facilitation, assessment, and learning outcomes. Focus groups were conducted over Zoom and both video recordings (.mp4) and transcripts (.vtt) were collected from these Zoom meetings. The transcripts were compared against the video files and edited to ensure accuracy. These edited/corrected transcripts were retained as the final data for this study.

The corrected transcripts from each focus group were reviewed and deductively coded to understand the content and key ideas expressed by the experts. The transcript was structurally coded to help code and categorize the transcripts [20] using the key areas for PBL implementation defined in this study: design, facilitation, and assessment. Finally, thematic analysis was used to classify the codes into noteworthy themes [19]. The results of this analysis are presented in the next section.

Findings

The following tables outline the ideas (paraphrased) that were extracted from the transcripts of both focus groups. They have been split into four categories: design, learning objectives, facilitation, and assessment and have been categorized by the focus group that identified each topic. (Design and learning objectives were split into two different categories in the findings with design reflecting *how* to design PBL activities and learning objectives discussing *what* should be studied.) Since the discussion in the focus group generally shifted to each topic as it was proposed, the frequency of how many times each idea was suggested/proposed was not used as a metric in identifying prominent themes, and only the ideas themselves were recorded as data.

Table 5 shows the ideas related to how PBL problems should be designed. PBL experts had almost four times the number of ideas about how to design problems as the aerospace faculty experts, which clearly speaks to the value of getting feedback from learning strategy experts in addition to only content-area experts when making curricular changes. PBL experts recommended design-based criteria such as authenticity and choice and commented on using a series of problems to help students solve a larger problem.

Table 5 *Design-specific focus group initial themes*

		Aerospace Expert	***PBL Expert***
1	Problems should be authentic to the practice of engineering.		**X**
2	Students should select/design their own problems.		**X**
3	Problems should be designed with a clear understanding of the learning objectives and how the project/problem will meet those objectives.		**X**
4	Problems should be purposefully designed to be engineering-based (with constraints, etc.) as opposed to a research-based problem.		**X**

5	Smaller, sequential problems embedded within the context of one larger problem should be employed as a way to fully immerse students in a given problem scenario.		**X**
6	Projects should be designed such that they are interdependent on the other teams' projects (ex. each team is responsible for one component of the layout of a city block.)		**X**
7	Projects should be designed such that they help students develop innovative skills, collaborative skills, and an understanding of society.		**X**
8	Problems should have a wow factor or something that students can get excited about in order to engage them and keep them motivated.	**X**	
9	Problems should be designed such that students feel their projects have a purpose for the greater good.	**X**	

Table 6 lists the specific learning objectives that should be covered in the proposed 1-credit, introductory aerospace engineering course in question. Questions/discussions about specific learning objectives were only asked of the aerospace engineering faculty experts, however PBL experts also identified general criteria for learning objectives through their discussions.

Table 6 *Learning objective-specific focus group initial themes*

		Aerospace Expert	***PBL Expert***
1	Learning objectives should be less driven by technical skills and more driven by the cognitive strategies and soft skills of practicing aerospace engineers.		**X**
2	A key learning objective for students in an intro to aero course should be the ability to critically think to solve problems.	**X**	
3	A key learning objective for students in an intro to aero course should be to become a self-directed learner.	**X**	
4	A key learning objective for students in an intro to aero course should be to apply analytic methods.	**X**	
5	A key learning objective for students in an intro to aero course should be to apply abstract knowledge to real situations/problems.	**X**	
6	A key learning objective for students in an intro to aero course should be to understand fundamental concepts of aerospace engineering.	**X**	
7	A key learning objective for students in an intro to aero course should be to understand and comply with related regulations.	**X**	
8	A key learning objective for students in an intro to aero course should be to effectively use quantitative information to inform decision making.	**X**	
9	A key learning objective for students in an intro to aero course should be to understand how different elements interact and influence each other.	**X**	

Of note is the fact that even though these answers were obtained primarily from the aerospace engineering faculty experts, most of the learning objectives identified point less to technical aerospace-specific content and more to problem-solving and general "how to effectively approach engineering problems" objectives. This suggests that - despite being perhaps underprepared for how to design and facilitate PBL, these faculty experts still understand and agree with the overall value this learning style offers. This also directly correlated with the commentary on learning objectives from the PBL researchers.

