Journal of Problem Based Learning in Higher Education

VOL. 11, No. 3, 2023 – Page I-III

Eighteenth Issue of the Journal of Problem Based Learning in Higher Education

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EDITORIAL

We are very happy to present volume 11, issue 3 of the Journal of Problem Based Learning in Higher Education. This year, we have already published two special issues, and this is our annual issue. It contains three papers and seven cases. Our number of full papers is smaller compared to what we normally publish but the two special issues have probably taken a few papers that might otherwise have found their way into the annual issue in more normal years. But this does not diminish the fact that we are very proud of this issue communicating essential studies and cases about PBL.

The three papers in this issue are all empirical papers looking into the effects and attitudes of implementing PBL approaches and techniques. They cover three different disciplines: project management in economics, early childhood teacher education, and sex therapy in psychology education, across five different countries, as well as they work with both quantitative and qualitative methods. These varieties in application of PBL and in the scientific research about it, some might consider a weakness. Believing that a less rigor systematics and lack of a dominating theory might produce less solid and equivalent results, thereby weaken the creation of a stronger common understanding of the field. But we believe it is a strength. We do not strive for a PBL unity in terms of well-defined beliefs and exercises. But rather see PBL as an inspiration to develop, test, and support different forms of student centered and contextually anchored pedagogical theories and practices. For that reason, we welcome the varieties, and the encouragement they bring.

Our seven cases, demonstrate the same palette of range and variety, as they come from all over the world – Brazil, Canada, China, Denmark, Turkey – and from a wide range of disciplines. They show different and very interesting cases of PBL being applied within areas of mathematical modelling, the role of the problem-analysis in PBL, how to use PBL in ergonomics courses, PBL in Global Health Education, PBL in sustainable waste

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management, using PBL to teach an open online Scratch programming course, and PBL compared to lectures in medical education.

We would like to raise a conversation with the readers and reviewers about the reviewing situation. We are extremely grateful for the time and effort each one of our reviewers put into the thoughtful reviews that are so essential for the quality of the journal. Thank you! Without your work, nothing would be published. This is also why we, each year, at the end of the final issue, publish the names of all the reviewers of this year's issues. We wish to show our appreciation, but we also hope that by naming the reviewers, they can get some kind of credit and recognition, or "proof", of their effort. We cannot pay reviewers or promise discounts from our university publishers; something which other and larger publishers sometimes use as a token of appreciation.

However, we, like so many other academic journals, find it increasingly difficult to recruit reviewers. In a recent newsletter from the Danish network *ForskerForum* (Research Forum), it was stated: "Classic peer review is under pressure. In the publishing system, the greatly increased publishing activity makes it difficult for journal editors to recruit peers" (*our translation*; Forskningsevaluering: På vej tilbage til ansvarlig praksis? - Forskerforum (dm.dk)). In our journal, we spend weeks and weeks sending out requests to review, asking a continuously growing mass of researchers, stretching the extent of our knowledge of the researchers we ask, and the specificness of the research field. Given each request adequate time to respond adds even more time between submission and review, to the frustration of us as editors and to the authors awaiting a response to their submission. We also experience that some reviewers have accepted to do a review, but later appear to be unable to perform this task, and must withdraw their acceptance, starting the whole process over again.

We think that a major reason for the difficulty in recruiting reviewers is the abovementioned increased production of scientific papers, hence the increase in demand of finding reviewers. At the same time, researchers need to conform to various benchmarks of which, to our knowledge, doing reviews each year is not included, while publishing papers is included as one of the foremost criteria for academic success and progress. This creates an imbalance between the two activities – submitting papers and reviewing papers – while the two remain interdependent. So, the incentives to submit are explicit and clear, and at the same time, each paper submission requires two reviewers. Nonetheless there are no obvious and visible incentives and therefore likely less motivation to review. This imbalance is something that we as a research community need to address, as the difficulty for journal editors – like us – to find capable reviewers increases literary from issue to issue.

Another matter concerning reviews is the question of language. We have experienced an incidence of some arrogance, at least this is how we have perceived the situation. One person wrote, as part of the explanation as to why this person declined doing a review for us: “The fact that there are multiple grammatical issues in the abstract is concerning to me”. The issue was, as far as the editorial board could see, that the abstract suffered from two incidences of singular verbs without an s added in the present tense. This strikes at another nerve in publishing. The dominating international language of research is English, of which the person we quoted above, is a native speaker. The board members and most of the authors in our journal, and most researchers in the world are not native English speakers. We have English as minimum our second language, to some it might be the third language. In the light of these facts, we find it important to state that at the stage of review, proper English should not be considered as a necessary obligation if the text is understandable. In the early stages from submission to publication, we believe the focus should be on the issues and studies the authors present, perceiving the authors as multinational and multilingual colleagues. Naturally, the reviews need to be critical and require a high level of quality from the papers, but a review is also part of an ongoing communication and discussion about the research. Hence, feedback to a paper is also a feed-forward; giving advice to a colleague about how to move forward. At the later stages, as a paper comes closer to acceptance, linguistic proofreads are compulsory and a proper scientific English is an essential requirement. Therefore, as a reviewer, we welcome you to comment on language and ask for better language, but please do not make it a prior obligation.

Like always, we would like to thank all the reviewers who have donated their time and wisdom to help improve the papers and cases in this issue:

Stine Bylin Bundgaard, Denmark
Robert Lawlor, Ireland
Barbara Rita Constantinidis, Argentina
Olga Timcenko, Denmark
Nikolaj Johansson, Denmark
Stefan Reinsch, Germany
John Vergel, Colombia
Susanne Dau, Denmark
Yihuan Zou, China
Armando Sanchez Godoy, Colombia
Eva Brooks, Denmark

Journal of Problem Based Learning in Higher Education

VOL. 11, No. 3, 2023 – Page 1-24
10.54337/ojs.jpblhe.v11i3.7514

Using Competition to Improve Students' Learning in a Project-Based Learning Course: The Systemic Impacts of the Data Science Olympics

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ABSTRACT

In this article, we presented our findings regarding an online project-based learning course, delivered to 64 students from the Federal University of Sao Paulo, Brazil, during the COVID-19 pandemic, in the second semester of 2021. The course had the goal of teaching Project Management by means of a competition (the Data Science Olympics). Our goal was to investigate the systemic impacts of the competition on learning. Data was collected by means of a questionnaire and from comments posted on the teams' websites. We followed a convergent parallel mixed methods approach. We analyzed the data using a causal loop diagram to connect the insights gained with quantitative and qualitative results. Our findings were as follows: 1)The use of competition in a project-based learning centered course helped the students to develop project management and data science skills, and fostered metacognition and knowledge sharing opportunities. 2)The Data Science Olympics increased the students' intrinsic motivation to learn. 3)The project-based teaching practices (scaffolding the students' learning, giving meaningful feedback to the students, and managing the activities) facilitated the students' learning. 4)The problems the students faced throughout the Project (dropouts, communication problems, lack of commitment, difficulty scheduling online team meetings) impacted negatively on the students' motivation.

Keywords: Data Science, Project Management, Project-Based Teaching, Competition, Systemic Impacts

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BACKGROUND

In this article, we discuss the systemic impacts of the combination of competition elements in a project-based learning centered online course. The course "Project Elaboration and Management" was delivered to 64 students of Economics from the Federal University of São Paulo Osasco Campus (thereafter UNIFESP), during the COVID-19 pandemic. The course was developed from October 2021 to January of 2022. Due to the pandemic, there were no face-to face-meetings. The course was developed by means of synchronous meetings and asynchronous activities. During the COVID-19 pandemic, the UNIFESP created a rule that the synchronous meetings were not obligatory. This rule impacted the course, as we will discuss later in this article. The students were divided into 12 teams of six students each (on average) that would work together during 12 weeks. During the first six weeks, the students studied project management concepts, planned their projects, and defined their study strategy (which member of their group should study which topic and when). They also began their studies of the topics included in the Data Science Olympics (Descriptive Statistics, Inferential Statistics, Regression, and R coding). In the following weeks, the teams continued their studies and were challenged together to solve, every week, the "Challenge of the Week" (a set of problems sent by the professor to the teams with the goal of preparing them for the competition. The final Challenge was the Data Science Olympics.

THEORETICAL REVIEW

Project-based learning (thereafter PBL) is an instructional approach in which the students learn by doing while working on a project (Krauss & Boss, 2007) that leads to the creation of a product, a service or a unique result (Project Management Institute, 2018). In PBL-centered courses, the students work in teams, following a master schedule that has well defined deliverables and milestones (Bender, 2012). In a typical PBL centered course, the students have voice and choice (Sahin, 2015): they have freedom to make decisions that include defining the team's strategy, choosing the team members' roles and responsibilities, and stipulating the project activities.

There are several ways of designing and delivering a PBL centered online course. In our course, we followed the ADDIE model (**A**nalysis, **D**esign, **D**evelopment, **I**mplementation and **E**valuation), a five-phased instructional design model (Figure 1). Ideally, the course is developed sequentially, from the Analysis phase to the Implementation phase (in Figure 1 the boxes represent the phases; the solid lines represent the path the project follows). Note that the Evaluation phase is in the center of the figure, connected to all other phases. This means that the deliverables of each phase are evaluated during the development of the project. However, real-world projects may not be developed in exactly the same way:

sometimes it is necessary to return to a previous phase, to make adjustments and corrections (represented in Figure 1 by the dashed lines).

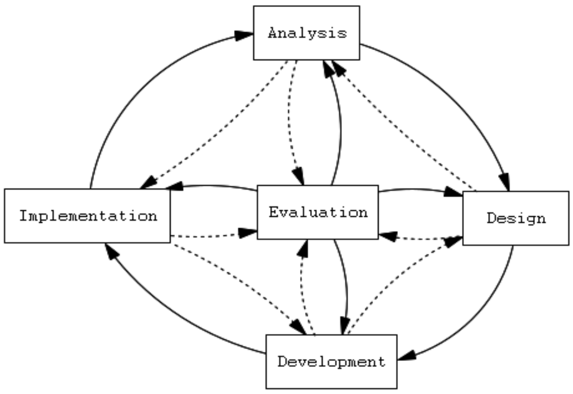

Figure 1. The Addie instructional model (based on Branch (2009) and McConnell (1996))

During the Analysis phase, the professor also defines the project's theme, aligning the learning objectives with the students' background. Researchers point out that the right choice of the project's theme is fundamental to the success of a PBL centered course (Moreira et al., 2011). The project should be interesting, motivating, challenging and meaningful to the students (Markham et al., 2003). The project's theme should be chosen wisely: if the project is very easy to accomplish, the students may lose interest; if it is too difficult, the students may become overwhelmed and stressed (Fregni, 2019). The project's theme therefore impacts the students' motivation which in turn may impact their learning effort (Arantes do Amaral & Fregni, 2022).

During the Design phase, the professor defines the course content and scaffolds the students' learning experience (Larmer & Boss, 2018) . He/She may define the project's schedule, the milestones, and the deliverables. In addition, the professor should create opportunities for sustained inquiry (Arantes do Amaral, 2021; Larmer, 2010). In other words, the students should have enough time to research what they need to learn in order to develop the project's activities (Larmer et al., 2015). More than that, the professor also should scaffold opportunities for the students to reflect on their learning, sharing their learning with their peers (Arantes do Amaral & Fregni, 2021; Rooij, 2009). In addition, the professor should schedule critique and revision activities (Larmer & Boss, 2018) in order to promote long-lasting learning (Fregni, 2019). During the Design phase of an online PBL-centered course, the professor should also choose (or create) the virtual learning environment (thereafter VLE), designing the user interface.

Throughout the Development Phase, the professor (ideally with the support of instructional designers) develops what was defined in the Design Phase. Course management systems (such as Moodle, Google Classroom) and website builders (such as Google Sites, Wix, Weebly) can be used for the development of the VLE.

During the Implementation phase, the course is delivered (Filatro, 2008) following the activities defined in the Design phase.

The Evaluation processes are present throughout the course: the professor (ideally with the support of instructional designers) evaluates the deliverables of each phase and makes the necessary adjustments. He/she also evaluates the students' performance and the effectiveness of the learning experience.

The use of ADDIE to develop online PBL-centered courses helps the instructor to have a better understanding of the students' needs, which helps to design the learning environment more efficiently (Shibley et al., 2011). Moreover, it also helps to develop and evaluate the course in an orderly way (Lu, 2021).

In recent years, competition has been used by teachers in PBL-centered courses to enhance students' interest in learning (Krithivasan et al., 2014) and to develop their skills (Willard & Duffrin, 2003). Although there are studies that reported the use of competition in combination with PBL, it seems that still there is a lack of information about the systemic impacts of this combination in online courses. Our research question then became: *What are the systemic impacts of using competition to improve the students' learning in a project-based learning centered course?* In this article we intended to answer this question.

THE INSTRUCTIONAL DESIGN MODEL

As discussed previously, to design and develop our course, we followed the ADDIE instructional design model (Arshavskiy, 2013). It took one month, previous to the beginning of the course, to develop the Analysis, Design and Development Phases. The Implementation Phase took twelve weeks and the Evaluation occurred throughout the project and one week after the end of the project.

The Analysis Phase

The Analysis phase began one month before the course started and lasted one week. During this phase we collected information about the students who would take the course. We learned that the students would be from the Economics department, most of them fourth-semester students, who had already taken two previous courses of Statistics/R programming and were going to take a course of Econometrics in the next semester. Based on this information, we decided to create a challenge that we called "Data Science Olympics" (thereafter DSO). The idea was that the students would work during twelve weeks in teams of five members, sharpening their skills (studying Statistics and R programming) to compete in the DSO. The preparation for the DSO should be accomplished by means of a project in which they would plan the team-learning strategy, define their roles and responsibilities, and execute their strategy. The DSO was created with the following goals: 1) provide the students the experience of learning by doing (learn Project Management while working on a project), and 2) improve the students' learning by promoting an opportunity for them to review and put into practice what they had learned in previous courses (Statistics and R Programming).

The Design Phase

The Design phase followed the Analysis phase and also lasted one week. During this phase, we decided to follow a project-based learning approach. We structured the course by defining the learning objectives, choosing the number of modules, defining the purpose of each module, the project theme (the DSO), the project's deliverables and the learning outcomes. The course was designed to have 12 modules, one module to be taught per week. Each module had from five to ten short video-lectures (five to ten minutes long). In addition, we designed the course's virtual learning environment (thereafter VLE) and its human computer interface.

The Development Phase

During the development phase we implemented what we had defined in the Design Phase. We created the VLE using Google Sites. We also created a set of 96 video-lectures and assembled the content on the website. In addition, we created a webpage with additional resources (links to free books about Project Management, Statistics and R programming). We worked intensively for two weeks, without the support of instructional designers.

The Implementation Phase

The Implementation phase began at the end of the Development Phase and lasted 12 weeks. During the Implementation phase the course was delivered. At the end of the first week of the course each team of the students created a website with information about their project. Each website had four pages: ***home*** (with information about the project), ***the team*** (with information about the students), ***the weekly activities*** (that would be fulfilled, as the course progresses, with information about what the students accomplished during each week of the project, the problems they faced, the actions they took to solve the problems and reflections about their learning), and ***the documents*** (one page with the links of the contents of the team's project management plans). The students' website had the goal of fostering metacognition (reflection about the learning process).

By the end of the second week, the teams created the first document, the ***project's charter*** (a document with the team structure, roles and responsibilities, the project's goal, the premises and constraints, the major risks and the team's strategy for winning the DSO). At the end of the third week the teams created the ***work breakdown structure*** (a graph that presents the tasks that should be accomplished by the teams). In the fourth week the teams delivered the ***project schedule network diagram*** (a graph that presents the sequences of the activities to be accomplished). In the following week the teams created the ***risk management plan*** (the strategies to mitigate risks) and by the end of the six week, the ***quality management plan*** (the actions that should be taken to guarantee the quality of the processes followed).

In the seventh week, the teams answered the First Challenge of the Week (ten questions about Descriptive Statistics). In the eighth week, they worked on the Second Challenge of the Week (ten questions of data manipulation with R). In the following week (week nine) they answered the Third Challenge (ten questions about Inferential Statistics, proportion hypothesis test). In the tenth week they worked on the Fourth Challenge (ten questions about hypothesis test of means). In the tenth week the teams solved the Fifth Challenge (ten questions about analysis of variance). In the eleventh week the teams worked on the Sixth Challenge (ten questions about Chi-Square and Contingency Tables). In the final week of the course the teams worked on the Data Science Olympic (ten questions about all the topics of the study). The professor analyzed the answers, declared which team had won the DSO and sent a certificate of achievement to the winners.

The Evaluation Phase

Along all of the twelve weeks the teams were required to upload the website with the information about the progress of the projects and with reflections about their learning. The professor evaluated each website every week, sending feedback (in video format) to the students by email. We asked the students to provide us with detailed explanations of what they had learned from watching the videos we created about project management concepts, as well as how they applied their newfound knowledge in their own projects. We evaluated the coherence between their explanations and the actions they took in their projects. Whenever we identified a lack of understanding in a concept, we provided the students with feedback that highlighted the deficiency and offered suggestions for improvement. This feedback was not limited to the text they created on their project's website but also encompassed the actions they were taking. Each group was demanded to follow the professor feedback (by explaining the activities in a more detailed way, by fixing documents errors etc.).

The students who had questions were asked to bring their questions to scheduled weekly synchronous meetings (using Google Meets), in order to share them with all students. Since the meetings were not obligatory (due to UNIFESP's rule), the number of students who attended the meetings varied. At the first meeting almost all students participated, but the number of participants diminished as the course progressed. On average, each meeting had four students.

In the final week of the course, the professor sent a questionnaire to the students. The questionnaire had the goal of gathering information about the students' perceptions about the course. Their answers were used in improving the course that would be offered the following semester.

METHOD

Research design

We followed a convergent parallel mixed method approach. In this approach the quantitative and qualitative data is collected simultaneously. The researcher then analyzes each piece of data separately. After that, the researcher connects the findings of each type of data (Creswell & Creswell, 2018). We used causal loop diagrams to make a systemic analysis (Arantes do Amaral, 2019) of the results.

Participants

Sixty-four students, 41 males and 23 females. The youngest was 17 years old, the oldest 37 years old, and the average age was 20 years old.

Data collection instruments

We collected data from the team's websites and from a questionnaire sent at the end of the course. The questionnaire had eight sets of questions, each with five closed-ended Likert scale questions (APPENDIX 1).

The first set of questions had the goal to measure the students' participation in synchronous activities. The second group aimed to collect data about the students' perceptions about the course management. The third was related to the effectiveness of the project-based learning approach. The fourth set of questions had the objective to gather data about the students' perceptions about the importance of what they have learned. The fifth had the goal of getting information about teamwork. The sixth set of questions aimed to collect data related to the learning effort. The seventh had the goal of gathering information about the ways the students learned. The eighth collected data about what the students learned.

Data analysis procedures

We analyzed the quantitative data by means of descriptive Statistics, using diverging bar charts. The qualitative data was analyzed by means of a language processing method(Yin, 2015). First we collected qualitative data (sentences that represent the students' perceptions about the project) from all teams' websites. Then we disassembled the sentences into small phrases. After that we grouped the similar sentences and created recurrent themes, sentences that aggregate the main ideas of each group. After we performed a systemic analysis, connecting the qualitative and quantitative data by means of a causal loop diagram.

RESULTS

In this section we will present the quantitative results (obtained from the answers to the questionnaire) and qualitative results (obtained from the projects' websites).

Results from quantitative data

The following diverging bar charts (Figure 2 to Figure 9) present the students answers (agreements or disagreements) to the eight sets of questions described previously. The identifiers (names that appear on the charts) are available in APPENDIX 1.

The answers were collected using the five-point Likert Scale, using the following color convention: 1-Totally Disagree (brown bar), 2-Disagree (Light brown), 3-Neither agree, nor disagree (Gray), 4- Agree (Light Green), 5-Totally agree (Green).

Set 1: Answers related to the lack of participation in weekly synchronous meetings

The students' answers to the first set of questions (Figure 2) shows that the majority of the students (86%) did not participate because they thought that the professor's weekly feedback addressed most of their doubts. In addition to that, 58% of the students answered that they saw no need to participate. The data also revealed that another reason for the low participation was that the majority of the students (53%) were also too busy taking other courses and 50% answered that they did not participate because they had no doubts. Only 22% of the students answered that they did not participate due to digital fatigue.

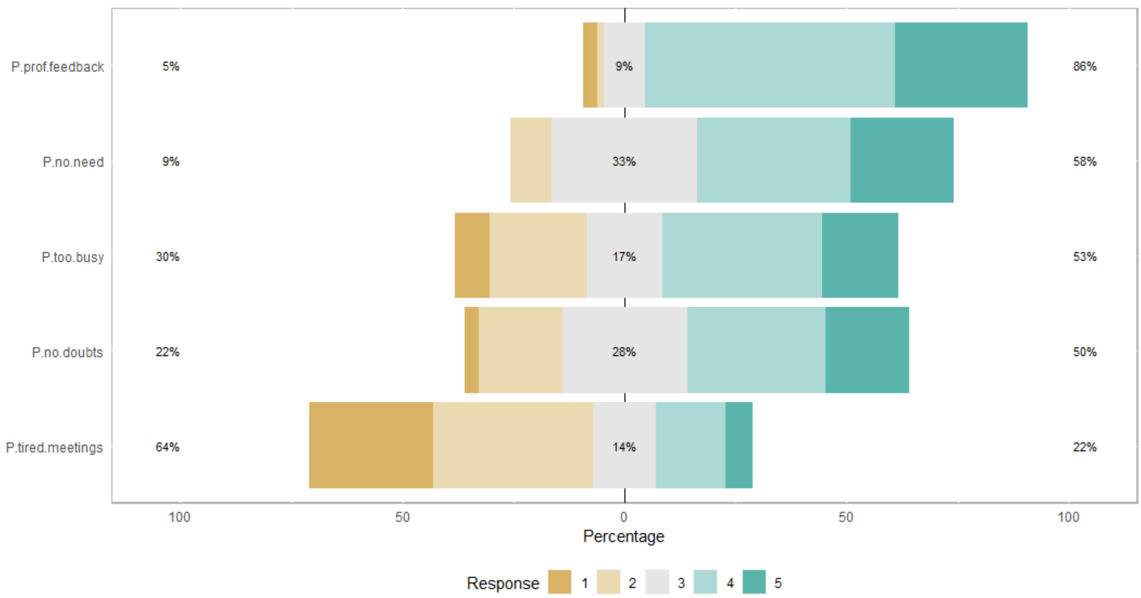

Figure 2. The divergent bar chart of the answers for the first set of questions related to lack of participation in synchronous meetings.

Set 2: Answers related to the course management

The students' answers to the second set of questions (Figure 3) show that for 88% of the students, the professor's feedback was adequate, 82% acknowledge that the course resources (books, video-lectures) were appropriate, 75% recognized that the professor demandingness was fair, 66% admitted that the course workload adequate and 61% acknowledge that the amount of topics covered in the course was acceptable.

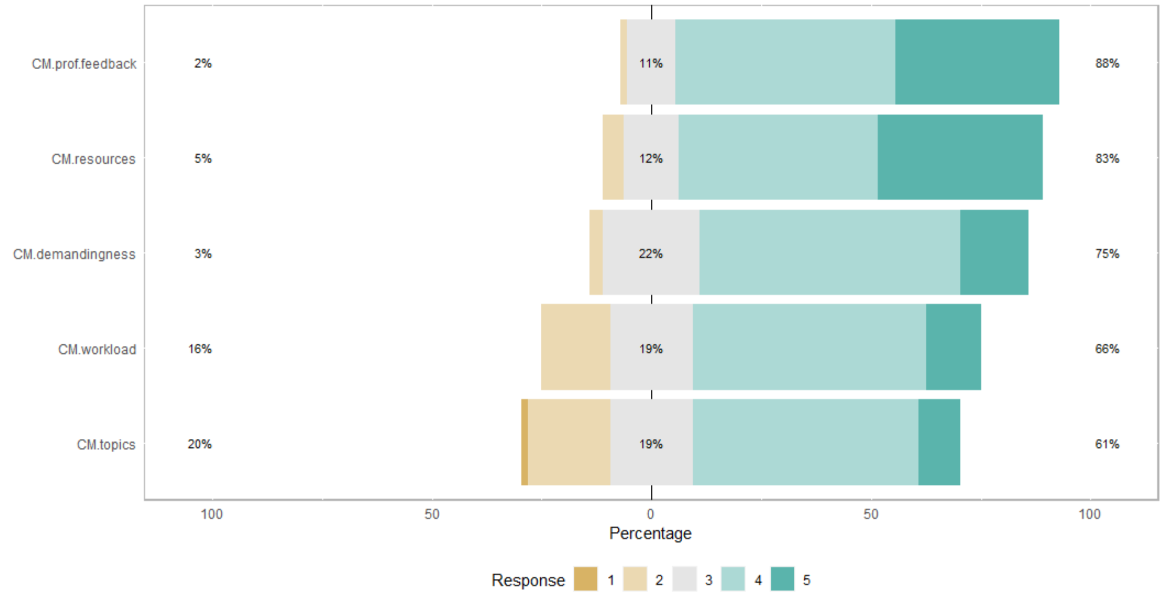

Figure 3. The divergent bar chart of the answers for the second set of questions related to course management.

Set 3: Answers related to the effectiveness of the project-based learning approach

The students' answers to the third set of questions (Figure 4) reveal that, for 86% of the students, the research they did to solve the Challenges of the week facilitated their learning, while 84% acknowledged that they developed R coding and Statistics skills. In addition, 83% of the students acknowledged that the PBL approach led to the development of their Project Management' skills, 81% recognized the PBL approach fostered knowledge sharing between teams and 64% of the students stated that the PBL approach increased their skills to work on real-life projects.

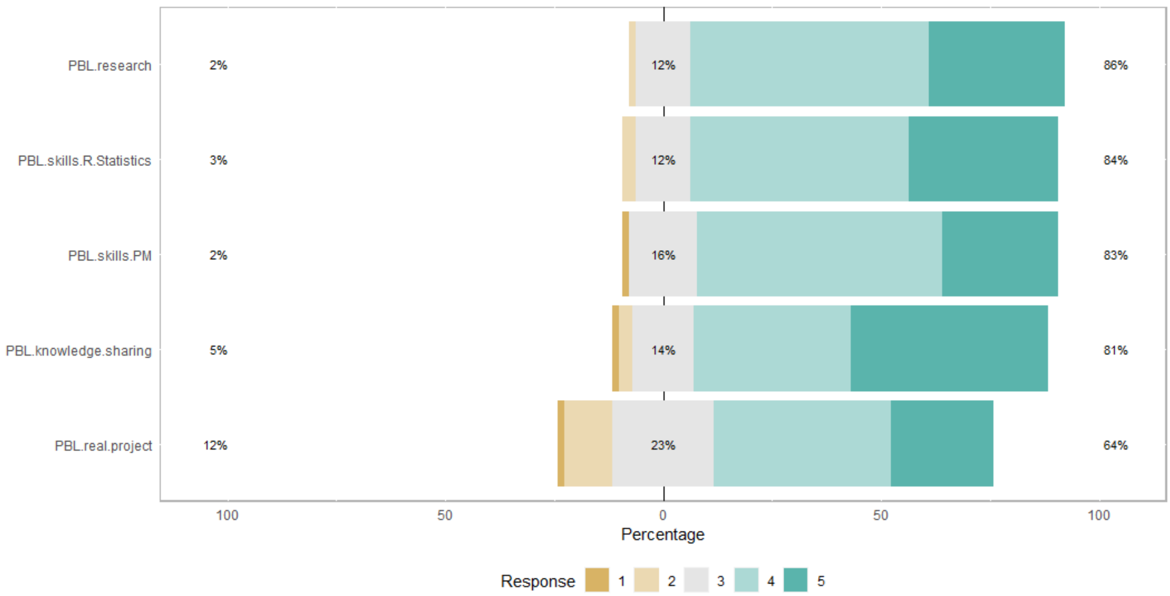

Figure 4. The divergent bar chart of the answers for the third set of questions related to the effectiveness of the project-based learning approach.

Set 4: Answers related to the students' perceptions about teamwork

The students' answers to the fourth set of questions (Figure 5) revealed that working in a team was a pleasant experience for 75% of the students; 73% answered that, in moments of difficulties, the students helped each other and 73% acknowledged that during the project the teams worked in harmony. Moreover, 70% stated that all team members contributed to the accomplishment of the Challenges of the Week. Finally, 55% of the students declared that the workload was fairly divided among the team members.

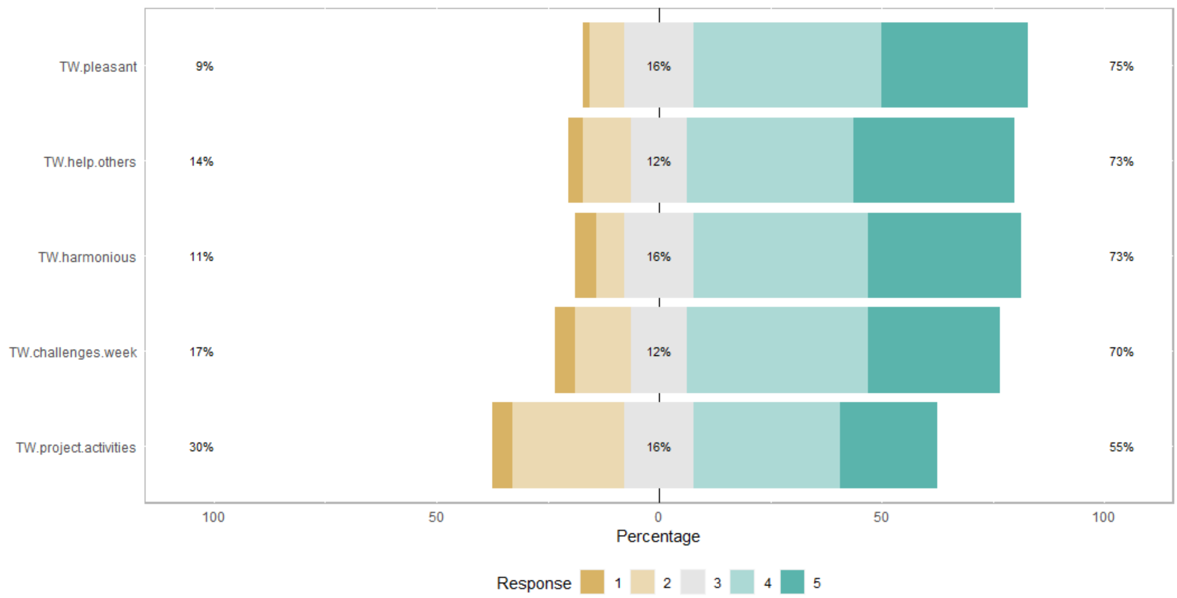

Figure 5. The divergent bar chart of the answers for the fourth set of questions related to the students' perceptions about teamwork.

Set 5: Answers related to the students' perception of the importance of what they have learned

The students' answers to the fifth set of questions (Figure 6) revealed that almost all students (92%) recognized the importance of their learning about teamwork; 84% acknowledged that what they learned in this course helped to understand other courses, 81% declared that what they learned would increase their employability, and 80% acknowledged the importance of what they had learned about Statistics, R and Project Management for their future professional life.

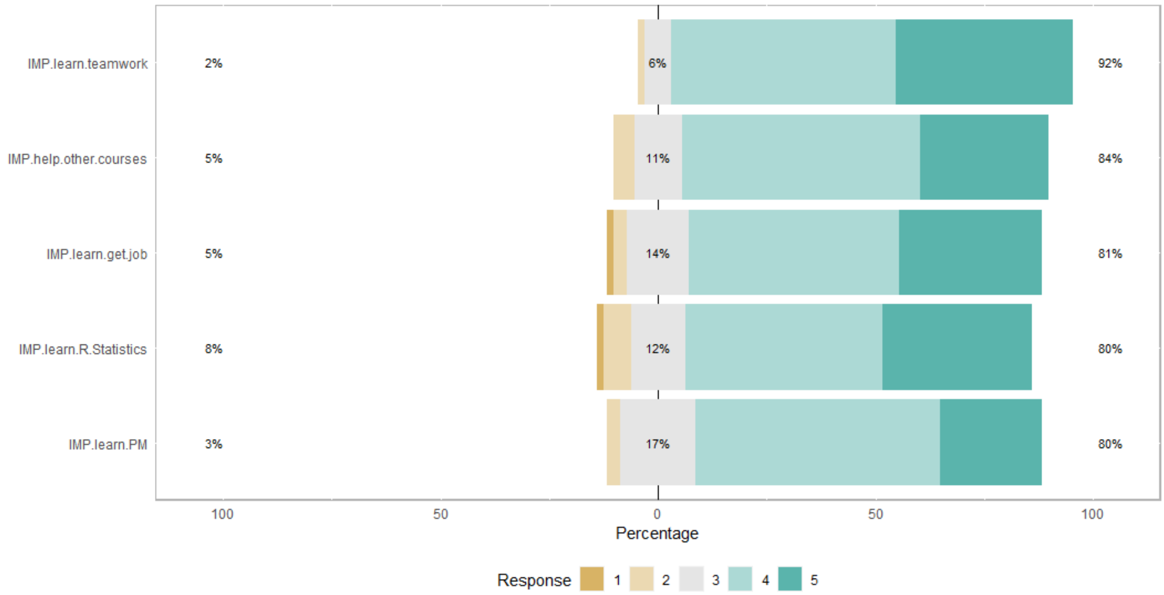

Figure 6. The divergent bar chart of the answers for the fifth set of questions related to the importance of what they had learned.

Set 6: Answers related to the learning effort

The students' answers to the sixth set of questions (Figure 7) revealed the 89% of the students made efforts to participate in project activities, 88% worked on the Challenges of the week (86%), 88% took actions to address the professor's recommendation, 84% dedicated themselves to study the courses' resources and 48% put efforts in following the other teams' projects.

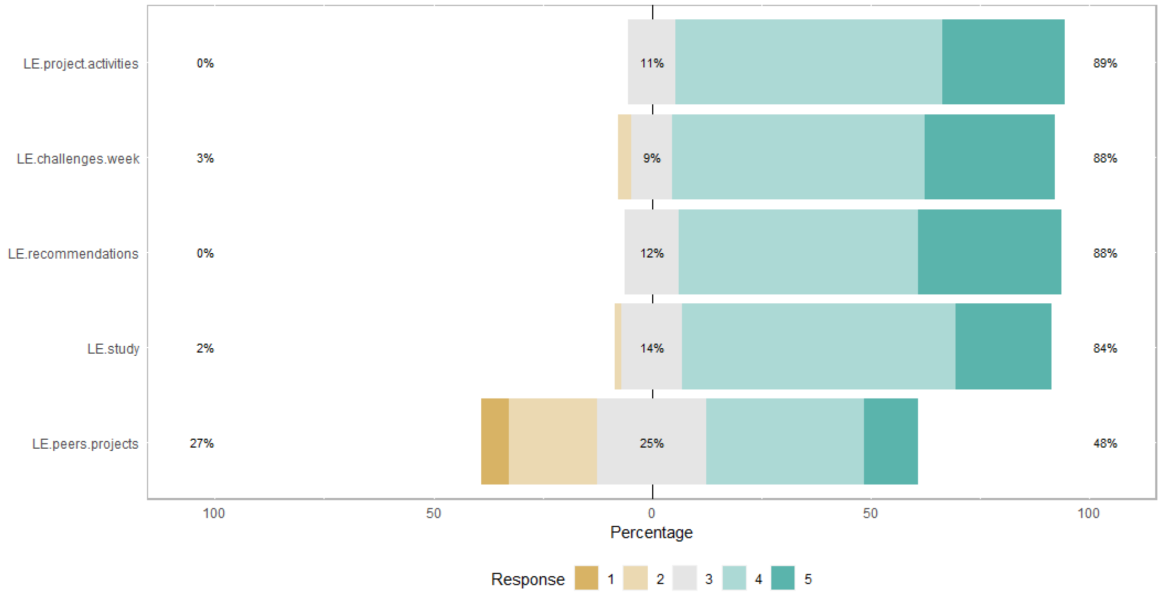

Figure 7. The divergent bar chart of the answers for the sixth set of questions related to the learning effort.

