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Article

Toward Creating Software Architects Using Mobile Project-Based Learning Model (Mobile-PBL) for Teaching Software Architecture

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Abstract: Project-based learning (PBL) promotes increased levels of learning, deepens student understanding of acquired knowledge, and improves learning motivation. Students develop their ability to think and learn independently through depending on themselves in searching for knowledge, planning, exploration, and looking for solutions to practical problems. Information availability, student engagement, and motivation to learn all increase with mobile learning. The teaching process may be enhanced by combining the two styles. This paper proposes and evaluates a teaching model called Mobile Project-Based Learning (Mobile-PBL) that combines the two learning styles. The paper investigates how significantly Mobile-PBL can benefit students. The traditional lecture method used to teach the software architecture module in the classroom is not sufficient to provide students with the necessary practical experience to earn a career as software architects in the future. Therefore, the first author tested the use of the model for teaching the software architecture module at Philadelphia University's Software Engineering Department on 62 students who registered for a software architecture course over three semesters. She compared the results of using the model for teaching with those results that were obtained when using the project-based learning (PBL) approach alone. The students' opinions regarding the approach, any problems they had, and any recommendations for improvement were collected through a focus group session after finishing each semester and by distributing a survey to students to evaluate the effectiveness of the used model. Comments from the students were positive, according to the findings. The projects were well-received by the students, who agreed that it gave them a good understanding of several course ideas and concepts, as well as providing them with the required practical experience. The students also mentioned a few difficulties encountered while working on the projects, including student distraction from social media and the skills that educators and learners in higher education institutions are expected to have.

Keywords: software architecture education; Jordanian higher education; project-based learning; mobile learning

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1. Introduction

The revolution brought about by technology has caused a transformation in the education system, especially with the integration and use of information and communication technologies. The use of technology has improved the learning outcomes for students [1]. Furthermore, the use of mobile technology has made its roots in the education system and has boosted the focus on mobile learning. Mobile learning is described as the process or system used to assess educational content and other resources using portable devices [2,3]. Contrary to this, another learning approach is project-based learning, which is also referred to as the inquiry-based instructional method, which assists learners in engaging well and accomplishing meaningful projects [4]. However, the combination of mobile learning with

project-based learning has the potential to serve as a unique learning experience and to elevate the level of interest of the students towards their educational goals.

Along with obtaining new information, the teaching of software engineering courses requires students to improve their skills. In teaching software engineering modules, combining such effective teaching approaches has significant benefits. PBL aids in the teaching process and involves students in practical projects that use their knowledge and skills. Moreover, it promotes communication and teamwork. However, m-learning, which involves using mobile devices such as smartphones and tablets to access learning materials and accomplish learning activities, can be advantageous since it enables students to learn whenever and wherever they wish. As a result, given that software engineering is a field that is always growing, combining the two approaches can be valuable while teaching, and more specifically when teaching software engineering courses.

In their third year of study, students of software engineering take a course on software architecture. Many researchers have studied and identified the difficulties and challenges in teaching software architecture courses to software engineering students. Moreover, refs. [5,6] analyzed why teaching software architecture is challenging and contrasted it with teaching other software engineering subjects. As the first author has been teaching software architecture for five years, she has observed that students frequently simply study in order to prepare for exams, which rarely results in long-lasting learning. Thus, she poses the following question.

Does developing a cooperative, transparent, and interactive learning environment encourage students to shift their attention from purely studying for exams, which has short-term learning benefits, to learning to develop their abilities and skills over time, which has long-lasting and self-motivated implications?

To answer this question, this paper proposes a teaching model called Mobile-PBL that combines m-learning and PBL learning styles. Students can use mobile devices to collaborate with their classmates while working on their projects, which develops a cooperative and interactive learning environment. By comparing the results when employing Mobile-PBL for teaching with those when PBL alone is used for teaching, the paper assesses the impact of using it and its capacity to overcome the challenges and the difficulties in teaching the software architecture module. Moreover, the paper answers the above research question using various students' evaluations.

The paper starts with the background of the two learning styles and how they are combined in the literature. Then, the paper proposes the Mobile-PBL model. After this, the model is evaluated and the results are shown and discussed. Conclusions and future works comprise the last section of this paper.

