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An Innovative Framework for Teaching/Learning Technical Courses in Architectural Education

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Abstract: This study presents a teaching/learning framework based on parallels between problem-based learning (PBL), constructivist pedagogy, and design, which enables students to learn technical courses in a way that promotes sustainable and self-directed learning. The study used qualitative content analysis of literature surveyed from scientific databases to determine thematic codes and find the relations. The theoretical framework was implemented in a case study conducted in a second-year course in building construction technology at Tishk International University, Sulaimaniya, Iraq. The results indicate that solving ill-defined problems increased student enjoyment in learning various subjects through several teaching methods including self-directed learning. The instructor's role is to facilitate learning rather than to provide knowledge by showing the solutions. This stimulates the students' curiosity toward understanding problems and approaching solutions through a game-based scheme. The suggested framework can be a guide for instructors teaching technical courses of any kind. This method equips students with technical knowledge that benefits them in their studies and their professional lives after graduation, as they can integrate both their design and technical knowledge.

Keywords: architectural education; technical knowledge/courses; constructivism; problem-based learning; pedagogical methods

1. Introduction

In architectural education, various teaching/learning methods coexist in the form of design-based, science-based, and expression-based modules as well as humanities and professional practice. These types of modules are rarely synchronized and have different content, teaching styles, durations, and epistemological foundations [1]. In design-based education, students undergo a specific learning process in the design studio that involves dialogues and collaboration with instructors and colleagues [2]. The applied modes and adaptability in the design studio make it comparable to constructivist pedagogy [3]. Constructivist education is based on the philosophy of constructivist learning, which has been used to create suitable curricula for diverse subjects [4]. Furthermore, by its nature, design is "a necessarily constructivist activity (both in terms of the design of concepts and the design of objects and processes); and . . . preceded constructivism by many millennia" [5].

In contrast, technical courses (science-based courses) are mostly lecture oriented and have become less critical subjects in the academic life of architecture students [6–10]. This has significantly diminished the role of technical knowledge in architectural education. The existing methods for delivering these courses align with neither the tradition of teaching/learning design in architecture nor with new teaching movements. Design education, specifically architectural design, exceeds simple problem-solving to include a conversational nature. In the studio, designers attempt to solve design issues under challenging circumstances [11] effectively. Emphasizing the parallels between cybernetics and design can explain the conversational character of design [12]. In a conversational learning environment, students participate in an engaging and thorough learning process. Constructivist epistemology centers the students' construction of their own knowledge. "Education based on constructivist epistemology thus provides students with opportunities to engage in activities designed to promote their construction of understanding" [1].

Gelernter [13] and Yunus [10] mentioned that the knowledge architecture students acquire in these technical courses does not transfer to their design projects. Furthermore, the courses are perceived as the dullest subjects in their education, revealing the unsustainability of this approach. These courses are seen in this negative manner due to the way they are taught, which is mostly lecture-based. The problem with these methods is that "the implicit authority of the lecture format obscures the conversational nature of learning rather than encouraging and demonstrating it" [14]. These methods have other shortcomings such as the dominance of the instructors' authority, one-directional manner of application, repetition of monologues, and the physical environment of the classroom [14].

Consequently, when architects work onsite, they realize that their knowledge of technical subjects is not equivalent to their knowledge of design. On the other hand, the market demands a high level of technical knowledge, and 'it is likewise fundamental for students to acquire these capabilities that are required in society today' [15]. Problems appear when architects perform based on what they have learned in these courses. They understand the difference between the realities of design and what they were taught in technical courses. The European Policies for Higher Education also emphasizes that technical knowledge should bear equal importance to design in architectural education [16,17].

For Schön, design requires both doing and thinking, and they complete each other. "Doing extends thinking in the tests, moves, and probes of experimental action, and reflection feeds on doing and its results. Each feeds the other, and each sets boundaries for the other" [18]. In this way, design, which is subjective, cyclical, reproducible, and repeatable, has adapted to second-order cybernetics and (radical) constructivist standpoints [1,19]. However, the current situation of teaching/learning in technical courses has not been inspired by radical constructivist principles in terms of active knowledge acquisition by the subject [20]. Existing problems faced by technical education courses are frequently researched such as in Carpenter [21]; Carpenter [6]; Dobson [22]; MacDonald and Mills [23]; Nicol and Pilling [7]; Ridgway [8]; Ridgway [24]; Ridgway [25]; Ridgway [26]; Spiridonidis and Voyatzaki [27]; Voyatzaki [9]; and Yunus [10]. However, a few studies have proposed a teaching/learning model for technical courses that is inspired by design education. The nature of the design studio model (the way design is taught and learned in architecture) is exceptional despite its drawbacks. The way design is taught in architecture is a problem-based method [28] that is inspired by constructivism [29] and considers a deep learning process [30]. Therefore, this research offers a framework, in line with problem-based learning (PBL), constructivist pedagogy, and the tradition of learning/teaching architectural design per se, for teaching/learning technical courses. The framework is intended to improve student engagement with these courses and encourage critical thinking and deep learning, while making technical learning as enjoyable as designing through a play-based method [31] that builds a better understanding of technical knowledge. The goal was to encourage students to adopt self-directed learning and connect the knowledge they acquired in technical courses to their design thinking.