Set 7: Answers related to the ways that the students learned

The students' answers to the seventh set of questions (Figure 8) revealed that students learned while following the professor's recommendations (88%) and sharing ideas with their peers (88%). In addition, they also learned while using project management IT tools (75%) and 64% acknowledged they learned by metacognition activities (writing in their websites, what they have learned week by week). Not many students (45%) admitted learning by following the other teams' projects.

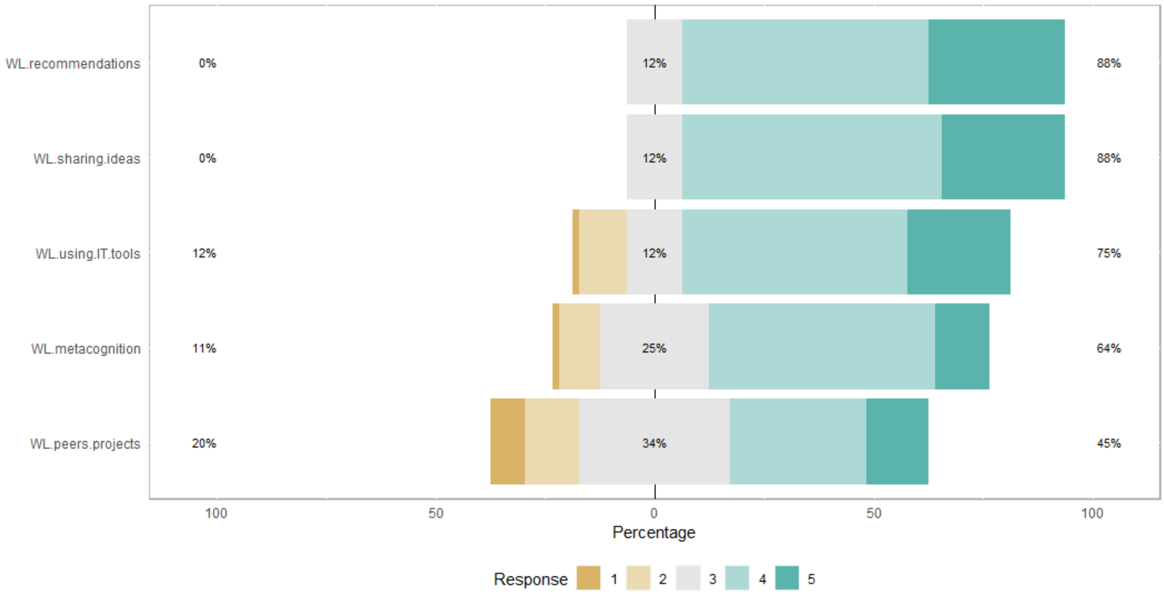

Figure 8. The divergent bar chart of the answers for the seventh set of questions related to the ways in which the students learned.

Set 8: Answers related to the students' perceptions about their learning
The students' answers to the eighth set of questions (Figure 9) revealed that, for the majority of the students (92%) that the overall learning experience was effective, 89% acknowledged learning about project management and about R coding (84%). In addition to that, the majority of the students answered that their learning about Statistics (80%) and IT tools (77%) was relevant.

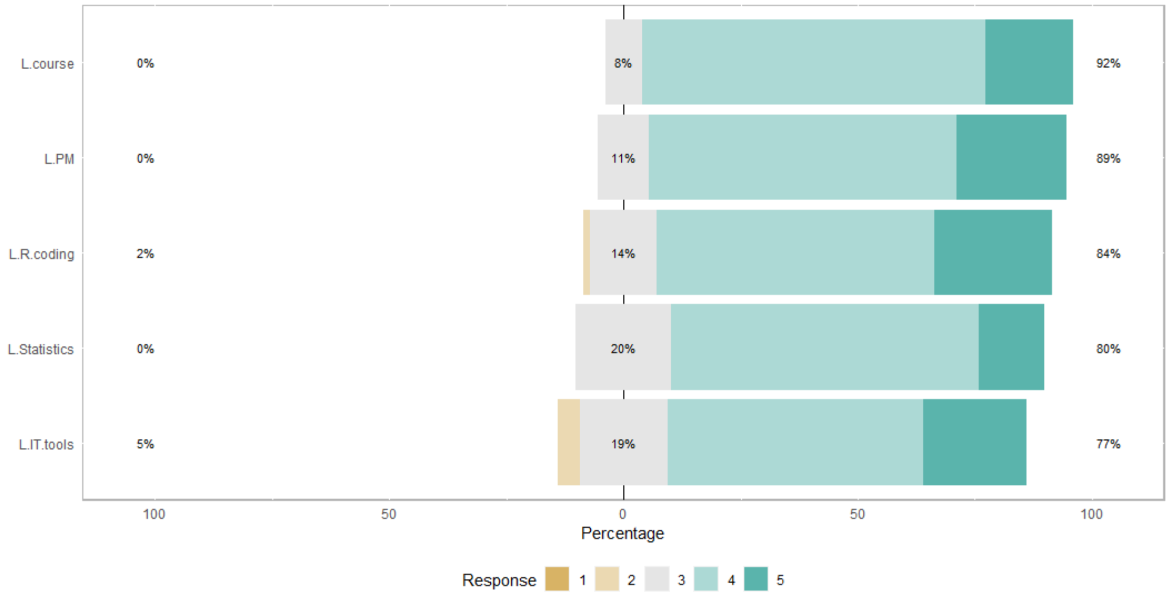

Figure 9. The divergent bar chart of the answers for the seventh set of questions related to the students' perceptions about their learning.

Results from qualitative data
Analyzing the data from the teams' website, we found the following recurrent themes (thereafter, RT):

RT1: The teams acknowledged that the course helped to learn Data Science, knowledge that would bring future career benefits
Through an analysis of the project's website, it became evident that all groups expressed a strong appreciation for the course, highlighting its significance in enabling them to acquire data science skills through the completion of the proposed challenges. Furthermore, they conveyed the belief that this acquired knowledge would be highly advantageous for their future careers and employment prospects.

One team's leader pointed out:

> The project was extremely important to us; we developed management skills, learned R software and Statistics. We think that these skills and knowledge will be crucial to our professional career development.

Another team's leader wrote:

> All team members agreed that the course experience was very enriching. Everything we learned (Statistics, R coding, team management) will give us a competitive advantage in finding a job.

RT2: The teams acknowledged that the course resources and the course management helped their learning

The students duly recognized the valuable contribution of the course resources, affirming their effectiveness in facilitating their learning experience. Furthermore, they expressed a strong affinity towards the comprehensive video lectures specifically addressing topics pertaining to Statistics. Notably, they emphasized the significance of the teacher's feedback, underscoring its instrumental role in addressing their queries and enhancing their conceptual understanding.

One team leader’s explained:

> The resources that we got from the course’s website were more than enough to improve our learning on Descriptive Statistics, Inferential Statistics and Regression. The teacher’s weekly feedback helped us to learn from our mistakes, which helped us not fall into the same errors in the following activities.

RT3: The teams acknowledged the importance of their learning

The students conveyed that the course held significant value for them, as it not only fostered their comprehension of project management principles but also facilitated the enhancement of their data science skills. Moreover, they acknowledged the acquisition of valuable teamwork abilities, including the capacity to deal with diverse opinions and perspectives.

One team member explained:

> The key learning, beyond learning Data Science, occurred when we faced problems; we developed skills in teamwork, communication, organization and collaboration. We learned to analyze different points of view and to reach consensus. We learned how to plan and replan, to analyze the project’s constraints and to use project management tools.

RT4: The teams faced problems (such as dropouts, communication problems, and lack of commitment) to different degrees along the project

The students communicated that the project presented various challenges, encompassing issues such as participant dropouts, inadequate commitment from team members, and diverse communication difficulties. These challenges exerted varying impacts on their respective projects. One team’s leader explained the problems with the dropouts and the lack of commitment:

> We had dropouts at the beginning of the course and one team member put little effort into the project's activities, increasing the burden for the other members.

Another team's leader explained the problems of communication:

> During the project we faced some communication problems (a few team members failed to participate in online meetings). Despite these problems, the project unfolded well, and we were able to accomplish the project's activities.

DISCUSSION

Based on the data related to the students' perceptions about teamwork (Figure 5) we may affirm that the more the students worked on the project activities, the more they developed their team working skills (Figure 10, feedback loop "Developing teamwork skills").

The data related to the students perceptions about their learning (Figure 9) revealed that they also developed their IT skills, since they made use of project management IT tools (such as the GanttProject software to plan and control the project) and website creator tools (such as Google sites, used to register the activities they have accomplished during the project. Therefore we may consider that there was also a feedback loop that led to the enhancement of their IT skills (Figure 10, feedback loop "Developing IT skills"). It is reasonable to conjecture that the development of teamwork skills -- added to the development of IT skills -- contributed to the development of their project management skills (Figure 10, feedback loop "Developing PM skills").

In addition, the students let us know (Figure 9) that they also learned R coding and Statistics. The qualitative RT1 (*the teams acknowledged that the course helped to learn Data Science, knowledge that would bring future career benefits*) reinforced the finding from the quantitative data. Therefore we conjecture that there was a feedback loop that led to the development of Data Science skills (figure 10, "Developing Data Science Skills).

Based on the evidence presented here, we may speculate that the four feedback loops described previously were driven by the addition of the competition component to a project-based learning centered course. The more motivated the students were to compete, the more they put effort into the project activities and in learning activities. In addition to that, the quantitative data (Figure 8) also revealed that the project-based learning approach created opportunities for the students to reflect about their learning and share their knowledge. Therefore we may speculate that there was another feedback loop related to the metacognition and knowledge sharing (Figure 10, feedback loop "Reflecting and sharing knowledge"). Reflecting on all the intertwined dynamics described previously, we came to our first finding:

> *The use of competition in a project-based learning centered course helped the students to develop project management skills (teamwork and IT skills), data science skills (Statistics and R coding) and provided activities that fostered metacognition and knowledge-sharing opportunities.*

This finding is aligned with the findings of other researchers (Issa et al., 2014; Willard & Duffrin, 2003) who pointed out that the combination of PBL and competition foster the development of 21st-century skills.

The data related to students' perception about the importance of what they learned (Figure 6) suggested that the students saw purpose in what they learned. Sense of purpose is one of the key components of intrinsic motivation (Fregni, 2019). Moreover, the motivation made them learn in different ways, such as by sharing knowledge with their peers, following professor's recommendations, and using IT PM tools. In addition, the qualitative data RT3 (*The teams acknowledged the importance of what they learned*) reinforces this insight. This led us to our second finding:

> *The Data Science Olympics increased the students' intrinsic motivation to learn.*

This finding is in accordance with the findings of other scholars (Lam et al.; Ocak & Uluyol, 2010) who pointed out the relationship between intrinsic motivation and learning effort in PBL-centered courses.

The data related to the course management (Figure 3) and the data related to the effectiveness of project-based learning approach (Figure 4) revealed that the professor's feedback, the course resources, and the professor's demands impacted positively on learning (we represented these positive impacts in Figure 10, by the exogenous variables "Effectiveness of PBL approach", "Learning resources" and "Following teacher´s demands"). This insight is reinforced by RT2 *(The teams acknowledged that the course resources and the course management helped their learning*). This led us to our third finding:

> *The project-based teaching practices (scaffolding the students learn, giving meaningful feedback to the students, and managing the activities) facilitated the students' learning.*

This finding is aligned with the findings of other scholars (Cable & Cheung, 2017; Larmer & Boss, 2018) who pointed out the importance of scaffolding the learning environment and giving prompt feedback to the students (Moallem & Webb, 2016).

On the other hand, RT4 (*The teams faced problems (such as dropouts, communication problems, lack of commitment, difficulties to schedule online team meetings) to different degrees along the project*) helped us to understand that the students also had problems that impacted negatively on their motivation (these negative impacts are represented in Figure 10, by the exogenous variables "Dropouts", "Lack of commitment," "Communication problems" and "Planning problems"). This led us to our fourth finding:

> *The problems the students faced throughout the Project (dropouts, communication problems, lack of commitment, difficulty to schedule online team meetings) impacted negatively on the students' motivation.*

This finding is aligned with the findings of other scholars who also pointed out problems caused by dropouts in online courses (Nistor & Neubauer, 2010). It is also aligned with the findings of researchers (Aksela & Haatainen, 2019; Arantes do Amaral, 2020) who pointed out problems that students face in PBL-centered courses (such as lack of commitment of team members, conflicts, and problems of communication between team members). We conjecture that this problem could have been mitigated if students had had a better participation in the synchronous online meetings and had been more committed to following the projects of the other teams.

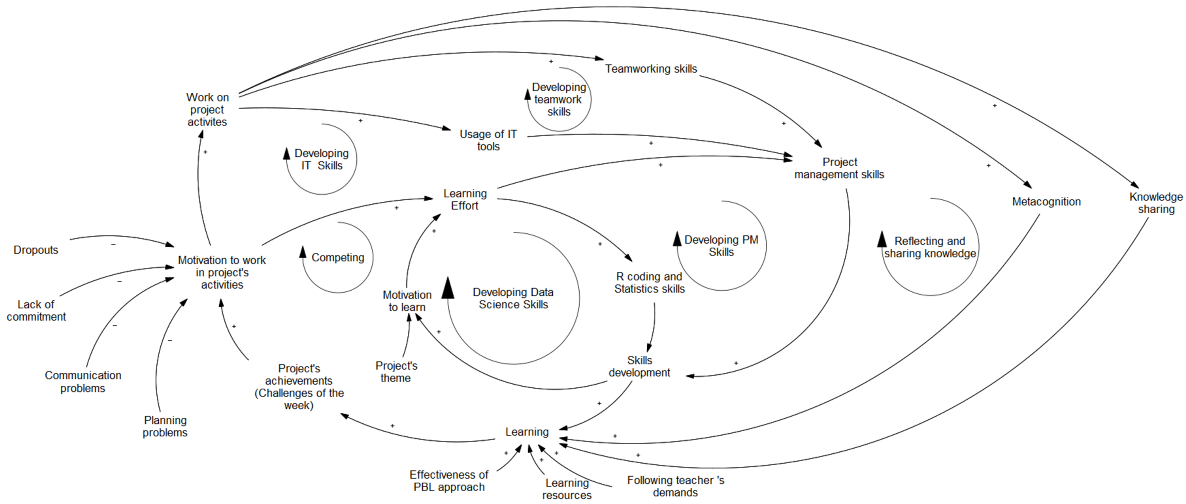

Figure 10. The course driven dynamics.

CONCLUSION

So, what did we learn from this experience?

Coming back to our research question (*What are the systemic impacts of using competition to improve the students' learning in a project-based learning-centered* *course?)* we identified that the competition triggered five dynamics: the development of Project Management skills, the development of Data Science skills, the development of Teamwork skills, the development of IT skills and the improvement of the knowledge sharing and reflection.

The project theme, Data Science Olympics, was indeed a good choice. It increased the students' motivation to learn and the project was a playful experience for the students. Moreover, the course helped the students to retrieve information from the previous course (Statistics), which fostered long-lasting learning. In addition, the course increased the students' intrinsic motivation, since they perceived that the learning that they experienced would be helpful for their future careers. We can affirm that the university's rule of making the participation in synchronous activities optional impacted negatively on the course since only four of the sixty-four students participated in our synchronous activities. We recognize that the University rule was necessary since it aimed to protect the students who, for problems related to the pandemic or problems related to technology, could not attend the meetings. However, we speculate if they had participated, the learning would be even better.

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APPENDIX-1

Group One: Questions about the lack of participation in synchronous activities	
Closed-ended Questions	Identifier
1. I didn´t schedule meetings because I felt there was no need for it.	P.no.need
2. I didn´t schedule meetings because I was too busy with other courses.	P.too.busy
3. I didn´t schedule meetings because I had no doubts.	P.no.doubts
4. I didn´t schedule meetings because the professor's feedback clarified my doubts.	P.prof.feedback
5. I didn´t schedule meetings because I am tired of synchronous meetings.	P.tired.meetings
Group Two: Questions about the course management	
Closed-ended Questions	Identifier
1. I think the course´s workload was fair.	CM.workload
2. I think the amount of topics covered was adequate.	CM.topics
3. I think the professor's demandingness was adequate.	CM.demandingness
4. I think the resources available (video-lectures, books) were adequate.	CM.resources
5. I think the professor´s feedback was adequate.	CM.prof.feedback
Group three: Questions about the effectiveness of the project-based learning approach	
Closed-ended Questions	Identifier
1. The knowledge sharing between team members improved my learning experience.	PBL.knowledge.sharing
2. The research I did to solve the weekly challenges improved my learning experience.	PBL.research
3. Working in this project helped me to learn/remember Statistics and R programming.	PBL.skills.R.Statistics
4. Working in this helped me to improve my project-management skills.	PBL.skills.PM

5. Working in this project improved my skills to work in future real-life projects.	PBL.real.project
Group four: Questions about the teamwork	
Closed-ended Questions	Identifier
1. Teamworking was a pleasant experience.	TW.pleasant
2. The team members worked in harmony.	TW.harmonious
3. All the team members put effort on the project activities.	TW.project.activities
4. All team members contributed equally to the accomplishment of the Challenges of the week.	TW.challenges.week
5. All team members helped each other in moments of difficulties.	TW.help.others
Group five: Questions about the importance of what they have learned	
Closed-ended Questions	Identifier
1. What I have learned about project-management will be important to my professional life.	IMP.learn.PM
2. Learning Statistics and R will be important to my professional life.	IMP.learn.R.Statistics
3. What I have learned about team working will be important to my professional life.	IMP.learn.teamwork
4. What I have learned in this course will help me in other courses.	IMP.help.other.courses
5. What I have learned in this course will help me to get a job.	IMP.learn.get.job
Group six: Questions about the learning effort	
Closed-ended Questions	Identifier
1. I put effort into studying all course materials (readings, video-lectures, etc.)	LE.study
2. I put effort into following the professor´s recommendations.	LE.recommendations
3. I put effort into accomplishing the project’s activities.	LE.project.activities

4. I put effort into following the other teams' websites.	LE.peers.projects
5. I put effort to accomplish the Challenges of the week	LE.challenges.week
Group seven: Questions about the ways that the students learned	
Closed-ended Questions	Identifier
1. I learned more when I wrote about my learning	WL.metacognition
2. I learned more when I discussed the project's activities with my team members.	WL.sharing.ideas
3. I learned more when I attended the professor´s demands	WL.recommendation s
4. I learned more when I followed the other teams' website	WL.peers.projects
5. I learned more when I made use of IT tools (such as project management software)	WL.using.IT.tools
Group eight: Questions about what the students perceptions about their learning	
Closed-ended Questions	Identifier
1. I think my learning about Project Management was adequate.	L.PM
2. I think my learning about Statistics was adequate.	L.Statistics
3. I think my learning about the use of IT tools was adequate.	L.IT.tools
4. I think my learning about R coding was adequate.	L.R.coding
5. I think my learning in this course was adequate.	L.course

*The possible answers for each-closed ended questions were:

1. Strongly disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly agree

Journal of
Problem
Based
Learning
in Higher Education

VOL. 11, No. 3, 2023 – Page 25-43
10.54337/ojs.jpblhe.v11i3.7527

Students in Early Childhood Teacher Education and Their First Experience With Problem-Based Learning: A Comparative Study From the Perspective of Students in Kyrgyzstan and Norway

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ABSTRACT

This comparative study examines how students from Early Childhood Teacher Education in Kyrgyzstan and Norway value their first experience with Problem-Based Learning. The study is a result of the collaboration between ECTE in Kyrgyzstan and Norway focusing on student-active learning. The research is important because there are few if any studies focusing on PBL in Early Childhood Teacher Education (ECTE), and little use of PBL as a basic norm in Kyrgyzstan. Our data consists of students' anonymous, written, open-ended questionnaires. These are analysed by means of qualitative content analysis. We found evidence that students value collaboration, and in this report, we describe their experiences with the PBL-method and suggest some implications for the quality of learning. We discuss and compare similarities and differences in students' experiences in light of cultural differences.

Keywords: Comparative study, Cultural context, Early Childhood Teacher Education, PBL

INTRODUCTION

The study is a result of a Eurasia-funded collaboration between Early Childhood Teacher Education (ECTE) in Kyrgyzstan and Norway focusing on student-active learning. We present a comparative study involving ECTE-students from International University of

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Central Asia (IUCA) in Kyrgyzstan and NLA University College (NLA) in Norway following the students' first experience with Problem-Based Learning (PBL). It is a comparative study using qualitative content analysis of students' anonymous, written, open-ended questionnaires collected in 2018 and 2019. As researchers, we represent private universities from two different countries and cultures.

The significance of the study concerns PBL used in ECTE. On a national level, the study introduces PBL into a Kyrgyz setting. A search for English- and Russian-language research articles on PBL in Kyrgyzstan reveals few studies on PBL in the medical sphere. It seems that neither theoretical nor practical aspects of the PBL approach have been researched and implemented within the educational system of Kyrgyzstan.

On an international level there is a substantial number of research articles on PBL in general and connected to higher education. There seems to be a general lack of research on PBL in Early Childhood Teacher Education. There are international studies on PBL and School Teacher Education from 1980 onwards, which are confirmed in literature reviews (Borhan, 2014; Rahmawati, Suryani, Akhyar & Sukarmin, 2020). In Norway PBL has mainly been developed and researched in the context of medical and social education. We have found three reports on PBL-projects in Norwegian teacher education (Nes & Strømstad, 1999; Helland 2004, 2007). This article is a contribution to research connected to PBL in ECTE, focusing on student experiences in different cultural contexts.

Our research question is the following: *How do students from Early Childhood Teacher Education in Kyrgyzstan and Norway value their first experience with Problem-Based Learning?* The paper will present similarities and differences in students' experiences of PBL in the light of the cultural and pedagogical context of ECTE.

NLA University College has had an interdisciplinary bachelor-programme based on PBL and the 7-step model (Pettersen, 2017, p. 66) as its main teaching and learning strategy in all disciplines of the ECTE since 1999. This means that all subjects every semester are taught interdisciplinary, as an integrated totality. From 2013 to 2022, there were staff and student exchanges between IUCA and NLA. The goal of the collaboration is to strengthen student-active learning and critical thinking in both countries. The Norwegian teacher-researchers have taught master classes on PBL with Kyrgyz students and developed workshops with staff, focusing on facilitating PBL-tasks. The IUCA-staff were less experienced in facilitating PBL, compared to the NLA-staff. Today IUCA staff are emphasizing the facilitation of PBL in their education programs.

There are differences at the state level in official laws and regulations on ECTE in Kyrgyzstan and Norway. The Norwegian government has enacted an overarching political decision relating to universities and university colleges (*UH-loven*, KD, 2015), and in addition a *Framework Plan* and *National Guidelines* for ECTE (KD, 2012; UHR, 2018). The Norwegian Educational Department has, in its report to Parliament (KD, 2017), recommended PBL as student-active learning, suitable for engaging and activating students and for promoting critical thinking (pp. 52-53). The collapse of the Soviet Union induced contradictory changes in the further development of Kyrgyzstan. National reforms for quality in education have encouraged new attitudes in the field of education. The state educational standards *Educational activities of the university* (Ministry of Justice, 2021) impose requirements on higher professional education. IUCA education is governed by local institutional regulations.

The promotion of PBL risks implementing a western learning strategy in a non-western culture (Gwee, 2008; Frambach, Talaat, Wasenitz & Martimianakis, 2019; Naji, Ebead, Al-Ali & Du, 2020). Research points to Asia as having a strong tradition for the authority of tutors and hierarchy of age and education (Gwee, 2008, p. 20). This is comparable to Central Asia in general, whilst on the other hand IUCA has a will to focus on democracy and strengthening their student's citizenship.

THEORY AND RELATIONSHIP TO PREVIOUS RESEARCH

In this section, we will present theory and previous research relevant for our research question. We assume that our readers are familiar with the basic theory on PBL. To be able to discuss the findings we also find it important to investigate research carried out on PBL in different cultural contexts.

Problem-Based Learning (PBL)

Although the PBL method was originally designed for medical schools, it has been adopted in diverse fields and educational environments to promote the use of authentic tasks, problem-solving, critical thinking and analysis, self-directed learning, and small-group collaboration (Nilson, 2010). In brief, PBL is a student-active approach that makes a fundamental shift from a focus on teaching to a focus on learning and the forming of habits through practice and reflection (Barrows, 1994). The process enhances students' learning, motivation and participation. Students and tutors are encouraged to work co-operatively and to become co-learners, co-planners, co-producers, and co-evaluators. The principal role of teachers is to provide the educational materials and to be a facilitator or a tutor monitoring the learners.

The PBL-method is grounded in social constructivist theories of learning, in which the individual and social aspect of learning is essential. The constructivist perspective on learning focuses on knowledge as individual interpretation of reality (Pettersen, 2005, p. 76). Savin–Baden & Major (2004) explain that a PBL-course gives the students "the opportunity to construct knowledge for themselves, to make comparisons with other students' knowledge and to redefine knowledge as they gain experience" (pp. 29-30).

Collaboration is thus an essential part of PBL, where learning communities participate and work closely on a common task, sharing, negotiating, and constructing new knowledge (Pettersen, 2017, p. 36). Collaboration is also important for team learning in PBL. Students' engagement is a crucial part of their success or failure in PBL work (Savin– Baden & Major (2004, pp. 74-77), and the approach requires communication, acceptance and mutual support on the part of all participants. «Collaborative learning is a pedagogy that has at its centre the assumption that people make meaning together and that the process enriches and enlarges them» (Matthews, 1995, p. 101). The ability to solve conflicts is necessary. Students must be able to make decisions together, attend to the perspectives of others, and question evidence as well as each other`s assumptions (Savin-Baden & Major, 2004, p. 73). This is knowledge acquisition with mutual responsibility. In the collaboration, a PBL-group also must utilize the skills of critical thinking, communication, creativity, problem solving and perseverance in the group and in the learning situation.

Another essential component of PBL is reflection. Barrows & Tamblyn (1980) point to the importance of reflection by saying that learning happens through solving problems and reflecting on the experiences. Reflection gives students an opportunity to talk about their experiences and to discuss how they can improve their skills. Grüthers (2011) describes reflection as challenging one's way of thinking, and points to the danger of taking everything for granted. She associates this with self-reflection, the ability to view and to evaluate ourselves (p. 74). Klemp (2013) seems to agree with this when she points at the necessity of taking a second look at things and thereby sharpening our thoughts. These reflections might be done both individually and in the PBL group.

Research on PBL in a cross-cultural context

This study examines the use of PBL among novice students on two different continents with different educational traditions. It is therefore relevant to search for research in a cross-cultural context. The research we present below is either from non-western countries or conducted within a cross-cultural student-group.

In the following, we will present some research from an international perspective (Gwee, 2008; Mohd-Yusof et al, 2013; Fung, 2013; Frambach, Talaat, Wasenitz & Martimianakis, 2019; Naji, Ebead, Al-Ali & Du, 2020).

Frambach, Talaat, Wasenitz & Martimianakis (2019), raise questions about the spread of PBL globally, arguing that it promotes a Western imperialist or neo-colonialist agenda (p. 932). They point to the challenges of "financial costs, physical requirements, demands on human resources” etc. (p. 934).) The PhD thesis by Fung (2013) also highlights the importance of the cultural context, saying, “it is paramount to consider cultural background when introducing an innovative education model” (p. 7).

Matthew Gwee from Singapore tries to identify the major challenges in implementing PBL in Asia. He points to the tradition in which the teacher has great authority within a social hierarchy based on age and education (2008, p. 17). This might make students avoid discussions and hesitate to make critical comments. On the other hand, Gwee (2008) points out, “The Asian culture emphasizes group before individual interest, including a group-oriented approach to the achievement of tasks” (p. 20). He thinks this is consistent with the aim of collaborative small student groups and underlines the importance of a safe environment, pointing to findings indicating that this is more important than culture in teaching and learning (p. 19).

Mohd-Yusof et al. (2013) point to the fact that western countries such as Denmark, score moderately low on Power Distance and Uncertainty Avoidance (Hofstede Insights, 10.11.2021): “Consequently, it is common for students to discuss among themselves topics and share their knowledge in collaborating on a problem or even to argue with a teacher” (p. 9). In data from Kazakhstan, we see a higher Power Distance and Uncertainty Avoidance. “In other cultures, with a higher Power Distance or a more masculine competitive nature such behaviour is much less natural or may even be unacceptable” (Mohd-Yusof et al., 2013, p. 9).

There seem to be few research articles on PBL in Central-Asia and in Russia, and none on PBL in ECTE. A website of the Osh International Medical University (Kyrgyzstan) indicates that their curriculum includes PBL (08.06.2022). Kapitonova et al. (2020) describe how PBL is introduced in medical universities in post-Soviet countries, among them Kyrgyzstan: “contributing to the optimization of the educational process”. In Azerbaijan, PBL is presented in management education (Mammadova, 2020).

There is a lack of comparative studies on PBL conducted on different continents with different educational traditions. This study answers the need for a cross-cultural comparative study investigating ECTE-students’ experiences with PBL.

METHODOLOGY

Analysis of responses from students in different countries requires consideration of the cultural background of students. In this chapter, we will present the epistemic framework and the methodology of a comparative study. The chapter will also present our choices, ethical considerations, and the analytic design.

Bray, Adamson & Mason (2007) say, “Rather than a mechanical identification of similarities and differences between two or more places it is suggested that attention be paid to the underlying context of these commonalties and differences, and to their causal relevance to the educational phenomenon being examined” (p. 88). This study therefore conducts analysis at both national and institutional levels (3.1) and will consider the cross-cultural and the educational context of the student groups. Stephens (2009) states, “the validity power of qualitative research depends on the researcher’s ability to […] establish cross-cultural comparisons and contrasts” (p. 6).

The validity of this study might be challenged, given the differences in culture, variance in students’ earlier learning experience, and complex linguistic landscape involving the use of English, Russian and Norwegian (see 3.5). Despite these factors, it is interesting to investigate how novice students with these different cultural and educational backgrounds experience their first meeting with PBL-tasks. At IUCA, both visiting and local professors use a language that is not their own mother tongue in their communication with each other. This practice extends to interactions with students as well. Words might have different meanings in different cultural contexts.

The questionnaires were written in English at IUCA and Norwegian at NLA. The IUCA-students could answer in Russian or English. Russian is the mother tongue for some of the IUCA students, but for others the mother tongue is Kyrgyz. All the questionnaire responses were translated into English from Russian or Norwegian by professional translators. We cannot know how or if the translation influences our understanding of the text, but we have cross-checked the translation with the original language of the text.

Epistemic frame

This is a comparative educational study using qualitative content analysis with student responses. Analysing data from different cultural contexts opens for different levels of analysis. We will conduct our analysis at the national level of two countries, the institutional level of two universities and the student-group-level.

ECTE-students from both Kyrgyzstan and Norway answered open-ended questionnaires right after they had finished their first introduction to PBL and their first PBL task. To ensure professional relevance, students were presented with a case relating to everyday life in a local ECEC either in Kyrgyzstan or in Norway. The 70 students from Norway (surveyed in 2019) were first-year bachelor-students, in the first weeks of their study. The 26 students from Kyrgyzstan (surveyed in 2018 & 2019), were a mixture of college students and first- to third-year bachelor students. The numbers in the student groups also differed, with seven in Norway and three to four in Kyrgyzstan. The local university professors attended as PBL-mentors in both institutions, but at IUCA, the visiting professors attended together with local staff. At NLA, students were given four weeks for their PBL-task, while at IUCA they had one week. These differences might have affected some of the responses and thus present a challenge to the validity of the study.

The questionnaires in 2018 and 2019 had multiple questions. We have chosen to focus on the three questions that are similar in both questionnaires, and which we consider central to the comparison of the ways in which PBL is understood. These questions focus primarily on the students' experience of their first PBL task. They evaluate the method and the quality of the group work and compare PBL to other learning methods.

The questions are:

1. How did you experience PBL as a student active learning method?
2. List at minimum two challenges and two joys connected to the PBL-work in your group.
3. How would you describe the quality of learning from a PBL process, as compared to other methods of learning?

Comparative study

This is a comparative study at a micro level with a focus on student experiences (Stephens, 2021; Kosmützky, 2018). An overall definition of comparative research might be "empirical research that collects data and/or carries out observations across national, geographical, and cultural boundaries in at least two of such entities, and systematically relates those entities in a comparative analysis" (Kosmützky, 2018, p. 1). Having data from educational settings in two continents, we find it important to consider Wahlström, Alvunger & Wermke's (2018) reason for a comparative education study: "The comparative research approach is viewed as a response to the internationalization of education policy while simultaneously recognizing that education is a highly regional and local activity" (p. 587). In our context, we recognise that "curricula differ significantly between national arenas because different national contexts offer various traditions and structures" (Op.cit. 2018, p. 593).

Qualitative content analysis

To understand and analyse our data we have used content analysis to determine the presence and relationships of words and statements in the student answers. These are elaborated and categorised into codes (Colombia Public Health, 2022). A text involves multiple meanings, and there will be some degrees of interpretation meeting the text (Graneheim & Lundman, 2003, p. 106). Krippendorff (2013) writes that such interpretation is necessary in order to make a valid inference with a text (p. 24). We took into consideration the translation of languages used by the students and the differences in educational contexts, to establish cross-cultural comparisons and contrasts (Stephens, 2009).

We then searched for visible, manifest content in the answers to each question separately (Graneheim & Lundman, 2003, p. 106), and immersed into the data to find meaning units and categories of interest for the research question (Graneheim & Lundman, 2003, p. 107). According to Graneheim & Lundman (2003), this constitutes the "what" of the data (p. 107). Going deeper into the analysis, we tried to answer the "how", finding codes and the underlying *latent* content (op.cit. p. 106). We analysed one question at a time and then looked for links between meaning units in our data.

Analytic design

All the attending students answered the questionnaires, with 70 students from NLA and 26 from IUCA. Answers from each student-group were systematized in tables for each of the questions. Next, we searched for meaning units in the responses before developing the codes. Based on the differences in group-sizes, we calculated the percentage of responses from each student-group.

