Establishing the Theoretical Constructs for e-Learning in Applied Architecture Programs

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***Abstract*—Addressing the challenge of bridging the theory-practice gap in academic programs, particularly in applied disciplines, remains a significant concern for the educational system, even in a theoretical course. This issue is particularly apparent in architectural programs where instructors strive to enhance their course plans by incorporating Applied Based Learning (ABL) tasks that connect theoretical and practical knowledge while emphasizing essential skills. This study assesses how well this strategy works in theoretical classes, even for distance learning. Thus, in the fall semester of 2022, a performance assessment module had been added to the online theoretical course "History of Architecture II," intended for second-year students. The study compared the learning outcomes of 41 students with relevant objectives through quantitative analysis using the Rasch model and WINSTEPS software as a tool. The study's findings show that their performance generally improves when students participate in group projects. However, the research also shows that when students participated in applied tasks, their learning ability indicators significantly enhanced, which is a novel approach to teaching architecture. This underscores the need to integrate more educational tasks with practical implications into theoretical courses aligned with architecture as an applied science. The findings can serve as a roadmap to enhance the efficacy of architectural online education.**

***Keywords*—learning competencies, learning outcomes, e-Learning, architecture program, applied-based learning**

I. Introduction

Because of the practical nature of architecture, integrating it into universities has been challenging [1, 2]. As a result, many educational institutions have developed curricula that aim to develop practical skills while logically incorporating the fundamental knowledge and abilities that graduates should have to support their day-to-day performance. However, due to pandemics, acquiring these competencies has recently faced unprecedented challenges, particularly the requirement for distance learning (i.e., e-Learning). Despite numerous efforts to implement Competency-Based Learning (CBL) and assessment in face-to-face education, the design of CBL and assessment in an electronic learning environment still needs to be improved. When Jordan's Ministry of Higher Education classified architecture as an "applied science," the situation became more challenging. Study plans should be created keeping the primary criteria in mind, with a practice component for most courses (including some theoretical courses) to guarantee that the various learning outcomes are considered.

This study investigates the effectiveness of acquiring applied-based architectural competencies in theoretical courses, even for distance learning. This study examines a theoretical course, 'History and Theory of Architecture II'(HTAII,) that the Hashemite University's Department of Architecture developed over fifteen years and was later taught online in the fall semester of 2022 after the COVID-19 pandemic period. The study demonstrates the inclusion of applied-based architectural competencies in e-learning, the outcomes of incorporating theoretical and practical structures and the development of a performance assessment module. The presented experience highlights potential challenges when implementing applied-based architectural competencies in e-learning. As online learning becomes more popular among architecture students, the results should guide the development of applied-based theoretical courses in architecture. It should also encourage using the performance assessment modules in theoretical distance learning courses because academics typically regard it as difficult, time-consuming, and requiring collaboration and thorough coordination. This is not to suggest standardization of architecture pedagogy. Due to the diversification and emergence of various specializations in architecture worldwide, there is no need to develop universal educational principles applicable to all scientific and professional settings. Instead, to improve the efficiency of the educational process and the quality of academic programs, a continuous evaluation of individual programs' status and introduction of flexible approaches and methodologies to bridge the gap between architectural education and practice will be required [3].

II. Literature Review

A. Applied-Based Competences: The Learning and Assessment Processes

Applied-Based Learning (ABL) is defined as "a process in which students apply knowledge and skills learned in traditional classroom settings to hands-on and/or real-world settings, creative projects, or independent or directed research, and then apply what they have learned from the applied experience to academic learning" [4]. Therefore, applied studies create "practical structures" in addition to "knowledge structures." The benefits of adding the practical component include students becoming more exposed to, aware of, and understanding of customs and cultures other than their own; students developing as knowledge producers; students acquiring and developing new skills; students becoming more interested and excited about learning; and faculty research and teaching being supported. [5].