2. Background

2.1. Mobile Learning Background

The use of technology has evolved the ways in which teaching occurs in the classroom. Today's students are digital natives and millennials that have a strong command of the use of technology in their everyday lives [7]. The fast speeds of wireless networks and mobile devices have led to student-centered mobile learning, which is now a new stage of development concerning distance learning and e-learning areas. Mobile learning can be attained via the use of tablets, smartphones, PDAs, and PCs [8,9]. These are economical and satisfactory tools and allow access to course materials anywhere. Therefore, the adoption of mobile learning can become an effective tool to deliver higher education in the future [10].

Mobile learning offers a flexible and convenient approach that enables students to access content and develop their skills whenever and wherever they wish. Mobile devices offer a variety of multimedia content and interactive features, making learning more engaging and interactive [11]. Mobile learning enables personalization and tailoring to individual learning needs, preferences, and styles. In addition, learning also facilitates communication and collaboration between learners and instructors, allowing for group learning and peer support [12].

2.2. Project-Based Learning

Project-based learning serves as a constructivist method of teaching that allows the exploration of knowledge areas as the students work on a specific project within an extended period of time [13]. The focus on project-based learning provides students with a myriad of learning opportunities as they are able to practice learning via the use of collaboration and group discussion in the completion of the project [14]. The learning method also supports the engagement and learning of the students and ensures that meaningful and purposeful communication is achieved. PBL is a student-centered teaching approach that involves students working on a real-world project that requires thinking critically, with the ability of solving problems effectively and through collaboration with others. In this manner, PBL promotes active learning, as students are encouraged to take ownership of their learning and become responsible. The aim is to allow differentiation, as students utilize their skills at their own pace and use their own strengths and interests to contribute to the project [15].

In addition to this, a significant aspect of project-based learning is the importance of using a variety of resources, ensuring self-directed work, presenting a final report, and incurring meaningful competencies while working [16]. Besides this, PBL also assists students in taking responsibility for their learning, understanding, developing, and applying academic concepts in practical output [17]. Students are able to make use of authentic materials and boost their theoretical and academic knowledge with applications in real-world practices [18]. The teachers' role is also profound in terms of project-based learning, and they ensure that the students are able to coordinate their actions together in finding an appropriate solution [19]. Thus, PBL has the potential to help university students in exploring and sharing information.

2.3. Mobile Learning with Project-Based Learning

Based on the growing popularity of e-learning and internet-based learning models, the exploitation of the characteristics and capabilities of mobile technology has emerged [20]. This has created a new learning opportunity for the educational field. Contrary to this, the mobile learning method restricts the student's interaction and collaboration in work, which can be attained via the adoption of project-based learning [21]. Serving as a constructivist pedagogy, the PBL method allows for raising questions and addressing issues regarding the topic under study [22].

Combining mobile and project-based learning is expected to allow learners to engage in hands-on, collaborative learning experiences while using devices to access information and other related resources. Mobile devices can help to facilitate research, data gathering, and communication during PBL. PBL, on the other hand, provides a context for learners to apply their mobile learning knowledge and skills [23]. It is also designed to confront and tackle the complex problems that the students investigate via a thorough understanding. Therefore, integrating mobile learning with project-based learning can help in generating a new, innovative, and unique learning experience for the students [23,24]. This means that the advantages associated with both methods will be combined, and the disadvantages associated with them will be eliminated. The use of mobile learning allows access to knowledge that is available online and is easily accessible [25]. It also ensures that sharing, reading, and listening are all focused at a time, providing complete educational support. Furthermore, the focus on mobile learning provides students with open distraction, lacks personalization, and also restricts social interaction [25,26].

This is reversed in the case of project-based learning. PBL is more focused on meaningful collaboration and fosters creativity and critical thinking. However, searching for knowledge is time-consuming in the PBL method and requires a hardworking and dedicated approach [27,28]. Therefore, the combination of both approaches helps to minimize the risk and maximize the benefits for the student's learning journey.

Only a few studies, such as [23,29], have specifically examined and assessed the combination of the two styles in higher education. There are not many studies, however, that look at combining both styles while teaching software engineering modules, particularly

when teaching software architecture. For example, ref. [23] asked students about their expectations, attitudes, preferences, and actual use of mobile devices in the context of a project-based course as part of a qualitative study that focused on the individual blending of mobile and project-based learning. Thus, their study only sought student comments and expectations related to mobile learning in terms of flexibility and organization, individual pace, collaboration, and multifunctional devices. The study, however, did not incorporate any empirical research findings. Moreover, ref. [29] provides an instructional model that combines project-based learning with mobile learning to enhance the proficiency of vocational high school students in computer assembly and fundamental network topics. At the stage of putting the design into practice, this research employs both the research and development technique and the experimental method and uses a questionnaire as an instrument. However, the approaches required in higher education institutions and specifically while teaching software engineering modules are different from those used in high schools. Furthermore, ref. [30] focused on surveying students for access to mobile devices for project-based learning and on what they use the devices for.