Table 7 *Facilitation-specific focus group initial themes*

		Aerospace Expert	***PBL Expert***
1	Failure should be both valued and accepted.		**X**
2	Students should be immersed in PBL immediately upon entry into the class, and this teaching strategy should continue throughout.		**X**
3	Facilitators should ask students probing questions in an effort to help them progress in their understanding of the project and related content.		**X**
4	Facilitators should introduce chaos into problems where/when they feel it can be managed.		**X**
5	Assign facilitators with different roles (such as “Teacher” and “Client”)		**X**
6	Manage student progress by including milestones that help ensure students are “on track” before moving on to the next phase of the project.		**X**
7	Ensure students have the background skills (fabrication, etc.) needed to complete the project		**X**
8	Students should be treated as junior colleagues (as opposed to the traditional teacher-student relationship) to help build a mindset that more closely reflects a practicing engineer.		**X**
9	A variety of different team sizes, groupings, and problem types should be utilized to reflect authentic engineering practice.		**X**
10	Instructors should not have preconceived ideas about “correct” solutions to problems that are posed.		**X**
11	Facilitators should build a culture where the process is more important than outcomes.		**X**
12	Lecturing should not be included in a PBL curriculum.		**X**
13	Students should be challenged to dig deeper than giving surface-level answers by practicing true problem-solving.		**X**
14	PBL environments should be operated similarly to how one would run a lab, where you have conversations and authentic conversations with student teams that are based on textbooks or lecture content but not delivered in the traditional lecture format.		**X**
15	Faculty must be enthusiastic about the content area for success.	**X**	
16	Facilitators need to understand the mindset and level of a young undergraduate (as opposed to speaking at a high-level researcher or industry professional level)	**X**	
17	Utilizing upperclassmen as teaching assistants can improve facilitation and offer growth opportunities for the upperclassmen as well.	**X**	
18	Class time should be spent in two-way discussion as opposed to in one-way communication from the instructor.	**X**	

With regard to implementation and facilitation, Table 7 shows the results of the focus groups discussions and data analysis. Not surprisingly, like in the discussion of design criteria, PBL experts had more suggestions for how to successfully facilitate PBL than the content-area experts. Again, in this section however, the ideas presented by PBL experts were more idealistic than the ideas proposed by the aerospace faculty. The comments from the aerospace faculty again were more rooted in logistically simple ideas, such as reducing facilitator workload and improving the experience for students in a PBL class by utilizing upperclassmen in supporting facilitator roles.

Finally, Table 8 lists the ideas expressed during the focus groups regarding assessment. In this category, however, we start to see conflicting ideas being presented. For example, while PBL experts suggest that "assessment should encourage skill-building" as opposed to "mastery and outcomes," the aerospace discussion suggested that "grades should be a conglomerate of homework, projects, classwork, and exams." Here we see perhaps the largest disconnect between the two groups.

Table 8 *Assessment-specific focus group initial themes*

		Aerospace Expert	***PBL Expert***
1	Failure is an important part of the learning process and that should be reflected in the assessment strategy.		**X**
2	Ensure that assessments match the learning outcomes (ex. Consider whether or not you are trying to offer exposure or mastery and assess accordingly.)		**X**
3	Behaviors should be rewarded above successes (failures should not be negatively assessed).		**X**
4	A portion of students' assessments should be a reflection of what went wrong and how students overcame that through engineering.		**X**
5	Assessment should encourage skill-building, not mastery and outcomes.		**X**
6	Assessments should be as authentic as the problems/projects and should reflect outcomes that practicing engineers would be tasked with. (Avoid the urge to over-assess with inauthentic tasks.)		**X**
7	Peer assessment should be included as part of the assessment strategy.	**X**	**X**
8	A balance between individual and group assessment should be used to ensure there is individual drive in each project.		**X**
9	Care should be taken to ensure assessments are equitable.		**X**
10	Tests are not an authentic assessment for engineers and should not be utilized in a PBL curriculum.		**X**
11	Grades should be a conglomerate of homework, projects, classwork, and exams.	**X**	
12	Exams should be graded for understanding, as opposed to simply looking for a correct answer.	**X**	
13	Assessing students' ability to follow directions is a valuable way to highlight the importance of following regulations in the aerospace engineering field.	**X**	