The following research questions were addressed to achieve this goal:

- What kind of framework helps teachers in achieving a lifelong, student-centered, and design-like learning environment for technical courses in architectural education?
- Which framework assists students in acquiring the necessary technical knowledge for their design projects?

2. Literature Review

2.1. Constructivism

Duit [32] states that constructivism has become an indispensable ideology for teaching/learning science-based courses. Radical constructivism and second-order cybernetics are the focus of this study. Radical constructivism views learning as a conversation between learners and the world around them [1]. Consequently, learners view learning as an accommodation process that involves changes in their prior knowledge while communicating with the environment [33]. Realists misunderstand radical constructivism as it "is not about 'truth,' but about fit to experience" [34] (p. 49). This definition is common to design education; in this sense, radical constructivism is specifically practiced when finding 'what works' in design [1]. Technical knowledge may be perceived as a complex dynamic system, particularly after "the new techniques developed in the last century and the general mechanization of production facilities led to sub-theories concerned with the achievement of forms" [12]. Technical knowledge can be built on the existing foundation students have in design concerning the built environment. When they incorporate this knowledge, it helps them imagine their designs more effectively. Through this comparison, the application of radical constructivism is a viable alternative for the teaching/learning of technical courses because "education based on constructivist epistemology thus provides students with opportunities to engage in activities designed to promote their construction of understanding" [1].

Considering design and constructivism's characteristics, Glanville [35] linked design and radical constructivism by defining design as the root of the cognitive act. Understanding this conception requires a dialogical and circular mechanism [2]. This cyclical process of design solidifies its relationship with cybernetics [12]. Moreover, "developments in design and cybernetics share yet more parallels, including their adoption, and eventual rejection of, the technical-rationalist approach" [36].

In the research *Radical Constructivist Structural Design Education for Large Cohorts of Chinese Learners*, Herr [1] applied a method grounded in radical constructivism and second-order cybernetics to teach/learn in a technical course (Structure and Materials Course in Architecture). She tested the method using a wide range of teaching techniques and modes of learning such as drawing in class, teamwork, and model making. The homework assignment 'Posing problems' was one of the teaching strategies similar to PBL that she used, which originated in the medical sciences and was then adapted to architecture. Following Donald Schön's writings on 'the reflective practitioner', similar approaches to education were developed, acknowledged as constructivism's adapted strategies [37]. The present paper explores the similarities between design, PBL, and constructivist pedagogy. In addition to these approaches, it also considers how learning from issues in the built environment encourages students to contemplate different factors affecting design and technical expertise while presenting their recommended responses to the issues. Thus, technical knowledge can be learned based on what students have already constructed in designing the built environment (their existing knowledge). When they construct this knowledge, it helps them to better imagine their designs. Additionally, the built environment can be the source of innumerable problems that students can learn from, and this new knowledge will be reflected in their design projects through a PBL approach, instigating a cyclic process. This comparison applies radical constructivism as a feasible alternative for this study and a framework for delivering technical courses.

The evaluation is also crucial, and one of the assessment approaches in this paper was that students evaluated themselves by writing learning diaries during the semester.

2.2. Design and Design Studio

When architectural education is discussed, the design studio is at the forefront. Design studio "simulate[s] aspects of working in professional practice. This environment is conducive to a constructivist approach to education as students can direct their paths through their learning and be responded to individually by their tutor" [14] (p. 405). Young apprentices work and learn in these collaborative settings, which are the opposite of individualized school environments known from other subjects [38].

Students of architecture attain theoretical and practical knowledge in the design studio, which assists their creative thinking. Design has long been seen as a constructive activity. The design studio, used by schools of architecture, is considered as the central focus of a constructivist approach as it is a shared place for students to think and work on their designs [14]. Students and teacher(s) sustain discussions on design in this learning environment. For this reason, the design studio is known to be the core of design learning [39]. The design studio for Schön is "a virtual world that represents the real world of practice" [2]. In this place, like-minded people collaborate and provide constructive feedback, which helps advance design concepts and proposals. Together, students and teachers participate in critical debates on design concepts [18].

Constructivism is a wide-ranging term with numerous branches such as radical, cultural, feminist, social, critical, and trivial constructivism [40]. It is often considered an umbrella for numerous ideas and associated principles and has had a longstanding influence on education [41]. Constructivist theory is identified for its comprehensive implementation in diverse educational stages [42] and learning types such as project-based learning (PjBL) [43] and PBL.

