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Experiences during the implementation of two different project-based learning assignments in a fluid mechanics course

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Abstract

Two different implementations of PBL projects in a fluid mechanics course are presented in this paper. This required junior-level course has been taught since 2014 by the same instructor. The first PBL project presented is a complete design of pumped pipeline systems for a hypothetical plant. In the second project, engineering students partnered with pre-service teachers to design and teach an elementary school lesson on fluid mechanics concepts. The goal of this paper is to present the experiences of the authors with both PBL implementations. It explains how the projects were scaffolded through the entire semester, including how the sequence of course content was modified, how team dynamics were monitored, the faculty roles, and the end products and presentations. To evaluate and compare students' learning and satisfaction with the team experience between the two PBL implementations, a shortened version of the NCEES FE exam and the Comprehensive Assessment of Team Member Effectiveness (CATME) survey were utilized. Students completed the FE exam during the first week and then again during the last week of the semester to assess students' growth in fluid mechanics knowledge. The CATME survey was completed mid-semester to help faculty identify and address problems within team dynamics, and at the end of the semester to evaluate individual students' teamwork performance. The results showed that the type of PBL approach used in the course did not have an impact on fluid mechanics content knowledge; however, the data suggests that the cross-disciplinary PBL model led to higher levels of teamwork satisfaction. Through reflective assignments, student perceptions of the PBL implementations are discussed in the paper. Finally, some of the PBL course materials and assignments are provided.

Introduction

There is growing evidence of the effectiveness of project-based learning (PBL) in preparing students to solve complex problems[1-7]. In PBL implementations in engineering, students are treated as professional engineers facing projects centered around real-world problems, including the complexity and uncertainty that influence such problems. Not only does this help students to analyze and solve an authentic real-world task, promoting critical thinking, but also students learn from each other, learning valuable communication and teamwork skills. Faculty play an important part by assuming non-conventional roles (e.g., client, senior professional engineer, consultant) to help students throughout this instructional and learning approach. Typically, in PBLs, students work on projects over extended periods of time that culminate in realistic products or presentations. There have been attempts to use PBL in a variety of engineering courses[1-7]; several have reported success stories[8-12] using PBL in fluid mechanics courses as well.

In this paper, two different implementations of PBL projects in a fluid mechanics course are presented. The first PBL project presented is a complete design of pumped pipeline systems for a hypothetical plant. In the second project, engineering students partnered with pre-service teachers to design and teach an elementary school lesson on fluid mechanics concepts. With the PBL implementations, it is expected that students: 1) engage in a deeper learning process where concepts can be reemphasized, and students can realize applicability; 2) develop and practice teamwork skills; 3) learn and practice how to communicate effectively to peers and to those from other fields; and 4) increase their confidence working on open-ended situations and problems. The goal of this paper is to present the experiences of the authors with both PBL implementations and their impact on student learning and satisfaction.

Class Setting

The Fluid Mechanics course in the Mechanical Engineering Technology program at this midsize university is a 3 credit 300-level course. The class meets twice a week for 75 minutes each time and it is offered in a hybrid mode (face-to-face and online – synchronous or asynchronous) in the fall semesters and fully face-to-face mode in the spring semesters. More than 80% of the students are already in their senior year when registering for this class. Traditionally, fluid mechanics is a challenging course due to its heavy mathematical content. In this study, as the course is part of a technology program, the course curriculum is concentrated on the use of the major concepts in industrial applications, therefore the problem solving, and project design are central to the teaching approach of this class.

The undergraduate engineering student population is very diverse. It ranges from traditional students to students in different age groups (with a large group of students returning to school after a long break period), full-time workers, active military students, veterans, students of underrepresented groups, and transfer students from community colleges. This diversity creates a non-coherent group of students in the class, with different study habits, background levels and needs that add to learning challenges of the subject matter and makes the teaching of the class very demanding. Another issue is that the Engineering Technology major math requirements are significantly lower compared to the long-established Engineering majors, and some concepts can only be explained in a holistic way without relying on the mathematical proofs. In this case, the problem solving, and practical applications should balance the mathematical rigor.

The course was originally structured in 4 main modules: static of fluids, dynamics of fluids, specialized topics on fluids, and turbomachinery, as shown in the “BEFORE” column in table 1. Each of the topics covered in each of the original four modules (“BEFORE”) are indicated in table 1 using the same color. The same colors for the topics are used in the “AFTER” column where the topics and modules were rearranged. The structure was later modified in Spring 2019 to accommodate for the 2nd PBL project (see column “AFTER” in table 1), as it will be explained next. After every module, the students were tested.