Thus, there is a need for empirical studies applying this combination while teaching software engineering courses.

2.4. Teaching Software Architecture

Software architecture, which establishes the structure and behavior of a software system, is a crucial process in software development. It makes it possible for software systems to achieve the quality attributes that are required by stakeholders, such as reliability, maintainability, performance, scalability, and safety [31]. Effectively teaching software architecture modules to students, however, is difficult and challenging [32–34] because it calls for both practical experience of applying architectural patterns and a good understanding of the fundamental concepts [35]. Teaching software architecture using the traditional lectures in the classroom is not sufficient because it will never provide a practical experience for the students. Teaching software architecture, designing, and implementing activities need a suitable context and problems with adequate complexity (for example, sufficient size, and complete and sufficient quality attributes) in order to provide students with a real, practical experience [32].

To improve students' learning experiences when teaching software engineering courses, alternative teaching strategies have also been suggested, including project-based learning (PBL) [36,37] and mobile learning [37].

3. Mobile-Project Based Learning Model (M-PBL)

While attempting to integrate the components of the instructional elements of the mobile learning features and PBL strategy, a novel M-PBL model is generated. The model combines the features of both learning approaches and provides the utmost advantages. The figure below presents the design of project-based learning in a combination with mobile-based learning to meet the needs of the students and the teacher. It will also aid in optimizing the information technology resources and will also develop problem-based learning competencies and skills.

Figure 1 presents insights into the integration of the two learning models. However, from the components of mobile learning, three areas have been identified. These include the front-end functions, the back-end management, and digital media and content. The focus of the front-end function is to send the information back and ensure that instant communication is maintained. The front end provides an interface for the users to interact effectively and also provides other elements of interaction [38]. The focus of the back end is to empower the main functionality of the mobile application. It helps to set paths, set materials, and monitor the overall functionality [39]. In addition to this, mobile learning also fosters digital media and content that helps students and teachers to upload and download lecture materials and other important information sources. Mobile learning

also assigns tasks, designs activities, designs instructions, provides adequate resources, evaluates the resources, and provides feedback [40].

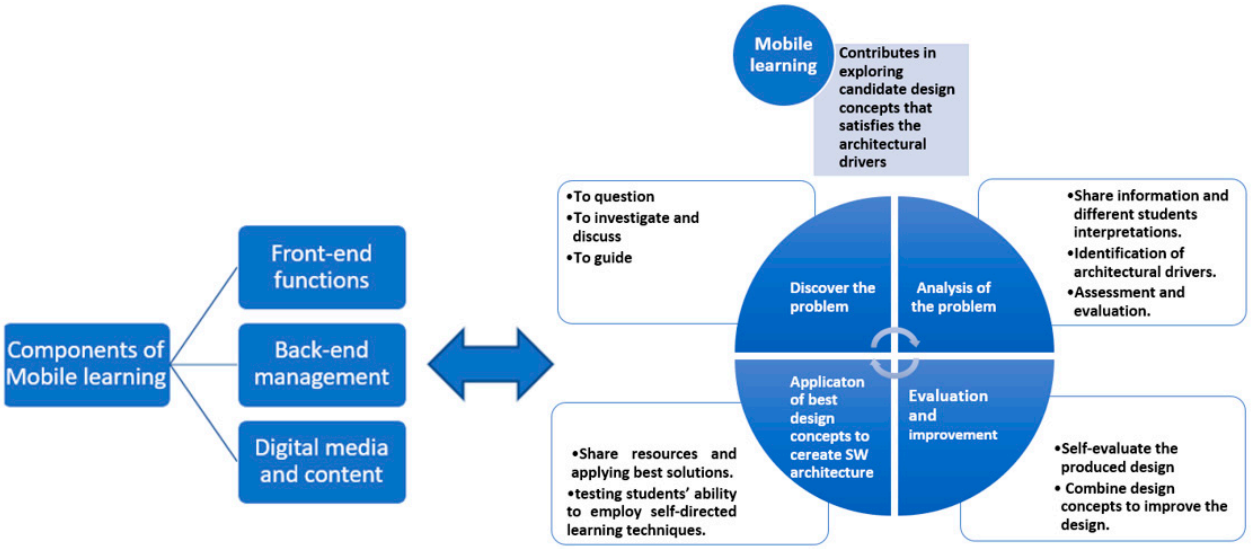

Figure 1. Integrating mobile learning and project-based learning (Mobile-PBL).