Table 1 illustrates the process of developing the codes (Granheim & Lundman, 2003), showing some of the 'meaning units' extracted from student answers in the questionnaire. The meaning units are condensed before they are categorised and coded. Table 1 exemplifies meaning units (student answers) ending with codes.

Question	Meaning unit	Condensed meaning unit	Code
1: How did you experience PBL as a student active learning method?	*The students discuss more, so the students therefore become more active* (NLA).	Discuss and being active	Collaboration
	This method helped me to make up specific questions to a problem, and to find solutions (IUCA 2019).	Problem-solving	Evaluating the PBL method
2: List at minimum two challenges and two joys connected to the PBL-work in your group.	*Coming to consensus was hard* (IUCA 2019).	Difficult to reach joint agreements	Collaboration
	Challenging that it takes a lot of time (NLA).	Time-consuming	Problems connected to the method

3: How would you describe the quality of learning from a PBL process, compared to other methods of learning?	*Using PBL makes you more active and involved* (NLA)	Involvement and collaboration	Active and reflective collaboration
	This method gives us the opportunity to properly solve a problem, and to set up our own specific goals. (IUCA 2019).	Finding help to solve problems/ set goals	Problem-solving

Table 1. Examples on the steps from question to codes.

Many of the meaning units and codes correspond across the questions, as illustrated in Table 1. The meaning units for the first question ("How did you experience PBL as a student active learning method?") were extracted into the following categories: *collaboration, evaluating the PBL method* and *learning outcomes*. From the second 'question' ("List at minimum 2 challenges and 2 joys connected to the PBL-work in your group."), the categories extracted from 'challenges' were: *collaboration and problems connected to the method,* and from 'joys', we found the categories: *collaboration, PBL as a method* and *learning outcomes.* To the third question ("How would you describe the quality of learning from a PBL process, compared to other methods of learning?") we found the categories: *active and reflective collaboration, problem- solving, improving the quality of learning* and *problems connected to the method*.

We will present the categories from the analysing process gathered in 4.1 – 4.3 as the codes *Collaboration, Valuation of the PBL-method* and *Quality of learning*.

Ethical considerations

It was a voluntary task to answer the questionnaires, which were answered with the researchers present. The questionnaires are all written on paper anonymously. It is not possible to trace an answer to a specific student, and the study is in line with the Norwegian national guidelines for research (Sikt). We did not ask for gender in the questionnaire because only the Norwegian university had male students and being a minority, they could be more easily identified.

It is also an ethical consideration to let the students answer the questionnaires in their 'mother tongue', making it easier to make a precise and honest answer. At the same time, we know that for some Kyrgyz speaking students Russian is their second language, and Norwegian students might be bilingual. This is not registered in the questionnaires but might affect the findings.

The data, the analysis and the discussions must be treated with respect for different cultural and educational contexts. As researchers, we represent the two involved countries and therefore have an insider knowledge of the different cultures.

FINDINGS AND DISCUSSIONS

The research question in this study is *How do students from Early Childhood Teacher Education in Kyrgyzstan and Norway value their first experience with Problem-Based Learning?* The responses reveal some similarities and differences in the students' perspectives. Analysing the questionnaires, we find that the students experience both advantages and disadvantages of PBL. The discussion to follow will take into consideration theory, earlier research, and the cultural context.

Collaboration

Savin–Baden & Major (2004) point to different social skills that are required of members of a PBL group (p. 73). These skills are important for collaboration, as they enable members to communicate clearly, to accept and support other team members, to resolve conflicts, to make decisions, and to elicit each other's viewpoint and perspectives.

Collaboration is an important code in our findings, connected to all three questions. We find a similarity at the student-group-level, with mostly positive responses on collaboration. The students in both groups report on different aspects by expressing how they value working in teams, being active when learning together, sharing knowledge and ideas, and discussing and looking for links between theory and practice.

Working together in groups requires students to take substantive responsibility and collaborate in order to discover, understand, and produce new knowledge (Davidson & Major, 2014, p. 21). Students from both countries report that they share new knowledge and ideas by being active when learning together. One student reports getting "new insight and new knowledge" (NLA) and another says, "we maybe learn better in that we actively discuss, argue and brainstorm" (NLA). Student quotes emphasize that they appreciate sharing knowledge. One student says, "[…] we get to discuss and talk together, hear each other`s point of view" (NLA 2019), and another says: "it activates our vocabulary, develops our critical and deep thinking" (IUCA, 2019). The majority of students in both groups indicate that they learn from each other and develop their knowledge in their groups. This is what Matthews (1995) describes as a collaborative learning process where students make meaning together in a process that enriches and enlarges them.

We find quotes that focus on students' engagement as crucial for success or failure in their PBL work (Savin– Baden & Major (2004, pp. 74-77). Students point to PBL as "a good method that allows everyone to participate" (NLA), and report that "sharing thoughts was very interesting and informative" (IUCA 2018). They also made statements like "each of us help, support, and add something important" (IUCA 2018). Regarding challenges, the NLA-students report that "some people don`t participate much" and that it was difficult "getting everybody on board" and that "some people didn`t care and didn`t want to take part anymore" (NLA). 28.6 % of the NLA students report challenges with collaboration, while 7.7 % of the IUCA students report the same. This might be explained by the difference in the number of students in each PBL group and the difference in the duration of the PBL work, one versus three weeks. The differences might also be due to cultural factors connected to Kyrgyzstan being a post-Soviet society that values common goals and group loyalty, whilst in Norway we are seeing a development from community-centeredness towards individualism. The Kyrgyz students' respect for visiting professors might also be reflected in their commitment to their work (Gwee, 2008).

Students from both groups, 19.2% from IUCA and 10% from NLA, express that it is challenging to understand PBL as a method and to follow the steps. This might be due to PBL being a new method and for the Kyrgyz students also language challenges.
The cases given as PBL tasks are stories collected from real life in ECEC in each country. This gives students an opportunity to connect theory and practice, and many students see this as a benefit of PBL-learning. They make statements like: "[…] it matches very well to our life" (IUCA 2019), "I learn more from raising things that you can actually experience" (NLA). Positive comments on cases connected to life in ECEC are given from both institutions, like this from IUCA (2019): "The method really makes it possible to touch upon important problems and situations that may arise in the process of raising children".

At an institutional level, we find that 5.7 % of the Norwegian students express that they preferred lectures to PBL, but we do not have similar findings among the IUCA students. It is difficult to conclude as to why students respond differently, but it might be connected to cultural differences and to PBL being a new method presented by visiting professors at IUCA. The students may have found it inappropriate to wish for a different method for teaching in this situation (Gwee, 2008).

Valuation of the PBL method

A similarity in the students' answers is that many respondents value the PBL-method as effective for the learning process. They say, "PBL is more practical compared with other methods" (IUCA 2019), "Much better than seminars. You dare to say more in smaller groups. (NLA), "Hundred percent quality. I can't remember such method which can help so good dissemble a situation" (IUCA 2019), "If you use PBL right, you learn better" (NLA) and "PBL method is very convenient and practical" (IUCA 2019).

The students discovered that the method helped them to become better at formulating research questions and finding solutions to a problem together. According to Savin-Baden & Major (2004), students are motivated to experience PBL, but each of them must provide their own thoughts to contribute to group discussions (p. 151). Murray-Havey, Poushafie & Reyes (2013, pp. 128-129) write that s*tudents' experience* of PBL-work makes them responsible for finding a research question. We have found students saying, "[…] from one small situation we were able to set up a few final results. We divided our problem into several categories and chose one final aim" (IUCA 2019) and "PBL forces me to think for myself and in collaboration with others" (NLA).

As mentioned, the IUCA-students were obliged to use a foreign language (English) in the PBL process, with visiting professors from Norway. IUCA-students commented on linguistic challenges. A difference in responses shows up at both an institutional and student-group-level because the IUCA-students had to use English to express their opinions in order to be heard and understood by others on an appropriate level (cf. Fung, 2013, pp. 115-117). They say, "I learned to […] present a presentation correctly" (IUCA, 2018), "Activate our vocabulary" (IUCA, 2018) and "It taught me to quickly generate my ideas" (IUCA, 2019). According to Gwee (2008, p. 20), one reason why Asian students do not participate actively in discussion may be the lack of language proficiency. The NLA students spoke their mother tongue but nonetheless report other kinds of challenges with language and understanding: "Finding words and terms. Putting together words and different categories" and "Good to be able to discuss and share good ideas".

A *difference* at the student-group-level is that 24.3 % of NLA-students comment on PBL being time-consuming. This corresponds to Grigg and Lewis (2018, p. 10) who find that students view time-management in PBL as being challenging and time-consuming. There are no comments on time-management from IUCA, which might be because of differences in the time allowed for the PBL tasks.

Students from the two institutions comment on PBL and problem solving from slightly different perspectives. NLA students say, "Difficult to find a problem. Can be difficult to understand" while a typical IUCA-response is "I thought it was hard to work on the steps, but it led to a good result" (IUCA 2019). From a slightly more positive angle, students also respond, "We get to thoroughly look at a problem and discuss it with one another" (NLA), "This method has step-by-step solutions. It has criteria that help solve a problem" (IUCA 2019) and "PBL work helps me to find connections inside the problem and organize them by order (IUCA 2019).

The student's responses reflected both cultural attitudes and peculiarities of their learning experience. The IUCA participants expressed their experience of the PBL method in less critical ways. This is probably due to their learning backgrounds at a national level where they are used to accepting their educators' knowledge with a 'blind respect' for their tutors (Gwee, 2008, pp. 17-18). After 10 years of school experience with a tradition of teacher-centred learning, 2-3 years of studying at IUCA with a focus on individual learning and student independent work may not be enough to change their learning attitude entirely.

Norwegian students are accustomed to expressing their likes and dislikes to their professors, and schools invite them to evaluate their learning outcomes on a regular basis. Despite these differences, we think that students from both countries might find it difficult to assess and criticize their professors' statements.

Quality of learning

The students in both institutions mention quality of learning as an important factor. As pointed to earlier, the majority mentions educational aspects and how they learn to find solutions. This section focuses on the students' responses to understanding and reflection, and how they value their importance for learning. It shows that the Norwegian students have a more critical view of PBL and its quality of learning than the Kyrgyz students do. It is difficult to ascertain whether this is due to national or institutional levels of cultural differences or to differences at the student group level.

The NLA-students point to the quality of learning by describing PBL as improving "the quality of learning, compared with lectures and seminars". Others say that "active participation results in good learning", and that "I learn more by talking with others" (NLA). A few NLA-students express doubts about the quality of their learning in PBL, asking if the answers are good enough, and one student expresses: "[…] don't always know what's right or wrong". This is consistent with current research. Savin-Baden and Major (2004) write of students being afraid of falling behind in learning when they use PBL (pp. 81-92), and Naji, Ebead, Al-Ali, and Du (2020) find that inexperienced students were uncertain of being on the right track (p. 9). It is a fundamental feature of PBL-tasks that there are no solutions that are correct or incorrect (Barrows, 1994, Pettersen, 2017, p. 13) and PBL-work demands new responsibilities and roles for the students (Savin-Baden and Major, 2004, pp. 81-82). These uncertainties are integral to PBL, and this may be difficult for inexperienced students.

Students also report on PBL as a method for reflection. Grüters (2011) states that reflection challenges the thoughts that we take for granted, and Klemp (2013) points at the necessity to look at things once more and thereby sharpen our thoughts. In our data, we find that NLA-students mention *reflection* multiple times. Kyrgyz students express the same with slightly different terms: "develops our critical and deep thinking" (2018). On the student-group-level, we see a similarity in this attitude towards reflection and critical thinking. On an institutional level, we see that 'critical thinking' is stressed as very important at IUCA. *Reflection* is a strong educational keyword on both a national and an institutional level in Norway and at NLA. An NLA-student responded that PBL is a "good arena for reflection […]. Makes you aware of what you believe – your attitudes [and] values". Other NLA-respondents say that it is good for reflection because it "makes us think for ourselves and reflect to get a broader understanding" and "get students to reflect and brainstorm" and to "achieve more reflection. Arrive at more than just the first and best answer". Reflection and evaluation of the PBL tasks and the quality of the group work are according to Savin-Baden and Major (2004) crucial for the learning process. We find this on both the institutional and the student-group level.

CONCLUSIONS AND IMPLICATIONS

We have pointed to gaps in existing research and find that our study contributes to these. Specifically, the gaps are connected to the use of PBL in Early Childhood Teacher Education and research on the use of PBL in Central-Asia. There is also a need for more comparative studies on PBL conducted in different continents with different educational traditions.

This study involves two countries with dissimilar historical backgrounds, cultural contexts, and educational approaches and philosophies. Despite the differences in earlier learning experience and language challenges, we find many similarities in the students' evaluation of PBL. Students express a largely positive attitude to their learning with PBL, highlighting collaboration, valuation of the method and quality of learning. The reason for the similarity in their evaluations can be seen in the students' remarks indicating that they recognise a connection between their given case and their future occupation (see 4.1).

The main differences between the NLA and IUCA groups seem to be on the national level, where we find that Norway has the most detailed academic regulations specifically concerning ECTE and student-active learning. There seem to be more cultural and educational differences on the national level than on the institutional level. Being a comparative study at a micro-level, the validity of this study is at a student and institutional level.

Institutional and political implications

This study has institutional as well as political implications. Students' responses show that they value PBL as a tool to promote their learning process, but at the same time comment on problems with understanding the PBL-method. NLA started to use the 7-

step-model (Pettersen, 2005) in their PBL-approach in 1999. Over a period of more than twenty years, NLA has developed this model to serve their ECTE. The model is being used at IUCA now.

We see that IUCA and NLA can strengthen student-active teaching and learning, and by doing so provide tools that can strengthen an interdisciplinary ECTE-education. At NLA, our study found critical evaluation of the size of the student-groups, difficulties in getting everybody to participate, and time-management. This means that NLA needs to reconsider its quality of instruction, group structure and size, and time management. For IUCA the use of PBL and the student responses has led to the creation of a new course, entitled Problem-Based Learning. For both institutions, these findings call for a further development of PBL as a student-active learning strategy.

A political implication of the study might be that the experiences with PBL in Early Childhood Teacher Education provide a tool for the professional development of Early Childhood Teachers. PBL gives the students experience in identifying and solving problems, which are relevant for their future profession.

Limitations and potential for further research

This study has its limitations. It is a comparative study on a micro level and does not answer for institutional or political levels in the two countries and it does not take into consideration the whole continents of neither Asia /Central Asia nor Europe. We are aware that there are many different models that exist within Problem-Based Learning and as mentioned in the introduction, the PBL-tasks in this study use only the 7-step model. This comparative study includes the experiences of PBL for a limited time sequence for the students involved, and it would be interesting to do a more long-term follow-up study with new students using PBL.

Another follow-up study can be to interview graduated students who attended the 2019-study and investigate the possible impact on their learning outcomes in retrospect, in their current work as Early Childhood Teachers. Further research on PBL in an intercultural context can involve video- documentation of student groups of both countries discussing their experience with PBL online.

In our study, we find that students comment on skills they have developed during the PBL-tasks. Many of these skills correspond to the 21st-century skills of OECD (2008): Critical thinking, Communication, Creativity, Problem-solving, Perseverance, and Collaboration. The 21st-century skills aim for worldwide impact, reaching across cultures and continents, and are therefore interesting for a follow-up study on PBL.

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Journal of
Problem
Based
Learning
in Higher Education

VOL. 11, No. 3, 2023 – Page 44-60
10.54337/ojs.jpblhe.v11i3.7678

A Case Example of Integrating Team-Based and Problem-Based Learning in Sex Therapy Courses in the U.S. and Austria

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ABSTRACT

Introduction: Team-based learning and Problem-Based Learning can be integrated for in person and online psychology or behavioral health related courses in higher education.
Statement of the Problem: Historically, team-based learning and problem-based learning have been considered separate (and seemingly competing) activities and not often conducted concurrently during a course.
Literature Review: A review of the literature on team-based learning, however, has uncovered some cases where team-based learning and problem-based learning were integrated together in a course.
Teaching Implications: The purpose of this article is to present a case example in which team-based learning and problem-based learning were integrated together in two master's level sex therapy courses: one in the U.S. and one in Austria. The article describes how this integration was achieved through outlining the activities of the class and the possible benefits seen based on self-report.
Conclusion: Integrating team-based learning and problem-based learning was an effective method for teaching two master's level sex therapy courses and may have relevant application to psychology classes and/or treatment-oriented topics in behavioral health.

Keywords: Sexuality, sex therapy, case studies, vignettes, psychotherapy

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INTRODUCTION

Since the COVID-19 pandemic caused in-person learning to be limited, educators all over the world have been tasked with the responsibility of taking offline courses and transitioning them into an online environment. Instructors have had to adjust their teaching of didactic courses to remote or online versions, which required a quick evaluation and selection of web-based teaching platforms, recording lectures, the development of new assessment processes, alterations in assignments, integrating document sharing and other changes (Dhonncha & Murphy, 2020). For those disciplines teaching professional knowledge, new strategies must be created to provide clinical and/or simulation training to replace the lack of practical and rotational experience while continuing to ensure a high level of quality of care (Dhonncha & Murphy, 2020; Savard et al., 2020; Torres et al., 2020). As the education continues to adapt to an ever-changing world, the advancement of Problem-based Learning (PBL) and future use of PBL in education must also adapt.

This article explores the integration of two learning approaches in psychology and behavioral health related courses: Problem-based learning (PBL) and Team-based learning (TBL). Specifically, this article looks at a case example in which two graduate level courses, one in Austria and one in the United States, found PBL and TBL to be compatible in their integration, though typically treated as mutually exclusive forms of learning, and were applicable to both in person and online learning. In short, our guiding question was: Would integrating PBL and TBL be an effective method to teach sex therapy? The integration of PBL and TBL as outlined in this case example may have wider applications to be studied regarding the delivery of psychology courses in an ever-adapting teaching environment amid a pandemic. While PBL has grown to incorporate many different approaches, the integration of PBL and TBL diversifies the application of PBL and furthers our understanding of the use of PBL as a teaching methodology.

TEACHING CLINICAL MATERIAL: TWO COMMON APPROACHES

Overview of Problem-Based Learning

Problem-based learning is often used in medical/clinical training. Medical educators first introduced PBL in the 1950s and it continues to be a favored method of learning in many medical schools (Allen et al., 2011). The introduction of PBL in medical/clinical training originated from the students needing opportunity to apply their academic knowledge to increase their skillset in solving real-world, complex problems (Barrows, 1996). Hypothetical cases are presented to groups. The hypothetical cases do not have an obvious solution. Thus, the group members must discuss the relevant elements of the case as it pertains to differential diagnoses. The role of the instructor differs from lecture-based teaching in that in a traditional classroom environment, the instructor serves as a "presenter of information, whereas the instructor of a PBL classroom becomes a facilitator of a problem-solving process (Allen et al., 2011, pg. 23; Khatiban et al., 2019). In a problem-based learning environment, the students are organized into groups where they collaborate and learn by solving real or realistic problems (Allen et al., 2011). PBL is focused on data acquisition and has a similar "process of inquiry" to that of a medical practitioner, which explains why it is appealing in medical and clinical training (Yew, 2011). The application of PBL has been expanded to many unique approaches and has been widely adapted for use in education of many different fields such as engineering, law, and economics (Savin-Baden, 2014).

Components and Structure of Problem-Based Learning

Although students are challenged intellectually, teamwork enhances their participation. PBL provides students with an active learning environment and fosters cognitive development through the exchange of knowledge between students (Allen et al., 2011; Savin-Baden & Major, 2004). PBL activates prior knowledge which learners then build upon in collaborative groups. To problem-solve, students are motivated to fill knowledge gaps through research and the study of related materials (Savin-Baden & Major, 2004). PBL benefits students by providing them with an environment in which they can interact both socially and academically. In PBL, group discussion deepens understanding, elaborates student's prior knowledge, and stimulates intellectual growth (Yew, 2011).

Overview of Team-Based Learning

Team-based learning (TBL) requires students to work together to gain knowledge with an explicit focus on the process by which that knowledge was acquired (Michaelsen & Sweet, 2011). TBL has been used across a variety of professional disciplines such as nursing, medical education, pharmacy, sociology, social work, business, and education (e.g., Branney & Priego-Hernández, 2018; Burgess et al., 2014; Burgess et al., 2017; Huang & Lin, 2017; Macke & Tapp, 2012; Ofstad & Brunner, 2013; Ozgonul, & Alimoglu, 2019; Stepanova, 2018). TBL focuses on the decision-making processes in education as opposed to an emphasis solely on students generating one correct answer (Ofstad & Brunner, 2013; Parmelee et al., 2012). Such learning hold students accountable for the material and fosters high levels of engagement in the learning process (Currey et al., 2015; Oldland & Currey, 2020; Oldland, et al., 2017). This approach is favorable in complex problem-solving situations where there may not be one correct answer. TBL encourages students to examine a host of possibilities through the exchange of knowledge between team members.

Components and Structure of Team-Based Learning

Essential to TBL is the element of pre-class preparation. Preparation beforehand may take many forms: visual, audio, text-based readings, etc. Another component is the taking of the Readiness Assurance Tests (RATs). These tests are completed at the beginning of the class and assess a learner's readiness to participate in the lesson. Testing is also conducted in a nontraditional way. First, learners are tested individually through Individual Readiness Assurance Tests (IRATs). During this administration, they are not told which items were correct. The students are then arranged into their established teams and take the same test collectively via Team Readiness Assurance Tests (TRATs) and receive immediate feedback regarding which answers were correct. Once the class convenes as a large group, teams are given a chance to explain their reasoning behind choosing an answer that is not correct.

After the class has completed both readiness activities, the class may review course material with the instructor. Subsequently, learners reform their groups to complete an application activity. The application activity is meant to give the students an opportunity to apply their knowledge to a real-life scenario relevant to the concept that they just learned. Each team works on the same scenario and chooses an answer (usually multiple choice) to discuss with the professor and the rest of the class by explaining their reasoning behind choosing it. The instructor awards points based on accuracy as well as critical thinking. Even if answers are "incorrect," logic is still taken into consideration when assigning grades.

Comparing and Contrasting PBL and TBL

Parmelee et al. (2012) note the primary differences between PBL and TBL in their assumption, their methods, the incentives shaping learner behavior, and the outcomes. In the assumptions about learning, PBL emphasizes student-directed knowledge whereas TBL focuses on the teacher identifying clear goals for each module and having students solve specific clinical problems. It is designed to assist students in solving real-world problems (Stegeager et al., 2013). The method of PBL is for the instructor to progressively disclose elements of a case and, with each disclosure, the learners discuss the important facts and information which will lead them to a diagnosis and/or treatment plan. In TBL, however, learners prepare in advance for the material and use the time to demonstrate their knowledge of potential solutions based on their preparation. Incentives for PBL can be the interest in the topic of the case, an end-of-term exam, or team evaluations. In TBL, the motivators are the individual and group readiness assessments, which are the primary (if not only) grade in the course (Parmelee et al., 2012). The outcome in PBL is to understand, in a small group format, how to identify what information is needed to learn to solve a complex clinical problem (Anwar et al., 2012); in TBL, the emphasis is on critically thinking about a problem and developing a way to be collaborative but still retaining autonomy within a larger group setting (Parmelee et al., 2012).

INTEGRATING TEAM-BASED AND PROBLEM-BASED LEARNING

Problems From Lack of Integration

Using TBL or PBL has frequently been handled in a mutually exclusive fashion (Burgess et al., 2017). Applying these frameworks separately can be problematic for student learning outcomes, curriculum development, and assessment of skills. First, to teach either of these approaches singularly can limit the potential for students to achieving learning objectives. Most of the application for PBL and TBL are in courses which require complex things and problem solving such as health care professional training programs. Non-integrative stances in any profession contribute to a further widening of health disparities (i.e., Pérez et al., 2020; Rice et al., 2019). Integrating both of these perspectives can model for students how to incorporate different perspectives in their own practices as they move forward in their professional lives.

Secondly, the value in what is learned through both PBL and TBL independently is significant and focusing solely on one can interfere with learners' outcomes. For example, grading readiness tests – a key part of TBL – has been demonstrated to result in students more frequently downloading reading material and receiving higher scores on the readiness tests (Koh et al., 2019), suggesting that not using a TBL approach may inhibit learners from accessing important course materials and readings. Similar problems are encountered by using a pure PBL approach; in some cases, it has been associated with students getting stuck on a problem and necessitating instructor intervention (Ishizuka et al., 2023). To tap into the benefits of both when feasible is advantageous to students.

Finally, teaching without consideration of team conversation, problem solving, and critical thinking way might negatively impact curriculum and result in individual course being taught with limited intentional connection to the other courses offered in a curriculum and ignores the developmental level of the student. Over the course of programs (and graduate work in particular), students are developing skills and building on those skills to be able to complete a capstone (a professional project, practice element, research product, etc.). Each successive course builds on the others when curriculum is designed well. Integration of PBL and TBL can help programs to identify spaces in degree programs when it is important to measure how well students can apply the material in real world settings.

A Call Toward Integration

Despite the primary differences in preparation and tone, there are some overlaps which can facilitate integration of PBL and TBL. In both modalities, student teams are formed and are the setting for the conversations about the clinical case. Another potential overlap exists in that both PBL and TBL have previously been implemented separately in medical training (Burgess et al., 2018). In Burgess et al.'s (2018) integrative approach, learners were to analyze a practice problem, develop a hypothesis, and work toward self-learning. The sessions were conducted by taking the established PBL teams and dividing them into smaller teams to participate in the TBL. The TBL sessions went over four weeks, a small portion of the yearlong PBL arrangements. Each modality had its strengths and weaknesses: the students were more competitive in the TBL format and appreciated the smaller groups and discussion. In the PBL opportunity, students enjoyed practicing problem solving and critical thinking in the case examples (Burgess et al., 2018). Similar results were found by Anwar et al (2012), who described a "significant synergy" (p. 722) when PBL and TBL are both utilized in a course, with groups consistently outperforming individuals.

This finding speaks to the diversity of PBL in its ability to integrate with TBL and enhance the learning experience of the students. The integration of the two approaches adds to our understanding PBL as a whole and offers a new approach to the use PBL which had previously been treated as mutually exclusive from TBL in the classroom. The specific use of PBL and TBL in master's level sex therapy courses provides a new PBL methodology that benefits the counseling profession and may provide a roadmap to improving sex therapy courses in their ability to strengthen critical thinking and problem solving as it relates to diagnosing, working through ethical issues, and other complex problems encountered in real-world applications of counseling. This PBL perspective in one's teaching can allow programs to plan across several developmental periods. For example, second-year engineering students using PBL were focused on solving complex problems; third years focus on application in practice and fourth years focused on design (Chen et al., 2021). Similar processes could be applied to a program's overall curricular design.

TBL-PBL INTEGRATION IN SEX THERAPY COURSES

Rationale for Integration within the Discipline of CFT

PBL and TBL could work well in a sex therapy course since the course is clinical and corresponds with the application types of courses with which PBL and TBL has historically been used. It has already been cited as an appropriate option for teaching in psychotherapy courses due to its emphasis on comprehension, critical thinking, and retention (Anwar et al., 2012; Touchet & Coon, 2005). The integration of the two approaches gives opportunity to the students to not only increase their academic knowledge, specifically through the preparation required outside of class for the TBL, but also to use this academic knowledge in application with complex problems through the PBL discussions. In addition, PBL has been shown to positively support professional identity development (Du & Naji, 2021), a criterion that needs to be taught in graduate training as cited in the Commission on Accreditation for Marriage and Family Therapy Education (COAMFTE, 2022).

Second, the complexity of sex therapy cases demands a complex method of teaching. Effective sex therapy is an integrative effort, with both diagnosis and treatment reliant on understanding the impact of several systems contributing to symptom development and maintenance. This involves teaching students to attend to a variety of domains: biological systems, individual psychology, couple dynamics (power, communication, neglect), cultural roles, norms, mandates, family-of-origin patterns, etc. (Hertlein et al., 2019). Pedagogically, were driven to integrate PBL and TBL as a way to teach students to address these significant complexities and provides an approach that emphasizes a well-rounded development of the acquisition and application of clinical knowledge. In sex therapy, it is unrealistic that one domain (biological OR psychological OR culture) is responsible for a client's symptoms. Therapists who are able to consider and account for each of these systems in their treatment of sexual cases are more successful than therapists who cannot attend to all of these domains.

Third, because of the complex interplay of biology and psychology inherent in sex therapy cases, the sex therapist-in-training needs to learn how to work in an interdisciplinary team setting as it pertains to treatment planning. Combining TBL and PBL into an integrated approach sets up a learning environment that both values individual knowledge, but also relies on teamwork to justify a solution to complex, clinical problems. In terms of counseling and specifically the sex-therapy field, clinicians will rarely be practicing outside of the supervision, discussion, and participation of other clinicians which requires the skills to not only effectively provide clinical services but to administer these services within a team-based, professional setting. Integrating TBL and PBL during the training of clinicians will prepare them to create their individual clinical judgements while delivering these judgements within inter-disciplinary environments.

ABOUT THE COURSES

Sexual Issues in Couple and Family Therapy (CFT 719)

This course was part of the required curriculum within a Couple and Family Therapy Master's of Science degree program. The program is housed within a department of psychiatry within a medical school associated with an R1 university in the Southwestern U.S. The course was a 16-week semester course that met once a week for two hours and 45 minutes each class meeting. There were 30 students enrolled in the course. This course started off being conducted in a classroom setting but was later moved to remote learning due to COVID-19. The hybrid structure was inspired by Franklin et al.'s (2016) example of teaching TBL both online and in-person in a hybrid course.

This course was taught using a combination of active-teaching methods such as team-based learning, problem-based learning, team events, and didactic information. Among these various methods, TBL was used predominantly where students were required to read the content prior to the class. At the beginning of the semester, students were divided in teams of six where most of the discussion and activities happened. This allowed for students to learn from each other, as well as collectively apply the content into therapy scenarios using case study examples.

Modern Sexology: Brain, Biology, and Behavior (PSY 840)

This course was structured as two full teaching days over two weekends. The class met twice a week for two weeks, five or eight hours per instructional period (26 hours teaching total). The course was housed within a graduate program at the University of Salzburg in Austria. Due to COVID-19, this course was taught online. The same structure used in the U.S. course was applied to the Austrian course. Students completed IRATs and TRATs, examined case examples with associated questions about diagnosis and treatment, engage in simultaneous sharing via an electronic poll in response to the questions in the case example, and periodically given PBL case examples through which to create a treatment protocol.

Team-Based Learning Activities

As aforementioned, TBL incorporates readiness assessments and focuses heavily on application of the material (Franklin et al., 2016). Periodically, students were required to take two Readiness Assessment Test (RAT) based on the readings for that week (see Appendix B). Each student first took IRATs independently. They then took the same test as a part of the team (TRAT). This was done so the students could also learn from each other and gain new perspectives on the same topic. Individuals completed the IRATs on a multiple-choice form; they then used the Immediate Feedback-Assessment Technique (IF-AT), a multiple-choice scratch-off card to complete the TRATs. The IF-AT allows teams to select one answer and scratch off that answer spot; if they are correct, a symbol will appear and they can move onto the next question. If they were incorrect, there will be no symbol and they have a chance to discuss as a team what the answer might be. Once the team made another selection, they could scratch off another response and see if they were correct. When the class transitioned to remote instruction, the TRAT was accomplished through setting up a quiz on the course electronic blackboard where the students had multiple attempts to answer the questions.

After the RATs, teams were led through an application activity. A case example was provided to all teams. Each team was asked the same questions about how to process the case. When in the physical classroom, the simultaneous sharing was accomplished through a point person from each team holding up a card that designated the team's answer. When that class transitioned to remote instruction and in the course in Austria which was entirely remote, the instructor used the "Poll" function in Zoom® for simultaneous sharing. The case applications consisted of a detailed example related to the topic and at least three multiple choice questions for team discussion. That process was as follows: (1) the team reads the overall case, (2) the team reads the questions, (3) the team goes over each answer and the logic behind each one, (4) the team votes on an answer, (5) the team presents the answer to the class and explains the logic behind it. For sample questions to the case example application exercise, see Appendix A. The remainder of the class period was used primarily for discussion and clarification of the content material.

In addition to the RATs, students engaged in three PBLs over the course of the semester. Case PBLs were used to help students develop specific skills in treating a certain condition or presenting problem and were detailed case examples carefully constructed by the instructor (Stentoft, 2019). At the beginning of the PBL class periods, the instructor used "Wheel Decide" (an online tool) to list theoretical frameworks that might emerge on the National Marriage and Family Therapy licensing exam and assign each team a theoretical framework. The students were then expected to create a treatment plan that attended to the following areas: defining the problem, identifying strategies, proposing solution/hypotheses, and evaluation of the success of their treatment. After each PBL was completed by the teams, the class reconvened, and the teams shared how they elected to treat the case based on their framework.

Another application exercise that was used in the course was the gallery walk (Francek, 2006; Rodenbaugh, 2015). In this TBL activity, each group is assigned the same problem. Once the teams have discussed and identified how they wish to solve the issue, they create a product (document, chart, etc.) that depicts their proposed solution. Each of the solutions are presented to the other teams during a simultaneous sharing event. The learners review the solutions provided by the teams through viewing the gallery of provided solutions (Francek, 2006). Prior to COVID-19, this was accomplished by physically walking from station to station (Francek, 2006; Rodenbaugh, 2015). Post-COVID-19, however, the gallery walk was achieved through having a leader from each group share their screen and present their solution, rotating through the groups, and then having a conversation as a class about the relative strengths and limitations of each approach.

Evaluation

Readiness Assessment Evaluations. The final component of TBL is evaluation. The scores on the RAT were calculated based on the number the student got correct. In this course, IRATS were worth 5 points each (one point per response; correct answers were awarded a point and incorrect answers were awarded no point). The TRATs were worth 15 points each. As aforementioned, TRATs were completed using IF-AT scratch cards. Team members were given three points for each answer correct at the first scratch; two points if it took two scratches; one point if it took three scratches; and no points if it took all four scratches.

Problem-Based Learning Evaluation. There are many rubrics widely available online to use for evaluating the PBLs. For this course, we used a modified version of the form offered by the Association of American Colleges and Universities located here: https://www.aacu.org/value/rubrics/problem-solving (McConnell & Rhodes, 2017). For a discussion of considerations in different PBL assessment rubrics, please see Brodie and Gibbings (2009).

Peer Evaluation. The students evaluated each team member on their contribution to the learning process. The rubric used was modified from the American Association of Colleges and Universities located here: https://www.aacu.org/value/rubrics/teamwork (McConnell & Rhodes, 2017). This was done twice during the semester: once mid-semester and once at the end of the semester. The evaluations were computed and added to the student's final grades. Each member of each team had to rate their team members on effectiveness and ability to work with others. This was an important part of the process because it showed who was helpful and a leader within the team. Each evaluation was considered during grading at the end of the semester. This provided each member with the opportunity to express any concerns or gratitude for any team member without causing commotion in the classroom.