The design studio model is essentially an example of a PBL approach. Design problems are given to students of architecture, and they seek solutions in a process. After completing a range of design projects, they are equipped with the knowledge necessary to design many objects or buildings.

Barrows and Tamblyn, the pioneers of PBL theory, proposed applying PBL at McMaster University in Hamilton, Ontario, Canada, in a medical school program in the 1960s. The primary purpose of applying the theory was to propose a solution to the existing curriculum requirement, which covered an enormous amount of material during the first three years of medical school. This material was difficult to absorb and often unconnected to what these students would practice when they graduated. Responding to this situation, a PBL curriculum was developed by Barrows and Tamblyn to support a curriculum relevant to the professional practice of physicians, which encouraged students to pursue relevant subjects, incorporated more self-directed learning and enhanced the value of teamwork [44]. PBL prioritizes a student-centered approach over the traditional teacher-centered classes, in which there is little room for PBL. On the other hand, a student-centered approach is well-suited to PBL, experiential learning, and discovery learning [45].

Game-based learning (GBL) is indeed an indispensable aspect of PBL and architectural design thinking since architectural design has a similarly fun and game-like nature [31]. Some psychologists, for example, Piaget, proposed learning via games. Games, or playing games, is as old as civilization [46]. "Play serves various functions. The most important one is learning … [it] supports fantasy, imagination, and creativity … [it] is always for fun" [31]. Psychologists believe it reinforces cognitive development [47] as well as symbolic thinking.

2.3. Learning from Nature and the Built Environment

Nature and the environment are always inspiring sources for learning, and this is especially resonant for architects. In architecture, the natural environment has outstanding value, and the built environment must act in harmony with the natural environment for architectural solutions to be effective. Consequently, an important goal in education is to acquire technological expertise. Architecture graduates should be aware of social values and environmental problems [48]. A lack of emphasis on how daily environments perform in architectural education is akin to medical science education without understanding the functions of the human body. Environmental awareness "legitimize[s] our profession" [49]. Norberg-Schulz applied Piaget's ideas to the architectural experience. He implies that studying climate directly may be less beneficial for architects; instead, they may need to consider only the elements that influence the buildings' physical characteristics [50]. In this sense, considering the built environment through a constructivist lens promotes learning both 'wicked problems' of design and 'tame problems'. Like social problems, design problems are never solved just once, but are solved again and again. Other science- and engineering-oriented problems are definable, with definite and singular solutions. These are called 'tame' problems [51].

The spatial experience studies of Piaget have supported the Norwegian artist, architectural theorist, and author Norberg-Schulz in his writings on the built environment and its various facets, which are emphasized in this research. Indeed, the theory of Norberg-Schulz comes from a previous period: the mid-20th century. This marks a convergence of the concepts that this research unites by drawing on design, PBL, and constructivist pedagogy. According to Norberg-Schulz, place understanding is a human experience facilitated by automated experience and personal readings of it. Through place understanding, the built environment helps individuals reflect and reinterpret the meaning of the buildings they encounter [52]. Piaget's child psychology experiments inspired Norberg-Schulz to extend this perspective to the concept of 'architectural totality', established by the built environment in its semiotic scope [53].

Norberg-Schulz defined the current concept of the built environment as created and controlled by architecture. He divided the so-called built environment, constructed by architects, into three types: physical environment, social environment, and symbolic environment.

These environments can be the primary reference points for architecture students to gain technical knowledge and incorporate it into their projects, using a structured approach that exposes students to problems related to their field of expertise. This method of addressing architecture in a thorough and inclusive way is a promising solution to the current problems in architectural education.

Learning from the Physical Milieu

PBL's instructional principles resulted from the constructivist methods that underpin PBL [29,37,54]. Architects design the built environment, so students must understand the problems they will encounter in this work. The key change aimed for in this research was grounded in PBL and connected to the built environment concept defined by Norberg-Schulz. The research intends to establish a part of the course curriculum around this concept. Instructors can teach based on ill-defined issues sourced from the built environment. The instructor's role in this situation can be as a facilitator who recommends an issue without providing a definite answer. The instructor may urge learners to reflect and search for specific knowledge to become self-directed instead of clarifying it. This is possible if instructors give students enough freedom to think of approaching ill-defined problems with the necessary motivation for the subject. Motivation is a key factor in student engagement with their education, and "the problem of motivation, the diagnosis, and treatment of learning and behavior disorders seem to receive the greatest attention" [37]. For situations where students lose their way, the instructor remains a mentor. The instructor can also guide the students by raising 'when, and how' questions. This concept is based on Vygotsky's [55] concept of scaffolding, which reinforces instructor and student interactions throughout the learning exchange relationship

Bashir, Ahmad, and Hamid [49] stated that '[t]he built environment and the landscape can be a powerful tool of learning'. These are mediums worth re-examining. Every issue from the natural environment can be a problem for the physical objects we make. In the case of rain, it may cause innumerable problems for a building, and there are countless factors and solutions to consider.