Contrary to this, the focus of the project-based learning model is based on four areas. Firstly, the discovery of the problem is necessary, which means that an investigation and research are carried out to generate the likely outcome. Furthermore, after the exploration of the problem, an analysis of the problem occurs, where the shared information is thoroughly assessed and evaluated. The problem is then improved by managing the sets of data and focusing on task production and self-evaluation. Thus, lastly, within the PBL model, the application of the best practices is ensured, and the best-identified solution is implemented.

However, the proposed model shows an integration of the two models. This means that the mobile learning advantages are combined with project-based learning, and an exceptional digital but collaborative outcome is attained where the students are able to engage socially with the real world, but the sources of information can also be available at one's fingertip. The proposed model focuses on knowledge retention and accessibility, encouraging continuous learning and development, and helps in increasing project completion rates. Furthermore, the model is also time-efficient and cost-effective, which further adds value to the model, making it a highly acceptable model for teaching software architecture in particular and software engineering courses in general.

4. Application of Mobile-Project Based Learning Model (M-PBL)

The desired properties when merging the two learning strategies are shown in Figure 2. The figure makes it clear that allowing students to perform projects and project-related tasks using their mobile devices has the potential to increase engagement and, as a result, reduce student distraction. For this, lecturers must deliver lectures in person, as well as use project-based learning and mobile learning. This already calls for lecturers to assign projects and assist students in person while giving face-to-face lectures.

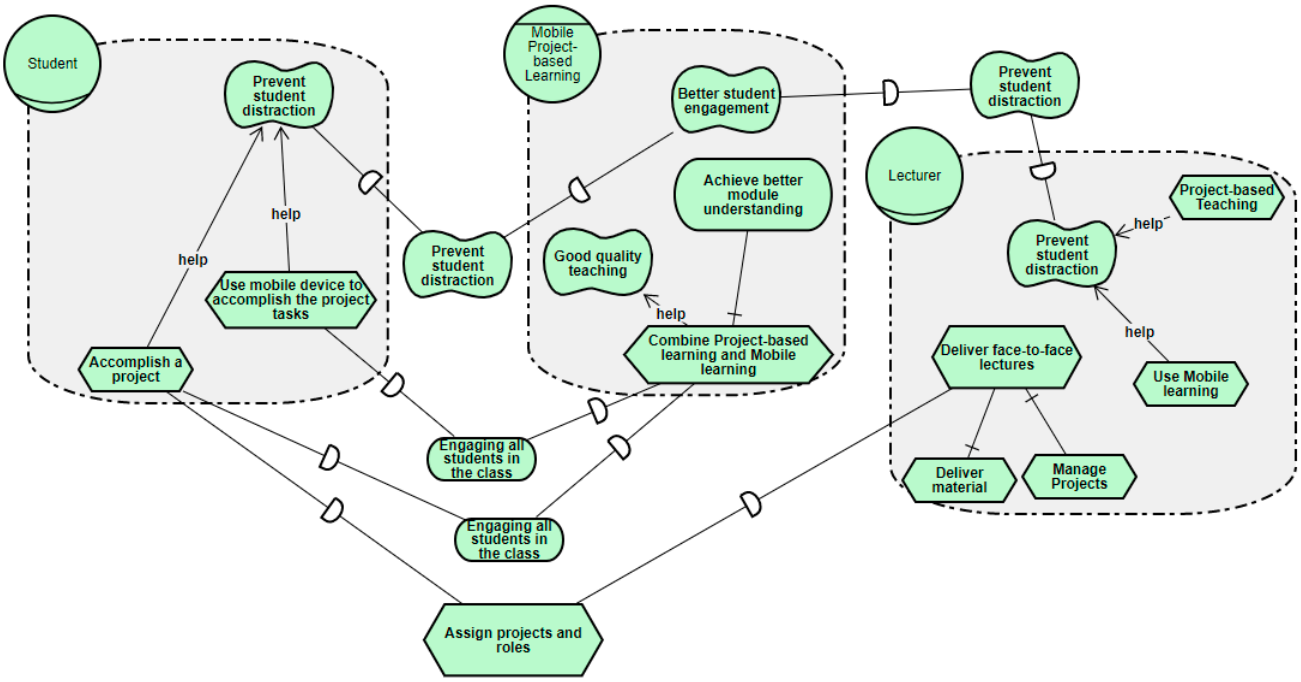

Figure 2. Goals of the mobile-project based learning model (M-PBL).