DISCUSSION

The integration of TBL and PBL for psychotherapy and counseling courses may be favorably indicated in those professions where there are case examples to be discussed or scenario-based learning is appropriate, even outside of the medical profession. For example, any of the mental health professions who have scenario-based learning in their licensing exams would benefit from having the TBL-PBL integrated experience. Instructors may choose to represent case vignettes that test concepts on the scenario-based exams. The problems faced by sex therapy students are those that are best suited for both PBL and TBL because of the nature of the licensing exams (case-based), will improve their effectiveness as a treatment professional by teaching skills to facilitate problem solving and negotiation to their own clients.

In addition to the benefit afforded to students, the integration also positively impacted the role of the instructor. To effectively integrative TBL and PBL, instructors need to be able to effectively facilitate group processes and discussions as well as being able to generate appropriate probing questions (Rico & Ertmer, 2015). In the Sex Therapy course, integrating TBL and PBL enabled the instructor to approach the classroom with enhanced creativity, openness, and provides a mechanism for the instructor to be more intentional about selecting reading and case vignette materials, and to be intentional about organizing students from different backgrounds to work together to solve a complex clinical problem. The instructor's role was finding problems (i.e., generating sample sexual problems that comprise a variety of dimensions typically presented in clinical care) and problem solving by guiding students to what needs to be considered to promote effective and inclusive care. In short, the PBL-TBL instructor has to be confident enough in their ability to mange group conversation and work with students to negotiate differences in their perspectives rather than offering the answer. Common questions the instructor asked in the sex therapy course was "How did you decide to value one perspective over another?" and "What decisions did you make in terms of whose voice was favored and why?" The instructor becomes a facilitator on process, not a disseminator of fact.

The role of the instructor is also to enhance communication and critical thinking skills for students (Latif et al., 2018). As future relationship therapists, the students need to be able to build and maintain working relationships with others, and teach and model effective communication. This in part is achieved through the instructor's thoughtful team assignment and organization (Walker et al., 2020). Students in the sex therapy courses were assigned based on their backgrounds in order to bring different perspectives to each problem to be solved but more importantly focused on building relationships with those who are different from themselves.

The integration described in this article was application in sex therapy courses. We have, however, also included this integration in Counseling Across the Lifespan. In that course, we provided cases of different issues from infancy to geriatric populations and had similar success. The integration compels the team members to identify the pertinent information in a case, whether it be assisting them to pull out information for diagnostic, rule-out, or treatment planning purposes. When students can extract information, present their rationale, and discuss these perspectives as a group, they integrate the knowledge from others into their critical thinking processes. They uncover more areas of consideration as they work through a complex clinical issue and how to solve it. Therefore, the PBL-TBL integration can be learned when there is a call for more experiential learning.

Implications for Practice

The integration of PBL and TBL diversifies the already expansive methodology of PBL and a learning practice and gives way to the possibility of its use in education for the foreseeable future. In a post-pandemic learning environment, the adaption of established courses is inevitable and with those changes will come changes in the learning styles of the courses. PBL and TBL as an integrated approach provides benefits to the counseling field in that it allows for the development of individual clinical knowledge while emphasizing the importance of using that knowledge within interdisciplinary teams. he integration of PBL and TBL can be used in inter-professional training programs where each team member can offer expertise specific to their discipline toward case conceptualization and treatment, thus fostering a value in interdisciplinary teams as the team member navigates their future profession. Counselors will often work with other professionals to provide wrap-around services to clients who may be experiences complicated issues that have play within multiple systems. Training clinicians to exercise clinical judgement within a team setting is paramount, and the integration of PBL and TBL gives new counselors the opportunity to develop this ability. The future of PBL in education within the therapy field highly benefits from its integration with TBL given the team-based delivery of counseling services in the real-world.

CONCLUSION

Effective teaching provides a mechanism for students to apply the information learned in nuanced ways that attend to context. The incorproation of TBL and PBL provides a gateway to not only learn the material, but provides a chance for application to unique systems and populations. Team-based learning and problem-based learning are two teaching methodologies which are often taught in mutually exclusive ways, yet both have a great deal of overlap and make a significant contribution in their efforts to teach problem solving in complex scenarios. Incorporating both approaches in mental health training encourages professional collaboration, assists students with identifying which information is relevant for diagnosis and treatment, furthers consideration of alternatives, and better prepares clinicians for licensure exams featuring clinical scenarios and decision points. Specifically, it enables instructors to ensure that the skills gained in the classroom will be generalized outside in real world settings.

PBL has seen much growth and adaption since its inception nearly 70 years ago (Servant-Miklos & Noordzij, 2021). While the world continues to adapt and change, the methodologies of PBL have also evolved. The integration of PBL and TBL is another cog in that evolution and speaks to the future of PBL. It is an approach that is highly adaptable to the needs of the education program. In the counseling profession specifically, there is great benefit to integrating PBL with TBL to give clinicians the opportunity to develop their individual clinical judgement and create team-based environments within which they can exercise that judgement. Clinicians will likely encounter team-based environments in real-world clinical practices, which calls for their training to occur within team-based environments as well. PBL enhances the TBL method and the integration of the two is an approach that expands our understanding and application of PBL in education.

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Journal of
Problem
Based
Learning
in Higher Education

VOL. 11, No. 3, 2023 – Page 61-73
10.54337/ojs.jpblhe.v11i3.7501

Integrating Mathematical Modelling into Problem Based Research: An Evaporation Activity

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ABSTRACT

Climate change put most species' survival in danger because it substantially affects the climate in which the species live, the quality of the water they drink, as well as the temperature of the air or water. When climate change increases the temperature of the climate, excessive evaporation occurs in lands, lakes, seas, and oceans. Our purpose in this paper is to introduce a mathematical modelling activity embedded in Problem Based Learning (PBL) that allows students to investigate factors related to evaporation. Mathematical modelling is a popular technique of teaching mathematic concepts and skills and a method of inquiry about scientific phenomena that interests scientists. In the present activity, students use secondary data from trusted websites to test their hypotheses. Students are engaged in analyzing and interpreting data, generating and testing models, and discussing and presenting findings with their peers. The activity allows students the opportunity to examine the relationship between variables and predict one variable using the other. The activity has the potential to foster students' computational and higher-order thinking skills.

Keywords: Problem Based Learning (PBL), Mathematical Modelling, Climate Change, Evaporation, Authentic Science

INTRODUCTION

Climate change jeopardizes the survival of most living forms on the Earth by altering global and regional climates, the water cycle, and the food chain. While some people still

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believe that climate change is a part of a natural cycle, scientific investigations have shown that humans played a major role in causing the current climate change in the Earth. In the geological records, one can observe the changes in the Earth's climate in a very long time. In the current climate change though, the rate and magnitude of the changes are faster and more severe than the ones in the geological records, which raises many concerns. For this reason, many countries are implementing policies to address climate change, regulating their economy, production, energy, and education sectors to mitigate its impact.

One effect of climate change is unusual and extreme weather events, including high temperature, extreme precipitation, or lack of precipitation, which can lead to excessive evaporation (Yoro & Daramola, 2020). While evaporation is a crucial part of the water cycle, excessive evaporation due to climate change reduces the amount of water available in soils and lakes, which are the essential sources of drinking and irrigation water (Mhawej et al., 2020). Because excessive evaporation has negative consequences on human life and the environment in many ways, teaching factors related to and how to control excessive evaporation are very important to cultivate an awareness of climate change.

Evaporation is a major topic in science education that serves as a foundation for understanding other essential concepts and explaining daily phenomena. However, teaching about water evaporation is challenging due to its abstract nature and the need to consider both macroscopic and microscopic levels of understanding (Wang & Tseng, 2018). Despite the fact that the concept of evaporation is introduced in the third grade of the National Science Curriculum in Turkiye, studies have shown that students at different levels and pre-service teachers have misconceptions about evaporation. These misconceptions include beliefs that "evaporated water disappears" (Tsikalas et al., 2014) and that "evaporation is a chemical reaction" (Hämälä-Braskén, Hemmi, & Kurtén, 2020). Furthermore, there are misconceptions about the factors that affect evaporation, for example, the belief that "heating is necessary for evaporation" (Karsly & Ayas, 2013), and "air current decreases the evaporation" (Coştu et al., 2010).

To address the aforementioned misconceptions and improve understanding of evaporation, different teaching and learning approaches have been utilized, for example, inquiry-based instruction, argumentation, and conceptual-change strategy. However, due to the COVID-19 pandemic's lockdown, most instruction has shifted to virtual or online classrooms, which poses challenges for implementing these approaches. Wang and Tseng (2018) compared the effectiveness of virtual, physical, and virtual-physical instruction on third-grade students' understanding of the change of state of matters, and found that virtual and virtual-physical instruction were more effective than physical instruction. Furthermore, most studies on evaporation have focused on what evaporation is, rather than what factors could influence evaporation. There is a need to teach about the factors that influence evaporation in non-physical classrooms. Mathematical modeling can be an effective approach for teaching about these as it involves defining variables and modeling the relations among them. This approach can be implemented in virtual or online classrooms, yet there are no studies that have utilized mathematical modeling to teach about the factors that influence evaporation. Thus, in this case study, we aimed to address this gap.

Our purpose in this paper is to introduce a Problem Based Learning (PBL) activity that incorporates mathematical modelling and enables students to investigate factors related to evaporation. PBL involves solving a real world complex problem and encourages students to learn with self-direction and collaboration (Johansson et al., 2020). Mathematical modelling instruction focuses on a real world problem, collaborative work, and sharing the outcomes with peers. Collaboration among scientists and peer review process are some major components of authentic scientific research (Ayar et al. 2014). Collectivist nature of science refers to the collaborative characteristics of the scientific practice. Sociological nature of science refers to the peer review and argumentation processes of scientific research. Both the collectivist and sociological nature of science are often ignored in school science classrooms.

Scientists use mathematical modelling across a wide range of scientific disciplines, including medicine, engineering, chemistry to social sciences economics, and education (Kaiser, 2020). Mathematical modelling enables scientists to predict and formulate the relations between variables of interest. Moreover, mathematical modelling is a popular instructional technique to teach mathematical concepts and skills in mathematics education (Erbas et al., 2014).

The activity we describe in this paper uses mathematical modeling in a manner similar to how scientists carry out their research. When students engage in authentic research activities, they are more likely to develop an accurate understanding of science and scientific enterprise. Many studies in the learning sciences have shown positive correlations between conducting authentic scientific activities and improved understanding of science and its enterprise (e.g., Ayar & Yalvac, 2010; 2016). In the present activity, students are asked to analyze and interpret data, generate and test models, and present and discuss their findings with their peers. Furthermore, because in the activity students examine the relationships between variables and predict one variable based on the other, it has the potential to cultivate higher order thinking and computational skills. The activity we describe here is an integrated activity that science and mathematical concepts and skills are merged to support students' intellectual and cognitive development in both areas (Alpaslan, 2017; Işık & Alpaslan, 2018).

As more online instruction is being implemented in recent years, many students lack the opportunities to be physically present in a laboratory setting and collect data directly from their experimental setup. Even when the students are able to attend physical laboratory settings, real world data related to climate change or evaporation cycle need to be collected from sources other than the location of the laboratory or the classroom. Using secondary data is an alternative to conduct authentic scientific investigations for students who are studying in their home locations and students who can attend physical laboratory or classroom settings. Trusted websites exist where students can obtain data they need for their scientific investigations. As with the present activity, it can be implemented in virtual classrooms at the students' locations because students utilize the data found on the Internet.

BACKGROUND

Evaporation

The International Glossary of Hydrology defines evaporation as the process of water changing from a liquid to a vapour at temperatures below boiling point" (International Glossary of Hydrology, 2012, p.114). Every surface on planet Earth that contains liquid water is the source of water vapour in the atmosphere. Continuous evaporation occurs on seas, lakes, streams, moist soils, snow-covered or ice-covered surfaces, and forests (Tao et al., 2018). Evaporation is an important part of the water cycle. The amount of water that evaporates on a global scale is equal to the amount of water that falls on the Earth as precipitation. With the effect of climate change, excessive evaporation can cause the unbalanced rainfall across the Earth at where some regions suffer heavy precipitation as rain or snow and some other regions would face the absence of precipitation and eventually drought. Therefore it is important to teach students about the factors related to evaporation and how to control it.

Mathematical modelling

Mathematics is a branch of science that emerged from the need to produce solutions to daily problems. It has provided the foundations of other scientific disciplines. Mathematics is a language that humans constantly use to express and solve their daily needs (Erbas et al., 2014). Mathematical modelling is the process of expressing the relationships between situations mathematically, whether directly related to mathematics or not, and creating mathematical patterns within those situations. Mathematical modelling is an effective tool for fostering creativity and problem-solving, allowing individuals to make interdisciplinary connections and apply what they have learned in their daily life.

The present activity follows a mathematical modelling process that consists of five stages as defined by Erbas et al. (2014). These stages are (a) defining and simplifying the real-life problem, (b) creating a mathematical model, (c) transforming, developing, and solving the model, (d) interpreting the model, and (e) validating and using the model. This process is iterative and non-linear. In the fifth stage, students have the opportunity to re-examine their research question, which fosters a feeling of ownership and belonging, thus increasing their motivation and engagement in the research. The present activity is designed based on this five-stage process. Haines and Crouch (2007) also defined mathematical modelling as a cyclical process, in which real-life problems are abstracted into mathematical language, analyzed, and the solution found is tested.

ACTIVITY

This activity is suitable for high school students and pre-service teachers who will be teaching at the high school level. It can be completed within two class hours (90 minutes total). In Table 1, we illustrate the connection between the objectives of the activity and the Next Generation Science Standards (NGSS Lead States. 2013). We asked 19 pre-service science teachers to complete this activity as if they are students whom they will be teaching. The pre-service teachers were grouped into teams of three to four individuals and worked collaboratively. The activity can be implemented in a physical classroom or in a virtual classroom (e.g., in Zoom), or can be given as a course project. In the present implementation of the activity, the participants worked in a virtual classroom environment (on Zoom with breakout rooms), which facilitated engagement more effectively because of the low number of participants per room.

Science And Engineering Practices	**Crosscutting Concepts**	**Disciplinary Core Idea**
Asking questions (for science) and defining problems (for engineering)	Cause and effect	HS-ESS2.D The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes influenced by human behavior and natural factors
Obtaining, evaluating, and communicating information	Scale, proportion, and quantity	
Engaging in argument from evidence	Energy and matter: Flows, cycles, and conservation	

Using mathematics and computational thinking	HS- ESS3.D Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.
Analyzing and interpreting data	
Developing and using models	HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

Table 1. Connections of the activity to the next generation science standards.

To implement a mathematical modelling activity, data are expected to generate a mathematical connection between variables and test the mathematical model based on logical or theoretical connections. Secondary data, which are data collected by someone else and provided to the researchers can be used to provide the necessary conditions. Using trusted secondary data from organizations including OECD (PISA data), NASA and other government meteorological services is a common practice in scientific research and publications. In this activity, the Goverment's Meteorological Services data were used to form a mathematical model and test it. Many factors affect evaporation, including climatic and geographic factors and water characteristics. In the present activity, pre-service teachers were allowed to investigate the relationship between evaporation and the selected factor using available data.

Among the materials needed for this activity are a computer with Excel 2013 or above and Internet access. We used an Excel file that contained the instruction for group and individual work. In the beginning of the activity, we instructed the pre-service teachers how to create a scatter plot with the trend/regression line, which showed the mathematical equation between two variables based on the selected mathematical relation (linear, exponential, logarithmic, or polynomial). Further information about how to add a trend/regression line in Excel can be found at the Microsoft Excel support webpage (Microsoft, n.d.).

Stage One: Determining Participants' Pre-Existing Knowledge on Evaporation

Before the activity starts, we recommend exploring and documenting participants' pre-existing knowledge on evaporation. In our implementation, we asked our 19 pre-service teachers to answer several open-ended questions including "How do you define climate changing?," "How does climate changing affect our life and the earth?", "What is evaporation?", "What is the role of evaporation on water cycling?", "What is the role of evaporation on the water scarcity" and "What factors affect evaporation?". In addition to the open-ended questions, we used a two-tier diagnostic test. The test, developed by Karsli and Ayas (2017), comprised seven two-tier diagnostic questions (i.e., a multiple-choice question followed by its explanation) and intended to map respondents' understanding of evaporation. Our 19 pre-service teachers' responses showed that they had sufficient knowledge on the definition of evaporation and climate, but limited knowledge on explaining factors related to and how they could affect life on the Earth.

Stage Two: Problem Statement

A mathematical modelling activity starts with a daily problem (Erbas et al., 2014). At the first stage of the present activity, we provided our pre-service teachers with a problem statement that read:

> "A group of researchers would like to determine the amount of water that evaporates in a lake annually. Because the researchers cannot measure the amount of water in the entire lake, they conclude that it would be easier to determine the amount of evaporation with the help of a factor related to evaporation. For this, the researchers first have to determine a variable related to evaporation. Then, they want to obtain an equation using the data provided by the State's Meteorological Service. However, they have been reminded that humidity can be a factor that influences the evaporation; thus, they want to create mathematical models for three different humidity regions of the country. Please help the researchers to compute the evaporation in a lake located in the city."

Stage Three: Determining Variables and Predicting

After being given the problem statement, the 19 pre-service science teachers were asked to discuss in groups and determine a factor that they believed was related to evaporation. Participants were given ten minutes to make an Internet search and review the available reading from the State Meteorological Service website (https://mgm.gov.tr/arastirma/buharlasma.aspx; See Figure 1). There were five groups of students and they selected five variables, including temperature, wind speed, latitude, sun radiation, and the number of sunny days. After selecting the variables, the students were asked to predict the relationships among them (whether it would be directly or inversely linear, logarithmic, or non-related).

Next, the students used the data from the State's Meteorological Services website and entered them in Excel. They created a scatter plot with a trend line for three different climate regions. There are various climate classification approaches in the literature, for example, Köppen climate classification and Thornthwaite climate classification. Each approach uses different parameters, for example, temperature and annual precipitation. In this activity, the Thornthwaite climate classification was used because it considers evaporation and humidity in climate classification (MGM, 2017). The full climate list of the provinces was given to the students in the handout.

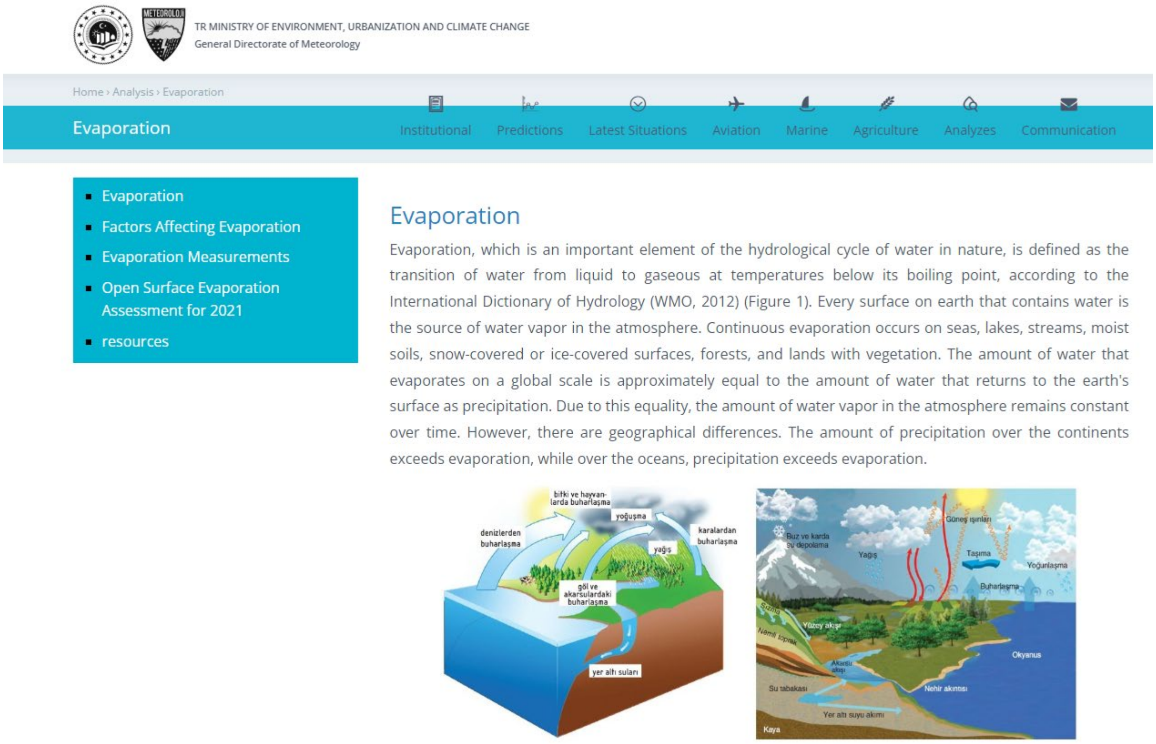


Figure 1. A screenshot of the MGM website on evaporation.

Stage Four: Creating a Mathematical Formulation

The students were asked to take note of the equations from the trend lines of the scatter plots for three regions. In groups, students discussed the following questions: "What kind of equation (e.g., linear, logarithmic, or other) did you obtain?" and "What you can tell about the relationships between evaporation and the variables you investigated?" The students usually created a linear relationship between variables. Students' responses indicated that they generally interpreted the equation as an inverse or direct proportion. One example of the graphs students obtained was the relationship between latitude and evaporation as shown in Figure 2. Students concluded that when latitude increases evaporation decreases.

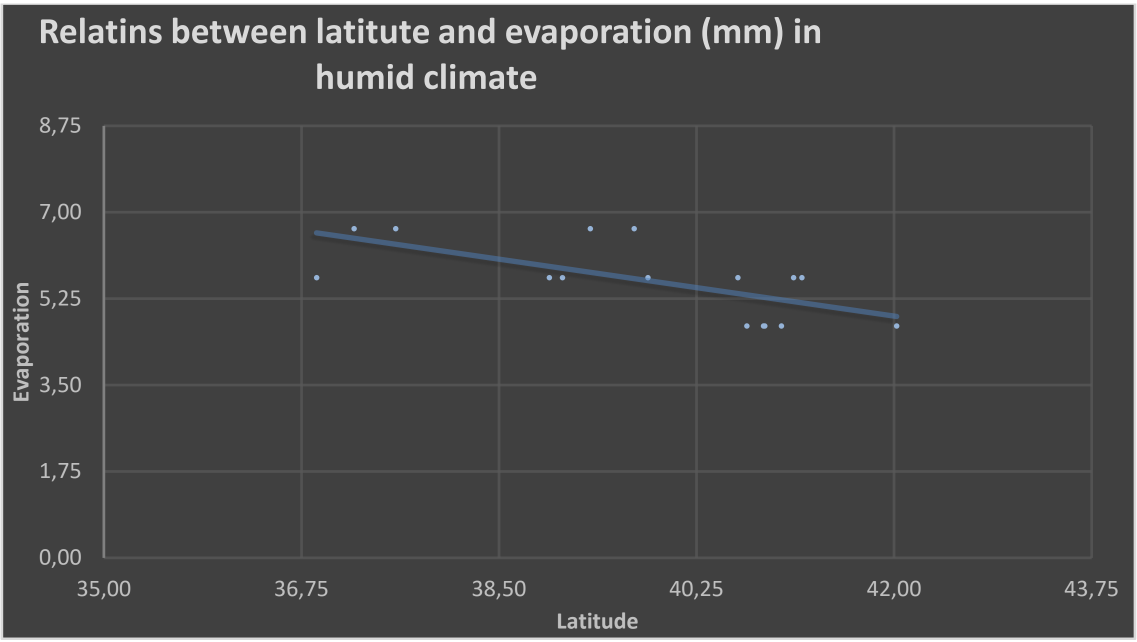
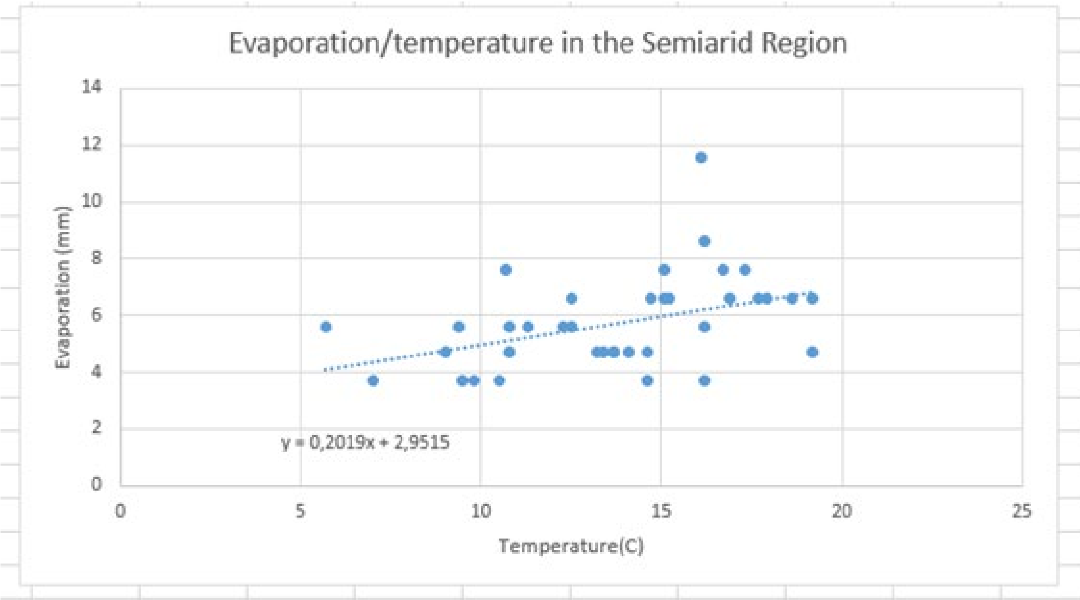


Figure 2. An example of students' work at stage 4.

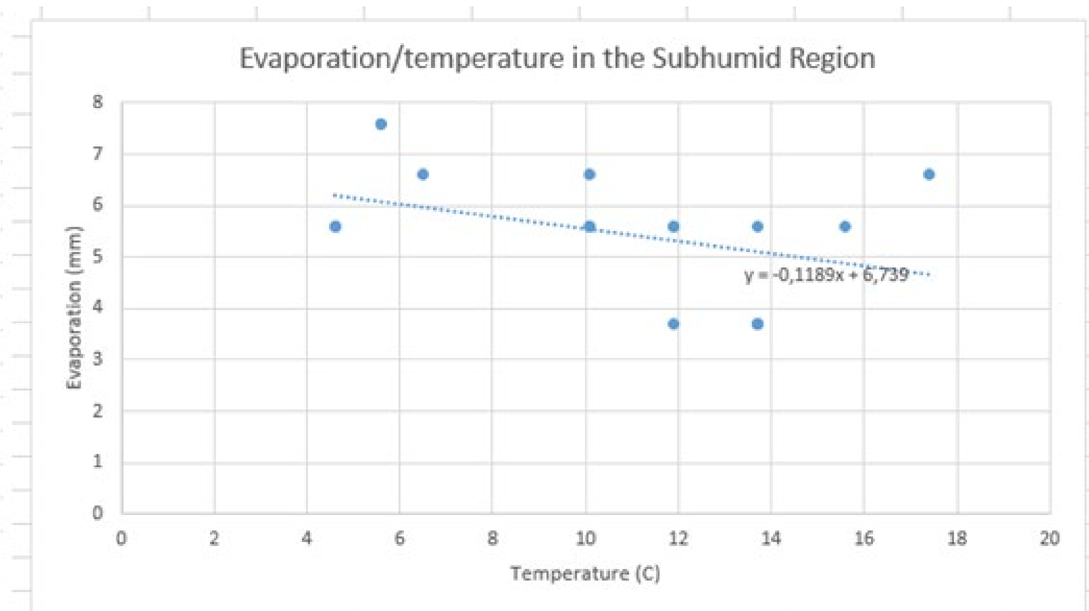
Stage Five: Validating the Mathematical Model

The next stage of the mathematical modelling is to validate and evaluate the mathematical model. If the model fails, the students should go back to stage three or four. At this stage, the students were asked to compare the mathematical models of three different regions of the country and determine if the equations were similar across the regions. They were asked to explain why the equations were different if they were, and to choose the best one. Humidity is one of the most critical factors affecting evaporation because it is related to the saturation degree of water in the air. Thus, students were more likely to obtain different mathematical equations across the three climate regions of the country.

Moreover, some groups found a reverse relation between evaporation and the variables. For instance, as seen in Figure 3, one group who examined the relation between temperature and evaporation found that the direction of the relationship between the two variables reversed across climate regions. In some arid climate regions, the relationship was directly proportional whereas in the humid climate region it was inversely proportional. This was a good result that allowed the students discuss the effect of the climate and to demonstrate how scientists can come up with different solutions for the same phenomenon. The students were asked to use the mathematical equation to find evaporation in a city of their choice and evaluate their equations. Based on their errors, they were to discuss and choose the best mathematical model.



a)



b)

Figure 3. a) The relation between temperature and evaporation was directly proportional in arid regions. b) The relation between temperature and evaporation was inversely proportional.

Stage Six: Output and Assessment

At the last stage of the activity, students were given some time to prepare their presentations. They were asked to include how they chose the variable, their guesses, and findings with graphs and equations. Students presented their ideas about the error of the models and how they justified their mathematical models for three climatic regions of the country. In addition, they shared their ideas about how to minimize evaporation. Some groups suggested building the windmills for generating energy at the edge of lakes so that it would reduce velocity of the wind and lessen the evaporation. The two-tier diagnostic test was re-applied. It was seen that students did well in the post-test compared to the pre-test. Their mean score increased from 3.7 (SD=.32) to 5.3 (SD= .49). A paired sample t-test showed that there was a statistically significant difference in favor of the post-test.

CONCLUSION

In the present study, our purpose has been to introduce a mathematical modelling activity to teach evaporation and related factors. In the activity, the students determined a variable, predicted its relationship with evaporation, collected and analyzed data with graphs, created a mathematical formula to show the relations between variables, and interpret and verified the formula for a particular situation. This activity has potential to increase awareness of how scientists work. This activity can be used to teach various subjects. We are in the age of the Internet and there are many different data resources that are freely available online. For instance, there are open data and educational resources to teach climate at the National Oceanic and Atmospheric Administration website (National Oceanic and Atmospheric Administration, 2018). Available data can be used to teach various science concepts related to climate change.

One thing should be noted that the connection between variables should rely on the logic, rationale, or theory. Any numbers can be related but it does not show that these variables are related to each other in reality. Therefore, it is important to give some time to students to do research or to provide materials on the links between variables. In this activity, students were given some time to read information and related factors on the State Meteorological Service website (See Stage 3). Also, it is important to let the students write their hypotheses so that they can really see what they are doing.

Another caution is that the instructor should know students' mathematical abilities. Although the mathematical models in evaporation are complex, we simplified it in the activity including one independent variable. High school or college students can easily recognize the graphical relationships of a logarithmic, inverse, direct proportion, etc. However, it is beneficial to let students discuss how the mathematical models in environmental science would be.

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Journal of
Problem
Based
Learning
in Higher Education

VOL. 11, No. 3, 2023 – Page 74-89
10.54337/ojs.jpblhe.v11i3.7792

Introducing a Problem Analysis Tool Implies Increasement in Understanding Problem Analysis Among Students: a PBL Case

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ABSTRACT

Problem-based learning (PBL) is the through-going didactics at Aalborg University, but literature shows how integrating PBL into project work is challenging for students. Studies indicate that students especially struggle with the problem analysis section, i.e., what it consists of, how the structure of the analysis should be, etc. Moreover, literature shows that ignorance among students leads to conflicts among group members. The aim of the study was to evaluate the consequences of introducing a problem analysis tool to master students working with a PBL project.

Data analysis showed an increase (with significant p values) in the following 5 topics: 1) the problem analysis term, 2) problem analysis structure, 3) scientific argumentation, 4) learn to analyze instead of explaining, and 5) using literature to argue for a scientific problem.
Significant results showed that students believed that they had increased their understanding of the term problem analysis after being introduced to the problem analysis tool.

Keywords: Problem-based learning, problem analysis, higher education, problem analysis tool

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INTRODUCTION

Problem-based learning (PBL) is a teaching and learning style that over the years has been implemented in several higher education programs (Amirikhorheh et al., 2014; Dolmans, 2019; Yew & Goh, 2016; Zakaria et al., 2019). Moreover, PBL has been shown to be beneficial in many ways, especially to improve students' academic competences and abilities (Chen et al., 2021; Demirel & Dağyar, 2016; Sukackė et al., 2022; Trullàs et al., 2022). Systematic reviews have shown that PBL is an effective and powerful learning style due to its up-to-date and alternative way of learning compared to traditional classroom teaching (Amirikhorheh et al., 2014; Hmelo-Silver, 2004; Trullàs et al., 2022; Zakaria et al., 2019). Overall, the characteristics of PBL cover students working independently together in groups consisting of 5 to 7 people focusing on a real problem (Barge, 2010; Demirel & Dağyar, 2016; Hasslacher et al., 2009; Holgaard et al., 20210; Holgaard et al., 2020; Savin-baden, 2020; Stentoft, 2019; Trullàs et al., 2022; Yew & Goh, 2016).

At Aalborg University (AAU) in Denmark, PBL has been a through-going element since 1974 in all offered education programs (Holgaard et al., 2020; Kolmos et al., 2008). Every semester, groups of students write a project report (consisting of problem analysis-, method-, solution-, result, and a discussion-conclusion section) (Barge, 2010; Holgaard et al., 2021; Kolmos et al., 2008; Telléus et al., 2023; Thomassen & Stentoft, 2020). Literature shows how integrating PBL into project work is a challenging exercise for students, and several studies also indicate that students especially struggle with the problem analysis section, i.e., what it consists of, how the structure of the analysis should be, how to make use of scientific literature, etc. (Azer & Azer, 2015; Nielsen, 2013; Thomassen & Stentoft, 2020; Thorndahl et al., 2018). Moreover, literature shows that ignorance among students leads to conflicts within groups (Azer & Azer, 2015; Bollela et al., 2009; O Doherty et al., 2018; Velmurugan et al., 2021; Wun et al., 2007).

Students with nonacademic bachelor's degrees, such as nurses, occupational therapists, and physiotherapists, have the possibility to be enrolled as master's students at AAU. After two years, they must achieve the same level of PBL didactics knowledge as students who have been studying their bachelor's degree at AAU for three years. Literature indicate how these students challenge with integrating PBL in the project work, especially work with the problem analysis part (Chen et al., 2021; Sukackė et al., 2022).

An attempt to overcome the lack of understanding the PBL principles has been to introduce a problem analysis tool. Therefore, the aim of this study was to evaluate the consequences of introducing a problem analysis tool to master students working with a PBL project.

METHOD AND MATERIALS

Participants

In total, 28 students were included. 17 participants were students from the master's program Clinical Science and Technology at AAU. Five participants were students from the master's program Digital Health Services (DHS) at The Arctic University of Tromsø, Norway, and the remaining participants were students from the bachelor's program in medicine at AAU. Table 1 gives an overview of the distribution and number of the included participants.