Table 1. Fluid Mechanics topics delivery structure. After every module, the students were tested.

	BEFORE	***AFTER***	
Test 1	Nature of Fluids	Nature of Fluids	Test 1
	Viscosity of Fluids	Viscosity of Fluids	
	Pressure	Pressure	
	Hydrostatic	Hydrostatic	
	Forces due to static fluids	Navier-Stokes eq - Bernoulli's equation	
	Buoyancy and Stability	Energy equation - Applications	
Test 2	Navier-Stokes eq - Bernoulli's equation	Forces due to static fluids	Test 2
	Energy equation - Applications	Buoyancy and Stability	
	Boundary Layer - Friction losses in pipes	Open channel flow	
	Minor losses in pipes	Instrumentation	
	Series pipeline systems	Water hammer & Cavitation	
	Parallel pipeline systems	Drag and Lift	
Test 3	Instrumentation	Impulse theorem	
	Open channel flow	Boundary Layer - Friction losses in pipes	Test 3
	Water hammer & Cavitation	Minor losses in pipes	
	Drag and Lift	Series pipeline systems	
	Impulse theorem	Parallel pipeline systems	
To Project	Turbomachinery	Turbomachinery	To Project
	Pumps	Pumps	
	Pumps – Affinity Laws	Pumps – Affinity Laws	
	Pumps – NPSH	Pumps – NPSH	
	Positive displacement pumps	Positive displacement pumps	

PBL Implementations

<u>1st PBL implementation</u>

The first PBL project had been implemented since Fall 2015 and it went through several modifications to make it more realistic. Students were told that they are a group of engineers working for an Engineering Consulting Firm that just got a contract from an important company in the area. The company was interested in building a new manufacturing facility. The plant had an automated machining line in which five machines were supplied with coolant from a reservoir. After the coolant gets dirty due to constant reuse, it must be disposed of. The students were responsible for the design of the pumped pipeline systems that handled coolant from the time it reached the plant in railroad tank cars until the dirty coolant was removed from the premises by a contract firm for reclaim.

This was a semester-long project where the instructor required students to work in teams of four members. The Comprehensive Assessment of Team Member Effectiveness (CATME) system was used to systematically assign the team members. A larger weight in the CATME criteria is given to student schedule compatibility.

A few days after the teams were formed, each team worked on a team charter to define the rules of engagement, and decided who will be the technical leader, the project manager, and the communications manager. The technical leader made sure the technical requirements are understood and fulfilled. The project manager oversaw the project plan, this included observing that tasks and assignments were completed and submitted according to directions. The communications manager was in charge of all team communications to make sure everyone in the team stayed informed and communicated with course instructor/"client," and also prepared meeting agendas and minutes.

As in any consulting company, the students were given a specific list of tasks to successfully complete the engineering design. The sequence of those tasks followed the course content delivery (table 1). Around week 7 students were asked to submit a progress report on the first half of the design tasks, and a final project report during finals week. There were grading rubrics for each of them, and the instructor shared these with the students. To help improve the quality of the course project, following some instructions and the rubrics, each of the students reviewed the progress report of another team to provide feedback through a peer-review process. They were asked to be respectful and serious in their comments.

The CATME survey was later used to evaluate the team performance. The instructor reviewed every comment each student gives to their teammates and the grade adjustment factor CATME offered based on each student's numerical inputs. The instructor intervened and talked to any team (or specific team member) that may not be performing well as a group. Most of the time this early intervention helped to keep the team dynamic balanced. However, following along with the idea of making the team dynamics more realistic and to avoid escalating problems, teams were allowed to fire a member as long as the other members agreed on doing it and communicated the decision to the instructor. The person who gets fired then completed a final test with only the last content of course, which involved a design of a smaller pumped system. Only a handful of students have been fired since this PBL implementation started in Fall 2015.

Also, the instructor met with the teams three different times in the semester. During those meetings the instructor played the role of "the client" or "the senior engineer in the consulting firm." These meetings prevented the students from falling behind and provided them with useful information to continue the design. Also, during the meeting, each team showed what they have done up to that moment. There were no points for attending the meetings.

To assess the PBL implementation, the students were required to take a shortened version of the NCEES FE exam at the beginning and at the end of the semester. They also took a final CATME survey and were asked to complete a set of questions reflecting on the project work.