Applied learning focuses on student-centered learning, integrating Theoretical Learning (TL) and Practical Learning (PL), and transitioning students to more adult and independent learning [6]. However, since the 1990s, when

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more emphasis was placed on the connections between education, training, and the "real world," a broader definition of applied learning has emerged. This broader definition promotes a contextualization approach to education that gives students agency and motivation while helping them acquire the essential knowledge and skills required for work, higher education, and community engagement [7]. Hence, Practical Learning is an interactive process of experiential, project-based, and other forms of active learning. It is a form of Task-Based Learning (TBL) that employs a constructivist approach and holds that students construct meaning through hands-on tasks, frequently involving manipulatives and opportunities for experimentation. Along with the PL comes experiential learning. According to Stiggins [8], Experiential Learning Theory (ELT) uses experience to set itself apart from cognitive learning theory (Fig. 1), emphasizing cognition and behavioral learning theory. The ability to apply knowledge quickly and what is learned to real-world situations is just one of the many advantages experiential learning offers teachers and students. Other advantages include the opportunity to practice teamwork, a common component of experiential learning, increasing student motivation for learning, and offering opportunities for introspection as students take the time to consider what they are going through.

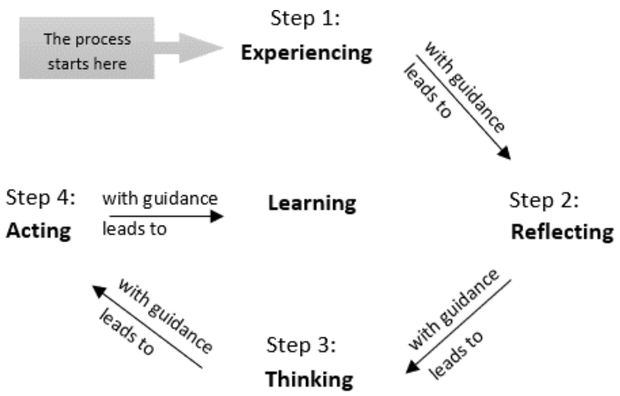

Fig. 1. Model of experiential learning theory [8].

Project-Based Learning (PBL) is about organizing a curriculum around projects. These projects highlight the inquiry-based learning process, which allows learners to access content, share ideas, and revisit their thinking. Project-based learning and projects are different; project-based learning is more concerned with the process, while projects focus more on the final product. Students are frequently required to gather resources, organize work, manage long-term tasks, collaborate, design, revise, and share their ideas and experiences with authentic audiences and supportive peer groups in Project-Based Learning. Because this can come in various shapes and sizes, there is no set 'number' of PBL types.

ABL can be linked to other models, such as competency-based assessment. A student's knowledge, skills, and behavior are considered competent after completing a course or program. Competencies are the practical skills and knowledge that allow students to succeed in various educational, professional, and social settings. Students can demonstrate the knowledge, skills, attitudes, values, and behavior gained by achieving the identified competencies [9]. Outcomes are used to gauge competencies. The result is what a student can do precisely and measurably. More than one measurable outcome can be defined for a given competency [10]. Nevertheless, competency-based learning could be objective or subjective because it is based on the premise that knowledge can be codified, repeated, and tested. Hence, a single task cannot identify specific competence. Also, it is necessary to incorporate yet-to-be-acquired knowledge and skills into learning tasks so that students can see a link to real-world cases [11].

The primary goal of competency-based assessments is to assess a student's competence or actual achievements. It entails defining learning objectives that include skills learners need to learn but are not yet proficient. The explicit specification of outcomes stated in advance and a clear understanding of what is being assessed and what should be accomplished provide a solid foundation for making reasonably objective judgments of accomplishments [2]. Thus, the foundation for this paper's efficiency evaluation is the integration of learning outcomes as knowledge outcomes with skills (both hard and soft skills) that support problem-solving for various future models. It defines competence as the abilities and knowledge required to complete a task. As a result, a competent person can achieve a specific or necessary task [12].

The architectural profession requires a lifetime education with theoretical and practical components. Due to their interdisciplinary nature and range of methodological approaches, theoretical aspects of education can serve as creative constructs by introducing criteria, enhancing knowledge, and establishing order. Simultaneously, cutting-edge task-based educational strategies and methodologies (like Project Based Learning) emphasize helping students develop the skills and competencies necessary to analyze and evaluate problems critically and perceive and comprehend the context in which their projects are being done. Architectural theory, history, and all relevant experience and knowledge from previous historical epochs form an essential foundation for building knowledge structures that help students understand contemporary architectural discourse [13]. Hence, in architectural pedagogy, rather than giving lectures about architecture theories and famous architects' work, a history or theory of architecture class might include tasks through which students practice theory exercises and deal with problems through critical thinking [14].