Name of the education	Level	Number of students in the groups
Clinical science and technology		
Project group 3	Master	6
Project group 5	Master	6
Project group 6	Master	5
Digital health services		
Project group 1	Master	3
Project group 2	Master	2
Medicine		
Project group 3	Bachelor	5
Project group 7	Bachelor	1
Total		28

Table 1. An overview of involved project groups who have been introduced to the problem analysis tool.

The problem analysis tool

The problem analysis tool aims to give an overview of how a problem analysis section can be structured in a PBL project report. Moreover, it gives an idea of which elements need to be covered. Below, a presentation of the different elements is visualized. A further elaboration on the development process of the problem analysis tool will not be given in this study.

The introduction
- Presentation of the initial problem

The problem analysis
- The socioeconomic consequences
    - Describing the incidence and prevalence (the epidemiology) of the disease
    - Describing the economic consequences
- The disease

    - Description of the characteristics of the disease
    - Complications related to the disease (physiological changes)
    - Characteristics of people suffering from the disease
- The conventional handling/organization/treatment
    - What includes the conventional handling/organization/treatment according to the literature?
    - Where does conventional handling/organization/treatment take place?
    - What does the literature say about the current handling/organization/treatment?
    - Why is there a need for alternative handling/organization/treatment according to the literature?
- The alternative handling/organization/treatment
    - Presentation of the alternative handling/organization/treatment
    - Problems related to the alternative handling/organization/treatment (what does the literature say?)
    - What remains to be solved regarding alternative handling/organization/treatment?
- The problem definition
- The problem statement

An evaluation questionnaire

To evaluate a progression in the participants' understanding of the problem analysis term, we developed a questionnaire. According to Beaton et al., it can be a comprehensive and time-consuming task to develop a validated questionnaire (Beaton et al., 2000). Therefore, Beaton et al. was not followed strictly, but used as inspiration in the development process.

Development of the questionnaire

First step in developing the questionnaire was to clarify what to measure. In this study, the participants' understanding of the problem analysis was to be investigated. Thereafter, relevant questions were formulated. Each question was rated on a Likert scale going from 1-5, where 1 = totally disagree, 2 = disagree, 3 = neither nor, 4 = agree, and 5 = totally agree.

Validation and adjustments of the questionnaire

The final questionnaire was validated by two individual evaluators. Both evaluators had been supervisor before and employees at the department of health science and technology, AAU. First evaluator was associate professor with a PhD and a Master of Science degree in biomedical engineering and informatics. Second evaluator was assistant professor with a PhD and a Master of Science in Clinical Science and Technology. Both went through each question and came up with suggestions. Subsequently, the suggestions were implemented in the final questionnaire.

The final questionnaire

In total, the final questionnaire consisted of 20 questions divided in three categories and a comment section.

Question 1-5 had focus on the students' understanding of the problem analysis term before being introduced to the problem analysis tool

Question 6-10 had focus on the students' understanding of the problem analysis term after being introduced to the problem analysis tool

Question 11-20 had focus on when to introduce the problem analysis tool

Data processing of the results

The final validated questionnaire was distributed to all participants.

Microsoft Excel version 2022 was applied to conduct postprocessing. The program was used to make descriptive statistics and produce plots to visualize the results. MATLAB (r2021b, Natick, Massachusetts: The MathWorks inc.) to conduct a statistical test for differences in scores. The Mann–Whitney U test was used to assess differences in scores prior to the introduction of the problem analysis tool vs. scores post-introduction.

RESULTS

In total, 28 students received an introduction to the problem analysis tool. The introduction took approximately 1 hour. Based on experience from previous years of supervising student groups, the supervisor presented the elements in the problem analysis tool on a big monitor in the room, where the students received the supervision. The supervisor went through each section with detailed description on how to understand the reason why the specific section should be included and how it could be covered. After going through each section in the problem analysis tool and all questions the students had, the supervisor helped the students to apply the problem analysis tool on their problem analysis.

Two to three weeks after the introduction, all participants were asked to evaluate their understanding of the problem analysis term. The results are presented in Figure 1-5. 5 topics were identified, all with significant p values (table 2).

Number of topics	1	2	3	4	5
p value	$p<0.001$	$p<0.001$	$p<0.01$	$p<0.001$	$p<0.01$

Table 2. An overview of calculated p values related to identified topics in the analysis. All p values were significant.

Topic 1: Problem analysis term

The participants were asked to describe how well on the Likert scale they understood the problem analysis term. The question was asked before they received the problem analysis tool, and the same question was asked after the problem analysis tool was introduced. Figure 1 shows two categories: 'before' and 'after'.

In the 'before' category, most answered 'doubt' or 'great doubt' about content of the term. In the 'after'-category, most students answered they no doubt about the content of the term.

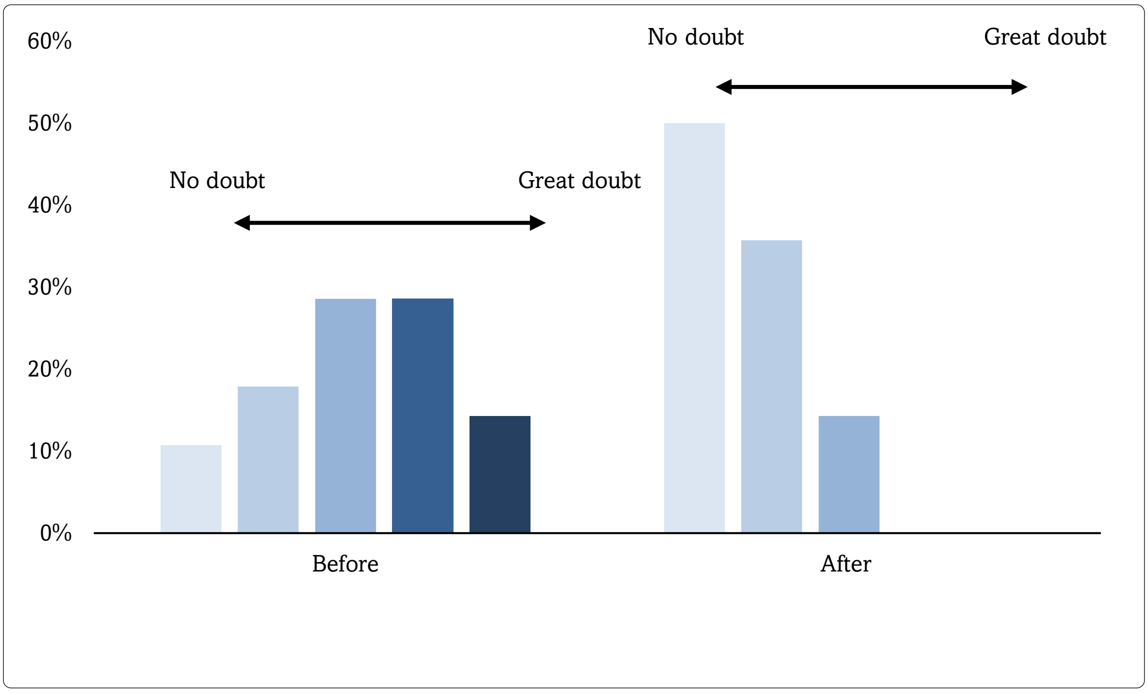

Figure 1. The participants' perception of the problem analysis term before/after the introduction (question 1 and 6).

Topic 2: Problem analysis structure

The participants were asked to describe how well on the Likert scale they understood the problem analysis structure. The question was asked before they received the problem analysis tool and after the problem analysis tool was introduced. Figure 2 shows two categories: 'before' and 'after'.

In the 'before' category, many answered 'doubt'. In the 'after'-category, most answered no doubt about the problem analysis structure.

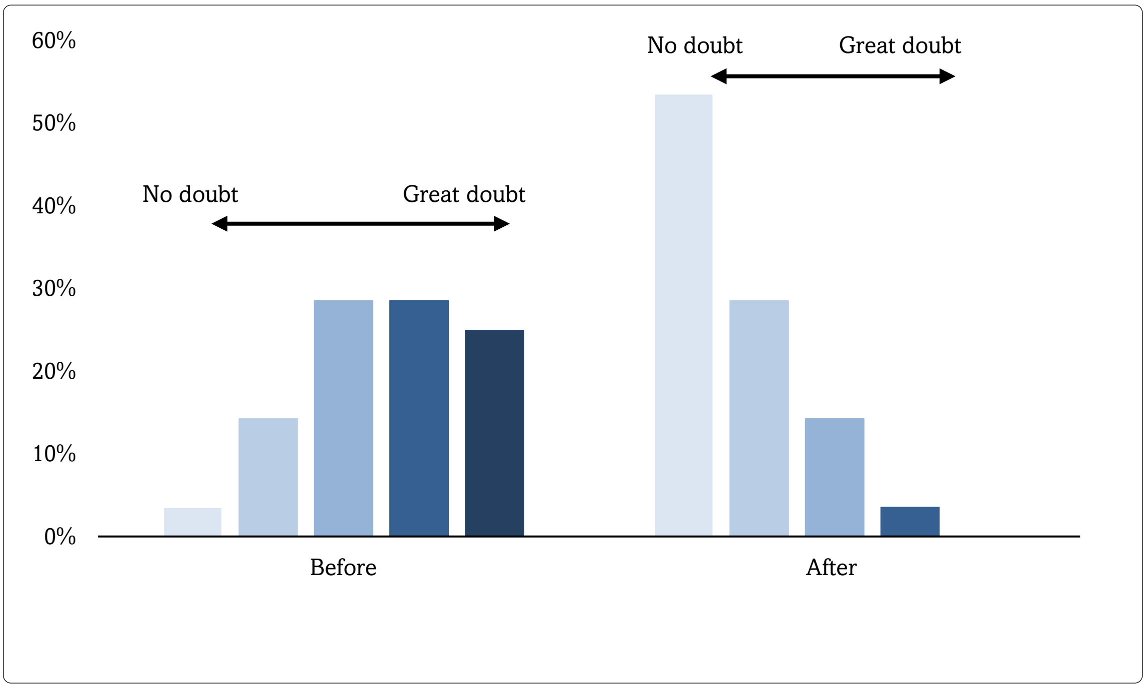

Figure 2. The participants' perception of the problem analysis structure before/after the introduction (question 2 and 7).

Topic 3: Scientific argumentation

The participants were asked to describe how well on the Likert scale they knew scientific argumentation. The question was asked before they received the problem analysis tool and again after the problem analysis tool was introduced. Figure 3 shows two categories: ‘before’ and ‘after’.

In the ‘before’ category, most answered, ‘neither or no’ closed, followed by ‘agree’ i.e., some were unsure, and some knew. In the ‘after’-category, most answered no doubt.

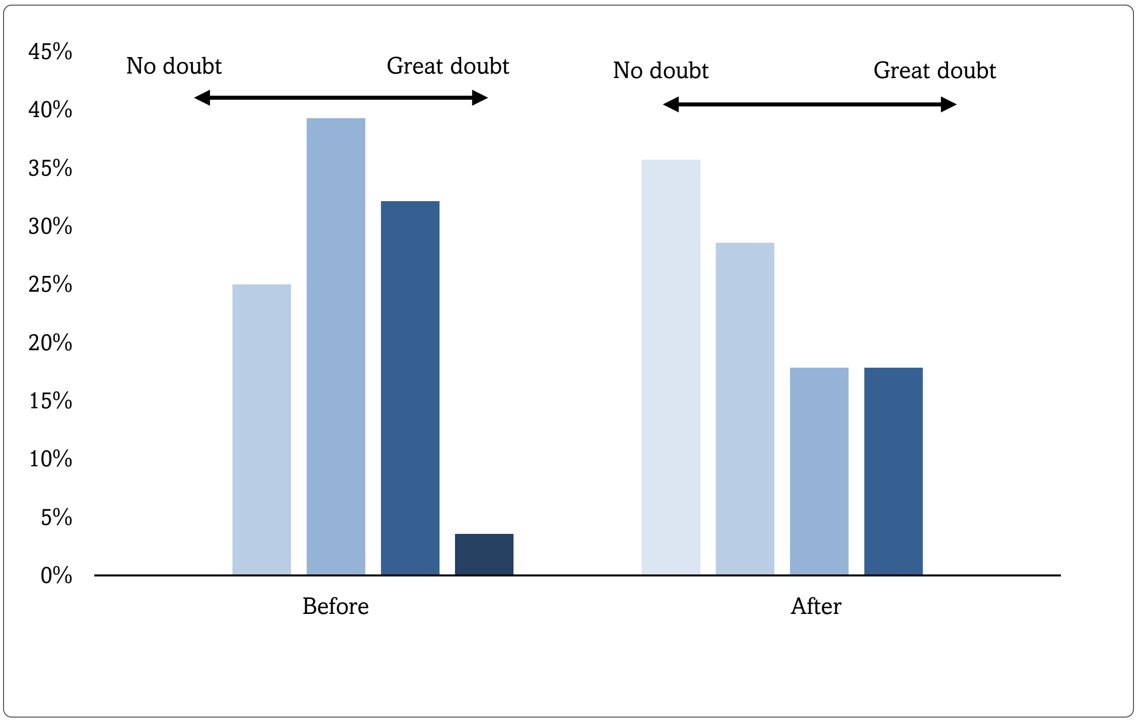

Figure 3. The participants’ perception of how to perform scientific argumentation before/after introduction the problem analysis tool (question 3 and 8).

Topic 4: From explaining to analyzing

The participants were asked to describe how well on the Likert scale they knew how to analyze a scientific problem. The question was asked before they received the problem analysis tool and again after the problem analysis tool was introduced. Figure 2 shows two categories: 'before' and 'after'.

In the 'before'-category, most did not become better informed on the term or had great doubt about how to analyze a scientific problem. In the 'after'-category, most answered 'no doubt' how to analyze a scientific problem.

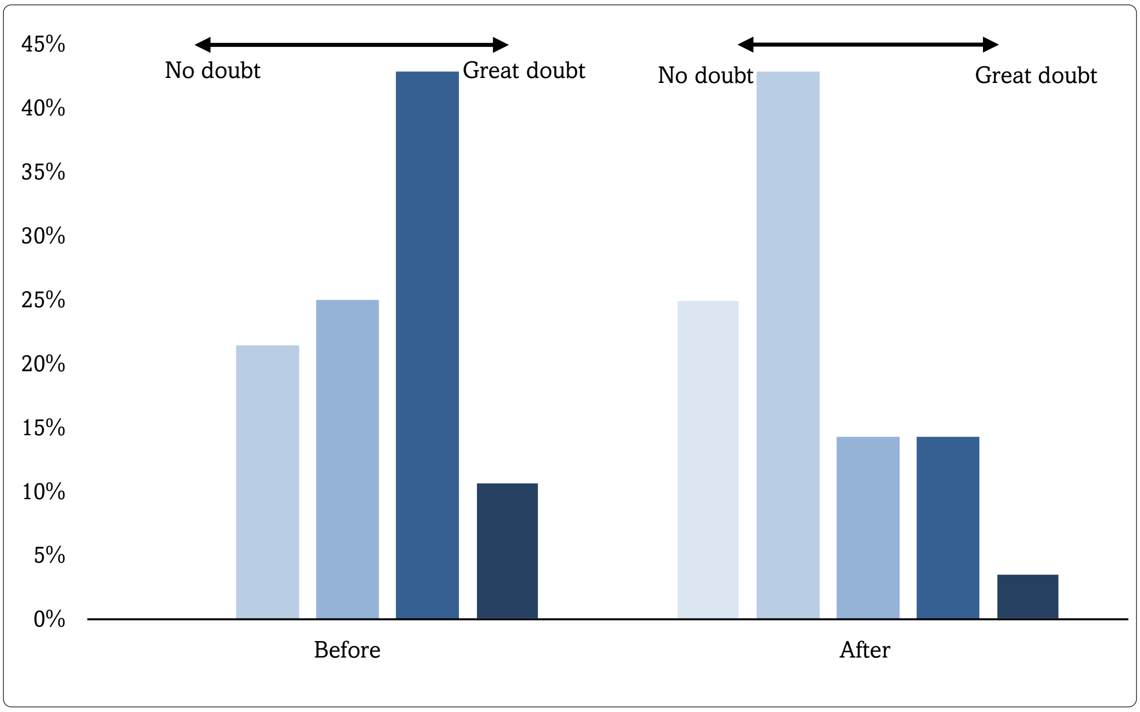

Figure 4. The participants' perception of their ability to analyze a problem before/after the introduction (question 4 and 9).

Topic 5: Using literature to argue for a scientific problem

Students were asked to describe how well on the Likert scale they knew how to use literature to argue for a scientific problem. The question was asked before they received the problem analysis tool and after the problem analysis tool was introduced. Figure 5 shows two categories: 'before' and 'after'.

In the 'before' category, the answers were divided into two groups. Most 'knew how to' use literature to argue, but many also had 'great doubt'. In the 'after'-category, most answered 'no doubt' how to argue for a scientific problem.

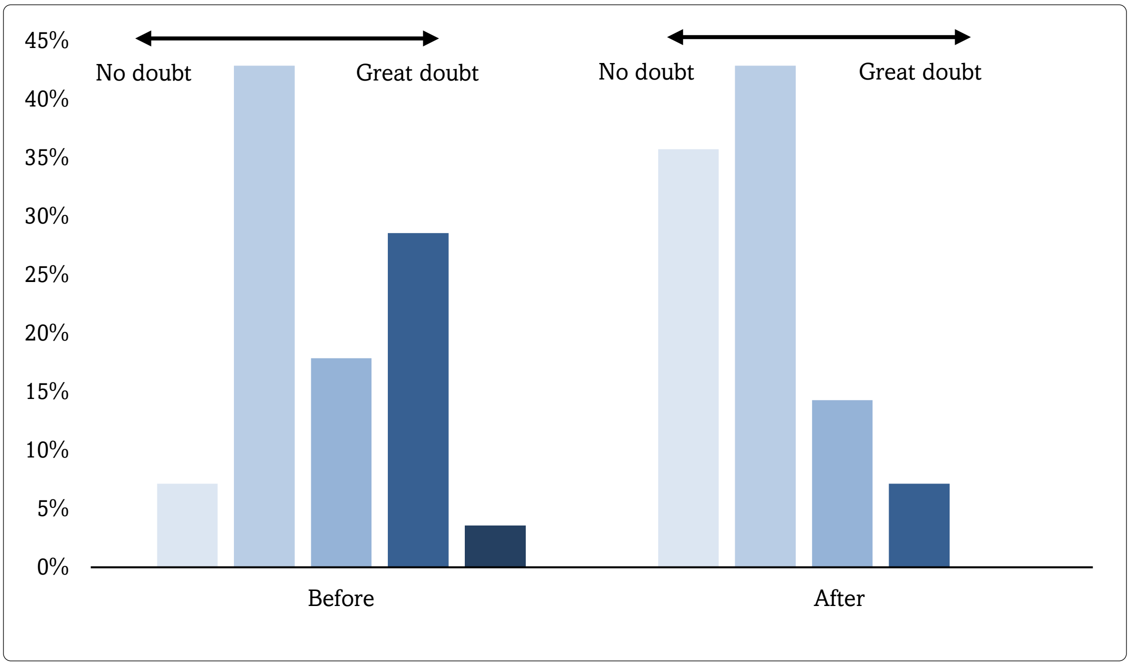

Figure 5. The participants' perception of their ability to use literature to argue for a scientific problem (question 5 and 10).

Introducing the problem analysis tool

The participants were asked to state when they thought it would be the best time to be introduced to the problem analysis tool. Figure 6 shows the answers. Some wanted to have the tool from the beginning of the semester, while others said it was the right time. Nevertheless, almost all participants disagreed on introducing the tool later in their semester.

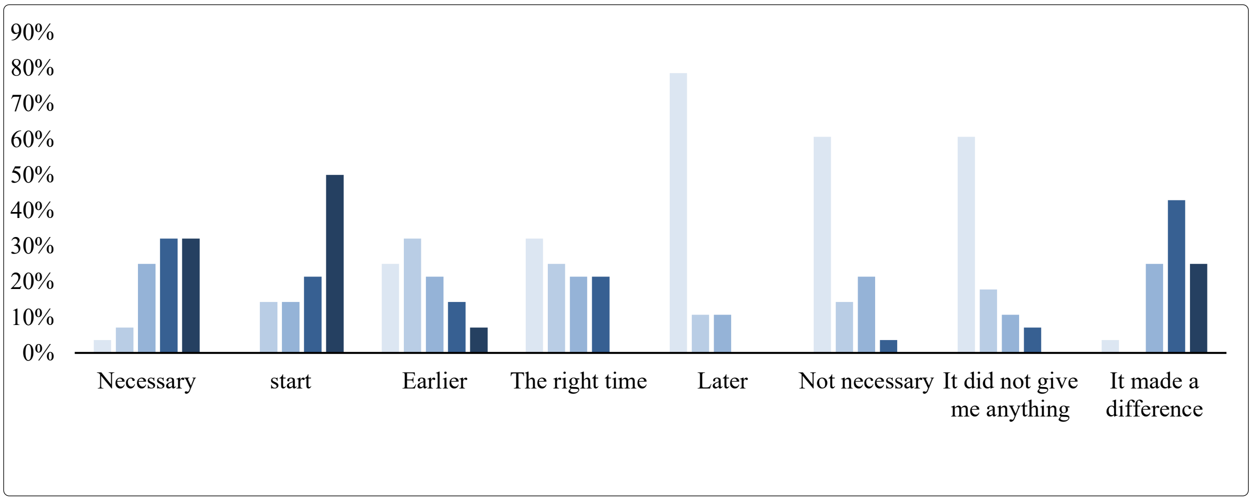

Figure 6. An overview of when the problem analysis tool should be introduced according to the students.

DISCUSSION

The aim of the study was to evaluate the consequences of introducing a problem analysis tool to master students working with a PBL project. Moreover, the students were presented to a problem analysis tool to become better to understand what a problem analysis was, what it consisted of, how to manage scientific argumentation, etc. Data analysis showed an increase (with significant p values) in the following 5 topics: 1) the problem analysis term, 2) problem analysis structure, 3) scientific argumentation, 4) learn to analyze instead of explaining, and 5) using literature to argue for a scientific problem.

Problem analysis term and structure

Figure one showed a comparison of how students understood the term 'problem analysis' before and after being introduced to the problem analysis tool. Some students knew the term, some had heard about the term without knowing what it included, and some had never heard about the term. The answers were expected since the students represented many different education programs. The opposite picture was seen after introducing the problem analysis tool. With significant p value ($p<0.001$), students no longer were in doubt about the definition of the term. Literature indicates that the problem analysis section is crucial for further progression (Hasslacher et al., 2009; Yew & Goh, 2016), and therefore, it may be inexpedient if the students are in doubt of the basis of the project, e.g., the problem analysis.

Most students agreed on having great doubt about how well they knew the problem analysis structure (83% answered 3 or more) before the problem analysis tool introduction. A significant p value, $p<0.001$, showed how most students no longer were in doubt about the problem analysis structure after being introduced to the problem analysis tool. The lack of being acquainted with the structure may be correlated with that this was the students' first semester at AAU (Holgaard et al., 2021). It may also be correlated to their background and educational institution where the problem analysis tool has not been a part of the methodological toolbox when writing projects. It would be relevant to spend resources on students, e.g., implementing a crash course where students have the possibility to practice the problem analysis structure in small project reports before writing a large project (Holgaard et al., 2021; Kolmos et al., 2008). Since understanding the problem analysis is the basis for working problem based, it makes sense to help students become better to this part.

Scientific argumentation

Figure three demonstrates how well students knew how to conduct scientific argumentation. Most students initially answered, 'neither or no' closed followed by 'agree', which refers to that students were unsure, and only knew a little. After introducing the problem analysis tool, a significant p value ($p<0.01$) showed that most students no longer were in doubt about how to argue for a scientific problem. Being able to make use of the argument model by Toulmin (claim, data or grounds and warrant) requires practice and a high academic level (Kneupper, 1978; Nielsen, 2013; Zohar & Nemet, 2002). At present, students' focus is probably on acquiring academic knowledge within specific areas, and therefore, they are not yet able to utilize the model by Toulmin since the model requires training. However, the more competent and qualified the students become, the better qualifications students have to make use of Toulmin' argument model (Kneupper, 1978; Nielsen, 2013).

Implications for practice

Studying a master program at university level requires students to be able to analyze. Moreover, students must improve their competences to analyze according to Blooms Taxonomy. Most students had great doubt about how to analyze a scientific problem before they were introduced to the problem analysis tool, which is very expectable since their prerequisites to analyze were untrained. Significant p value of $p<0.001$ showed how most students no longer were in doubt about how to analyze after receiving the introduction to the problem analysis tool. The significant changes may indicate that it is matters to spend extra resources on giving students the problem analysis tool (Nielsen, 2013).

The exact time for when a problem analysis tool should be introduced was not clear in the results, e.g., some students thought would like the introduction earlier, i.e., in the beginning of a semester, others thought it was the right time. 90% of the students thought it should be introduced later in the semester. From a pedagogical perspective, there are pros and cons related to handling out the tool at the beginning of a semester. On the one hand, students feel safe if they have models or tools they can rely on when navigating in a new academic field. On the other hand, it can be educative for students if they by themselves try and thereby gain experience, which they do not get if they get the model from the beginning of the semester. According to the psychologist Lev Vygotsky's theory zone of proximal development, learning is about supporting students to the extent that is necessary to motivate and encourage them to pass across a comfort zone (Eun, 2019; Wass & Golding, 2014). When it comes to the students included in this study, for a period test if the problem analysis tool could be introduced in the beginning of the semester for some years and then evaluate the effects. Vygotsky's zone of proximal development theory is also relevant when it comes to understanding why a crash course on practicing small projects is relevant. It helps students to find comfort in writing projects, taking risks, overcome small projects before they must write large projects.

STRENGHTS AND LIMITATIONS

A strength of the study is, to our knowledge, that there is no problem analysis tool developed. Another strength is that the problem analysis tool has been tested on students from different master programs. A limitation of the study is that the problem analysis tool is only tested on 28 students. Even though the results are significant, it would have increased the validity of the problem analysis tool if more students had been included.

CONCLUSION

Significant results showed how students believed that they had increased their understanding of the problem analysis term, problem analysis structure, scientific argumentation, and abilities to analyze instead of explaining. When to introduce the problem analysis tool depends on different pedagogical perspectives. Future work includes testing the problem analysis tool on a larger group of students.

Acknowledgement:
Thanks to the students who were willing to participate in the study.

Authors' contributions
All authors contributed to the concept of the study, the study design, and the writing process of the study. The authors read and approved the final manuscript.

Funding
There is no funding behind this study.

Declaration of interest:
The authors report there are no competing interests to declare.

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Journal of Problem Based Learning in Higher Education

VOL. 11, No. 3, 2023 – Page 90-104
10.54337/ojs.jpblhe.v11i3.7886

Using Problem-Based Learning (PBL) in an Undergraduate Ergonomics Course

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ABSTRACT

Ergonomics courses typically cover a range of topics related to the design and organization of workplaces to optimize human performance and well-being while minimizing injury risk and discomfort. This study introduces the PBL application steps to attract attention to the importance of noise not only in workplaces but also in daily life. The driving question is determined as "How can we assess and minimize the perceived daily noise exposure of people to sustain hearing health?". Then, the students are asked to evaluate the PBL activities at the end of the term. Among the students who completed all activities, 60% strongly agreed, 32% agreed that PBL contributed to the understanding of the subject, and only 8% stated that PBL didn't make a significant contribution when learning the topic of concern. The PBL framework developed for "noise" has the potential to be enhanced and adapted for other topics in this course.

Keywords: Ergonomics, noise, undergraduate course, PBL

INTRODUCTION

There are several methodologies to transfer knowledge and skills to the students. Problem-based learning (PBL) is a student-centered approach in which students learn about a subject by working to solve an open-ended problem that drives the motivation and learning (Blumenfeld et al., 1991). Project-based learning (PjBL) is defined as an approach designed to give students the opportunity to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world (Brundiers & Wiek, 2013; Krajcik & Shin, 2014). PBL aims to enhance

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instructor/student interaction and enhance creativity, critical thinking, collaboration, and communication skills of students. This study summarizes the application steps and outcomes of PBL for an undergraduate course. First, the studies related to PBL and PjBL are identified and a limited number of applications for engineering courses are discussed. Blumenfeld et al. (1991) state that PjBL helps students pursue solutions to non-trivial problems by asking and refining questions, debating ideas, making predictions, designing plans and/or experiments, collecting and analyzing data, drawing conclusions, communicating their ideas and findings to others, asking new questions, and creating artifacts. By this means, PjBL has the potential to motivate students and enhance disciplinary learning. Guo et al. (2020) also confirm that PjBL is a promising approach that improves student learning in higher education. Boisadan et al. (2022) implemented a PjBL approach during mid-March to mid-May 2020 (the Covid-19 pandemic) with 281 engineering students that were grouped into 48 teams. The results regarding the motivation were very positive and the flow and self-rated performance were high.

Hallinger (2021) reviews 14130 Scopus-indexed documents on PBL published between 1972 and 2019. It is concluded that research on PBL is significantly larger than other approaches related to active learning. Gonzales & Batanero (2016) summarize the results of a PBL research project on student learning to compare with more traditional teaching methods in Construction Engineering courses at the University of Huelva. PBL was identified as an effective and more efficient teaching method and the students have tended to show greater creativity in their problem-solving approach. Condliffe et al. (2017) state that the methodology is extensively used in engineering with good results. The design of PBL promotes students flexibility and connections to working community (Potvin et al., 2022).

Gomez-del Rio & Rodriguez (2022) apply PBL in the mechanical design subject of the Mechanical and Chemical Engineering lab. Rehmat & Hartley (2020) focus on science, technology, engineering, and mathematics (STEM) education. The quasi-experimental and repeated measures design study considered the content knowledge and critical thinking skills. The application results for problem-based learning and traditional learning groups revealed a significant difference.

The professional world is not satisfied with the traditional curriculum, also, many countries shift to outcome-based accreditation procedures in Engineering. Beddoes et al. (2010) state that these are the main reasons that project and problem-based learning is becoming more common.

The problems for the engineering disciplines should derive from real life or be a very close representation of it. The applications that the students are likely to meet in the context of their future professional lives should be considered in the curriculum.

However, based on the current accessible literature, it can be stated that there are a limited number of PBL applications in engineering courses and almost no study related to "Ergonomics". The main contributions of this study are structuring a PBL application for an undergraduate Ergonomics course and assessing the students' perception for the learning process.

The PBL application in this study aims to inspire learners and motivate good learning experiences with practical experiences. The overall implementation of the application has been presented in following sub-sections. Section two provides the problem statement and the methodology and steps of PBL-based learning. The relevant evaluation of each activity of the methodology is defined in detail. The third section provides the attainments and results obtained. The paper is concluded in the fourth section.

METHOD

This section aims to provide basic information on how PBL is used in an engineering course when teaching the concepts of an environmental factor that is critical not only in industry but also in real-life. This application aims to emphasize the importance of noise, one of the environmental factors, in working environments and daily life. The students are expected to learn main principles of noise (sound, pressure, loudness, etc.), the importance of obtaining and organizing data, and they will be able to experience and practice different noise levels in various real-life environments.

Participants

The PBL application is completed with undergraduate students enrolled to an Ergonomics course in Industrial Engineering, at the Faculty of Engineering and Architecture, Eskisehir Osmangazi University. It is assumed that no student requires Special Educational Needs (SEN).

Research design

The main steps of the PBL application and its relationship with the action words for Bloom's Taxonomy are given in Figure 1. Knowledge is related to definition, identifying, and describing the basics of the problem. In this step, the basic concepts related to noise must be reviewed from the written documents and conducting related experiments. By this means, it is possible to understand, explain, describe, interpret, and summarize the problem in concern. In the apply step, the sources of noise can be defined and illustrated. After the required modifications, the shared database can be structured. Based on several new location suggestions, the database for noise measurement locations can be compared, classified, and analyzed. In the evaluate step, the noise measurements are recorded and values are assessed. In the final step, a written product such as a poster can be created.

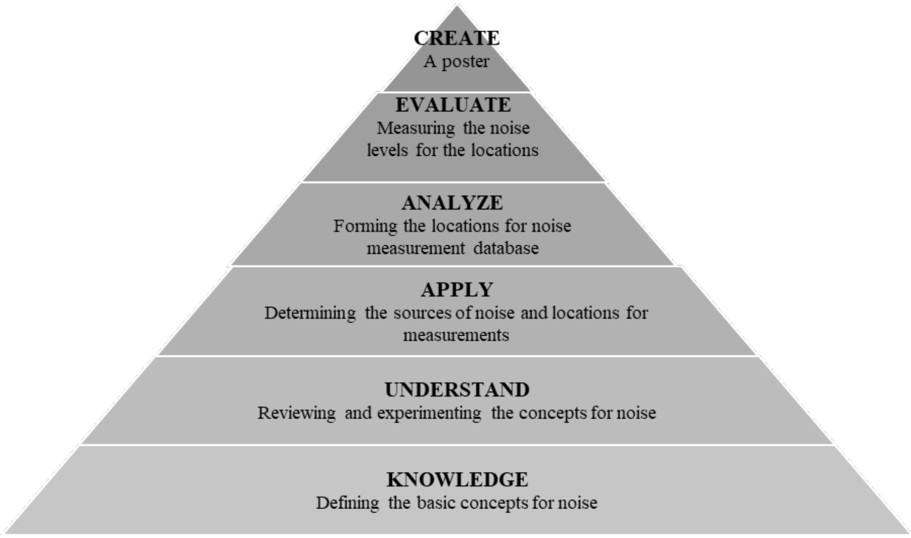

Figure 1. The main steps of the PBL application related with Bloom's Taxonomy.

The PBL application is structured for a 5-week period and integrated into a 15-week undergraduate course. Basic activities for the PBL application are summarized and described in Table 1.

No	Name of the activity	Work process	Description
1	Introduction	Introducing PBL principles	*Discussing the project aim, defining the activities and schedule. *Information on ethics.
2	Basics	Remembering and experiencing main principles of noise	*The students are requested to: *Review the course notes shared at DLP *Make a visit to the Science and Experiment Center
3	Assessment	Quiz 1	*Aims to assess if the main principles are understood
4	Specifying measurement locations	Identifying the main locations to measure sound level	*Professor suggests locations from daily life *Students discuss other possible locations for measurement *Students submit their suggestions by use of DLP
5	Measurements	Data collection and reporting	*Students download and select a free app for noise measurement. *The location of the measurement, data, and time is recorded. *Students submit their measurements
6	Reports	Forming a database of noise level measurements	*The students share their measurement values and related critical information
7	Written product	Forming a poster	*The students design a poster to summarize the activities and achievements during the project *Students submit their file by use of DLP
8	General assessment	Quiz 2	*Aims to get the feedback from students concerning the project and activity design

Table 1. The activities defined for the PBL application.

The students are informed about the aim of PBL and the schedule is provided during the course hours. The students are requested to review the course noted shared from Distance Learning Platform (DLP) and make a visit to Eskisehir Science Experiment Center [URL.1.]. There are several experiments and detailed information in this center related to astronomy, pressure, balance, mechanics, basic machines, electric and magnetism, optics, chemistry, energy, natural events, and scientists. The students are suggested to visit the noise experiments such as whispering bowls, speech pipes, xylophone pool, audible pipes, and buzzer in a vacuum.