In Fall 2019, the design tasks were modified after the course sequence was adjusted to accommodate for the 2nd PBL implementation (more details in the next subsection). Table 2 summarizes all the described activities. For more details on the assignment given to the students, the reader is invited to download it from: https://tinyurl.com/FirstPBL.

Table 2. Schedule of 1st PBL project scaffolded activities throughout a semester.

Activity	Due By	Grading
1. FE test	Week 2	2.5%
2. Team charter / Team tasks	Week 3	2.5%
3. Meeting client	Week 5	
4. Progress report (TASKS 1 to 9)	Week 7	15.0%
5. Peer-review to progress report	Week 9	10.0%
6. CATME midterm survey	Week 10	2.5%
7. Meeting client	Week 12	
8. Meeting client	Week 15	
9. Final Engineering Report	Week 16	65.0%
10. FE test / CATME final survey / Project reflection	Week 16	2.5%

2nd PBL implementation

This 2nd PBL scheme has been implemented since Spring 2019. From that point on, the 1st PBL scheme had occurred in the fall semesters, while the 2nd PBL scheme had occurred in the spring semesters when the class was offered fully face-to-face. The students were assigned a semester-long project where their creativity, knowledge of fluid mechanics concepts, and skills to work with people from other disciplines get tested. In this case they were told that a hypothetical company "Engineering is for all" is interested in designing and developing learning products for kids in elementary schools in the local area. They required the help and skills from them as engineers to develop them. They wanted the products to follow a similar (but not the same) idea as the one developed by the Museum of Science in Boston (https://www.eie.org). The students needed to pick a fluid mechanics topic, develop a hands-on demonstration activity on the topic, and create a lesson plan that can be used by an elementary school teacher on his/her own.

For the fluid mechanics topic, they picked from this list:

a) Viscosity
b) Density
c) Buoyancy and Stability of floating/submerged objects
d) Friction
e) Bernoulli's principle
f) Open channel flows
g) Drag and Lift
h) Forces in general

Those topics were selected following the Standards of Learning (SOL) used by the local elementary schools. Since the students quickly started in the semester working on their project around one of those topics, the sequence of lectures in the class was modified to make sure the content had been covered by the time the students needed to work on the elementary school lesson (see table 1). All those topics were fully covered by about the 5th week of the semester.

Since the project involved teaching elementary school kids, the engineering students were partnered with elementary pre-service teachers from the College of Education who are critical for a successful elementary school lesson. In addition, the fluid mechanics instructor partnered with a faculty member from the College of Education who taught a science methods course to the education students. Both faculty members worked on reaching out to nearby schools interested in getting their elementary school students involved. They also made sure to clearly synchronize the information provided to all engineering and education students in their courses.

The students were required to work in a cross-disciplinary team of five, with three engineering students and two education students. The team members were assigned at the very beginning of the semester also using CATME. A few days after the teams were formed, each team worked on a team charter to define the rules of engagement and decide who will be the project manager and the communications manager on both the engineering and education sides. The students were also asked to contribute to their own Google Site template that served as a platform for team communication throughout the semester.

There were four main events for this project: 1) classroom visit to the assigned elementary school, 2) cross-disciplinary teaching/learning where engineers taught science/engineering to educators and educators taught pedagogy to engineers, 3) dress rehearsal where their elementary school lesson were presented in front of peers and experts, and 4) the actual final elementary school lesson delivered to the elementary school students. For each of those four main activities, there were preliminary assignments the teams turned in for both instructors to provide feedback. Those four activities took place during class time and their attendance is mandatory.

In the visit to the elementary school, the teams had the opportunity to meet elementary school students. The visit helped the kids to get excited about the final lesson activity and the college students could learn about the kids' preferences and experiences which helped them to develop a culturally responsive lesson. On the 2nd main activity, education and engineering students learn from each other in an effort to better equip them for the lesson preparation. The "dress-rehearsal" in front of experts in the area of education and engineering aimed at giving important feedback to the students for the purpose of improving their lesson. The "dress-rehearsal" is also observed by another student team and each of the students in that team provided feedback through a peer-review process. Finally, the final engineering lesson was delivered to elementary school kids at the end of the semester.

As in the other PBL implementation, the CATME survey was used mid-semester to evaluate the team performance. Following their evaluation of the CATME results, both instructors intervened and talked to the teams as needed. On this 2nd PBL project, firing was not allowed. As in the previous PBL, the students were required to take a shortened version of the NCEES FE exam at the beginning and at the end of the semester, take a final CATME survey, and complete a set of questions reflecting on the project work. Additionally, the engineering students were asked to work on a small engineering project in which they were evaluated on the topic of pumped system design. Table 3 summarizes all the described activities. It is important to point out that during the semesters affected by COVID, all those activities were performed online. It created some challenges that were overcome by giving the students even more detailed instructions and templates to follow. For more details on the assignment given to the students, the reader is invited to download them all from: https://tinyurl.com/SecondPBL.