The architectural theory course is typically presented as lectures. In the case of an ABL, teaching the (HTAII) course is suggested through an integrated approach that combines traditional lectures and experiential-based tasks. In addition to the body of information that could be taught in a typical lecture style, experiential learning could be developed by seeing a phenomenon interacting with it and analyzing its dynamics [15]. Through a series of in-class and off-campus exercises, it is suggested that experiences can give students control over their learning while advancing their understanding of the body of knowledge presented in conventional lectures. Sitting in class, listening to the teachers, and learning pre-packaged and ready-made interpretations only gets students so far. Scholars advise students to write about, discuss, and connect their learning to prior knowledge instead [16]. To foster active and experiential inquiry-based learning, communication, and collaborative learning, the architecture theory course was developed by combining some in-class and extracurricular activities.

B. Applied-Based Competences: The Distant Learning Method

An active classroom learning environment can help better integrate theory and practice and hence achieve the competencies of an applied-based course. When we think of active learning, we envision instructional tasks that require students to perform duties while also thinking about them [17]. The dynamic learning model distinguishes itself from other learning models by emphasizing experience rather than merely listening as a means of knowledge acquisition [18–20]. Experience is the main factor in all learning, according to Boud and Miller [21], and it cannot be bypassed for learning to occur [17]. Instead of being from irrational thought or hasty action, fundamental knowledge comes from integrating thinking and doing and making the mind reflect on the act [17]. This should be held in situations involving online learning.

Perhaps even more than in-person students, online learners require many opportunities to engage with others in distance learning to express themselves, develop tolerance for others, and acknowledge their varied identities. This will help compensate for any physical void left by their absence [22]. Interaction and social presence can be promoted through course design that supports active communication between students and instructors through synchronous online classes and discussion forums [23]. Current theories and frameworks for online instruction have also provided direction as the online learning environment has developed. Teachers need a workable model for effective online learning environments incorporating the newest and best ideas [24]. Therefore, online instruction in architecture should include various tasks to help students meet the learning objectives of the lesson and their specific needs. For students to be creative and go beyond what was taught in the online class, opportunities should be given to apply what they have learned to real-world applications. Along with online learning, social media advancements give students new synchronous communication opportunities that will help them form more cohesive learning groups and advance meaningful education. To give online students more meaningful experiences when participating in formal online tasks, Davies [25] proposed that phatic aspects of online learning be developed using MIATs—adult learning theories and how they relate to online education [26].

The role of technology in education and learning methodologies is expanding. Recent developments in digital technology have made it easier to apply machine learning, deep learning, and Artificial Intelligence (AI) techniques to predictive modeling and toxicity classification. In addition to helping with practical online resource searching in job applications, Artificial Intelligence (AI) and Machine Learning (ML) techniques develop algorithms for pattern recognition and continuous learning from data [27]. The authors of a recent study titled "Machine Learning Based Recommendation System for Web-Search Learning" concentrate on creating a model to examine learners' search habits and areas of interest when gathering information online. The model maps text and video content using sensors to capture eye movements and navigation. The experiment results show learners accessed images more often than text or videos, with Google and YouTube being their favorite channels. Students watch videos for longer on average. Examining quiz attempts after internet searches revealed increased participant engagement, highlighting the significance of comprehending students' online behavior and preferences.

According to Bhaskaran *et al.* [28], an intelligent recommender system was created for real-time e-learning applications to optimize performance by customizing recommendations to each learner's unique learning style. With the help of a hybrid method based on split and conquer strategy-based clustering, the novel approach enabled the recommender to automatically adjust to learners' needs, interests, and knowledge levels.

After extracting valuable patterns from learners using a cluster-based linear pattern mining algorithm, the system made intelligent recommendations based on ratings of frequently occurring sequences. Tests carried out on various learner populations and datasets showed that the suggested model greatly enhanced recommendation performance, leading to higher completion rates for recommended lessons when compared to learners who did not have recommender cluster categorization. The significance of creating a learning model to improve the role of students and learning tasks in online learning was highlighted by this study and others included in the literature review.

III. Materials and Methods

A. Applied-Based Competences for e-Learning: A Perspective from Jordan

The second-year history and theory of architecture courses focus on two essential skills. First, students should be aware of the parallel and divergent histories of architecture as well as the cultural norms of various indigenous, vernacular, local, and regional settings in terms of their political, economic, social, ecological, and technological components in the first unit, which focuses on the history and global culture. Also, students must comprehend the various needs, values, behavioral norms, physical capabilities, and social and spatial patterns that set different cultures and people apart in the second unit, which focuses on cultural diversity and social equity. The course plan and student assessment structures were competency-based structures.