As PBL enhances student critical thinking [56], it is a crucial precursor to challenge-based learning (CBL) activities [57]. With this method, which is part of a PBL process, students may gain useful information from solving the issue of rain on a building's roof, for instance. They may learn about the materials' properties and other technical knowledge without memorization by proposing a solution for a leaking roof. Additionally, they acquire expertise and knowledge when solving problems. Rather than showing students the answers directly, they learn independently and may be able to tackle other challenges in various environments. Similarly, students learn to design from the completion of several design studio assignments, and this enables them to solve future design issues in a range of buildings.

In architectural education, technical aspects, which focus on how to actualize design concepts, have a similar essence to play. Reno [58] states that construction education can be an expression of an inherent interest in arranging components in a rational sequence. The comparison is based on a child interacting with some items or puzzles for hours to comprehend the world of objects. By comparing this to studying building technologies in architectural education, the author criticizes the fact that the mere theoretical description of this topic, properties of the materials, and construction assemblies may be useless for student learning.

GBL can be included in the framework using many mechanisms, one of which is the process of gamification. For this reason, Vygotsky's scaffolding is successful. Learners require various types of assistance, which can be adapted to the learning process and successful for the curriculum. The instructor must know when to increase the amount of help offered and gradually taper off the level of assistance.

This study's framework generally depended on the PBL method and game-based theory concerning the students' learning approaches. It conforms to typical constructivist pedagogy. Figure 1 represents a gradual procedure focused on PBL for constructing technical knowledge from the built environment. The instructor's position is vital in the proposed framework; they should be conscious of coordinating and contributing to the process. Changing the students' role in a PBL environment causes changes in the instructors' roles and responsibilities. In PBL, the instructor should occupy several positions as a facilitator, role model, assessor, information provider, resource developer, and planner [59].

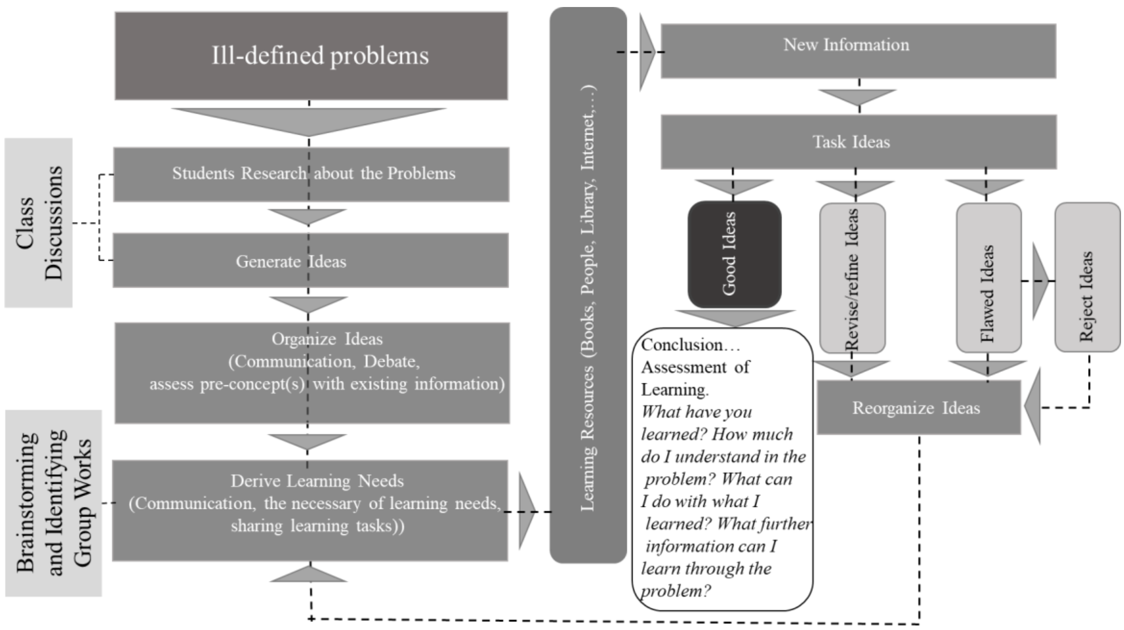

Figure 1. A problem-based learning (PBL) concept process was adapted from Wang et al. [60].