Table 3. Schedule of 2nd PBL project scaffolded activities throughout a semester. The main activities are highlighted.

Activity	Due By	Grading
1. Post Bio on Google Site, complete FE test	Week 2	2.5%
2. Team contract / Team tasks	Week 3	2.5%
3. School visit PowerPoint draft	Week 4	5.0%
4. School visit reflection & power point presentation	Week 5	10.0%
5. Presentation Draft of Engineering Concepts	Week 7	5.0%
6. Peer teaching of engineering concepts and 5E's of inquiry-based learning	Week 8	10.0%
7. Draft Engineering Lesson/Dress Rehearsal	Week 10	2.5%
8. CATME Mid-term evaluation	Week 11	5.0%
9. Dress Rehearsal Engineering Lesson	Week 14	10.0%
10. Feedback on dress rehearsal to peers	Week 14	2.5%
11. Final Engineering Lesson	Week 15	20.0%
12. Project reflection / FE test / CATME evaluation	Week 16	10.0%
13. Small Engineering Project	Week 16	15.0%

Evaluation of the Implementations

Students' learning and satisfaction for both PBL implementations were evaluated and compared. A shortened version of the NCEES FE exam, the CATME survey, and reflective assignments were utilized.

A shortened version of the NCEES FE exam

Students completed the FE exam during the first week and then again during the last week of the semester for the purpose of assessing students' growth in fluid mechanics knowledge. The 16 questions can be found here: https://tinyurl.com/shortenedFE. Students' scores from the FE exam were analyzed using analysis of covariance (ANCOVA) to test for potential differences between the two PBL implementations. Initial scores were used as control variables in this analysis. This analysis was based on a sample of 80 students (1st PBL scheme = 40; 2nd PBL scheme = 40).

The Comprehensive Assessment of Team Member Effectiveness (CATME) survey

The CATME survey was completed mid-semester to help faculty identify and address team dynamic problems, and at the end of the semester to evaluate individual students' teamwork performance and satisfaction. For the purpose of this paper only team satisfaction was observed. The rest of the rich data CATME offered will be presented in a separate paper in the future. Data from 110 students (1st PBL scheme = 53; 2nd PBL scheme = 57) on satisfaction were compared using a one-way ANOVA. The satisfaction scale consists of three items on a 5-point scale ranging from 1 to 5, where 5 = very satisfied.

Reflective Assignments

For the 1st PBL project, students were asked to answer the following questions:

- Do you think what you learn is important for your professional career?
- Where do you think you will be using everything you learned?
- How would you explain the project and your contribution to the project in a job interview?
- How would you explain how your strengths helped you contribute to the project in a job interview?
- How would you explain in a job interview how your weaknesses affected your ability to work on this project and how did you address them (or what part of the class helped you address them)?
- Explain the technical strengths and weaknesses in your project.
- If you were starting the class over again, what advice would you give yourself to ensure that you had a successful semester and a *successful final project?*

While for the 2nd PBL project, students were asked to answer, among other questions, the following:

- What did you learn? What did you learn about engineering? What did you learn about teaching?
- How did faculty support students to make these adjustments? How helpful/necessary did students find this support?
- How valuable was this Engineering Lessons Project? What was valuable about this experience? What was challenging? Do you have any suggestions for improving the project in the future? If so, please share your thoughts.
- What factors affected your motivation for this project over the course of the semester? For example, did your instructor impact your motivation, the topic itself, your relationship with your teammates, your interactions with the kids, feedback you received etc. Please consider factors that positively affected your motivation as well as factors that negatively affected it and consider how your motivation may have changed over time.
- How did teaching an online lesson rather than an in-person lesson change the way this project affected you? For example, do you think you learned more or less as a result? Did you learn different knowledge or skills than you would have learned by preparing for and teaching a face-to-face lesson? Please explain your response.

- What did you learn from working with the education students? Please explain.
- How did this project affect your vision of teaching careers?
- How has your understanding of fluid mechanics changed as a result of this project?

The whole set of questions can be found in the assignment in this link: https://tinyurl.com/reflection-assignment.