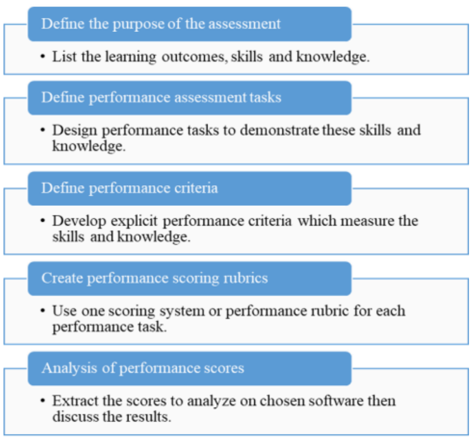

Fig. 2. The methodology and performance assessment guidelines.

According to Stiggins, the assessment design should come first in the educational design process [8]. To create performance evaluations, four general principles are used to structure students' performance assessment guidelines (Fig. 2). This initial step produces a hierarchically ordered skill decomposition of the pertinent knowledge and skills [11].

B. Learning (Course) Structure

Using a variety of theoretical, social, political, economic, cultural, and environmental contexts as a knowledge base, architectural graduates must be able to construct abstract relationships and comprehend the impact of ideas on real-life works of architecture. Also, students should possess various skills, including writing, research, speaking, drawing, modeling, and thinking creatively about architecture. Hence, the course's learning outcomes involved monitoring the student's progress in their understanding of the terminology of architectural history, philosophical theories of architecture, and local and regional architecture and their effects on building design (coded as LO1 and LO3) and, secondly, their understanding of the history of engineering, technical, and structural sciences, and transmission of new typologies, construction materials and techniques, and aesthetic values, and their effects on the spatial, social, and technical aspects of local and regional architecture (coded as LO2 and LO4). On the other hand, they understand various periods' architectural styles and forms, use this knowledge in the design studio, and differentiate between the original architectural types and their development through the ages (coded as LO5 and LO6).

The theoretical foundations of the history of architecture were laid in the first section of the course, which began with early Christian architecture and ended with Rococo architecture. This section included online instruction with interactive lectures and lasted eight weeks (half of the 16-week first semester of 2022). It puts into practice a "transfer learning" strategy that prioritizes the teacher and how students are taught. To help the students attempt to understand, explain, analyze, and synthesize the various historical theories of architecture during the covered periods, the course's objective was to help them build a solid theoretical foundation and a list of vocabulary words. Consequently, this phase gave the students the knowledge and skills to develop a hierarchically ordered skill decomposition [11].

The course's second segment used a task-based learning approach. For an additional eight weeks, students collaborated to experience, reflect, consider, and act on predetermined theoretical topics (Fig. 1). This learning model starts with more straightforward tasks and works to more difficult ones. Students need the information to complete their assignments successfully and gain the most learning from them. These additional details relate to students' knowledge and the information required to complete the learning tasks. More importantly, they gave the students 'supportive information,' allowing them to concentrate on the unique qualities of more complex skills [11]. The student used a notebook portfolio to present this 'supportive information,' which served as an open forum for the student to show off their abilities and give a rundown of the knowledge and skills he had acquired by the end of the course.

As a result, a project-based learning strategy was used to give students access to information, a forum for discussion, and a chance to review their prior learning. First, students were divided into groups to examine the architectural styles within the early Christian-Rococo spectrum; each group comprised three to four students. They created PowerPoint presentations at this point and discussed them with their colleagues to experience the designated architectural style together through actual cases. The students were then allowed to reflect on and critically evaluate the use of these old styles in the recent past, both inside and outside Jordan. Recent cases that revived the classical styles were then taken into consideration. The creation of physical models and the preparation of a poster were part of this phase. Finally, the students collaborated in groups to submit projects based on procedural information, giving them practical knowledge.

The final part of the course involved conducting a final exam at the end of the semester. A final exam is a reliable instrument that can be used to evaluate how well the student performed on the knowledge-practice skills they encountered during the semester. The circumstances under which the students are assessed at this point are standard. The project-based experiential model and the knowledge model established at the beginning of the semester received 40% of the course grade, with the remaining 40% going to the final exam. A midterm exam given after the eighth week and worth 20% of the course grade determines another course grade.