There will be more than one option for gamifying or relating the learning materials through GBL and its inclusion in the framework. Numerous technological tools can be implemented. Kahoot, for example, which is a GBL platform and a free of charge website, can be used in this context. This learner-interaction mechanism engages learners in pre-made, unplanned, or game-like quizzes, topics, and surveys [61]. Although students are generally enthusiastic about GBL, instructors may be confused about their role. This may be caused by both the uncertain policy of learning through games and the instructors' pedagogical degrees [62]. GBL places new "demands upon teachers' pedagogical, professional and managerial skills" [63]. Instructors can organize the material into special patterns incorporating the above GBL basics. Students will engage in play that uses the course material to tackle the proposed question and earn points. Kahoot can be accessed via computers, tablets, and cell phones without opening an account, which means that students can play/study anywhere and anytime.

There cannot be a clear, correct response to the proposed framework's problems regarding the environment. The emphasis is on a broader definition of design as constructivists understand it.

Nonetheless, as Buchanan wrote, design is a 'wicked problem' with two stages: problem formulation and problem solving. The last one often causes other problem formulations in a circular process [64]. The whole cycle will unfold in various ways to search for innovative solutions; each student group can have various principles and suggestions for potential problems.

3. Methodology

A qualitative research method and case study were applied in this study. The former was focused on literature-based theoretical data and research documents. For this reason, the research concentrates on PBL, constructivism as a theory of learning and design, and delineates the parallels between them. Qualitative content analysis is an appropriate way to evaluate the data as this approach offers an interpretation of the topic under review and collects information about it. This technique of content analysis can be used to compress the content of many texts [65].

A deductive content analysis approach was also applied in this study. This method is appropriate when conceptualizing a theory-based approach. The interpretations of these terms are defined by a pre-existing theory, in this case, constructivism, and data flows around the ideology and the literature concerned [66]. The deductive method was applied in this research to create the relationship between constructivism and design, and then the related literature and learning theories were considered that underpin this relationship, namely PBL. Content analysis was applied to handle the huge amount of text data obtained from journal articles, books, manuals, instructions, and online media. The qualitative data analysis program Atlas.ti was used to simplify the process. For example, after choosing articles by titles and abstracts, these were entered into Atlas.ti to determine the extent to which they were related to the subject, and they were then organized according to thematic codes to determine the relationships. The resulting themes are shown in Table 1 below:

Table 1. Review of content for selected studies that identify the key themes.

Themes	Selected References	Main Outcome Points
Nature of Design & Architectural design	Alexander [67]; Dutton [68]; Farivarsadri and Alsaç [31]; Lawson [69]; Paker Kahvecioğlu [70]; Pitt [71]; Razzouk and Shute [72], Simon [73]; Schön [2]; Schön [74]; Doyle and Senske [75]; Paker Kahvecioğlu [70]; Lawson [76]; Samsuddin [77]	• Play nature; • Design & technical knowledge integration; • Art and science; • Artistic and technical imagination; • Represents practice; • Social learning; • Solving design problems; • Deep learning occurs.
Semiotics and learning	Bandura and Walters [78]; Conway and Roenisch [79]; Cunningham [80]; Lawson [81]; Lemke [82]; Shareef and Sani [83]; Wastiels and Wouters [84]; Wastiels et al. [85]	• Significance of building materials in semiotics; • Unforgettable learning; • Learning is process-based in semiotics; • Semiotics provides a powerful means to understand the environment;

Table 1. *Cont.*

Themes	Selected References	Main Outcome Points
PBL	Barrows [44]; Barrows and Tamblyn [86]; Boud and Feletti [87]; Crotty [88]; Ertmer and Glazewski [89]; McKay and Kember [90]; Pagander and Read [91]	• Promotes learning outcome, lifelong learning, effective learning; • Involving students in solving a problem; • Autonomous, collaborative and cooperative learning; • Unforgettable learning; • Student-centered, small-group works.
Play, GBL& Gamification	Becker [92]; Dell'Aquila et al. [93]; Deterding et al. [94]; Khoo and Gentile [95]; Koster [96]; Lasley [97]; Palmer and Petroski [98]; Savignac [99]; Zichermann and Linder [100]; Van Grove [101]	• Deep learning unconsciously or willingly; • Enhances engagement, it is fun; • Gamification is a problem-solving activity; • GBL is significant in learning and reinforces confidence; • Play/game activates motivation in learning; • Game/play accelerates PBL; • Play, PBL, and semiotics are interconnected.

Based on Table 1, the relations between the key themes were defined, and it was found that the parallels between them could contribute to the offered framework. These relationships are shown in Figure 2.