The questions are different because the projects and their purposes are different. When analyzing students' reflections, thematic analysis was used to understand students' experience of PBL[13]. The researchers analyzed students' reflections using the initial codes based on the outcome of this study (e.g., team interaction, perceived learning, perceived value of the project). Through multiple rounds of coding and discussion, we added and modified codes (e.g., project structure, instructor and TA interaction, motivation) and subcodes (e.g., satisfied with team interaction, suggestions for improvement) as new topics emerged. As a result, a final codebook was established. Using this codebook each researcher coded their assigned data set and codes were compared between the researchers to check the inter-coder reliability, which resulted in all codes having over 80% agreement[14].

Results

The ANCOVA results suggest no significant differences in the FE exam between the two implementations, $F(1,75) = 1.12$ ($p = 0.29$), after controlling for the student's pre-test scores. Thus, the type of PBL approach did not have an impact on fluid mechanics content knowledge as assessed by the shortened version of the FE exam. In contrast, when analyzing CATME team satisfaction, results revealed that there is a significant difference between the two PBL implementations regarding students' satisfaction, $F(1, 106) = 5.9$ ($p = 0.017$). Thus, students who participated in the second PBL scheme (cross-disciplinary project) reported being more satisfied than their counterparts who participated in the first PBL scheme.

Regarding the students' comments on the 1st PBL project, they seem to appreciate the level of exposure to a team dynamic as they handled an authentic engineering project:

> *... I do think that the semester project and time management skill that I have learned throughout the course will greatly impact my career and my professional life.*
>
> *The aspects of this class that will be transferred over into my professional career will be how to work within a group and time management. Overall, the semester course project assisted with increasing my teambuilding and team cooperativeness within a project environment with detailed tasks and deadlines.*
>
> *I think what we learned will be very important towards my professional career because working in a group setting is vital in today's work environment.*

They also believe that the 1st PBL implementation has technical value that will help them to be the engineer they want to be:

I believe that this project gave a valuable lesson in relationship toward this engineering project, fluid mechanics and future employment projects. I believe that in my professional career, we will be asked to not only complete detailed projects for clients, but also work in team environments.

I think what I have learned from this class and this project is very important for a professional career. Learning that you will not have all the answers you need to design something is what I think is most important. Learning how to work with the requirements and limitations for a design is also important because that is what you will be given by your client. This project has shown us some of what you will experience in a real-world job setting.

The course concepts thought very easy to understand individually, once combined added a new way to look at various key components throughout systems. This is both a strength and weakness as I had never seen how system components when isolated reacted differently once combined with an overall large system.

On the other hand, on the 2nd PBL implementation, the engineering students had to cement and really understand the engineering concepts to be able to teach it to the education students and elementary school students:

This project allowed me to reexamine basic concepts of fluid mechanics as I reexplained them to groups who may not have had any previous knowledge of said concepts. By explaining them to someone new I learned some new things about something I already learned while teaching it to someone who never learned it.

My actual understanding of fluid mechanics as a whole was more defined because of the project and while we didn't go over the complicated ones, the concepts we did implement into our project design made my understanding of them much more solid.

The engineering lessons project provided me with valuable experience. This is the first time that I have taught other people anything. I have noticed that to teach something, you have to understand it on a fundamental level. This helped me with my engineering class.

The project deepened my knowledge of fluid mechanics.

Somewhat similar to the 1st PBL scheme, on the 2nd PBL scheme, students found that another important takeaway from collaborating with education students to teach engineering to elementary students is their development of professional skills, especially their communication skills with those of different backgrounds:

The project taught numerous professional development skills including collaborating in both an online environment and working with other fields other than engineering. I would apply what I learned in communicating with all future groups including those in which we primarily were in an online working environment.

Not everything was positive though, in both PBL implementations students strongly felt that the workload in the course was too overwhelming, giving them a negative feeling towards the projects. This is a comment on the 2nd PBL scheme, but similar comments were found for the 1st PBL scheme as well:

This was not super valuable to our development as it was a lot of work and time for a minimum amount of professional development, the professional development I'm referring to is working among a team of differing individuals, helping less experienced people understand difficult engineering topics, and communicating effectively in an online work environment. These skills easily could have been learned in less time and less effort instead of in such a long and complicated project. The challenging part was how much time it took away from my other studies or my studies of content in this class itself as often I found myself spending more time on this project rather than studying the difficult course content of this class.