C. Assessment Structure

A rubric is a scoring guide with standards for assessing student work directly related to one or more of the program's learning outcomes and a rating scale with various performance levels. They can evaluate how well students perform on exams and other tasks. Analyzing overall scores and sub-metrics created to measure more specific performance elements is straightforward when using rubrics with checklists, rating scales, and analytical scales. For each criterion, analytical scales specify levels of performance. Analytical scale scoring is frequently more accurate and enables the identification of growth areas. The analytical scales, however, take more time to develop and thoroughly explain each performance level [29]. The broadest classification level or designation will also be called "competencies," typically assessed at the program level [30].

Competencies serve as the foundation for distance learning assessments. For example, critical Thinking and Representation is the competency area for the (HTAII) course. The mid-level categorization will be called "Learning Outcomes" (LOs). LOs frequently reflect the education being provided at the course level. The most in-depth level of learning will be referred to as "parameters," it will include precise, measurable, and quantifiable actions or outcomes that show learning outcomes measured through the diverse course assignments and learning modules. A parameter should be easily assessed using a single question or component. The same rules apply to learning outcome specification and parameter specification. This makes it possible to determine the dependability and precision of parameter measurements [9]. The two primary considerations when creating assessments are explicit language and the efficacy of the evaluation rubrics. The reliability of the assessments is increased by these scoring rubrics, which reflect the understanding of the course objectives shared by students and evaluators [31].

The Learning Outcomes (LOs) and Student Performance Criteria (SPC) are defined to assess the overall performance of the students in this course. The instructors represent quantifiable parameters demonstrating the quality of each learning outcome performance when it typically happens in course tasks. While various tasks were treated as variables, these constant parameters were measured separately. Using scoring rubrics, which allowed for informative scoring on a variety of criteria, the effectiveness of each task was assessed. Each measure had five proficiency levels, ranging from excellent to good, fair to weak, and not achieved, according to the (HTAII) performance scoring rubric; an example of the presentation task is given in Table 1.

Table 1. Presentation task rubric

Presentation	Distinctive	Good	Fair	Poor	Not Achieved
Introducing building profile, style, explaining philosophy, symbology, historical, social, and cultural background—**P1**	Explain profile, style, factors, symbology philosophy	Describe profile, style, factors	Mention Profile, style	Style	Not covered
Architectural design, relationship between the buildings features—**P3**	Analyzing architectural design, features terminology, relationship between the building's features	Describe architectural design, features terminology, relationship between the building's features	Mention architectural design, features terminology	Features	Not covered
Structural systems, constructions, building materials—**P4**	Analyzing structure loading, construction, building materials, terminology	Describe structure, constructions, building materials, terminology	Mention structure, constructions, building materials, terminology	Structure and constructions	Not covered
Employing appropriate communication and representational media—**P8**	High representational media and new media tools, sequence, high resolution	Good representational media, sequence, fair resolution	Appropriate representational media, sequence	Weak representational media, sequence	Weak representational media, without sequence
Analytical sketches and drawings of architectural style—**P5, P6**	Analytical sketches and drawings 80%	Analytical sketches and drawings 50%	Sketches and drawings without related analysis	Images	Mostly text presentation
Effectively communicating orally— **P7**	Strong and clear language connected to slides, strong body language	Reading effectively directly from slides, having good body language	Fair reading and oral sentences, good body language	Weak oral and body language	Confused

Feedback on a student's performance is given in the form of a narrative report or a grade, as per the specifications of the assessment form and scoring rubric for each task. An analytical or comprehensive evaluation is then based on the student's performance on each criterion. To ensure the accuracy of the knowledge evaluation to the closest actual value of the evaluation's validity and to link it each time with the learning outcomes with the change of tasks, the performance evaluation parameters and criteria were derived from the learning outcomes. Whether a holistic or analytical approach to performance assessment is preferable for guiding students as they complete the task depends on the rubric, which outlines precise performance benchmarks at various proficiency levels. The entire unit or collection of units is subject to this kind of assessment. In addition to assessing the fundamental skills the student needs to develop to acquire this knowledge and cognitive competence, it calls for observation of performance, questioning, and, in some cases, reviewing documentation or other types of evidence. These skills are those related to architectural communication and presentation.