While some divergent opinions were expressed between groups, this is also the only area where there is any commonality between the two groups found. Both PBL and aerospace experts expressed that it is important to include a peer component in assessments, a belief which has been expressed by other researchers as well [15], [16].

Discussion and Conclusion

In this final section, the findings related to problem design, learning objectives, facilitation, and assessment will be discussed relative to the related literature. The themes that emerged from these findings are shared before concluding with the implications and importance of this study.

Discussion

In terms of problem design, the findings parallel existing research in areas such as using a progressively more challenging problem approach in problem design [9]. As noted in the findings, PBL experts generally have more idealistic ideas for design (such as making projects interdependent, etc.), and the aerospace faculty's design suggestions were more rooted in suggestions that would engage students in a less logistically complex way. Finding ways to keep faculty from becoming overwhelmed by PBL instruction is an important factor for a successful curriculum design [5], and the disconnect between the suggestions of these two groups (shown in Table 3) reflects that ideology.

Related to facilitation, research indicates that a mixed-methods approach that balances "traditional instruction" with PBL projects has been shown to be a successful way to approach PBL in an engineering curriculum [10], [11]. However, the findings of this study show that PBL experts recommended full immersion into PBL and specifically state that lecturing should not be used. As noted previously, finding ways to facilitate students' progress through ill-structured problems can be challenging for engineering faculty and some comments related to how to manage this were shown in the findings. For example, "facilitators should ask probing questions" and "introduce chaos when they feel it can be managed." However, most of the feedback for facilitation was general and not specifically aimed at helping to identify an overall strategy for how to facilitate students as they work through each problem. Whereas Schmidt's 7-step process for PBL implementation offered a specific roadmap for how to work through ill-structured problems [2], the ideas related to facilitation that were expressed in these focus groups spoke less to process and more to general facilitation concepts.

Finally, related to assessment, research suggested that exams do not accurately measure student performance in PBL [14]. The aerospace faculty seem somewhat tied to these assessment strategies. This is likely because - as noted in the literature review - a widely agreed-upon and effective tool for assessing student performance for ill-structured problems in engineering has not been developed. This finding only highlights the continued need to develop a tool that fills this gap.

Emergent Themes

Two main themes emerged from the thematic analysis of the transcript data.

Theme #1. Faculty suggestions were predominantly logistically grounded, whereas researcher suggestions were more idealistically grounded. Aerospace engineering faculty experts' discussion was often very logistically grounded, as if they were imagining how they could actually implement this learning style into their courses. The feedback from the PBL researchers was, at times, more idealistic. This speaks to the need to find a balance or consensus between the two groups that highlights criteria both groups can agree on.

Theme #2: There is very little overlap between the curriculum design recommendations from the aerospace faculty and PBL researchers. The two different groups of experts identified almost exclusively unique ideas about what is important to consider when transitioning from a traditionally taught course to a PBL course. This reiterates the importance of considering the input from both groups to optimize the transition to this new teaching strategy.

As noted previously, this activity was performed as a pre-Delphi study activity to collect ideas to use in a modified Delphi study that utilized these two groups of experts. Given that the starting ideology from each of these two groups is almost exclusively *not* overlapping, the question of whether it will be possible to find convergence through a Delphi study when two different groups of expert participants are included in the same study surfaces. The results of the Delphi study will be analyzed and published subsequently to answer that question.