A Quiz, given in Appendix 1, is defined at the DLP and conducted in the second week. The first question in Quiz 1 aims to identify whether the students have any prior information on PBL and if they think the methodology is suitable for the Ergonomics course. The second and third questions aim to gather information on whether the students completed the defined review activities. The rest of the questions aim to assess if the main principles of noise are understood.

Examples of main locations for sound measurements are shared by use of DLP with the students such as construction site, house, transportation, and the like. Then, the students are encouraged to discuss possible locations to measure noise levels. By use of DLP, each student submitted more specific locations from daily life such as cinema, shopping mall, bazaar, apartment elevator, classroom, canteen, and urban transportation (i.e., tram, bus). During the data collection and reporting activity, the students downloaded a free app to their cell phones. The sound levels that can be exposed in daily life were measured and recorded. Based on the reported data, the database for measurements was revised and shared with students by the course instructor. The students compared measurement values with standard limit values and made comments on daily exposure values.

The “written product” of the PBL application was defined as forming a poster. The posters, highlighting the importance of hearing health, summarized the activities and achievements during the project and were uploaded to DLP as a file by each student. The rubric for posters is formed of three elements as context, performance, and visuality. The assessment is made as distinguished, proficient, basic, and unsatisfactory. A detailed rubric for poster can be requested from the author. As the final step of the PBL application, the feedback from students concerning the project and activity design was received by a Questionnaire with five questions (Appendix 2).

RESULTS

116 students were enrolled in the Ergonomics course during the 2021-2022 Spring term which lasts 15 weeks. The PBL application influenced 25% of the final exam, which counted 60% towards the overall course grade. The remaining 40% of the overall course

grade was assessed with a written midterm exam. The activities related to PBL were assessed considering the results of Quiz1-review of the topic (20%), Submitting data collection location suggestions (5%), Submitting data reports on time (10%), Submitting the poster (50%), and Quiz 2-questionnaire for feedback (15%).

The schedule for PBL activities and assessment criteria is announced in the second week of the course. However, all students who are registered to the course did not participate in the quizzes or submitted the requested documents from DLP. It is not mandatory for the students who have failed the course in previous terms to attend the face-to-face classes. There is also a possibility that these students have not followed the instructions announced from DLP.

To avoid any misleading comments for the PBL application, the comments for the 45 students who completed all PBL activities (Quiz 1, Suggestion, Data collection, Poster, and Quiz 2) during the Ergonomics course are considered.

The comments of students for the first question of Quiz 1 "*Choose the answer that best describes your opinion on PBL and PBL application for the Ergonomics course.*" are as follows:

- *I heard about PBL. I think that the methodology is not suitable for the Ergonomics course*: 2%
- *I heard about PBL. I think that the methodology is suitable for the Ergonomics course*: 44%
- *No idea*: 3%
- *I did not hear about PBL. I think that the methodology can be applied for the Ergonomics course*: 46%.
- *I did not hear about PBL. I think that the methodology can not be applied for the Ergonomics course*: 5%

89% of the students answered the second question of Quiz 1 "*I read the document shared from Distance Learning Platform.*" as "Yes", confirming that they have reviewed the file shared by the instructor. 46% of the students declared that they had visited the Science Experiment Center and gave a positive answer to the yes/no question of Quiz 1 "*I visited the Eskisehir Science and Experiment Center during the stated time period to support the basic knowledge I learned about noise*."

The Science and Experiment Center visit and participation in discussions aimed to help students to review the concepts of sound and noise. Answers to the first three questions were not included in the grading. Considering the rest of the questions, the average of Quiz 1 is 71 and it can be considered that students have a basic knowledge of the topic in concern.

The students were asked to suggest locations for data gathering and then measure noise levels. The average grade for the activities is 76 and 77 respectively. Based on the noise level database, the students formed a scenario, calculated a noise exposure level, designed a poster, and submitted by DLP. Interested readers can request example posters from the author.

Quiz 2 is conducted to obtain students' feedback and suggestions.
The comments of students for the first question of Quiz 2 "*Evaluate the contribution of your PBL application to the understanding of the subject*." are as follows:

- *It was very helpful*: 60%
- *Was useful*: 32%
- *Didn't make a significant contribution*: 8%
- *Did not contribute*: 0%
- *I have no idea / I did not participate in the application*: 0%

The students were asked to evaluate the PBL activities. 51% specified that they had difficulties when creating the poster. 30% stated that they had problems in creating a daily exposure scenario.

Based on the feedback from the students, it is possible to revise and restructure future PBL applications. The comments of the students provided for the open-ended question in Quiz 2 can be grouped under the outcomes of PBL, difficulties faced during PBL activities, and suggestions for a specific PBL activity.

Students' comments reveal that the PBL application was useful in learning and practicing the concepts related to noise. A number of selected comments are given as follows:

- *It was an application that we had not done before.*
- *It will be very useful to implement project-based learning for different subjects in other courses too.*
- *It was a very instructive application.*
- *It was enjoyable to research and measure about the noise.*

The PBL application was new for the students. Therefore, students suggested that further in-class demonstrations and examples might be helpful. Related comments are as follows:

- *I think this and similar activities can be made. The duration for analyzing data can be longer.*
- *An exemplary study can also be done during the class. Such as measurement and evaluation from the phone.*
- *I had difficulties in forming the exposure chart. I didn't know exactly how to do it.*

To enable consistency and ease of evaluation, instructions for poster preparation were shared with the students. Students suggested that there would not be any limitations for the page number and the style. On the other hand, some of the students suggested to present the poster in the class and discuss the activities.

- *The poster preparation instructions make the preparation process more difficult.*
- *I'd prefer to make a presentation rather than preparing a poster.*
- *Discussion of the poster face-to-face in class with friends would be better.*
- *New arrangements can be made in the size and outline of the poster.*

CONCLUSIONS

This study revealed that the PBL application, a new teaching method for the students, had attracted attention and was stated to be very useful for learning the topic in concern. The information and document transfer for the PBL application was conducted by utilizing the internet computer technologies that the students are familiar with.

There are a few limitations that may impact the findings of this study. The PBL application was designed for a specific topic of a single course, which may be considered as a limitation. Instead of bolting the PBL activities, integrating PBL more into the course program can be more useful for the students. The successful outcome can depend on the detailed and well-structured PBL design.

The majority of the students enrolled in the Ergonomics course found this PBL application very useful to learn the topic. However, this result cannot be generalized for other topics of the course. In the following studies, the PBL application can be restructured to cover other environmental factors in the Ergonomics course such as illumination. The students may be encouraged to present their posters with other students enrolled to the course, the groups from workers of the metal industry, medical school undergraduate students, and/or high school students. By this means, it can be possible to discuss the importance of "noise" from different points of view.

The PBL application can be considered a promising approach that improves student learning. In this study, the PBL application steps for a course are introduced and the students who are enrolled in the course participated in the PBL activities. Further studies can be structured to assess and quantify how PBL improves student learning. A comprehensive study by defining control and experimental groups can be conducted and the results of statistical analysis can be compared.

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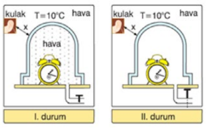
Appendix 1: Quiz 1 – Assessment of main principles of PBL and noise

1. Choose the answer that best describes your opinion on PBL and PBL application for the Ergonomics course.
- o I heard about PBL. I think that the methodology is not suitable for the Ergonomics course.
- o I heard about PBL. I think that the methodology is suitable for the Ergonomics course.
- o No idea.
- o I did not hear about PBL. I think that the methodology can be applied for the Ergonomics course.
- o I did not hear about PBL. I think that the methodology can not be applied for the Ergonomics course.

2. I read the document shared from the Distance Learning Platform.
- o Yes
- o No

3. I visited the Eskisehir Science and Experiment Center during the stated time period to support the basic knowledge I learned about noise.
- o Yes
- o No

4.



State I. The noise from the striking clock can be heard easily
State II. There is no air in the bell glass and no sound is heard from the striking clock
Select the correct answer based on the results of this experiment.
- o Air insulates sound
- o As the ambient temperature increases, the sound travels faster
- o The clock cannot work in an environment without air
- o As the ear approaches the bell glass, the sound intensity increases
- o Sound cannot propagate in an environment without air

5. Which of the following information about sound waves is incorrect?
- o The louder the sound, the greater the distance the sound can reach
- o The speed of sound waves depends on the type and temperature of the medium
- o The speed of sound in solid medium is greater than its speed in liquid medium
- o Sound waves emanating from the source propagate globally
- o As the temperature of the air increases, the speed of sound in the air environment increases

6. I- In a period of one period, sound waves travel as long as the wavelength
II- Whether the sounds are high-pitched or low-pitched is a result of the frequency of the sound
III-High-pitched sounds are called loud sounds, low-pitched sounds are called low loudness
IV-The intensity of sound waves is inversely proportional to the amplitude of the wave
Which of the following is the correct answer?
- o I-II-III-IV
- o I-II-III
- o II-III
- o III-IV
- o I-II

7. Which of the following information about sound waves is incorrect?
- o Sound waves exert pressure on surfaces by transferring energy
- o Sound waves are transverse waves
- o Sound is a mechanical wave
- o Every vibrating object is a source of sound
- o When an object vibrates, it transmits sound waves as a result of the compression and dilution of air molecules

8. *"A person who cannot see or hear the sound of the train can hear the sound of the train when he puts his ears on the tracks."*
Based on the given statement, in which option is the information(s) given correct? (Temperature is constant)
I-Sound propagates faster in solids than in gases
II-The speed of propagation of sound in solids is higher than the speed of propagation of light in air
III-As the train approaches, the speed of sound propagation increases

- o I-II
- o I-III
- o II
- o I-II-III
- o I

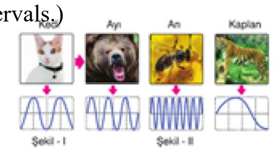
9. "*The speed of sound is measured as 430 m/s in K, 1400 m/s in L and 745 m/s in M.*"
Based on the given statement, assuming that the ambient temperature is equal, in which option are the states of substances K, L, and M correctly given?
- o Liquid-Gas-Solid
- o Solid-Liquid-Gas
- o Gas-Liquid-Solid
- o Gas-Solid-Liquid
- o Liquid-Solid-Gas

10. "*Different sounds are obtained from a sound source whose amplitude can be changed.*"
Which of the statements given in the options is true?
- o Sound with a low amplitude is carried farther away
- o Variability in amplitude does not affect the frequency of sound
- o The amplitude of the sound decreases as the amplitude is increased
- o The frequency of the sound increases when the amplitude is increased
- o The amplitude of the sound increases, the intensity of which is reduced

11. Which option provides the expressions to fill in the blanks?
When an object vibrates ..... occurs. But the object should be in a material such as .... or .... When the object vibrates in .... no sound is generated.
- o sound, air, water, ın vacuum
- o energy, air, vibration, air
- o movement, sound, air, water
- o sound, solid, liquid, excess
- o with sound, space, air, energy

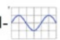
12. Which of the statements given about sound frequency is true?
- o The loudness of the sound depends on its frequency
- o It is a measure of the energy of the sound source
- o The human ear can hear sounds of any frequency
- o It is a measurement related to the intensity of the sound
- o The loudness of the sound is related to the frequency of the sound

13. The sound wave of a cat is represented in Figure-I. Accordingly, which of the graphs given in Figure-II can be correct for the sound waves of bears, bees and tigers? (Graphs have equal time intervals.)

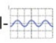


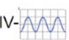
- o Bear, Tiger
- o Bee, Bear
- o Bear
- o Bee, Tiger
- o Bear, Bee, Tiger

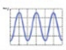
14. Wave graphs of some sounds produced in equal time have been created. Accordingly, in which option is the frequency of the given sound wave different from the others? (The pods are evenly spaced.)

I- 

II- 

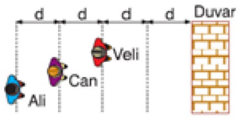
III- 

IV- 

V- 

- o III
- o IV
- o V
- o II
- o I

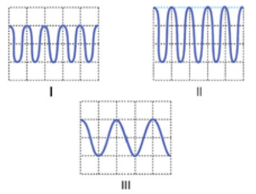
15. In the figure, the distances of three people to the wall are represented.



I-Only Ali and Can's voices reflect off the wall
II-Ali, Can and Veli can hear the echo of their own voice
III-Can hears the echo of his voice before Ali
Which option gives the correct statement(s)?

- I
- II-III
- I-II-III
- III
- II

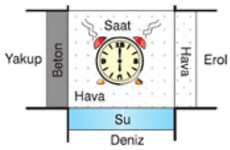
16. Sound waves obtained in 1 second in the same environment are modeled as in I, II and III.



For these sound waves
A-The sound with the highest intensity is the sound II
B-The sound with the lowest height is the voice III
Sounds C-I and II have equal intensities and different heights
Which option gives the correct statement(s)?

- A
- A-B-C
- B-C
- B
- C

17. As stated in the figure, there are different items between a room with an alarm clock and the environments where students are located.



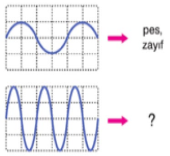
Three students listen to the sound of the alarm clock and make the following comments.
Yakup: I hear the sound of the clock first.
Deniz: Since sound propagates slowly in liquids, I hear the sound at the latest.
Erol: The voice reaches me at the latest.
Which option provides the right comments?

- Yakup
- Yakup, Deniz
- Erol
- Yakup, Erol
- Yakup, Deniz, Erol

18. When the sound encounters an obstacle, ...
When written in the blank place, which option leads to an incorrect sentence?

- may be reflected.
- it spreads in the form of waves in all directions.
- part of the sound passes through obstacles.
- part of the sound is swallowed up by the obstacle.
- the intensity of the reflected sound is less than the intensity of the incoming sound.

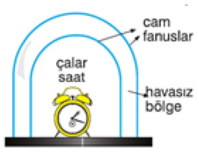
19. Wave graphs of the sounds produced in the same period of time by two different sound sources, K and L, are given in the figure.



According to the definition for the sound wave K, which of the information given in the options for L is correct?

- o high pitched-intense
- o low-pitched-loud
- o low-pitched-intense
- o high-pitched-loud
- o high-pitched-weak

20. A person cannot hear the sound of the clock ringing, which is placed in glass bells as shown in the figure.



Which of the interpretations given in the options is correct?

- o If the watch is made to sound more violently, the sound can be heard
- o If the air in the innermost bubble is evacuated and the air is filled between the two lanterns, the sound of the clock can be heard
- o In order for the sound of the clock to be heard, the ear must be very close to the lantern
- o If the space between the two lanterns is filled with water, the sound can be heard
- o If the innermost bubble where the alarm clock is located is deflated, the sound can be heard

21. Your views on the topic of sound and noise...

- o I think it's very important for working life.
- o I have no idea.
- o I think it's important in our work and daily lives.
- o I think it's very important in our daily lives.

Appendix 2: Quiz 2 – Questionnaire for feedback

Question 1. Evaluate the contribution of your PBL application to the understanding of the subject.

- It was very helpful
- Was useful
- Didn't make a significant contribution
- Did not contribute
- I have no idea / I did not participate in the application

Question 2. In the following years, when it is planned to repeat the implementation of PBL with the subject of sound, do you have a different proposal?

- No changes are required
- The application scope is extensible. (e.g. taking measurements in enterprises, etc.)
- The application time can be increased.
- The application can be carried out with groups of students (e.g. minimum 2, maximum 10).
- The results of the application can be presented to other students, high school students, relevant business employees.

Question 3. In your opinion, which subject is the most suitable subject for PBL application within the scope of the Ergonomics course?

- Lighting
- Vibration
- Musculoskeletal Disorders
- Manual materials handling
- Instrument and panel design
- Sound-Noise
- I have no idea

Question 4. Specify the activity that challenges you the most during the implementation of PBL.

- I completed the application steps without difficulty.
- I had difficulty in determining the measurement locations.
- I had difficulty in choosing and using the application to take measurements.
- I struggled with the daily exposure scenario design.
- I had a hard time creating a poster.
- I had difficulty recording the measurement values.

Question 5. Other topics that are not included in the questions, that you want to specify with the application...

Journal of
Problem
Based
Learning
in Higher Education

VOL. 11, No. 3, 2023 – Page 105-118
10.54337/ojs.jpblhe.v11i3.7584

Interdisciplinary Pedagogy through Problem-Based Learning: A Case Study in Global Health Education

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ABSTRACT

This case study piloted an interdisciplinary Problem-Based Learning course, utilizing Hung's (2006) 3C3R model. We explain the course design, curriculum, and implementation. We collected qualitative written questionnaires from students who participated in the course to investigate their learning experiences. As a result, students shed light on lessons they learned throughout the course, which led to the creation of a lessons learned guide for future instructors. This guide encompasses 8 lessons that were gleaned by both qualitative student feedback and instructor reflections from the course. These lessons include allocating in-class time to work on projects, using a modular approach in the course design, presenting students with real-life problems related to the topic of the course, providing in-class case studies for students to get acquainted with examples of previous work, grouping students from diverse academic backgrounds together when possible, utilizing online and librarian resources, surveying the classroom on their comfort with self-directed learning beforehand, and including a self-reflection piece at the end of the course.

Keywords: Problem-based learning, PBL, interdisciplinary, 3C3R model

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INTRODUCTION

Interdisciplinary learning is characterized by integrating knowledge from more than one discipline to address a central theme, problem, or scenario (AI-Saleem, 2018; Boon & Van Baalen, 2018; Ivanitskaya et al., 2002). During this process, students may bridge disciplines together to construct new perspectives and insights (Ivanitskaya et al., 2002; Stentoft, 2017). One common approach to exercise interdisciplinary learning is through Problem-Based Learning (PBL) (Braßler, 2016; Garrett, 2019; Imafuku et al., 2014; Kaplan et al., 2016). PBL is described as a didactic approach that allows students to engage with interdisciplinary learning, as it requires students to work in collaborative groups to identify a problem, learn and apply their knowledge to the problem, and reflect on what they have learned throughout the process (Hmelo & Ferrari, 1997; Hmelo-Silver, 2004; Stentoft, 2017).

Initially, PBL was created as an instructional method at McMaster University in Canada, to help medical school students integrate knowledge into clinical practice and navigate an abundant amount of information (Kim et al., 1999.; Maudsley, 1999; Savin-Baden & Major, 2004). Similarly, sufficient evidence has demonstrated that interdisciplinary PBL approaches offered at the post-secondary level have benefited student learning outcomes, leading to an enhanced understanding and competency across subject matters, in addition to students reporting that bridging disciplines was entertaining (Braßler, 2016; Garrett, 2019).

Given the benefits of PBL from previous literature, we created a Global Health and Human Biology course. The purpose of this course was to allow students to bridge human biology and global health concepts, in order to address a global health threat and generate creative solutions. Ultimately, the relevance of this course was to expose students to the reality of working with a limited financial budget in order to address a health issue in a particular geographical area, similar to what many private and public sector organizations seek to achieve. In doing so, students were exposed to the reality of the vast effort it takes to address these real-life health problems, and had the opportunity to become global citizens as they faced these challenges.

Theoretical Framework

As educators around the globe aim to create effective PBL courses, Hung (2006) developed a conceptual framework to systematically optimize the creation and exercise of PBL within a classroom setting. *The 3C3R model: A Conceptual Framework for Designing Problems in PBL* (Hung, 2006) includes the combination of two parts - core and processing components (Figure 1).

Core components

The core components are comprised of *content*, *context*, and *connection* (the 3 C's). These core components are intended to provide learners with the fundamental concepts to help develop a greater understanding of the real-life problem's topic. The content section involves the sufficiency of knowledge obtained regarding the topics within the course (Hung, 2006). A key element within this section is to create specific learning goals and objectives to maximize the potential for students to obtain the adequate content required for their problem-solving journey (Hung, 2006; Tawfik et al., 2013). The context section of this model explores the setting in which the course material is learned among students (Hung, 2006). It is recommended that content is learned within a similar context that it will be applied, thus allowing the knowledge to be recalled and used more easily (Godden & Baddeley, 1975; Halpern & Hakel, 2003). Lastly, the connection section serves to integrate the content and context together, with the intention of guiding learners to build unique conceptual frameworks surrounding the topic of their problem (Hung, 2006).

Processing components

The processing components are *researching*, *reasoning*, and *reflecting* (the 3 R's). Working alongside the 3 C's, the 3 R's support the engagement of the problem-solving process for the real-life problem (Hung, 2006). The researching section involves learners researching the necessary information within the domain of their problem. Simultaneously, the reasoning section promotes the application of the knowledge gained from researching, allowing students to put their knowledge into practice and develop problem-solving skills to generate new ideas, hypotheses, solutions, and engage in meaningful dialogue (Hung, 2006). During this process, Hung (2006) emphasizes the importance of calibrating the learner's comfort level of self-directed learning that is needed to adequately address and solve the given problem. In connection with establishing an appropriate level of self-directed learning, Barrows (1986) classified three levels of self-directedness within PBL into teacher-directed, student-directed, and partially student-and-teacher-directed. Additionally, within these two phases, Tawfik and others (2013) suggest incorporating a problem-solving protocol for students to identify essential characteristics of the problem and couple them into their research (Tawfik et al., 2013). Finally, the reflecting section allows students to reflect on what they have learned throughout their problem-solving process (Hung, 2006). During this section, undergoing a summary or self-evaluation of the problem-solving skills gained are key components of PBL that help achieve quintessential learning outcomes (Hung, 2006; Rinehart et al., 1986; Savery & Duffy, 1995).

The overall significance of the 3C3R model is that it provides a systematic method for instructors to design and implement effective problems within a classroom setting (Hung, 2006).

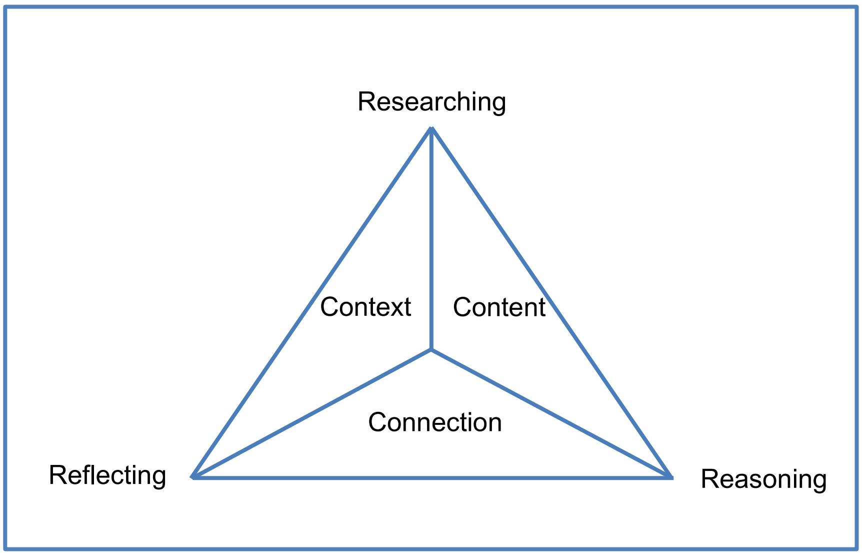

Figure 1: 3C3R PBL Problem Design Model.

With the potential impact that PBLs can have on post-secondary student learning experiences, we sought to create and pilot an interdisciplinary PBL course, which was designed utilizing the 3C3R model. The purpose of this study was to gain insight into the impact of this interdisciplinary PBL course, in order to understand how such a post-secondary pedagogical approach can contribute to higher education.

METHOD
- CONTEXT AND CONTEMPLATION

Overview of the 3C3R PBL model and designing an interdisciplinary course that is problem-based

Using the 3C3R model as a guide, we developed a third-year post-secondary PBL interdisciplinary course, entitled *Global Health and Human Biology*. This was a lecture-based course offered once a week in the Winter semester through the Department of Health & Society at the University of Toronto Scarborough Campus. Importantly, this course was designed with the following specifics to include the core and processing components within the 3C3R model:

Core components:

To incorporate the core components, we created two learning goals and utilized a three-tiered modular approach for the entire course. The learning goals for this course were twofold: to understand the dynamic connection between human biology and global health, and to address global health challenges by applying the science of human biology. The purpose of the learning goals were to establish the interdisciplinary nature of the course and to ensure students were made aware of the learning goals. The structure of the course was in the form of the following three consecutive modules: the first two modules aimed to provide students an overview of human biology and global health as well as the context in which they connect with one another. Here, students were provided with in-class lecture-based case studies of health issues around the globe and how they are addressed by world leaders and organizations. Within the third module, the aim was to apply the connection of these two disciplines by introducing students to real-life problems, (which were different than the in-class examples in the first two modules) that involve an understanding and application of both human biology and global health knowledge. The real-life problems were selected based on being able to relate the content the students learned from the first two modules to the context of real-life global health challenges. The purpose of the three consecutive model structure was to allow students to first reach content and context acquisition, and subsequently be exposed to a real life scenario where they must connect the content and context together to solve their real world issue.

Processing components:

To incorporate the researching and reasoning sections, we created a seven-step problem-solving protocol for each group to follow in their projects (Table 1), similar to what Tawfik and others (2013) suggested. The purpose of this protocol was to provide students with a balance between freedom and structure in their researching phase. We did not want to overburden students given the vast amount of information that is available to solve their challenges, therefore, this protocol acted as guide for students to explore their creativity while having a general guide to follow. Additionally, this protocol was useful to standardize all group reports and presentations in terms of expectation and project deliverables. Students then collaborated in teams of 5-6 during the third module of the course to create a rough draft report submission. After which, each group received feedback from the course instructor. The purpose of this report was for the instructor to assess and calibrate the amount of additional support, if required by any group(s). We chose to select a partial student-and-teacher-directed learning, wherein students submitted rough drafts of their projects prior to their final presentations and reports. We did not investigate if students had been previously exposed to other PBL courses, and as such we utilized this self-directed learning approach as a buffer in order for the instructor to further support and provide feedback to learners in their problem-solving process, if needed. Lastly, each group created a final presentation and report on their respective projects (Table 2). For the reflection section of this model, after each group presented, fellow classmates had the opportunity to ask questions to the presenting group, allowing students to engage in active discussion and reflect on their problem-solving journey.

Participants

Participants represented third to fifth-year undergraduate students who were enrolled in the *Global Health and Human Biology* course in the Department of Health & Society at the University of Toronto Scarborough Campus (UTSC) in the spring semester of 2019. UTSC is known as a satellite campus of the University of Toronto, which is located in Scarborough, Toronto, Ontario, Canada. The campus provides a wide range of undergraduate studies, including Computer & Mathematical Sciences, Arts and Humanities, Social Sciences, Life Sciences, Business Management, Physical & Environmental Sciences, and Psychological & Health Sciences. The Department of Health & Society offers programs that encourage an interdisciplinary perspective to understanding health, aiming to develop well-rounded students prepared for future careers across diverse fields. Females make up the bulk of this department, and there is a diverse age range across all students. Majority of the Department of Health & Society students come from Life Sciences and Social Sciences backgrounds. This rich class makeup allowed for meaningful exchange among students in their group projects. A total of 58 students were enrolled in the course, and 43 students participated in this research study.

Data Collection

The goal of the study was to investigate the impact of this interdisciplinary PBL course, in order to understand how such a post-secondary pedagogical approach can contribute to higher education. We created a student participant questionnaire to explore reflections and lessons learned throughout this process that are theoretically grounded in the 3C3R model. As such, these reflections and lessons learned may serve as guidance for other educators who wish to utilize the 3C3R model. The interviews of participants involved the administration of a written questionnaire in class from a researcher. The questionnaire was in English and lasted for approximately the last 25 minutes of class. During this time, the researcher explained the purpose of the study and administered the consent forms. The researcher read over the consent form aloud to the class, including the two interview questions on the questionnaire. Students who did not wish to participate had the opportunity to leave the classroom. After which, the researcher collected the consent forms and administered individual paper copies of the questionnaire to the individuals who consented. The researcher remained within the class as students filled the questionnaire to answer any questions or comments they had. To maintain student anonymity, the consent form was first administered and collected from students. After which, all students who consented to participate were given the questionnaire and were instructed not to place their name, sex, year of study, or any identifying information on the questionnaire. Within the questionnaire, participants were asked what experiences and lessons they acquired from their group projects as it pertained to the course. Specifically, the questionnaire included the following two questions:

1: What has been the impact of your group projects on your learning, particularly as it pertains to bridging the disciplines of global health and human biology?

2: Enumerate any three lessons you have gleaned from undertaking your group projects as it applies to bridging the disciplines of global health and human biology. Provide examples where necessary.

Evaluation of PBL Implementation

Data Analysis

After the questionnaires were collected, participant responses were transcribed to an electronic format, which led to approximately 43 pages of text. A general inductive approach (Thomas, 2006) was used to analyse this data in relation to the 3C3R model, where relevant quotations were categorized into the various components of the model. Using this analysis method allowed the raw data to be condensed into distinct categories of the 3C3R model.

Reflections and Lessons learned:

From this process, student quotations were used as a guide to showcase the lessons learned from creating and implementing an interdisciplinary PBL course, that was grounded in the 3C3R model. Importantly, these lessons were created with the input from both the student responses, as well as instructor reflections from the course. Overall, these lessons are intended to serve as a guide for educators who wish to create interdisciplinary PBL courses utilizing the 3C3R model. The lessons for each component included:

Content

1. **Meet the family:** Allocate timeslots within class sessions for students to work on their projects. This allows the instructor to provide further support (if needed) for students during their content acquisition journey. In doing so, the instructor can help plant clues if students feel stuck or need further guidance.

2. **Model me this: Consider utilizing a modular approach.** Dividing the course into modules may allow instructors to first provide a sufficient breadth of content and context, followed by students completing their real-life group-based problems. This course comprised of three modules, which helped align and execute the course objectives. The first two modules focused on content and context acquisition, and the last module provided the opportunity for students to complete their real-life PBL projects.

Context

3. **Let's get real:** When possible, present students with real-life problems related to the field of the intended course to maximize the potential for context validity. One student shed light on this by explaining *"it is essential to understand the country of focus [with] a very holistic manner, you cannot scale your innovation without truly understanding the culture..."* (Participant 28). This student reflection highlighted the importance of taking the context of the target population into consideration when creating their intervention to solve their health problem.

4. **Can I get an example?:** Provide in-class case studies for students to get acquainted with examples of previous work and inspire them. This helped one student as they expressed *"I realized how important closing cultural and linguistic gaps are. I analysed studies that showed greater compliance to treatment after incorporating nurses that spoke [the] same language as the target group"* (Participant 12). This student response demonstrated how an in-class example provided them with a greater perspective to addressing language barriers within a health setting.

Connection

5. **Make each layer of your cake different:** Group a diverse range of students who come from various academic backgrounds into the PBL course design, when possible. This may maximize the potential for students to share their area of expertise with each other and facilitate richer discussions to connect the content and context together. One student in particular stated that they learned to *"work in a group with people from a variety of disciplines*" (Participant 20) and another who expressed that *"innovative ideas stem from a variety of different disciplines…. [it] is most effective when many ideas and thoughts from different domains are combined to create an effective solution"* (Participant 30).

Researching

6. **Transformers unite:** Include appropriate website links to each group that are relevant to their problem and incorporate a class session on effective online searching with university librarians. This aims to guide students on their research journey and have reliable sources they can turn to, as well as have the opportunity to conduct further research themselves. University librarians can provide an abundant amount of information to students on their way to becoming scholars themselves.

Reasoning

7. **Complete this survey for a chance to win:** Survey the classroom through a brief questionnaire on their comfort with self-directed learning beforehand, in order to

calibrate the appropriate level needed. Hung (2006) described three levels of self-directed learning within PBL which are teacher-directed, student-directed, and partially student-and-teacher-directed learning. Gauge a sense of what students are comfortable with and give them a challenge that they can feel gratified when they overcome. For inspiration, Khiat (2015), created and validated a self-directed learning diagnostic tool for students in an adult learning institution in Singapore.

Reflecting

8. **How did we do?:** Consider including a self-reflection piece in your course. In doing so, these self-reflections may offer the opportunity for students to reflect on their PBL journey, forge new connections through their reflection entries, and provide further input for instructors to incorporate into future PBL course designs (Ezezika & Johnston, 2023). Students shed light on the personal skills gained from undertaking these projects such as *"teamwork, communication" and leadership skills"* (Participant 16). Another student elaborated that during this project *"we were able to think outside of the box and come up with innovative solutions… [that] improved our group dynamics and I believe that teamwork skills were also enhanced" (Participant 28*).

CONCLUSION

One goal for interdisciplinary educators in higher education is to develop engaging interventions that lead to effective learning strategies for students. Creative pedagogical practices to interdisciplinary learning, such as PBL, can help achieve this goal. Through applying the 3C3R model as a guide into the design, creation, and implementation of an interdisciplinary PBL course, this case study led to eight lessons learned from this journey. It is our hope that these lessons are useful for other educators when designing and implementing PBL courses.

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APPENDIX – TABLE 1

You have been given $500,000 to create a response that aims to address one of the following health challenges:

1. Potential Ebola Epidemic in Congo or Guinea
2. Acute toxic encephalopathy in India, Vietnam or Jamaica
3. Nutrition Transition in Tanzania, South Africa or Kenya
4. Indigenous health in Canada with a focus on Tuberculosis or Diabetes

In teams of 5-6 students, you are asked to design a response. Each team will focus on one of the aforementioned themes with its own unique economic, geographic, and cultural environments. For this reason, the first step in any successful project will be to develop a thorough understanding of the landscape in which your project will take place.

You will create a report that must include the following:
A brief description of the biological basis of the problem: Describe and quantify the biological aspect of the problem you will address and provide Information/references that outline the biological basis of the problem.

A brief description of what already exists: Describe what other evidence you have been able to find that targets the problem you are aiming to solve. What is the quality of that evidence? Are there any trends worth considering? Are there any theories or frameworks to support this evidence? Include a brief outline of how you chose to approach your country, the unique circumstances in this population, and any evidence that informed the target for your response.

Description of WHAT your response is: How are you responding to this issue? Who are you, and where are you based out of? Who is involved? How does it address some of the needs regarding this health issue? How is your response evidence informed?

Description of HOW your response functions: How does your response "work"? What is the role of your employees, stakeholders, volunteers, or other major constituents? How will your target population access or engage with this response? Do you have a logic model or visual model that can explain how the implementation process will occur? How valuable do you think the government in your target country will find this response? Will they be likely to appreciate this response? What is the feasibility of response plans?

Impact & Evaluation: What will be the impact of your response? What is considered a "successful" response? How will you be collecting data/keeping records to measure and evaluate this "success"? How does your program align with/against other types of responses that exist? What's missing?

Historical & Ethical Considerations: How does your group's social positionality (age, class, race) impact the role your response plays? What do you know about the historical progression of how this issue came to be? What are some of the ethical questions you anticipate will come up in creating this response? Do you anticipate that your response might compromise the comfort and safety of your target population, and how will you address this?

Budget of Expenditures: What are some of the anticipated costs of creating a response like this? Will you be hiring people from different divisions? How many people will you hire to support this response and what will you pay them? Do you expect there to be any upkeep/logistical costs? Do you anticipate your response will make money? If so, how?