To evaluate the effectiveness of the proposed Mobile-PBL model, the adoption of an appropriate application and evaluation methodology is important [29]. With the use of an appropriate methodology, the effectiveness and efficiency of the model is analyzed, and the use of the Mobile-PBL model for teaching software architecture courses is evaluated.

Approximately 30 students taking the software architecture course were chosen in the current scenario. As shown in Figure 3, the lecturer (the first author) divided the students into ten groups of three students each and gave each group five projects to complete over the semester (one project at a time, not all together). All class projects were required to assess the effectiveness of the Mobile-PBL model.

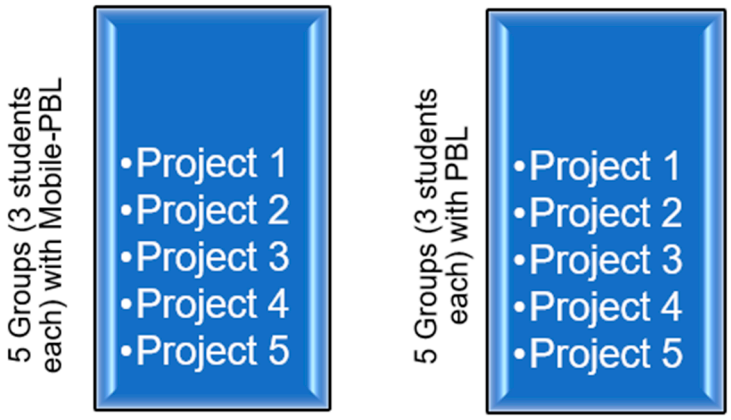

Figure 3. Application methodology.

As shown in Figure 4, the lecturer structured each project into a number of phases, with a variety of tasks and specific deliverables to be accomplished for each phase, which made it simpler to assign each student a task to complete.

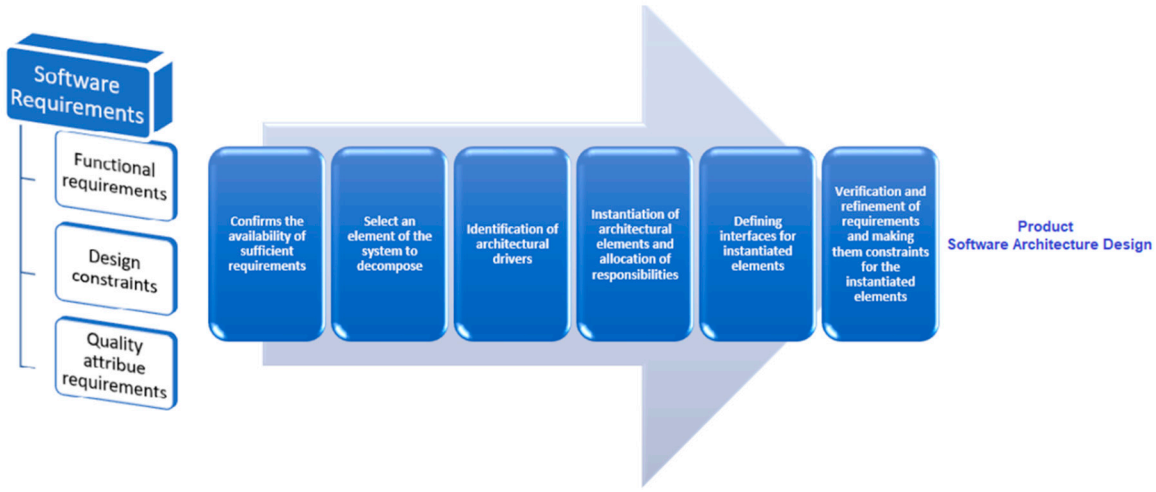

Figure 4. Project tasks inspired by attribute-driven design ADD2 [41].

For each project, the lecturer gave two 90-min lectures to the students, providing them with adequate time to complete the project's essential phases. Furthermore, to accomplish the tasks during the assigned phases, the lecturer enforced Mobile-PBL for five groups, where she allowed students to make use of their mobile devices to help and assist in working. The other five groups used the PBL style only, where the lecturer did not allow students to make use of mobile devices; rather, she granted them permission to utilize the faculty's computer lab. The groups were asked to complete their tasks, and, at the end of each of the two lectures that were assigned for the project, the lecturer marked students' work as finished or unfinished. Thus, the same ten groups completed all five class projects during the semester by making use of the same methodology.