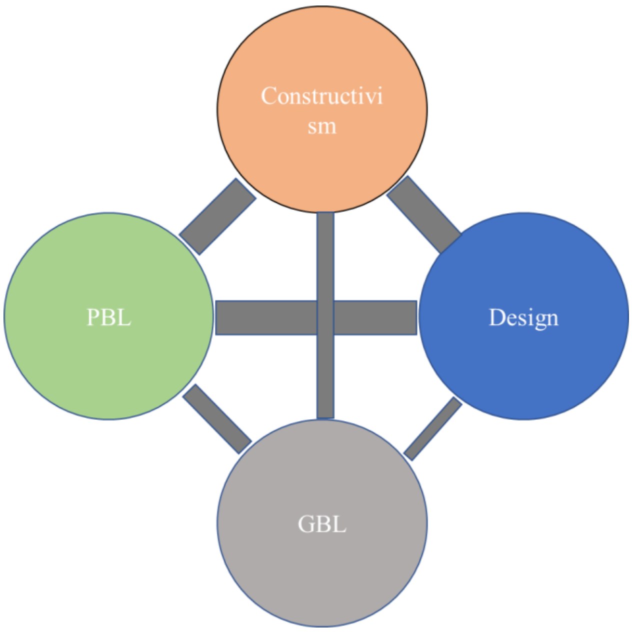

Figure 2. The relation between the main themes.

In the framework, learning is self-directed, the instructor's role remains as a facilitator, and the learning environment becomes a cooperative environment where the students work in small groups and share knowledge with each other. Table 2 shows the suggested framework's organization to be applied in the teaching/learning of technical courses by presenting the instructor's role, learning types, the learning environment, and the expected consequence.

Table 2. The organization of the proposed framework.

	Instructor's Role	Learning Type	Milieu	Consequence
The Framework	• Instructor assists as a facilitator	• Self-directed learning	• Learning from problems • Cooperation instead of competition • Active knowledge attainment • Small group (3–5) students	• Ubiquitous PBL • Concerned with knowledge incorporation and professional practice

Based on the theories above-mentioned and considering PBL strategies, a student-centered learning framework was prepared and is presented in Figure 3. The offered framework was tested in a case study that is discussed below. Several learning strategies have been applied, and the results are presented.

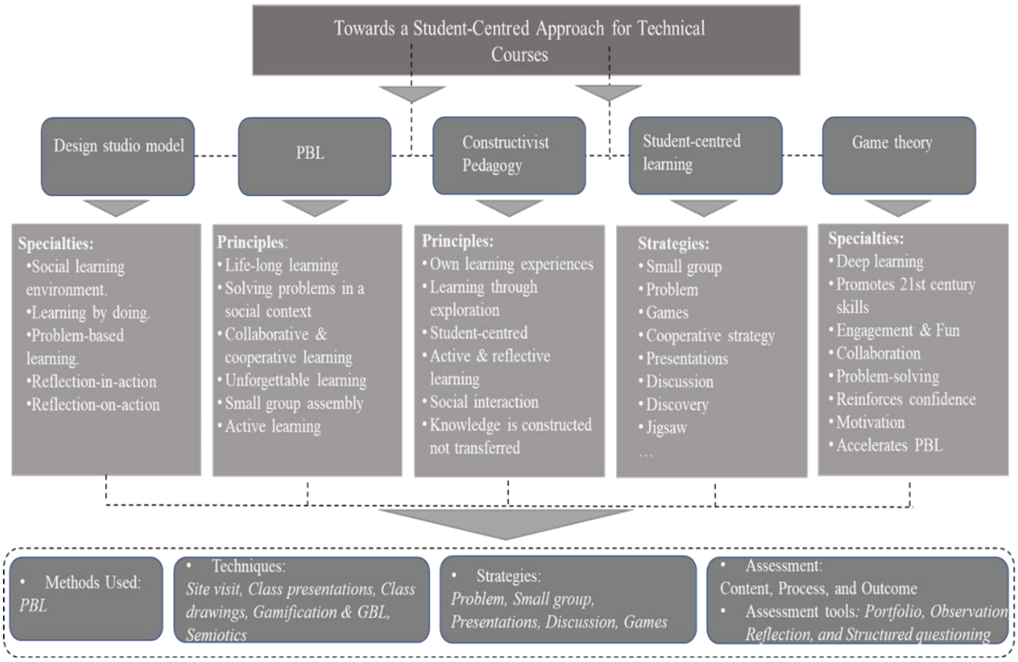

Figure 3. The diagram of a student-centered framework for teaching/learning technical courses by the authors.

4. Experimental Application of the Framework

In Spring 2019/2020, the first author had the opportunity to take a construction course titled Building Construction Technology I. This is a technical module with a class size of 21 students that is required for first-year students in their second semester of the BSc program at Tishk International University in Iraqi Kurdistan. The Architectural Engineering Department opened in 2014, and other educators have offered this course in previous years. These teachers made individual efforts to offer the course and did not adhere to a particular pedagogy like the framework provided in this research.