Conclusions

This paper presents the instructor experiences implementing two different project-based-learning schemes in a junior to senior level Fluid Mechanics course in an Engineering Technology Program. The results showed that no major differences were observed in terms of the learned fluid mechanics content; however, the data showed interesting preliminary observations regarding teamwork satisfaction. Through reflective assignments, student perceptions of the PBL implementations were discussed in the paper. The perceptions were found to be good and students seemed to appreciate the projects, although some believed the workload was overwhelming. In addition, access to all the PBL course materials and assignments were provided. In conclusion, as an indication of PBL success, a few former students have reached out to the instructor to highlight some of the long-term benefits of the PBL implementations. An email correspondence from one student is shared below to illuminate the positive benefits of PBL experiences for engineering students in their fluid mechanics course::

Hey Dr. XXXX,

I wanted to reach out to you and give you a sort of update from a former student. I accepted last Tuesday, and will be starting this coming Monday, an offer from [Company Name] as a Project Engineer. I'll be moving down to [City, State] to finish up a $24M contract they have with the [Client] there, upgrading their [Fluid Mechanics] Unit.

I definitely have to say, and feel free to blast this to all of your current students, the projects you had us complete in all of your courses helped immensely with not just getting the job, but feeling comfortable walking into it next week. Being able to walk into an interview and recite numerous projects you did relating to real world situations showed not just the knowledge, but the determination it took to complete such hefty assignments.

So a big thank you to you for instilling both knowledge and commitment during your courses. I hope all is going well there and I definitely intend on keeping in touch.

Thanks again,

[Engineering Program Alum]

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References

1. J. Dofe and S.T. Kurwadkar, "Project-Based Learning: Contrasting Experience Between Traditional Face-to-Face Instruction and Virtual Instruction," *Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference,* 2021. https://peer.asee.org/37616.
2. S. Hamoush, E.H. Fini, M.M. Parast, and S. Sarin, "The Effect of Project-Based Learning (PBL) on Improving Student Learning Outcomes in Transportation Engineering," *Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC,* 2011.
3. A.C. Heinricher, P. Quinn, R.F. Vaz, and K.J. Rissmiller, "Long-term Impacts of Project-Based Learning in Science and Engineering," *Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia,* 2013.
4. K.M. Ranly, F. Jao, and K.L. Curtiss, "Project-based Learning: An Integration of Real-World Project in a 3D Design Class," *Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida,* 2019.
5. A. Shekar, "Project-based Learning in Engineering Design Education: Sharing Best Practices," *Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana,* 2014.
6. R.R. Ulseth, J.E. Froyd, T.A. Litzinger, D. Ewert, and B.M. Johnson, "A New Model of Project Based Learning in Engineering Education," *Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC*, 2011.
7. A. Yousuf, M. Mustafa, and A. De La Cruz, "Project-based Learning," *Paper presented at 2010 ASEE Annual Conference & Exposition, Louisville, Kentucky*, 2010.

8. A. Meikleham, R. Hugo, and R. Brennan, “Fluid Mechanics Project-Based Learning Kits: An Analysis of Implementation Results in a Blended Classroom,” *14th International CDIO Conference, Japan,* 2018.
9. W.A. Mokhtar, “Project-Based Learning (PBL): An Effective Tool to Teach an Undergraduate CFD Course,” *Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC,* 2011.
10. M. Pérez-Sánchez, and P.A. López-Jiménez, "Continuous Project-Based Learning in Fluid Mechanics and Hydraulic Engineering Subjects for Different Degrees" *Fluids,* 5, no. 2: 95, 2020. https://doi.org/10.3390/fluids5020095.
11. B.J. Wie, D.C. Davis, P. Golter, A. Ansery, and B. Abdul, “Team building in a project-based learning Fluid Mechanics and Heat Transfer course,” *ASEE Annual Conference and Exposition, Conference Proceedings,* 2011.
12. R. Wulandari and R.E. Santoso, “Measurement of Student’s Learning Interests in Fluid Mechanics Subject through Project Based Learning Model Using SCAMPER Strategies,” *Proceedings of the 2nd International Conference on Vocational Education and Training (ICOVET 2018),* 2019. https://doi.org/10.2991/icovet-18.2019.53.
13. G. Guest, K.M. MacQueen, and E.E. Namey, “Introduction to applied thematic analysis,” *Applied thematic analysis*, 3(20), 1-21, 2012.
14. C. O’Connor, and H. Joffe, “Intercoder Reliability in Qualitative Research: Debates and Practical Guidelines,” *International Journal of Qualitative Methods,* 2020. https://doi.org/10.1177/1609406919899220.