Implications and Conclusion

This study attempts to shed light on the ideas of two different yet important groups of experts - PBL researcher experts and aerospace engineering faculty experts - on how to thoughtfully transition an introductory aerospace engineering course from a traditional, lecture-based approach to a PBL approach. The findings were categorized into four areas: design, learning objectives, implementation and facilitation, and assessment. While many of the ideas proposed by the experts was supported by ideas from existing research, there was very little overlap in what each group deemed important, specifically in the design, facilitation, and assessment categories. There does seem to be some agreement on what the learning objectives of this class should be, however, and that these learning objectives should be driven more by cognitive strategies of practicing engineers than by specific technical skills. This lack of overlap between the two groups of experts highlights the need to consider knowledge from both pedagogy and technical experts when making a teaching strategy transition like this and is a lead in for future work to see if agreement can be reached between these two groups.

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Appendix A: Focus Group Scripts

PBL in Engineering Expert Script

INTRODUCTIONS [10 Minutes]

Introductions

Brief overview of the research project

DESIGN [20 Minutes]

We are using David Jonassen's idea of problem typology as a foundation for problem design. Our plan is to include problem types of selection, troubleshooting, design, and case analysis. What are your initial impressions of these classifications?

What type of problems did you create and how did you create them?

FACILITATION + ASSESSMENT [20 Minutes]

Tell me what you think faculty-student interaction in a PBL environment should look like?

How should assessment look in a PBL environment? [How do you assess process and student thinking? What form should artifacts take to allow for that type of assessment?]

PARTING THOUGHTS [10 Minutes]

What are you telling faculty who are implementing PBL for the first time?

What are you telling students who are experiencing PBL for the first time?

Aerospace Engineering Faculty Expert Script

INTRODUCTIONS [10 Minutes]

Introductions

Brief overview of the research project

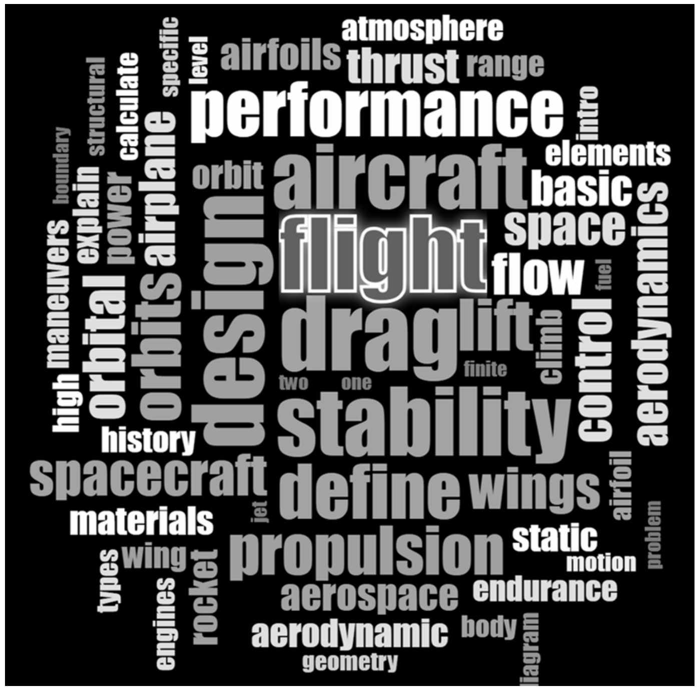
LEARNING OUTCOMES + ASSESSMENT [15 Minutes]

What are the three most important learning outcomes of an introductory aerospace course?

How would you assess those learning outcomes?

TOPICS [15 Minutes]

We created a word cloud that pulls terms from existing intro to aerospace syllabi from across the country. Looking at this cloud, what stands out and do you agree with it?



Are there other terms that you would expect to see that are not in the word cloud? What is there that shouldn't be?

EDUCATIONAL ENVIRONMENT [15 Minutes]

For a 1-credit hour course, that meets once a week for 75 minutes, describe what you would like to see in terms of faculty-student interaction

This is a course for sophomores, so in terms of problem-solving, discuss the extent to which you believe students can go beyond the content presented in class