Students attended an initial lecture that provided an overview of the course and outlined their responsibilities in the class. The lecture introduced upcoming tasks, and students were asked their opinions on the inclusion and exclusion of certain subjects. Based on an online multiple intelligence test, the students were split into small groups. The test reports indicated the students' personality types and learning styles. While the students enjoyed this activity, some objected to the division of groups according to test results because they wanted to be with their friends with whom they had previously worked. Nevertheless, they were convinced to remain in their assigned groups because choosing who to work with will not always be possible in their future careers. Unlike in previous semesters, the course did not have a final exam, and marks were instead given based on the tasks outlined below.

4.1. Student Class Presentations

For class presentations, the instructor provided topics on various construction subjects. Each group worked on a specific topic within a predetermined timeline for their presentation. Students played the instructor's role in the presentations. This helped the instructors determine which teaching style was most favored by the students because the students used the method that they preferred. Throughout the semester, there were numerous student presentation sessions, which allowed us to cover more material than in a lecture-based class. The students were enthusiastic and presented as much useful information as possible in the allotted twenty-minute time limit for each group. The benefit of these sessions was that students, depending on their prior knowledge, participated in dialogues and discussions, and together they constructed new knowledge and learned from one another. In fact, "the implicit authority of the tutor is, even in a constructivist approach or a one-to-one conversation, to some extent unavoidable" [14]. However, an attempt was made to reduce the dominance of the instructor's authority, allowing students to cover alternative subjects in the class based on their prior knowledge or current research. This facilitated many constructive discussions about the course content and teaching methods. This was the atmosphere that von Glasersfeld [102] had in mind when reminding educators to promote an encouraging atmosphere for discussions between students and instructors as well as between students and their classmates, and foster open-minded and inquiring attitudes. Through observations and the students' entries in their learning diaries, we found that students favored these class presentations and self-directed learning as they were responsible for the class management.

4.2. Classwork Drawing Activities

Class drawings are not uncommon in construction courses, and we felt it essential to uphold the practice. In the topics discussed in the student presentations, they were expected to include crucial information that had to be drawn in class. Students practiced the practical application of this skill by drawing construction details in the class [103] and covered all subjects from the building foundation to the roof over the semester. This task complemented another activity: site visits. This was beneficial because students sometimes had difficulty imagining some of the details during drawing sessions in class (Figure 4), and site visits gave them the chance to test them visually as shown in Figure 5. The instructor collected the class drawings and returned them to students at the end of the semester, so that they could see their improvement.

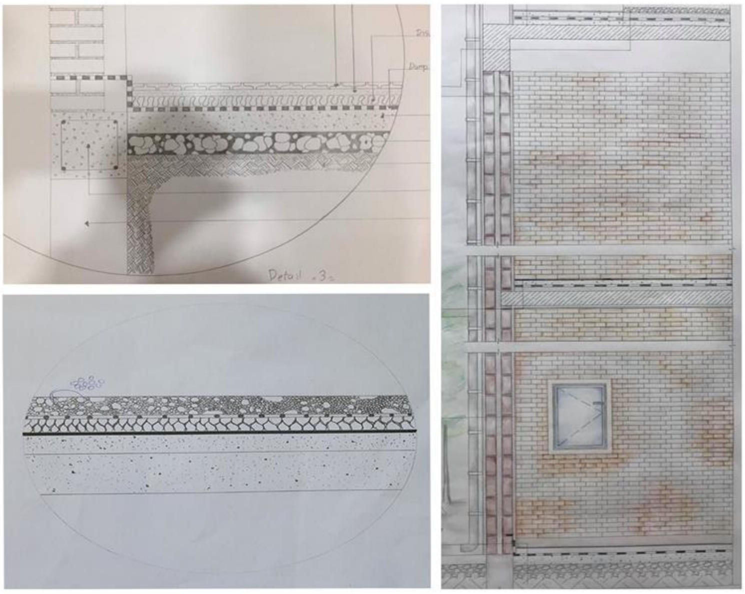

Figure 4. Examples of student class work.

Figure 5. Construction site visits to check the technical details.

4.3. Site Visits

During the semester, site visits were a vital activity and were designed to test the information learned from in-class presentations and drawings. The projects observed were deliberately chosen according to the stages of construction that had been studied thus far. At the beginning of the course, for example, students saw a project at the base level. They were given a chance to explore construction materials and discuss what they saw at the site with the building's architects and engineers. By having cyclical feedback in this way, the activity followed the principles of cybernetics. Students were expected to write a paper on what they observed on each site visit.

4.4. Game-Based Learning

To apply GBL and playing games, the free online platform Kahoot was chosen. It is accessible on laptops, mobile phones, and tablets, and its rich features allow effective content delivery. These features include photographs, uploaded movies, and questions to be answered. Links to exercises can be sent to the Google class or the social media page for the course. In Kahoot, students collected points based on their answers to the assignments and the time taken to submit the answer. The program then identified the top five winners, and the outcomes were shared with the students to increase motivation. Students received these activities with enthusiasm.