A parameter can be repeatedly measured across various tasks if it indicates a particular learning outcome and skill. Because of this, it was challenging to conduct performance analysis at the level of the entire task and one learning outcome. It offered a precise parameter for assessing students' performance within a single task, within a single parameter, and thus within the entire task, which cannot be disputed. There are eight measurements made. P1–P6 represents the learning objectives, while the primary competency and necessary skill to demonstrate define P7–P8 (Fig. 3).

The grades obtained from rubrics for each task evaluated eight parameters. The first group of parameters covered the knowledge and understanding learning outcomes are coded from P1 to P6; they identified and measured as follows:

- P1: Explaining the nature of architectural design concepts about various factors over time; defining architectural styles and charting their evolution over time; applying design philosophy and its interactions with contexts in architectural design; and describing the succession, development, and growth of various cultures, as well as the influences of earlier on later. This parameter was assessed using questions two on the MID exam, two on the final exam, and one on the presentation evaluation criteria.
- P2: Investigating, applying, and assessing various theoretical and philosophical concepts, a question on both the mid-exam and the final exam. The poster also includes one of the criteria for rating this parameter.
- P3: Defining the vocabularies of architectural and structural elements and explaining the relationship between them and using traditional design principles; this criterion was measured with a palm question in the mid and final exam and discussing them in the presentation. The model is calculated as the ability of students to show the relationship between architectural and structural features.
- P4: Describing and analyzing the characteristics of construction techniques in terms of structural elements, materials, technology, and labor available over time. Students had to explain and explore one of the examples in the mid-exam and final to demonstrate their

understanding of construction methods and building materials. Concerning the project, they were instructed to include in-depth explanations for this aspect in the presentation poster, present a section of the model in sectional form, and use appropriate materials that reflect the techniques and materials used in the building's original construction.

- P5: Improving analytical and critical thinking skills and using them to differentiate between architectural styles. It was determined by many questions, whether in the midterm or final exam, requesting explanations and analytical drawings demonstrating the student's understanding of architectural and structural concepts in historical buildings. Critical thinking implications for students are complex, so it was measured by explaining their projects analytically in presentations and posters.
- P6: A comparison of structural and architectural elements from different historical periods. This parameter was primarily measured by several questions on the midterm and final exams; because each group of students chose a different historical structure to research and analyze, a comparative analysis was optional in the students' projects. As a result, the project needed to track it as additional analytical parts in presentations and posters.

The second group of parameters is students' intellectual and presentation skills, which measure the ability to visualize and graphically express forms in two and three dimensions. It was one of the program learning outcomes considered when developing the (HTAII) course learning outcomes.

- P7: Communicating architecturally (orally, in writing, and through modeling) and clarifying concepts through drawings, sketches, and detailed models.
- P8: Presenting the idea using appropriate representational media and sophisticated graphic design skills, including computer technology. They should also use the proper tools and methods to create a neat, proportional model.

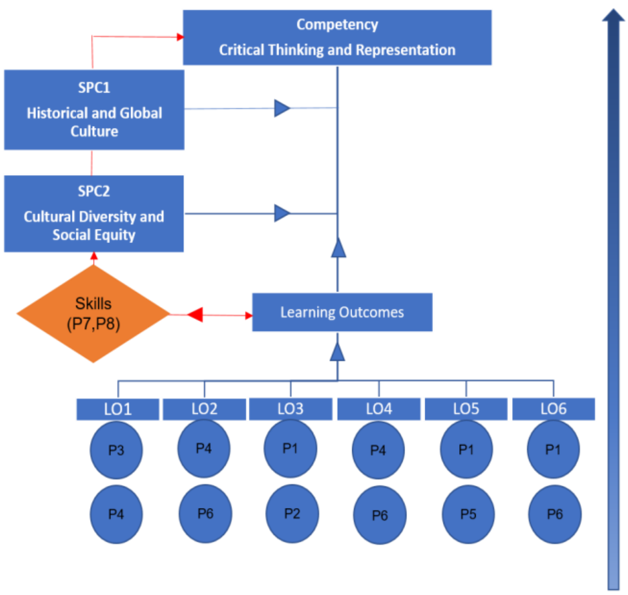

Fig. 3. Course plan.