5. Reflections on the Application Methodology

In order to develop a thorough understanding of the core concepts of software architecture, students with Mobile-PBL were allowed to use mobile devices to access learning resources provided by the lecturer, such as lectures, videos, and articles. Thus, students were able to learn at their own pace because the learning resources were always available. Because Microsoft Teams is Philadelphia University's official platform for teaching and learning, and since [42] evaluates the platform's effectiveness, students used Microsoft Teams on their mobile devices to access the material recommended and uploaded by the lecturer. Moreover, students worked in groups to build software architectures that fulfilled the quality attributes that were provided in the requirements in the project specification. In other words, students were given sufficient software requirement specifications and they were required to apply an attribute-driven design (ADD) to build software architectures that achieved the quality attributes that were specified in the software specification. This could also offer students the chance to practice creating software architectures in a real-world setting.

It was difficult to determine what to offer the students as a project specification, since, if they were given the full SRS, they would spend the entirety of the two lectures allocated for the project reading the SRS, rather than starting with the design process. This was difficult since students need to have a thorough definition that includes both the architectural drivers and the functional requirements. Thus, the lecturer gave them a summery that contained only what they needed to build the architecture, instead of a full SRS.

At the end of each lecture, the lecturer recorded remarks about the completion of each phase. The lecturer marked each phase as either completed or not, and then the lecturer calculated the completion percentage for each project. Thus, all projects had a completion percentage at their completion. The lecturer then contrasted the outcomes of the two group

categories—those who utilized project-based learning without mobile learning and those who did—to compare the results.

In the following two semesters, again, the 'software architecture' module, with a combined student enrolment of 32 students in both semesters, was taught using only mobile project-based learning.

In addition to the lecturer's comments about the used model, a focus group at the end of each semester was held and a short feedback survey was distributed to the students to collect their thoughts on the model.

6. Results

The percentage of the five projects that were assigned to students over the semester that were completed is shown in Table 1. The project completion percentage for the first five groups was higher than the completion percentage of the other five groups. In the focus group session after finishing the five projects, students admitted that using their mobile devices while working on projects was beneficial, while those who did not use their devices indicated they were not interested in visiting computer labs and stated that they attempted to work on the projects in the cafe. One of the students commented,

Table 1. Project completion percentage.

	Project 1	Project 2	Project 3	Project 4	Project 5
Group 1 (with Mobile-PBL)	90%	98%	95%	100%	100%
Group2 (with Mobile-PBL)	92%	100%	100%	100%	98%
Group 3 (with Mobile-PBL)	90%	88%	85%	90%	95%
Group 4 (with Mobile-PBL)	85%	88%	85%	90%	88%
Group 5 (with Mobile-PBL)	86%	82%	88%	85%	85%
Group 6 (with PBL)	65%	58%	62%	62%	50%
Group 7 (with PBL)	60%	55%	62%	65%	65%
Group 8 (with PBL)	84%	83%	82%	85%	80%
Group 9 (with PBL)	80%	85%	80%	80%	75%
Group 10 (with PBL)	72%	70%	66%	65%	60%

> *"I'd rather stay seated at the cafe than go upstairs to the computer labs. You would have given me a greater chance to do the necessary activities during the lecture if you had let me use my phone".*

The lecturer permitted the five groups that did not utilize Mobile-PBL to repeat the final project with Mobile-PBL so that they could benefit from it. Both the lecturer and the students could recognize a significant difference in how each student completed the project, although not fully complete, but with the ability to select the appropriate architectural pattern and to provide justification for their decision.

The findings of the survey completed by students who received education utilizing Mobile-PBL over the three semesters are shown in Figure 5 (the 15 students who employed PBL alone are also included because they were allowed to use Mobile-PBL to repeat the last project). The findings show that most students who used Mobile-PBL strongly agreed or agreed that the approach improved their engagement, reduced the task completion time, increased their motivation to learn, helped to address the issue of individual student differences, increased the availability of information, and helped to improve lecturer and peer support.