4.5. Problem-Based Learning

Architects face various issues that arise from the natural environment when designing buildings, especially problems from nature. In order to prepare students for these situations, they were asked to consider the effect of rain on the built environment. The students were tasked with finding a solution for the effect of rain on buildings, without knowing which part of the buildings might be affected or being shown an example method or expected solutions. We believed that by working on this ill-defined problem, students could study other topics related to the potential consequences of rain on various building parts to identify the risks and then create solutions. Students may acquire knowledge of materials, structures, construction techniques, and other factors in order to develop a plan. Such tasks were assigned to small groups (3–4 students), so that they could learn to share prior knowledge and methods of logical thinking with each other. Facilitators tried to improve the students' problem-solving and reasoning skills and help them become self-directed learners while handling the small groups [104]. Instructors must spend a significant effort organizing the process and guiding students. They need both an awareness of epistemology and professional knowledge, and so not all instructors may be qualified to implement this method.

4.6. Self-Reflecting Reports and Learning Diaries

Learning diaries were required from the students as a self-assessment tool from the beginning to the end of the semester. The learning diary reports were substantial, and the instructor was able to determine which topics the students had learned most effectively and which parts needed revision and improvement. Roughly 86% (18 out of 21) of the reports showed that the sessions in which the students were least engaged were those delivered by the instructor. One of the students wrote: '*I can be easily distracted by instructor's class lectures as there are no activities but sitting and listening*'. At the same time, most of them described their group presentations as beneficial and memorable. One of the students in the report wrote that: *'When our group was preparing a class presentation, we were spending a huge effort on collecting relevant information because we had to prepare for discussions in the class'*. Another student mentioned how Kahoot assignments were interesting and helpful in seeking new knowledge in addition to the competition to be one of the top winners when names were shown after each session. Concerning the activity sequences, two students proposed having site visits before the class drawings and stated that they could better perceive the details to draw after the visit. Overall, students were interested in a learner-centered approach. For each session, they also recorded the new knowledge they encountered and what they had already known. At the end of one report, the student wrote: *'I hope we have other classes delivered as such, no matter how much time I spent, but I feel the difference between myself before and after this course'*. Most students indicated that the knowledge they gained was indispensable, and that they applied it in their design projects even if they were not required by their instructors to include construction details in their final assignments as shown in Figure 6.

Figure 6. Some examples of the final assignments where technical subjects are highlighted.

In applying the framework in one of the technical courses in architectural education (Construction Technology I), it is apparent that it can be applied to other technical courses such as structural courses, building physics, and building services. These courses have the same technical nature, and almost all are taught in a lecture-based manner. However, they have their own specific content, and each can serve the design process differently. The framework can change how these courses are taught and increase student interest regarding the course content.

Based on both the learning diary reports and observations of the students' final assignments and design projects, the offered framework effectively engaged students in the technical courses and encouraged them to apply the knowledge provided in these courses. However, in light of the small sample size and its limit to one course, the results of this study may fall short of being generalized to a broader population. Future studies that cover a longer time period and apply more techniques may be undertaken for further research.

5. Conclusions

This study highlights the parallels between design, PBL, and constructivist pedagogy to prepare a framework for delivering technical courses. The study seeks to determine the interconnections between design, constructivism, and technical knowledge. PBL is used as the main concept, and other theories that complement design, constructivism, and PBL such as game theory also contribute. To this end, the concept of the built environment by Norberg-Schulz was considered regarding ill-defined problems in physical milieus. The Norberg-Schulz concept was influenced by Piaget's writings on spatial experience, and according to this concept, the built environment is divided into physical, social, and symbolic environments. PBL can be applied explicitly to the physical environment, and technical knowledge can be learned based on the framework.

Building Construction Technology I, one of the technical courses in architecture study and a compulsory course for the first semester of second year architecture students, was considered here. Based on the framework, several teaching strategies such as the students' class presentations, classwork drawings, site visits, and games were applied to help the teacher create an enjoyable and interactive learning environment to deliver the course's technical knowledge. However, the method of learning from problems that exist in the built environment was not applied; we thought it more appropriate for an advanced step in the next semester (Building Construction Technology II). As a self-assessment tool, students were required to keep learning diaries to record what they learned during the semester. Having implemented the framework through the case study, the results show that the offered framework has the potential to change the teaching/learning of technical courses, which are often considered the least engaging subjects, despite their significance in architectural education. We also recognized that students were responsive to the framework prepared in this study as self-directed learners. They reported that in addition to the learning outcomes, they enjoyed the semester and were able to apply what they learned in their design projects. The framework prepared as part of this research can be adapted to all technical courses and can be customized according to the course content.

In future research, the results of the unapplied parts of the framework can be discussed including learning from social and symbolic milieus, and the impact of the framework on the students' design projects can be addressed. Additionally, the framework can be scrutinized based on student feedback and learning outcomes.

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