Table 1. Description of problem-Based Learning Project for the Course.

APPENDIX - TABLE 2

PBL Project Theme	Project Descriptions
Ackee Poison Prevention Efforts in Jamaica	The idea was to provide educational material regarding the dangers of ackee poison, create an elementary school snack program, and display warning signs in specified sites with ackee fruits. The proposed solution from this group was threefold: to educate school children, as the majority of cases of ackee poison occur in children, implement a seasonal afterschool snack program because snacks high in Riboflavin decrease adverse effects of possible ackee poison toxicity, and to post warning signs near sites that have ackee fruits.
Resolving the Nutritional Transition in Nigeria	The idea was to create a community garden targeted for elementary school students. The proposed solution from this group was to provide elementary school students a hands-on experience with cultivating and maintaining community gardens. The community gardens would have employees that include chefs to guide and coach students how to make culturally adapted and nutritious meals, nutritionists to provide educational workshops on healthy eating, and volunteers such as farmers and community leaders to provide their expertise on sustainable farming practices. Nutritional transition in Tanzania.
Nutritional transition in Tanzania	The idea was to use a gym rewards program to facilitate active exercise and healthy eating. The proposed solution from this group was to implement a gym rewards program within elementary schools, that include trained physical educators to teach seminars and engage in physical activities, and in turn will gain rewards that can be redeemed for healthy delicious snacks.
Nutrition Transition in Kenya	The idea was to create produce kits and distribute them within the community. The proposed solution from this group was twofold, produce a kit that promoted agriculture and education in farming skills and create farming and food utilization classes from farmers. This kit will include seeds of various fruits and vegetables that are suitable for the climate and soil in Kenya, along with educational material on cultivating agriculture. The classes will be held by farmers to educate community members.
Potential Ebola Epidemic in Congo	The idea was to collaborate with healthcare workers and community leaders to educate the surrounding community on the transmission of the Ebola virus. The proposed solution from this group was to work with isolated communities across the Congo to join forces with healthcare professionals, community leaders, and Ebola survivors to educate the public on how Ebola spreads and the benefits of vaccination.

Potential Ebola Epidemic in Guinea	The idea was to ensure that traditional burial practices are carried out safely within Forecariah, Guinea, in order to reduce and minimize the transmission of EVD (Ebola virus disease). The proposed solution by this group was foster community engagement surrounding safe burial practices from community healthcare workers, while simultaneously building trust with family members.
Indigenous Health in Canada (Diabetes)	The idea was to create greenhouses to address access to adequate nutritious foods. The proposed solution from this group was to incorporate multiple greenhouses throughout areas with poor food proximity across high density populations in Indigenous communities. Additionally, community leaders and members would run the greenhouses and allow traditional practices of planting and harvesting.
Acute Toxic Encephalopathy (India)	The idea was to create educational support surrounding acute toxic encephalopathy. The proposed solution from this group was to implement an education and food provision program that consists of two parts: educate a team of trained volunteers and elementary school teachers about safe litchi consumption, and incorporate a food support team of existing local food bank providers near litchi orchards
Acute Toxic Encephalopathy in Vietnam	The idea was to create educational support surrounding acute toxic encephalopathy. The plan was to create an educational program with workshops. The proposed solution was to implement these workshops with the administration of glucose tablets to improve health and nourishments among elementary school children.
Tuberculosis in Inuit communities	The idea was to collaborate with nursing and high school students to address Tuberculosis within Inuit communities. The proposed solution for this group was to partner with nursing students from Nunavut Arctic College to go to homes of patients with an Inuit community leader of a volunteer to provide medication and education regarding the treatment. Additionally, to foster inclusiveness and engagement within the community, high school students from Inuksuk High School can have the opportunity to gain volunteer hours in working with this project.

Table 2. Brief description of each group's proposed solutions to the global public health related problem.

Journal of Problem Based Learning in Higher Education

VOL. 11, No. 3, 2023 – Page 119-129
10.54337/ojs.jpblhe.v11i3.7828

Problem-Based Learning Approach Facilitating Sustainable Waste Management

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ABSTRACT

This work provides inspiration to foster Problem-Based Learning (PBL) in teaching practices related to waste management. Problem-Based Learning is about providing a learning environment where students can work practically and theoretically with problems of relevance for society. In this learning process, students themselves will define societally important problems and direct the problem identification, problem analysis, and problem-solving processes. The PBL approach at the engineering and technical faculties at Aalborg University acts as a case of inspiration to exemplify how the structure of a problem-based project can foster students' competencies and agency to contribute to a circular economy related to waste.

Keywords: PBL, problem design, process analysis, contextual learning, education for sustainability

INTRODUCTION

Exploring and developing sustainable solutions for future management of waste within a Problem-Based Learning (PBL) environment involves having a perspective both upon the general needs, being the overall goal of sustainability, and the more specific setting, being the actual context of waste management identified in a particular location.

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Education for sustainability (ESD) is characterised as strongly contextual, as illustrated by this quote about ESD "it should be applied and grounded in the local economic, social, and ecological context and community, followed by regional, national, international and global contexts" (Sterling, 1996, p. 22). For waste management, the complexity and the global aspects outlined in this quote are easy to spot. Let us just mention some of the aspects such as increased globalised product and waste chains, where multiple stakeholders are having an impact on the perceptions, strategies, and practices related to waste management.

In sustainable waste management and circular economy, we are facing several challenges including the amount of waste, diverse regulations of production and waste management as well as the increasing complexity of the way materials are combined in the products, which we eventually come to characterise as waste, and which adds to the complexity of reducing waste amounts through circular strategies (Bocken et al., 2016; Tisserant et al., 2017; Kristensen & Mosgaard, 2020). Added to these more structural issues, are serious concerns regarding health issues when formal and informal sectors are handling waste, notably in developing and transitional economies (Ezeah et al., 2013; Ferronato & Torretta, 2019). When identifying and opening for solutions addressing specific problems within waste management, PBL offers an approach that enables combining sustainability with contextual learning.

PBL is one of the pedagogical approaches which has been known for its emphasis on contextual learning (see for example Guerra, 2014; Guerra & Holgaard, 2019), as it rests on a constructivist and experiential learning perspective emphasising active and participant-directed learning. Kolmos et al define PBL learning principles from three approaches (Kolmos et al., 2009, p. 11) from a cognitive learning approach emphasising both the problem, the project, the experience, and the context; from a collaborative approach centred around working in teams through participant-directed learning; and finally, from a content approach focusing on inter-disciplinarity, exemplarity and the close relation between theory and practice.

The emphasis on exemplarity makes students able to transfer experiences from one situation to another and thereby be ready to cope with unexpected new challenges preparing them for solving real-life problems during their studies as well as in work life. All together this empowerment of student agency, this focus on contextual learning, and this call for exemplarity in the PBL approach is very much aligned with the change in paradigm in higher education including a strong emphasis on sustainability that Sterling (2014) argues for.

However, introducing problem-based learning calls for an experience-based approach to get inspiration from comparable cases and appropriate the learnings to the specific context. In this chapter, we exemplify how the structure of a problem-based project can foster student's competencies and agency to contribute to sustainable waste management. The framework has been specifically developed in the context of waste management in developing and transition economies but is relevant also in the global north. We demonstrate the framework by drawing on the PBL approach used at the engineering and science faculties at Aalborg University (AAU), Denmark. AAU has a strong tradition for problem-based learning and has since its foundation in 1974 had a systematic approach to PBL, placing real-life problems in the core of the learning process throughout the curricula.

THE OVERALL STRUCTURE OF A PBL PROJECT

Working problem-based can be very challenging and therefore suitable educational framing and guidance should be provided. Working with real-life problems through students' semester projects or projects connected to courses is core to the PBL approach. Structuring the PBL project is the first essential step in the process of working problem-based, offering an overall framing of how a Problem-Based Learning project is designed.

In Figure 1, an overall structure for a PBL project is presented. The reflection-based feedback loops underline that students' reflections on their outcomes in a specific context can inform further analysis and offer inspiration to curriculum design. As in all cases, the learning objectives in the curricula provide both opportunities and boundaries for the learning process. If the learning objectives are defined in a very narrow and technical way, the following learning process will be shaped by this intention e.g., focusing on the redesign of a technology or a service. A subject or a theme to trigger the problem design process could for instance be waste sorting technology focusing upon narrow and technical learning objectives. If learning objectives are also focused on contextual learning, the trajectory will point towards more open problems and the output of the project will most likely be more inclusive, e.g., focusing on presenting action plans or different scenarios for change.

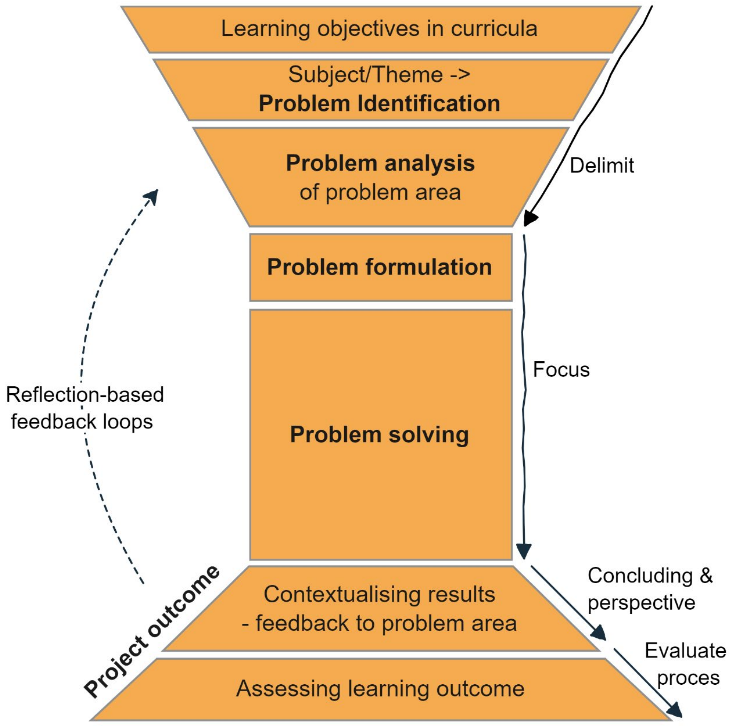

Figure 1. The different phases in a problem-based learning process (modified from Holgaard et al., 2014).

Students working with the process of delimiting and hereby designing the problem is one of the most distinct characteristics of the PBL approach at AAU. In this process, students are trained to identify problems and to balance creativity and analytical skills to target their problem-solving. For example, in designing a waste management system for a municipality, students must use their analytical skills to analyse the context of use, identifying stakeholder interests as well as state-of-art considering both current regulations and available technology. They also must engage their creative skills to appropriate state-of-art to the context of use – to combine existing solutions in new ways and maybe even contribute by a new approach to waste management.

When the problem is well-defined, the problem-solving process starts by presenting a question to direct the further inquiry process and introducing the methodology to solve the problem. As illustrated in Figure 1, the problem-solving process is narrower, whereas the students specialise in their chosen subject. The ambition in a PBL project is however that no project outcomes stand without being questioned and assessed more broadly considering the complexity of the societal context.

PHASES OF A PBL PROJECT

In the first part of a problem-based project, the problem is identified, analysed, and formulated as an outset for problem-solving. This phase has been characterised as a problem design process (Holgaard et al., 2017). In the problem design, students define the important issues in a societal context. By using concrete theories and methods during this learning process, students engage in a problem-searching process of mapping reasons and explanations to complex issues. In this process, the problem area is explored and defined.

The aim is that learning moves beyond the purpose of acquiring knowledge of methods, tools, and theory and will include learnings to apply this knowledge to a society of complexity. In this sense, the 'exemplary principle' (Negt, 1981) comes into play by linking student's experiences to present societal problems, and in this process, students can learn to take a critical stand on the present status and use what Mills (2000) termed sociological imagination to explore alternative futures. Through the problem design process, the students identify and argue for an overall problem of relevance to society which is narrowed down to a manageable problem formulation, taking into consideration the time available for doing the project as well as the competence level and reach.

Figure 2 gives a detailed overview of how to approach and carry out the problem design process (steps 1 to 3) followed by the problem-solving process (step 4) and the project outcome (step 5).

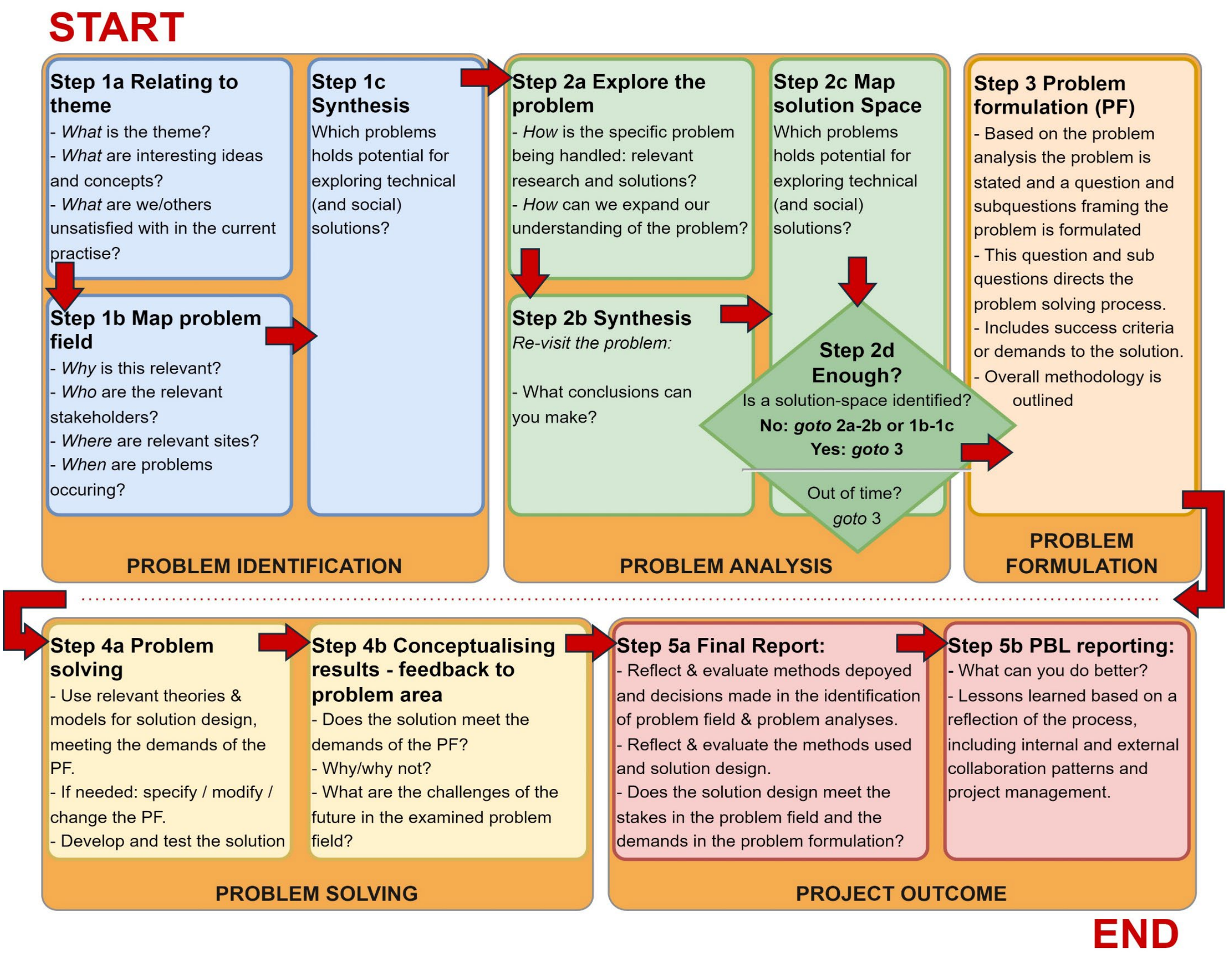

Figure 2. Steps of problem-based learning (developed based on Holgaard et al., 2017).

WHEN PROJECTS FOLLOW THE MISSION OF SUSTAINABLE WASTE MANAGEMENT

In exemplifying the problem design process, we use the process outlined in Figure 2 related to the area of sustainable waste management to illustrate how the PBL phases are used to address a specific mission.

To illustrate the process of designing a problem a project carried out in the second semester of undergraduate education "Cities, Energy and Environmental Planning" at the Technical Faculty of IT and Design at Aalborg University, Denmark will be introduced. The project group was involved in a pilot project regarding waste management on the Island of Bornholm in Denmark. The aim was to contribute with relevant studies on how to implement successful organic waste sorting in households on the island of Bornholm.

Step 1a Relating to theme

In the first part of the problem identification students will be "relating to a theme" to understand the underlying assumptions of addressing a given theme. In this case, the underlying assumption is that waste management is needed, and students validate this assumption.

From there, students study different overall aspects of the theme. For example: How is waste handled today? What are the challenges connected to the handling of waste? What different types of waste relate to which problems? What can be characterised as sustainable waste handling? What interesting ideas or examples from elsewhere are to be explored? The overall answer to such questions is: It depends. Therefore, students typically narrow down the theme guided by a particular context of study.

Step 1b Mapping the problem field

When the students have an overview of thematic discussions and choose a specific context of study, the inquiry becomes more specific. The basic tool for the mapping exercise, applied by the students, was the classic "Five Ws and one H" (5W1H), which is also recommended by Holgaard et al. (2017). This is the first step that directs the project engaging in W-questions like; 1) *What* are the concepts normally used for analysis of waste management problems? 2) *Why* is waste management in Bornholm relevant to address? 3) *Who* are the relevant stakeholders involved in the waste handling on Bornholm and what types of stakeholder relations can be mapped regarding waste management on Bornholm? 4) *Where* are the sites and/or flows of waste which may be problematic on Bornholm? Can we identify relevant sites and/or exact flows of waste which is problematic on Bornholm? 5) *When* do we see representations of state of the art, i.e., what interesting ideas or examples from elsewhere are to be explored? Often students have difficulties understanding the 'when' question in the 5W1H-method, and by experience it is easier understood as a 'what' question. And finally: 6) *How* should the problems be addressed, taking notice of which problems are being handled in the current situation and which are not? The last question is especially important for the PBL approach, as it forces the students to maintain attention to both the working and non-working in the problem field, and thereby indirectly supports an understanding of the institutional context of the problem and a holistic problem-solving strategy.

It is however important to note that the mapping of the problem field provides "potential problems" and not validations of every of these problems in the specific context at the specific time – it is a phase of opening to different types of problems which can be considered in the following phase.

Step 1c Synthesis

In the case presented, mapping the problem field has thereby opened attention to a range of issues connected to waste management on Bornholm. Being able to handle the problem requires that it is narrowed down focusing on what could be interesting to analyse due to waste management and which problems are likely to hold a potential for introducing solutions within the frame of the study regulations, the curriculum, and the learning objectives.

This narrowing down the problem builds upon what has been investigated in steps 1 and 2 – pointing toward where to identify openings for working with current technical and/or societal issues. In the case of waste management topics which students can choose to work with could be technical solutions to sort different types of waste, the policy and safety procedures regarding this type of waste, or how to change people's routines and perceptions of waste. As the point of departure, students will choose an initiating problem to be further validated and defined.

In this case, the initiating problem is the implementation of effective sorting and collection of waste in households involving multiple stakeholders. The aim of students was thereby to contribute with relevant studies on how to implement successful organic waste sorting in households on the island of Bornholm. This choice was aligned with the curriculum framing having an extended focus upon how to motivate students by facilitating stronger collaborations between students and the local community.

Step 2a-d Problem analysis

Based upon the choices taken in the problem identification the process moves into an in-depth problem analysis which requires the use of scientific methods to address the narrowly defined problem considering how actors address the specific problem and state-of-art including relevant research and already existing solutions in the field to explore the problem (4a). At this point in the process, this is done to expand the understanding of the chosen problem.

In the case of waste management on Bornholm, the group was characterized by having close collaboration with practice in the problem design phase. The group was in contact with the local waste management company, other students who had worked with similar topics, and researchers within the field. After exploring the problem, the different understandings of the problem were synthesised and prioritised to clarify the perspective taken in this specific project (2b). Together with a theoretical approach to sustainable waste management the input and discussions with stakeholders from practice students chose to work with concerns and perspectives from the waste company and the municipality having an agenda about optimizing waste sorting and collection on the island Bornholm being characterized by having small narrow streets.

From this point, students can map the solution space (2c), which might include different types of solutions from different perspectives e.g., political, technical, economic, social, or environmental. To identify solutions to these issues the students decided to bring forth a range of perspectives: Interviewing and working with the waste company, interviewing the municipality, interviewing the renovation company, providing surveys to citizens, carrying out citizen's focus group interviews, and interviewing renovation staff. Among the different perspectives identified, students narrowed down the solution space to collaboration between stakeholders to optimize the waste sorting and collection of waste on Bornholm.

Step 2d Attention to the link between the proposed solution and learning objectives
In this case, the students thereby were able to propose a relevant solution to the problem aligned with stakeholder interest, within the frame of the curriculum and learning objectives, and their engagement. If this is not the case, the problem analysis must be critically reviewed and revisited.

In a time-limited project, the students might be forced to address a less validated problem, if the path of the problem analysis has not been as beneficial as expected. However, the approach and the contextual insights in the problem analysis will by no means qualify the solution.

Step 3 Problem formulation
Based on the first 2 steps students are ready to state the problem to be addressed together with a question that will guide the problem-solving process. To address the problem of implementing effective sorting and collection of waste in households and thereby addressing a stakeholder group with a high degree of diversity, students formulated the following question based on their process analysis:

"How can the intentions of the waste management company regarding sorting and collection of organic household waste on Bornholm be implemented, with a particular focus on the narrow city centres and cooperation between actors?" (Olesen et al., 2016).

Step 4a-b Problem solving

After having designed and formulated the problem students have a guide to their problem-solving, even though the problem formulation may be altered during the problem-solving phase due to new insights. In the presented case, solving the problem of waste management in a narrow city (4a) a solution to the problem was developed building upon multiple experiences among relevant stakeholders. Concluding that when implementing sorting and collection of organic household waste on the island of Bornholm, three factors should be considered: 1) Inclusion of citizens, 2) Inclusion of urban structures 3) An increased and interdisciplinary cooperation between actors (Olesen et al., 2016).

The conceptualisation (4b), understood as ideas and understandings embedded in the solution, must be carefully re-aligned with the problem design and the problem formulation. Furthermore, the conceptualisation might also inform the ideas and understandings related to the current field of study. In this case, a conceptual model including the three aspects presented in the solution is a way to frame the experiences of the case in a way that opens for other contextual links.

Step 5a-5b Project outcome

Finally, the project outcome is reported (5a). In this case, the project outcome was documented in a two-step model, whereas one report addressed the outcome of the project related to the problem, and the other report (process analysis) related to the outcome in terms of student learning during the PBL process. This underlines that PBL is not only an educational means but also a means to have an impact on society – in this case, related to waste management on Bornholm, Denmark (5b).

To sum up, the problem-based project created a framing where students collaborated with local stakeholders concerning issues related to sustainable waste management by addressing; the anchoring of the new local recycling centre, citizen's participation in local climate protection solutions, and exploring new developments of businesses in the district. What characterized these collaborations was students' participation in enhancing relevant discussions and solutions to local challenges on waste collection.

FINAL REMARKS

Changes towards problem-based learning processes imply a curriculum including learning objectives that support the approach, and this means an open curriculum where learning processes are facilitated rather than instructed. Working explicitly with open-ended problem-solving provides students with incentives to interact with society. Instead of instructions and pre-defined problems, students can be facilitated by a framing emphasising problem design as well as problem-solving. Problem-based learning seeks to transform students from passive listeners to agents of change, and outcomes from study projects can combine students learning with societal impact. This paper is a modest attempt to outline how this can happen on a project level in the case of sustainable waste management.

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Journal of Problem Based Learning in Higher Education

VOL. 11, No. 3, 2023 – Page 130-144
10.54337/ojs.jpblhe.v11i3.7390

Using Scratch to Teach Coding in Massive Online Open Courses: A Systemic Analysis

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ABSTRACT

In this case study, we present our findings regarding a massive open online Scratch programming course. The course, which followed a project-based learning approach, was delivered from July 4 to 30, 2022 to 186 students in Brazil. The students were challenged to develop individual coding projects. Our research goal was to investigate teaching and learning course dynamics. We followed a convergent parallel mixed-method approach. We collected quantitative and qualitative data by means of questionnaires. We were able to identify five intertwined feedback loops that drove the educational process. Our main findings are as follows: 1) The development of coding skills was driven by the effort of watching video-lectures, remixing of peers' codes, and by sharing knowledge between the students. 2) The project-based learning approach created opportunities for the students to collaborate and exchange ideas.

Keywords: Massive open online course, Scratch, Systemic analysis

INTRODUCTION

The Federal University of Sao Paulo (thereafter UNIFESP) has an online extension program that aims to provide free educational opportunities to the communities. The course *Introduction to Programming with Scratch* was designed to teach the main concepts of coding using the Scratch programming language. The target audience were children aged from 5 to 14 years old, although the course was open to anyone who wished to enroll.

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The course was designed to work in an asynchronous way: it has a virtual learning environment (Google Classroom) and a website with 96 pre-recorded video-lectures (on average, each 10 minutes long).

The course was divided into four modules, each with a set of videos and exercises. We suggested that the students work on one module per week. However, since all modules were available to the students from the first day of te course, they could study at their own pace.

In the first module, we presented the basics of the programming environment and how to work with sprites and backgrounds. We also taught the input and output functions.

In the second module we explained the basics of the programming: loops, conditionals, boolean operators, mathematical operations, and string and list manipulation. In the third module, we taught the concepts of global and local variables, subroutines (blocks), clones, backpacks, and concurrency. We also explained the basic concepts involved in creating games. In the fourth module, we taught how to create animations, geometric shapes, and interactive stories.

In each module we offered practical challenges, requesting the students to work on a given code and remixing it (changing and improving the code by adding new functionalities).

The course lasted four weeks: in the first week of the course the students were asked to choose an individual project theme. The students were free to choose the theme of their own preference: it could be an educational game, an animated card, an interactive story etc. – anything that they were able to create using the Scratch programming language.

In the following weeks the students were asked to develop their projects with the support of the professor and with contributions from other students.

The course had a supportive virtual learning environment (VLE), a Google Classroom. In this platform the students were able to follow each other's projects, interact by making comments and remixing their codes. The students were also able to clarify their questions with the professor.

LITERATURE REVIEW

Scratch is a visual programming language developed by the MIT Media Lab in 2007. Scratch allows the students to create games, animated stories, animated cards, animated dance contests, virtual tours, newsletters, interactive stories, interactive science simulations, tutorials, and music (Brennan, 2011; Maloney et al., 2010). In addition, Scratch also allows the users to import music clips and 2D images (photos and pictures), record voices and sounds, and create graphics and drawings (Resnick & Rusk, 2020).

The MIT Scratch environment has a set of tools that allows the students to program, exchange ideas, work collaboratively, reuse other users' codes (remix) and program external devices such as microcontrollers and robotic kits (Kordaki, 2012; Resnick et al., 2009). The MIT Scratch environment has thousands of users and communities of people (most of them children) from all over the world (Robinson & Resnick, 2017).

Scratch has been used in schools to introduce the concepts of coding, mathematics (Dohn, 2020), science (Yamamori, 2019), music videos (Fields et al., 2015), artificial intelligence (Estevez et al., 2019) and educational robotics applied to STEM (Plaza et al., 2019). Researchers point out that people who learned Scratch as its first programming language have more facility in learning more advanced topics in computer science (Amoni et al., 2015).

Scratch was created with the goal of developing the students' programming skills and creative learning (Fagerlund et al., 2021; Sefton-Green, 2011; Su et al., 2022). Some authors (Beghetto, 2021; Bustillo & Garaizar, 2016) point out that creative learning is a form of learning where the students have freedom to define whatever they want to create (projects, products, toys) and figure out their own ways of doing so.

The scholars involved in the creation of the MIT Scratch environment (Robinson & Resnick, 2017) suggest that to promote creative learning the students should work on projects that they are truly interested in, collaborating with peers, sharing ideas and knowledge, and doing playful experimentations.

In our course, we created a Google Classroom forum in order to allow the students to share their project ideas, receive feedback from the participants and from the professor. More than that, we encouraged the students to create an account on the MIT Scratch environment. By so doing, they were able to share projects with and to remix projects from people from all over the world.

Researchers point out that project-based learning (thereafter PBL) is an educational approach that is suitable to promote creative learning (Pirker et al., 2016) since it allows students to work collaboratively in projects, sharing knowledge and creating meaningful artifacts (Arantes do Amaral et al., 2015). Nowadays, scholars are using PBL integrated with Scratch in order to teach programming (Wang et al., 2014), to promote mathematical computational thinking (Hadi & Atiqoh, 2021), and to foster creative learning (Husna et al., 2019). Although there is a reasonable amount of research covering the use of Scratch combined with te PBL approach, it seems that there is a lack of information on the dynamics of MOOCs that teach how to program using Scratch. Our research question then became "What are the dynamics of learning present in MOOCs that teach students to program using Scratch?"

METHODS

Research Design

We followed a convergent parallel mixed method approach. In this approach, the quantitative and qualitative data are collected simultaneously (Creswell, 2013; Kennedy & Edmonds, 2016). Each type of data is initially examined separately; after that, they are analyzed together (Kennedy & Edmonds, 2016). By comparing both types of data we were able to have a better comprehension of the teaching and learning dynamics presented in the course.

Participants

Three hundred and forty-five (345) students enrolled for the course. However, 159 never participated, and only 186 participated in the first course activities. Seventy-four (74) students finished the course.

Of the students who finished the course, 55% were female and 45% male. The youngest was 7 years old, the oldest 61 years old. There were 16 children (aged less than 18 years old) and 57 adults. Of the adults, 59.6% have graduate degrees.

Fifty percent (50%) of the students were between 21 and 46 years old, thus the interquartile range was 25 years. The mean age was 33.8 years, the standard deviation was 15.6 years.

The course was opened to students from all over the country, although most of the students were from the State of São Paulo (90.5%). We also had students from seven other States (Rondônia (1.4%), Rio Grande do Norte (1.4%), Rio de Janeiro (1.4%), Pernambuco (1.4%), Alagoas (1.,4%), Sergipe (1.4%)) and from other countries (1.4%)). More than half of the students were teachers (50.7%), 39.3% were K-12 teachers, 9.8% teach at universities and 1.6% teach in NGOs and Corporations.

Instruments to collect data

We collected the data by means of a questionnaire sent to the students at the end of the course. The questionnaire had 21 closed-ended questions and 7 open-ended questions.

The close-ended questions had the goal of collecting demographic information (sex, age, academic background, profession) and measuring the students' participation, effort, and learning. We defined eight variables: four to quantify the students' effort and participation (table 1, Appendix 1), four to quantify the students' learning (table 2, Appendix 1).

The open-ended questions had the objective of gathering information about the students' feelings and perceptions about the course.

Data Analysis Procedures

The quantitative data was analyzed using descriptive statistics, while the qualitative data was analyzed using the language processing method (Graham et al., 1993). We connected the findings of the quantitative data and qualitative data by means of a systemic analysis (Arantes do Amaral, 2019). In descriptive statistics, we used measures of central tendency (mean, median) and measures of dispersion (interquartile range and standard deviation) to analyze the data. We used stacked bar charts in order to visualize data related to students' answers that made use of 3-point Likert scale questions. We used R software to do all calculations.

As previously stated, we used the language processing method to analyze the qualitative data. By using this method, we were able to break the long paragraphs (the answers to the open-ended questions) into small sentences, group similar sentences, and discover the recurrent themes.

RESULTS

Results from quantitative data

In this section we present the stacked bar chart that summarizes the answers of the students to the quantitative Likert scale questions. Figure 1 presents the levels of the five variables (Appendix 1, table 1) used to quantify the students' effort and participation. The levels low, medium, and high are represented by the colors brown, grey and green, respectively. The explanation of the meaning of each variable is described in APPENDIX 1.

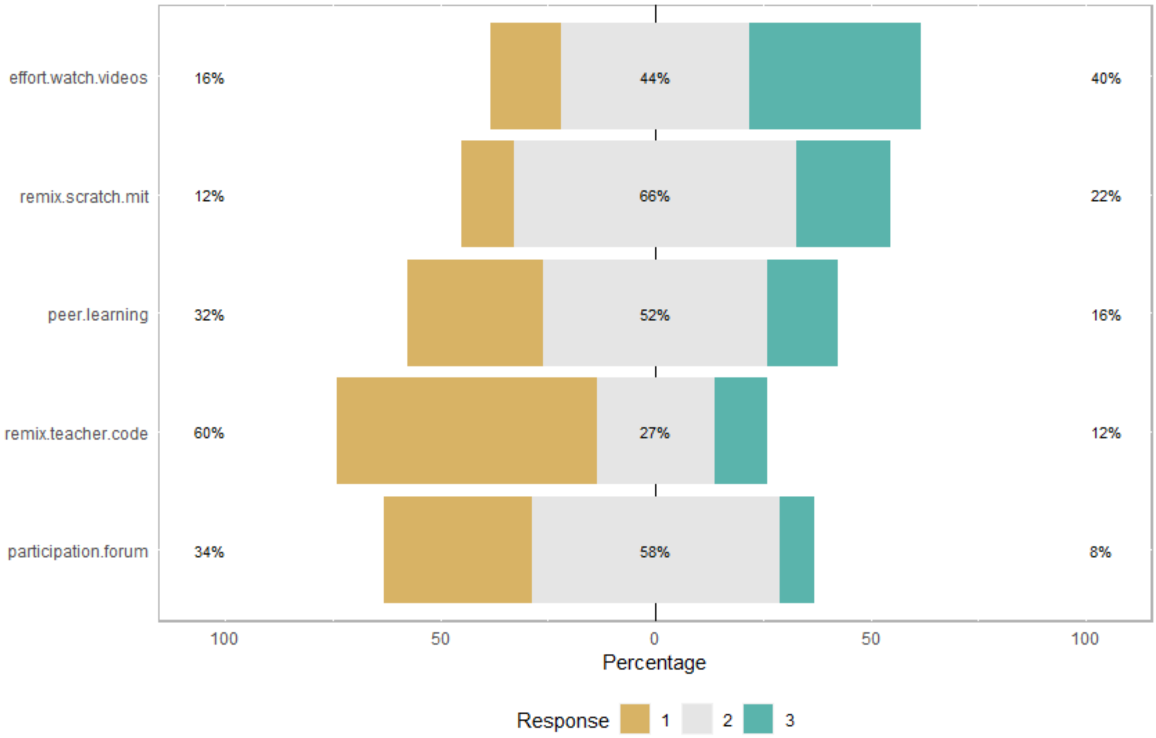

Figure 1. Effort and participation.

Figure 2 presents the levels of the three variables (Appendix 1, table 2) used to quantify the students' learning and satisfaction.