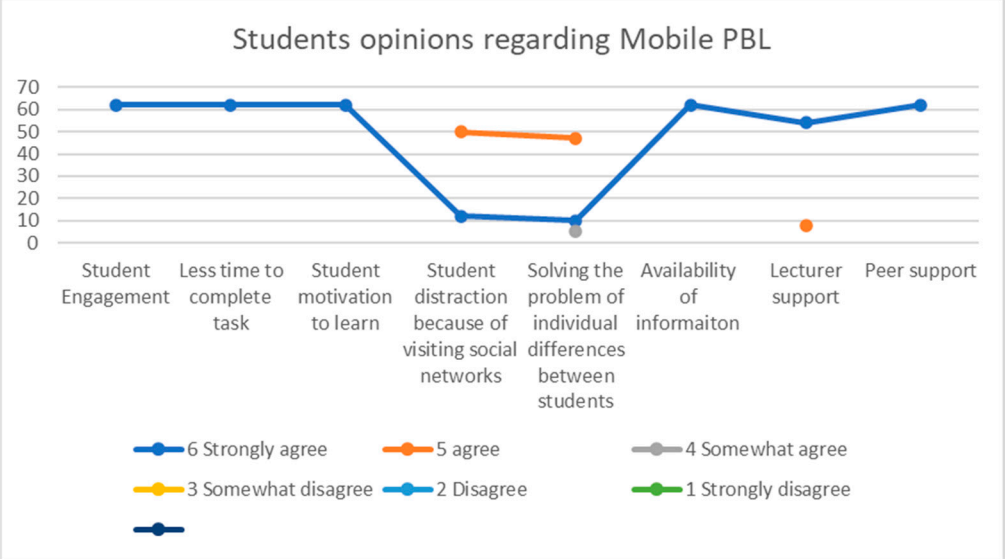

Figure 5. Students' opinions regarding Mobile-PBL.

On the other hand, it can be seen that most students agreed on the fact that mobile project-based learning caused distraction.

For the 15 students who originally used PBL without mobile learning, the results of the survey were as shown in Figure 6. It can be seen that only three students strongly agreed that using PBL increased their engagement, and two students strongly agreed that PBL helped to solve the problem of individual differences between students. When compared to the results above when using Mobile-PBL, it can be seen that using our model achieved better results.

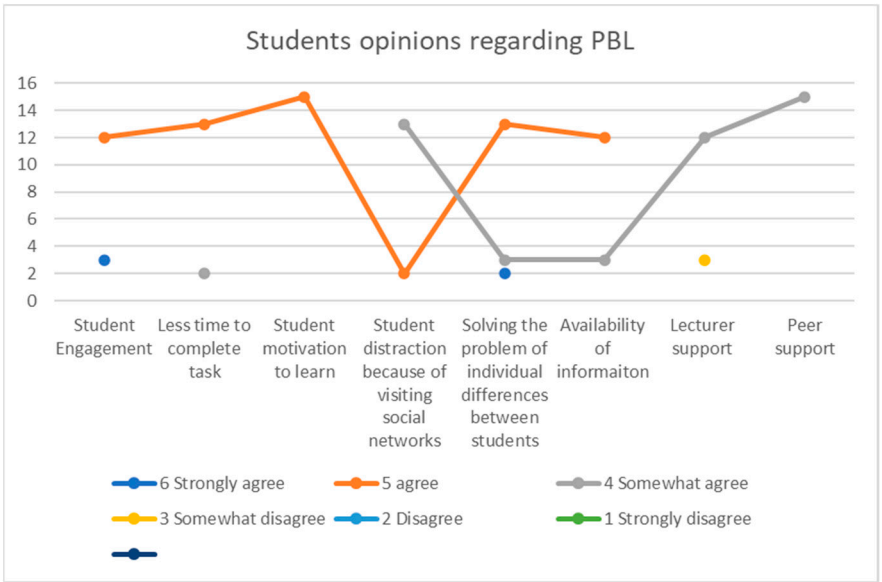

Figure 6. Students' opinions regarding PBL.

7. Discussion of Results

The goal of the study was to establish a new Mobile-PBL teaching model that might improve students' engagement. Thus, this study was an innovative effort to propose the Mobile-PBL model and use it with university students. Testing of the proposed model shows that there is a correlation between employing the Mobile-PBL approach and the students' performance and ability to complete the project work, where the project completion

percentages for the first five groups in the first scenario were higher than the completion percentages of the other five groups. Moreover, it can be seen that Mobile-PBL increased students' motivation and achieved better student engagement. Mobile learning, in other words, can be termed as learning based on the utilization of digital devices, including smartphones and tablets, aimed at accessing educational content and resources. Learning has become crucially important in the current digital age, as mobile devices are easily available and learners are seeking more flexible learning experiences. Mobile learning offers numerous benefits, including increased convenience, engagement, and collaboration. Mobile learning has improved access to education, particularly for learners who face barriers to traditional forms of education. Overall, mobile learning is revolutionizing education as well as training based on the provision of accessible and flexible opportunities to learn. Students are able to use mobile devices to record data, access multimedia content, communicate with team members, and document the progress of their projects. Thus, the Mobile-PBL approach aided university students in exploring and exchanging knowledge, which made finishing their projects quicker and more efficient by facilitating group collaboration and expanding the material available.

PBL contributes to the model by giving students the ability to discover problems through questioning, investigation, and guidance. Moreover, it allows students to analyze the problem so as to apply the best design decisions to solve the problem. Projects allow the testing of students' ability to employ self-directed learning techniques, problem-solving strategies, teamwork abilities, and subject-matter knowledge. PBL through mobile learning is an important approach to education because it offers learners a more engaging learning experience. PBL through mobile learning offers opportunities for the exploration of real-world issues, to conduct research, collaborate with peers and experts, and apply their knowledge as well as skills in meaningful ways. The usage of devices in PBL makes the learning process more accessible, flexible, and convenient for learners, as they can work on their projects while developing related skills such as critical thinking, communication, and collaboration, which are highly valued in the modern workplace.

Thus, mobile learning contributes to the approach by increasing the availability of information, increasing students' motivation, and making problem solving easier. This was demonstrated in the first scenario, where it was found that while students were typically unmotivated to study software architecture, they were extremely motivated and encouraged to research and read about architectural patterns and select one to use in their projects when employing the Mobile-PBL model. PBL through mobile learning is an important educational approach that promotes active and student-centered learning, as well as the development of essential skills for success in the changing educational and business world.

8. Limitations

8.1. Limitations of the Study

Although the survey's respondents were students who took three courses in software architecture using the Mobile-PBL model at the Philadelphia University Software Engineering Department, the reliability and the validity of the model would have been increased if the survey had included students who took the course in other universities' software engineering departments. Future research may also consider extending the study to other universities' departments of software engineering.

Moreover, this study was based on what students believed. Future research should take into account other e-learning stakeholders, such as educators and administrators.

8.2. Limitations of Mobile-PBL

Educators may choose not to take on the amount of work required for applying Mobile-PBL. Furthermore, traditional educators may not accept the usage of mobile devices in the classroom since they believe it will cause distraction and waste lectures.

Additionally, mobile devices may be out of reach for students from low-income backgrounds, and they may experience poor internet connectivity or a low bandwidth, particularly in remote locations with limited internet infrastructure. In addition, some students expressed dissatisfaction with the amount of work and the number of hours required to complete their projects each week. They stated that they worked on the project at home after the first lecture in order to finish it for the following lecture.

9. Conclusions and Future Work

This paper proposes the Mobile-PBL model for teaching software architecture courses in order to address the challenges of teaching the course. We combined the use of mobile devices (smartphones and tablets) as a tool for learning with PBL. The findings reveal that the students appreciated using the Mobile-PBL approach in their learning and had positive thoughts about it. The results demonstrated the model's capability to offer students the hands-on training necessary to secure a career as an architect. For students, mobile learning combined with PBL offers numerous benefits, as evident in terms of empowering students to take ownership of their learning. Students can ensure project completion based on the efficient utilization of their strengths and interests to contribute to the project, and they can access learning materials from anywhere using their mobile devices. Furthermore, PBL through mobile learning provides opportunities for students to develop essential skills that are highly valued by employers and are crucial for success in the contemporary world. Overall, mobile learning with PBL can create engaging and impactful learning experiences that prepare students for future challenges and opportunities, preparing them for the professional world.

The model also has the potential to assist lecturers in overcoming the difficulties and obstacles that they may encounter when teaching the software architecture module, despite the fact that it suffers from a large amount of work necessary and a lack of defined norms and standards. Other modules and disciplines may also benefit from the teaching model.

Future work should therefore consider developing standards for lecturers to use the Mobile-PBL approach in various university disciplines. Future initiatives should also take into account the views of educators and other stakeholders in higher education institutions with regard to the application of the Mobile-PBL approach in academic settings.

In light of the fact that varied perspectives from various university departments would surely enhance the research, it is advised to investigate restrictions and facilitating activities in future work.

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