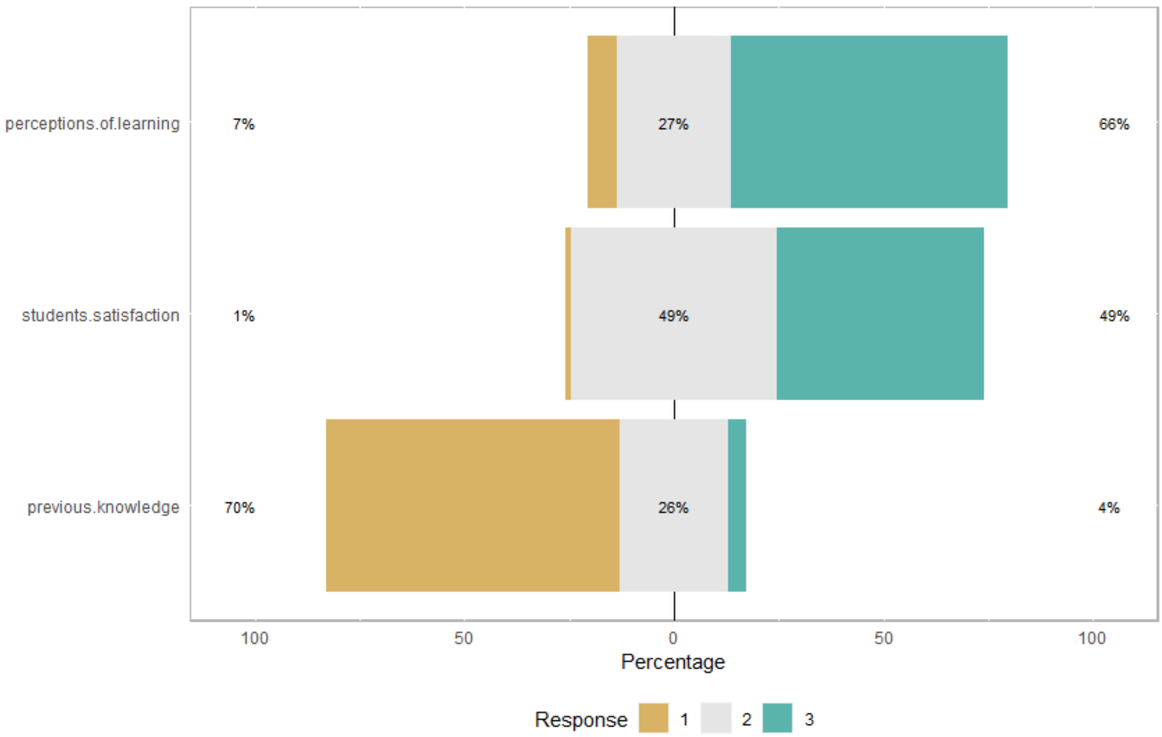

Figure 2. Students' learning.

In the discussion section, we will discuss the impacts of each variable described here, connecting the quantitative data to qualitative data.

Results from qualitative data

Analyzing the qualitative data, we were able to identify five recurrent themes (thereafter, RT).

The recurrent themes below summarize the answers of the students to the open-ended questions.

RT1 – The students learned a significant amount while working playfully on projects that interested them.

RT2 – The professor´s feedback motivated the students to learn, improving their coding skills.

RT3 – The course was well structured, the video-lectures were easy to follow, and the professor's feedback facilitated the learning.

RT4-Remixing code was fun, helping to develop the students' coding skills and motivating them to learn.

RT5-The project created opportunities for students to learn how to program, collaborate with other students, and share knowledge.

The recurrent themes show that the course was a joyful experience for the students: they learned by doing, playing, and remixing code. Moreover, the data revealed that the course was well-structured and delivered efficiently. In the discussion section, we will connect each recurrent theme (qualitative results) with each identified variable (quantitative result), performing a systemic analysis.

DISCUSSION

Returning to our research question (What are the dynamics of learning present in MOOCs that teach students to program using Scratch?) we were able to identify five intertwined feedback loops that drove the learning dynamics (Figure 3).

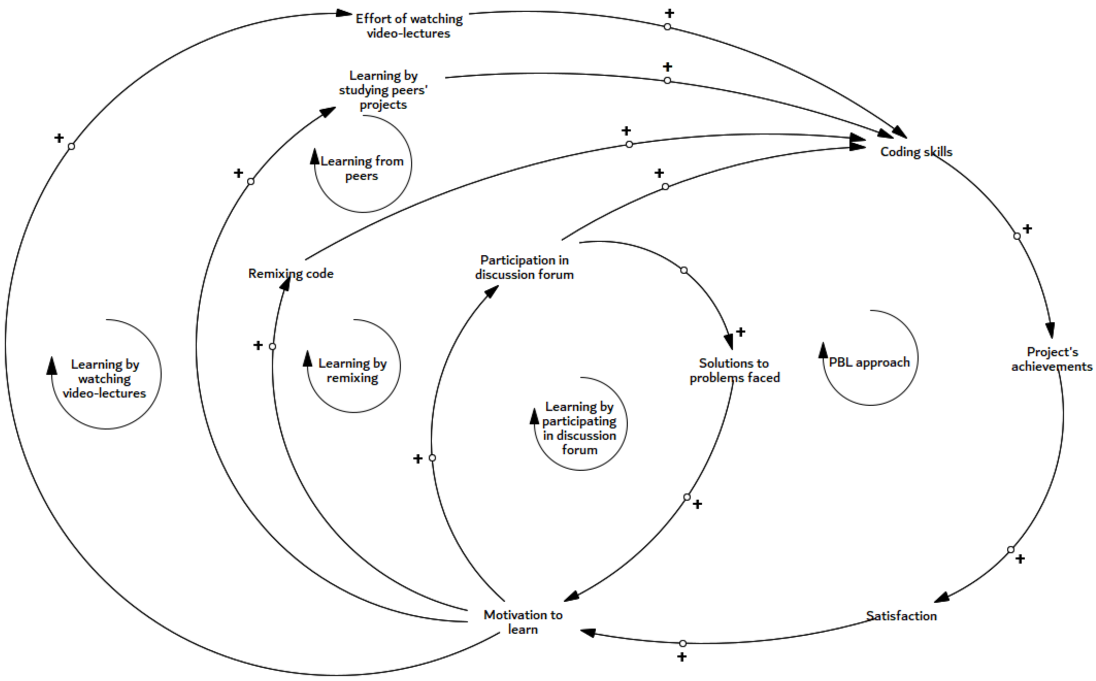

Figure 3. Feedback loops driving the course dynamics.

Feedback loop 1: Learning by participating in discussion forum

More than half of the students (Figure 1, variable "participation.forum") reported that they participated at a medium (58%) to high(8%) level in the discussion forum. In addition, RT2 let us understand that the professor's feedback helped the students learn. Therefore, the more the students participated in the forum, the more they encountered solutions to the problems they were facing, thus increasing their motivation to learn (Figure 3, feedback loop "Learning by participating in discussion forum"). This finding is aligned with the findings of other researchers, who have studied the impacts of the use of discussion forums in learning (Almatrafi & Johri, 2018).

Feedback loop 2: Learning by remixing

The majority of the students (Figure 1, variable "remix.scratch.mit") remixed projects from the MIT Scratch community. For 22% of the students, the remix was high; for 66% it was medium. The students did not have the same interest in remixing the teacher's code (Figure 1, variable "remix.teacher.code"): only 39% of them remixed the code made available. We may speculate that the students prefer to remix projects from the MIT Scratch community because the number of projects was higher there and the themes of the projects were much more diverse. RT4 helped us to understand that the remixing process not only helped the students to learn how to code, but also a fun activity that motivates them to learn more.

Therefore, we may infer that the more the students remixed code, the more they developed their coding skills, increasing the project's achievements and motivation to learn (Figure 3, feedback loop "Learning by remixing"). This finding is aligned with the findings of other scholars (Kang, 2019; Robinson & Resnick, 2017) who point out that remixing code improves learning.

Feedback loop 3: Learning from peers

In relation to the sharing of project ideas, 16% of the students (Figure 1, variable "peer.learning") affirmed that the amount they learned from peers was high, while and 52% stated that the amount was medium. RT5 allowed us to understand that knowledge sharing was present in this course. Therefore, we may infer that the more the students learned by studying projects of their peers, the more they developed their coding skills (Figure 3, feedback loop "Learning from peers"). This finding is in accordance with the findings of other researchers (Pinto & Escudeiro, 2014).

Feedback loop 4: Learning by watching video-lectures

The students let us know that more than 84% of them had watched the video-lectures (Figure 1, variable "effort.watch.videos"). In addition, RT3 let us understand that the video-lectures were easy to understand. Therefore we may consider that watching the video-lectures facilitated the development of coding skills (Figure 3, feedback loop "Learning by watching video-lectures"). Other researchers have pointed out the importance of video-lectures in MOOCs (Diver & Martinez, 2015; Johnston, 2015).

Feedback loop 5: PBL approach

RT1 let us know that the students enjoyed the project-based learning approach. This approach allowed them to learn by doing, by interacting with their peers (Figure 1, variable "peer.learning"), by remixing code (Figure 1, variables "remix.scratch.mit" and "remix.teacher.code"),by participating in the discussion forum (Figure 1, variable "participation.forum") and by watching the video-lectures (Figure 1, variable "effort.watch.videos"). It is interesting to note the students' development of skills in coding: at the beginning of the course, 70% of them had little knowledge of coding (Figure 2, variable "previous.knowledge"), while at the end of the course 66% of the students acknowledged their knowledge level was high (Figure 2, variable "perceptions.of.learning"). More than that, for 49% of the students, the course delivered beyond their expectations (Figure 2. variable "students.satisfaction"). Therefore we may affirm that the PBL approach led to the increase in the number of projects accomplished, increasing the students' satisfaction and motivation to learn (Fig 3, feedback loop, "PBL approach"). This finding is in agreement with the findings of other scholars, who have used PBL to teach how to program with Scratch (Hadi & Atiqoh, 2021; Voinohovska et al., 2019).

Based on the five feedback loops described previously, we came to the following conclusions:

1) The feedback loops 1,2,3 and 4 let us understand that the development of coding skills was driven by their efforts in watching video-lectures, remixing their peers' codes, and by knowledge sharing among the students.
2) The feedback loop 5 lets us understand the importance of the PBL approach, since it creates the opportunities for the students to collaborate and exchange ideas.

FINAL REMARKS

Using MOOC and PBL to teach programming with Scratch was very effective. The MIT Scratch learning environment allowed the students to code online, to easily share their code and to learn with each other students and members of MIT Scratch community. The project-based learning approach encouraged the students to follow their interests, creating projects that they were passionate about.

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APPENDIX -1

Variables that quantify students' effort and participation		
Variable	**Meaning**	**Levels** **We considered a "reasonable number", a number between five and 10 a "large number" a number higher than 10.*
remix.scratch.mit	it quantifies the effort of remixing code of from people of the MIT Scratch community	low (the students remixed few projects) medium(the students remixed a reasonable number of projects) high (the students remixed a large number of projects)
remix.teacher. code	it quantifies the effort of remixing the professor's code	low (the students remixed few projects) medium(the students remixed a reasonable nuumber of projects) high (the students remixed a large number of projects)
peer.learning	it quantifies the students' effort of learning with the projects of other students	low (the students learned nothing or little with his/her peers) medium (the students have learned in a reasonable way with his/her peers) high (the students learned a significant amount with his/her peers)
participation. forum	it quantifies the students' effort of participating in the discussion forum	low (the students had none or almost no participation) medium(the students participated in a moderate way) high (the students' participation was high)
effort.watch. videos	it quantifies the students' effort of watching video-lectures	low (the students watched few video-lectures) medium (the students watched a reasonable number of video-lectures) high (the students watched all or almost all video-lectures)

Table 1. Variables created to quantify students' effort and participation.

Variables that quantify students' learning		
Variable	**Meaning**	**Levels**
perceptions.of.learning	it quantifies the students' perception of learning at the end of the course	low (the students learned less than they expected to learn) medium (the students learned what they expected to learn) high (the students learned more than they expected to learn)

students.satisfaction	it quantifies the students' satisfaction with the course	low (the course did not meet the students' expectations) medium (the course met the students' expectations) high (the course delivered beyond the students' expectations)
previous.knowledge	it quantifies the students' previous knowledge in programming with Scratch	low(the students had no knowledge or little knowledge of programming with Scratch) medium (the students had some knowledge of programming with Scratch) high (the students had some advanced knowledge of programming with Scratch)

Table 2. Variables created to quantify students' learning.

Journal of
Problem Based Learning
in Higher Education

VOL. 11, No. 3, 2023 – Page 145-156
10.54337/ojs.jpblhe.v11i3.7779

Improved PBL Hybrid with LBL is Beneficial to Fundamental Knowledge Acquisition in a Large Class Prior to Medical Internship

Qing Li, Wenjia Wang, Youjun Mi, Yafei Dai, Yu Luo, Yaqin Ling, Juan Li *

ABSTRACT

Since pre-internship medical students appeared inefficient in acquiring fundamental knowledge in large classes, a hybrid instructional method of problem-and-lecture-based learning (PLBL) was designed to leverage the complementary strengths of PBL in reasoning under minimal guidance and LBL in immediate knowledge retention. We improved PBL (IPBL) in its instructional process and grading in a way that's feasible in large classes, divided in IPBL almost 50 students into 7-10 squads as a figure simulating student counts in classic PBL class to strive for each squad member to achieve the same level of knowledge, and applied IPBL to about half of the instructional contents while LBL to another half for their complementary strengths. In this case, PLBL led to more number of test questions correctly answered by all students in a class, more students in higher test score buckets, and higher student perception scores on the methodology. PLBL facilitates fundamental knowledge acquisition in large classes within 50 students prior to medical internships.

Keywords: PBL, large class, hybrid, internship, LBL

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INTRODUCTION

Due to the shortage of teachers in public medical colleges, lecture-based learning (LBL) has been the conventional approach to fundamental knowledge transferring for pre-internship students, who attempt to form a comprehensive knowledge framework out of large pieces of information based on systematic explanations from teachers. However, LBL, where peer interactions are rare, often leads to a lack of creative and critical thinking exercises for students with limited enthusiasm and initiative (Chotiyarnwong et al., 2021; Zhao et al., 2020). Problem-based learning (PBL) has been used as a discussion-centered educational system (Bandy, 2021) facilitating students' self-learning and independent thinking (Bains et al., 2022; Demikhova, 2016) because instructors no longer occupy the focal point in classes. Although PBL seems to have become a preferred instructional method in medical education (Amoako-Sakyi & Amonoo-Kuofi, 2015), classic PBL is used in small classes of 7-10 students (Dulloo & Pathare, 2013) rather than large classes (Burgess et al., 2020; Ellaway et al., 2015).

PBL in large classes was recently applied to medical interns instead of pre-internship students. Web-based PBL for clinical cases promoted presentation and self-learning capabilities with 18 squads of 8-10 nursing interns each (Ding & Zhang, 2018). Offline patient-playing PBL received positive feedback on information-gathering and communication with 49 squads of 4 medicine interns each (Norose, 2013). In addition, PBL was an add-on component for LBL applied in a large classroom with 45-85 biochemistry undergraduates in Canada and the U.K., improving problem-solving skills and test scores (Klegeris et al., 2013; Klegeris & Hurren, 2011). However, the improved test scores were on short essays of case analyses (Lian & He, 2013) rather than fundamental knowledge in stomatology course (Qin et al., 2010), and the scores on three out of five cases were not significantly different from those in LBL while the other two were slightly better (More et al., 2020). It showed that large class PBL, whether by itself or as an add-on component for LBL, was used only for interns to study clinical cases and had limited outcomes. However, tutors offered LBL to target medical interns who were stuck at learning key issues of clinical cases after PBL and helped them acquire practical knowledge and deepen their understanding of clinical reasoning (Ishizuka et al., 2023). Such evidence pointed towards the potential of a hybrid between PBL and LBL in large classes which needed a refinement for teaching process to transfer fundamental knowledge to students without internship experiences.

PEDAGOGICAL FRAMEWORK

Problem-and-lecture-based learning (PLBL) was designed as a novel instructional method in large classes (Figure 1), combining complementary strengths of PBL in reasoning under minimal guidance (Jiménez-Saiz & Rosace, 2019) and LBL in immediate retention of fundamental knowledge (Solomon, 2021) for students. Student discussion is essential in PBL, and classic PBL requires a small number of 7-10 students to be efficient (Jiménez-Saiz & Rosace, 2019). We thus improved classic PBL (IPBL) in its instructional and grading processes to be more suitable for a large class with almost 50 students. Before class started, students were divided into 7-10 squads to imitate a similar student count of 7-10 in a classic PBL setting, and the squads were assigned to find and figure out key issues on instructional content of two class hours through in-depth squad-discussion without tutors' guidance. During class, to strive for every squad member to obtain the same level of knowledge, a squad and then a member of the squad were randomly chosen to present one issue, followed by other members' supplemental views, based on which a squad-score was determined. Additionally, the teacher-centered lecture is the essential element of LBL, beneficial to fundamental knowledge learning. LBL was thus used in half of the curricular content while IPBL in another half for their complementary strengths. In short, PLBL's strategies focused on squads of size 7-10 to imitate the number of students in classical PBL, the squad-score on random presentation, and the respective application of IPBL and LBL in different halves of the curricular content.

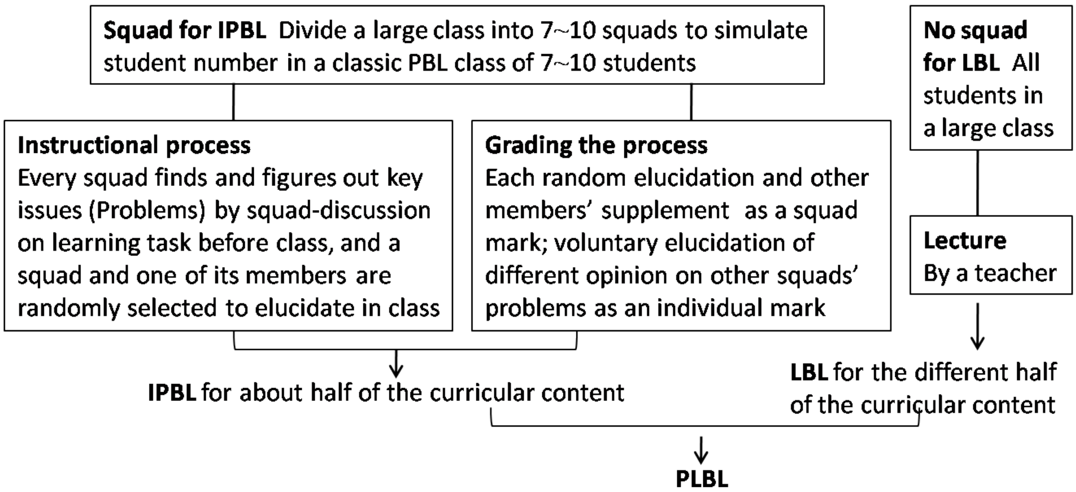

Figure 1. The instructional design of problem-and-lecture-based learning (PLBL).

IMPLEMENTATION

Participants

A total of 189 junior students were enrolled in a mandatory pathophysiology course during the spring semester in 2018 (n=92) and 2019 (n=97) majoring in clinical medicine at the Medical School of Lanzhou University in China, where students do not yet have clinical internships. The students participating in the case were randomly divided into

PLBL (n=46 in 2018, 48 in 2019) and LBL groups (n=46 in 2018, 49 in 2019) in every year. PLBL group was randomly divided into 7 squads (sub-groups) for IPBL teaching to imitate student number of 7-10 in classic PBL.

For ethical considerations, the students were briefed on the case purpose and process without any adverse effect on this course grade because test questions were composed of objective questions. The participants filled in the informed consent form, and the procedure was approved by the Curriculum Development and Ethics Committee School of Basic Medical Sciences at Lanzhou University in China.

Instructional design in PLBL

Pathophysiology, a theory course, was applied to PLBL as a sample for fundamental knowledge learning in the large class in the case.

Distribution of curricular content

The curricular content consisted of ten chapters based on the syllabus of pathophysiology. PLBL groups received IPBL on random four chapters (Fever, Hypoxia, Edema and Hepatic failure) and LBL on the other six chapters (Acid-base imbalance, Shock, Disseminated intravascular coagulation, Respiratory insufficiency, Cardiac insufficiency and Renal insufficiency), while LBL groups received LBL on all ten chapters. Both groups had the same instructor.

IPBL's process and the process grading

As figure 2 shows, before IPBL class for PLBL group, each squad was assigned to look for and figure out 5-6 problems (key knowledge points) by squad-discussion on two class hours of teaching content. 3-4 of the problems were on the studying (upcoming content), 1-2 on the studied (previous content not limited to pathophysiology), and another 1-2 on the unstudied relevant to the studying. Such arrangement aimed to build students' continuous thinking from health to disease and even diagnosis and treatment for disease. Then the squads submitted their problems and answers online to the instructor one day before class to facilitate guidance in class.

In class, the instructor, using playing cards for randomization, selected a squad and one of its members to elaborate on one of the squad's problems followed by other members' supplemental views, and every squad member got the same mark regarding the elaboration and supplement, a system that aimed to facilitate comprehensive discussions among squad members on every problem before class. Afterwards, other squad members elaborated individual opinions of their own accord on this problem to obtain an individual mark, leading to more open discussions. Such procedures repeated until all squads presented their problems or class ended. The squads that were not able to present, if any, would receive a mark by averaging all other squads'. The instructor summed up the key knowledge points by analyzing students' presentations and provided a relevant clinical case for squad-discussion post-class. All squads were assigned to submit a new relevant case with analysis one day before next class.

Similarly in next class, a squad and a member of the squad were randomly chosen to present the cases, followed by the instructor's summary.

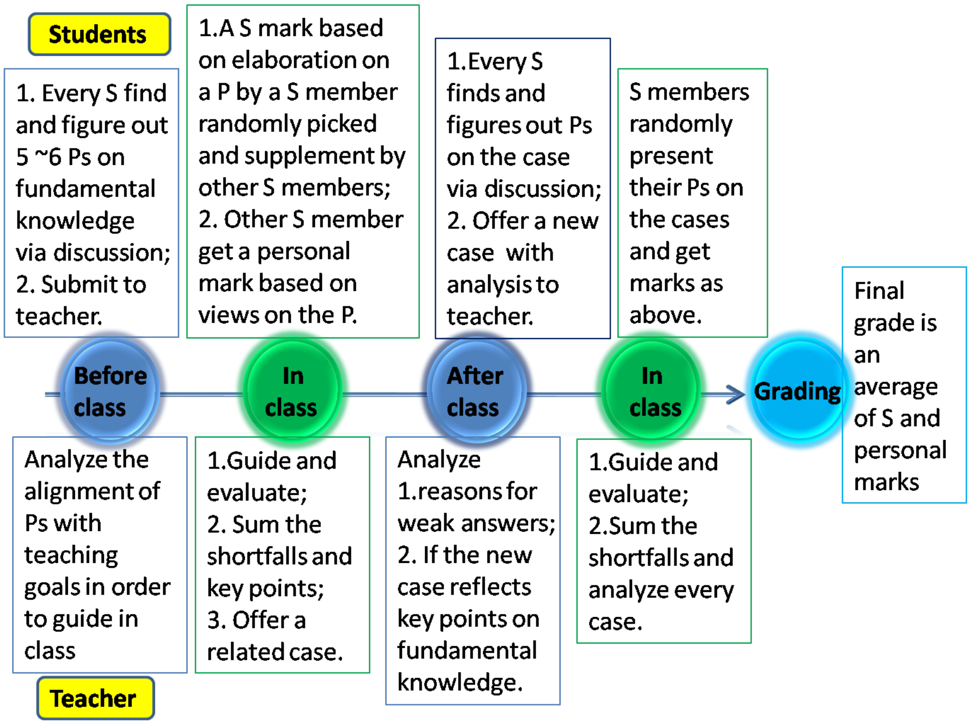

Figure 2. The instructional process and grading of improved problem-based learning (IPBL).
Note. P, problem; S, squad

EVALUATION

Final exam

A written exam was administered in classroom at end of the course simultaneously for the students of PLBL and LBL groups in each academic year. The exam questions consisted of 100 multiple choice questions that were categorized into three difficulty levels according to Bloom's taxonomy of "recall", "understanding", and "application" (More et al., 2020; Singh et al., 2016). There were 40, 36, and 24 questions of respective difficulty level to compare PLBL with LBL. 42 of the 100 questions were from the 4 chapters where IPBL was applied, of which 16, 16, and 10 questions respectively correspond to the three difficulty levels to compare IPBL with LBL.

Questionnaire

A set of questionnaire was designed as 20 statements for the students' feedback on three elements: method of PLBL, engagement in teamwork, and learning skills (Table 4). There were 6 statements on methodology of PLBL that was not carried out in LBL group. As a result, 20 statements were anonymously conducted among PLBL group while 14 statements among LBL group. A perception score on a five-point scale from 1 (strongly disagree) to 5 (strongly agree) was calculated to assess the extent in favor of PLBL over LBL.

Data Analysis

The final exam was assessed by Pearson's χ^2-test for the three difficulty levels. The independent T-test was used for average marks on the final exam and perception scores on the students' feedback. SPSS 19.0 for Windows software (SPSS, Inc., Chicago, IL, USA) was used to conduct statistical analysis of data and the level of significance was set at *p* value less than 0.05 for all the tests.

RESULTS

There were no statistical significance between IPBL and LBL on the final test score

42 questions from the 4 chapters applied IPBL in PLBL group while LBL in LBL group in the final exam. Students' average marks were not significantly different between the two instructional methods of IPBL and LBL ($p>0.05$, data not provided). Furthermore, the number of questions correctly answered by all students in a class was put into contrast, which also showed that IPBL alone did not perform better than LBL ($p>0.05$, Table 1). Overall, the data suggested that IPBL's application in a large class was not more efficient in fundamental knowledge learning than LBL for the students prior to medical internships.

Module	Number of students	Recall (16 questions)	Understanding (16 questions)	Application (10 questions)	Overall (42 questions)
2018 IPBL	46	14	9	2	25
LBL	46	12	8	1	21
2019 IPBL	48	13	10	3	24
LBL	49	13	9	2	24
$p(\chi^2)$ 2018	92	0.365(0.821)	0.723(0.126)	0.531(0.392)	0.381(0.769)
2019	97	1.000(0.000)	0.719(0.130)	0.606(0.267)	1.000(0.000)

Table 1. IPBL-LBL comparison of the number of questions correctly answered by all students in a class in final exam.

Note. Data from the 4 chapters undergoing IPBL teaching in group PLBL while LBL teaching in group LBL.

PLBL performed better than LBL on the final test score

However, PLBL, a hybrid of IPBL and LBL, exhibited different outcomes from LBL in the final exam (Table 2 and 3). In spite of indifference on average marks ($p>0.05$, data not provided), PLBL group fared better in "understanding" components ($p=0.033$) in the year of 2019, and better in overall performance than LBL group in the two years of 2018 and 2019 ($p=0.026$, 0.047), because of more questions correctly answered by a maximum number of students (Table 2). Furthermore, more students in PLBL group (p=0.002) obtained A score (high, 80~100 marks) and fewer students (p=0.001) in B (low, 60~79 marks) than LBL group, while comparable (p=0.298) in C (no pass, 0~59 marks) (Table 3). Such evidence suggested that PLBL, by combining IPBL and LBL, worked better than LBL in a large class to transfer fundamental knowledge to students prior to medical internships.

Group	Number of students	Recall (40 questions)	Understanding (36 questions)	Application (24 questions)	Overall (100 questions)
2018 PLBL	46	27	18	6	51
LBL	46	22	11	3	37
2019 PLBL	48	28	20	5	54
LBL	49	26	11	3	40
$p(\chi^2)$2018	92	0.251(1.317)	0.093(2.829)	0.267(1.231)	**0.026**(4.944)
2019	97	0.166(1.920)	**0.033**(4.589)	0.439(0.600)	**0.047**(3.934)

Table 2. PLBL-LBL comparison of the number of questions correctly answered by all students in a class in final exam.
Note. Data from the 10 chapters undergoing hybrid teaching of IPBL and LBL in group PLBL while only LBL teaching in group LBL. Bold type: there are statistical differences.

Exam score bucket	PLBL(n=94)	LBL (n=95)	p (χ^2)
A. High (≥80)	21(22%)	6(6%)	**0.002**(9.909)
B. Low (60~79)	56(60%)	77(81%)	**0.001**(10.450)
C. No pass (≤ 59)	17(18%)	12(13%)	0.298(1.082)

Table 3. PLBL-LBL comparison of the number of students getting score buckets in final exam.
Note. Full mark was 100. Data from the 10 chapters undergoing hybrid teaching of IPBL and LBL in group PLBL while only LBL teaching in group LBL. Bold type: there are statistical differences.

There was a considerable acceptance from students of PLBL on methodology as well as ability training

From analyzing feedback from 94 students of PLBL group and 95 students of LBL group in the two years (Table 4), the sum of perception scores was higher in PLBL than LBL (p=0.031) according to the 14 statements that both groups went through. Furthermore, there were significant differences in the survey between PLBL and LBL on fundamental knowledge learning (p=0.035), engagement in teamwork (p=0.032), problem-finding (p=0.041), problem-solving (p=0.039), learning motivation (p=0.037), presentation (p=0.049), and information management (p=0.036). Especially, PLBL's method obtained top perception scores in "IPBL in large classes" (4.44±0.83), "IPBL hybrid with LBL" (4.51±0.74), and "fundamental knowledge learning" (4.47±0.77) with 3, 3 and, 2 statements respectively, coming only after problem-finding (4.82±1.05). It suggested a definite and considerable acceptance by the students prior to internship for PLBL's methodology on fundamental knowledge learning in large classes under the instructional strategies as well as ability training on learning and teamwork skills.

Classification of statements		Statements	Perception score (*Mean*±*SD*)		
			PLBL(*n*=94)	LBL(*n*=95)	*p*(t)
Method of PLBL	IPBL in large classes	1.IPBL's squad numbers were efficient. 2.IPBL's instructional process and grading were efficient. 3.IPBL was appropriate for large classes.	4.44±0.83	-	-
	IPBL hybrid with LBL	1.Necessary to blend LBL and IPBL. 2.PLBL preserved advantages of LBL and PBL. 3.Efficient to assign different half of contents to IPBL and LBL.	4.51±0.74	-	-
	Fundamental knowledge acquisition	1.Help the knowledge understood. 2.Help the knowledge vivid.	4.47±0.77	3.80±0.84	**0.035** (2.095)
Engagement in teamwork		1.Improved peer interaction 2.Increase engagement in teamwork	4.03±0.86	2.37±0.66	**0.032** (2.107)
Learning skills	Problem-finding	1.Easier to focus on the key problems. 2.Helpful to identify problems.	4.82±1.05	3.44±0.70	**0.041** (2.084)
	Problem-solving	1.Improve skill to solve problems. 2.Easier to find a way to problems.	4.38±1.01	2.41±0.82	**0.039** (2.088)
	Learning motivation	1.Improved learning motivation. 2.Promoted interest in learning.	4.03±0.72	3.39±0.94	**0.037** (2.092)
	Presentation	1.Allowed me to present better. 2.More willing to express.	3.01±0.66	2.28±0.43	**0.049** (2.043)
	Information management	1.Improved the ability to collect and sort learning materials. 2.The materials I searched were more relevant.	3.80±0.87	2.41±0.49	**0.036** (2.096)
Sum for 14 statements (5×7=35)			29.13±4.27	20.33±3.91	**0.031** (2.110)

Table 4. Classification of statements and comparison of perception scores on PLBL and LBL.
Note. Bold type: there are statistical differences.

REFLECTIONS

PBL has predominantly been focusing on patient cases, a strategy to enhance skills and competencies necessary to bring science into professional contexts (Stentoft, 2019).

Although the benefits of PBL are well-known, there are aspects open to improvement such as “How does PBL work in different specific contexts?” (Hung et al., 2019).

To achieve a small-class outcome of classic PBL in large classes, two strategies were used to realize the same gain of knowledge for every squad member in IPBL class besides squad count imitating student count of classic PBL. One was to randomly pick a squad and its member to elucidate one of the squad’s problems found and contemplated by squad-discussion before class. The other was to have all members of a squad get the same mark (squad-score) for a problem according to the elucidation and subsequent supplemental views of other squad members. These measures encouraged every squad member to actively engage in and study on every problem during squad discussions, making IPBL feasible in the context of large classes. Such feasibility and effectiveness were demonstrated by students’ feedback on “IPBL in large classes” with a high perception score (Table 4).

Whether a stand-alone or add-on to LBL, PBL predominantly occupied the center stage in clinical cases for medical interns who could more easily understand theoretical implications of fundamental knowledge due to their internship experiences (Stentoft, 2019; Yan et al., 2017). In our case, IPBL was implemented for students without internship experiences to learn fundamental knowledge, which was not demonstrated to be more favorable in terms of test scores in final exam than LBL (Table 1). However, IPBL combined with LBL, namely PLBL, displayed better learning outcomes for fundamental knowledge on “understanding” in year 2019 and “overall performance” in years 2019 and 2020 (Table 2), and more students got scores at the high bucket (Table 3) than LBL. The outcomes of PLBL were also identified by the feedback on “fundamental knowledge learning” with a higher perception score than LBL (Table 4), indicating that PLBL was efficient in transferring fundamental knowledge to students without internship experiences.

Also, the advantages of PLBL over IPBL or LBL suggested the complementarity of IPBL and LBL. Likewise, a recent study reported that students unfamiliar with clinical practice had preferred LBL because of its remarkable effect on immediate knowledge retention over PBL (Solomon, 2021). A systematic review supported an eclectic system in which the pedagogical tools from LBL and PBL were used cooperatively in the best interest of education and satisfaction of students (Jiménez-Saiz& Rosace, 2019). However, PBL was an add-on component to LBL applied together to all instructional contents in the eclectic system (Ishizuka et al., 2023; Klegeris et al., 2013; Klegeris & Hurren, 2011; Lian & He, 2013; More et al., 2020; Qin et al., 2010). In the case, PLBL leveraged the complementary strengths of IPBL in independent reasoning and LBL in immediate knowledge retention by applying each of them to half a curriculum, resulting in superior outcomes on fundamental knowledge learning as well as students’ acceptance with a high perception score on “IPBL hybrid with LBL” (Table 4). Additionally, PLBL was unsurprisingly more helpful in ability training of “learning skills” and “engagement in teamwork” than LBL according to the feedback (Table 4).

In summary, IPBL effectively simulated classic PBL’s outcomes because of its strategies on squad count, random presentation, and grading system. PLBL’s hybrid strategy achieved a synergy of IPBL and LBL each applied to distinct instructional contents. Hereby, PLBL was suitable and effective for students without internship experiences to learn fundamental knowledge in a large class within 50 students.

The precondition in classic PBL to have a low student count of 7-10 for instructional effectiveness inspired the strategy in PLBL to form 7-10 squads among students in a large class. Assigning squad-scores according to random presentations facilitated comprehensive discussions among squad members to realize learning outcome for one whole squad in a way similar to one sole person. Analogizing one squad as one “student”, a large classroom can have at most 10 “students”. Theoretically, the appropriate sample size is up to 100 students in a large classroom, though further research is needed for settings with more than 50 students.

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