Despite attempts to assess these two abilities through exams and evaluations of their performance in written and visual modes of expression and communication as necessary prerequisites for answering some questions, their performance in the various project tasks far outperformed that in the different project tasks, which may be explained by their reliance on computers and other technological tools when using these abilities, particularly the project model.

The student's performance for each parameter is shown as a general result, demonstrating the progress of students' performance with group project tasks more than in exam questions so that the highest percentages of grades A and B appear when the project task is completed. The highest percentages reach grade C in exam questions.

Returning to the first square through which the horizontal distribution of these parameters on the course's learning outcomes was designed, it is possible to refer vertically to the cognitive competencies that the student must acquire to find the ability to evaluate performance in the course clearly and on a solid basis by referring to examine each student's performance across all parameters and compare one student's performance across multiple tasks.

The structured process of developing the rubric, which included revision and improvement after each application, took two years and was taught entirely online. This helped to increase the rubric's validity and reliability as an assessment tool. The following steps were taken in developing the rubric during these phases:

1) The rubric was developed through several iterations, starting with a draft the course instructors created on the Microsoft Teams platform. Rather than allocating a single score for all criteria, an analytical rubric was utilized to score each criterion separately. The performance criteria in the draft version were centered on Learning Outcomes (LOs), and each criterion's weight percentage was specified, adding up to 100%. The scoring categories included three levels: unacceptable, average, and excellent.
2) The rubric was tested over two years, and flaws were identified each time. The process evolved through two stages. In the first stage, the performance criteria were outlined with eight quantifiable parameters that measured the knowledge and skills necessary for task completion and reporting. These parameters were taken from the course learning objectives. Proficiency levels were increased from three to five to ensure a stable scoring system. Five cells containing textual descriptions of the proficiency criteria were developed to create a matrix, adding written text and percentages to instruct the user while choosing the appropriate proficiency level. In the second stage, the descriptions were provided, and more clarifications were added to highlight the differences between quantity and quality and connect with the learning outcomes and their weights. Significant changes were made during these developmental stages, guided by expert advice and a literature review. This provided proof of the validity and reliability of the scoring system.
3) The rubric's usage was explained to the class at the beginning of each task, and the syllabus for the course contained the rubric's requirements. Students were

asked to use the rubric, which included explicit and straightforward assessment criteria. Students' feedback was also considered. A thorough review of the rubric criteria and comparisons to earlier iterations were conducted. The rubric was improved and modified based on these reviews.

4) Finally, teachers assessed the course's tasks using the modified rubric. An Excel file was created to document the evaluation points for every student, parameter, and task. Information for all students was gathered and arranged in a single file to facilitate its usage in the WINSTEPS program and examine the outcomes.

WINSTEPS is a statistical software package for analysing Item Response Theory (IRT). IRT is a psychometric theory that examines the relationship between a person's test-item response and their underlying ability or trait. WINSTEPS is widely used in educational testing and research based on the Rasch model. It is suitable for examining and validating item difficulty and individuals' (students') competency in response to their course grades [32].

Using the Rasch Model, each person with a certain amount of a given latent trait specifies the probability of a response in one of an item's categories. Rasch measurement for LOs assessment opens the possibility of evaluating the quality of learning performance through Learning Performance Measurement [33]. Based on this model, it is easy to conclude that the success rate of students in working on test items depends on their ability level and the item difficulty level [34]. The probability of success for each task shows a relationship between students' ability in response to the difficulty of tasks, and it is equal to:

$$Pr = \frac{\exp(\beta v - \delta i)}{1+\exp(\beta v - \delta i)} \tag{1}$$

where:
βv = the ability of person v
δi = the difficulty of assessment item i

The first step to start the calculations was the table of marks distribution according to tasks and learning outcomes assessment parameters generated from the rubrics. Then, grades were assigned to each task based on the mark distribution as follows:

A = 5, B = 4, C = 3, D = 2, F = 1

After that, the Rasch Analysis Software (WINSTEP) processed the task marks according to the grade category to produce the results and Logit values of model parameters, items difficulty (tasks) as displayed in Table 2, and person ability (students) as shown in Table 3. Accordingly, the probability of each student completing each task of LOs was determined.

Table 2. Logit value distribution of each item

Item	Logit value	Task
Q1	0.726	Mid exam
Q2	0.237	Mid exam
Q3	1.136	Mid exam
Q4	1.306	Mid exam
Q1	1	Final exam
Q2	0.76	Final exam
Q3	1.34	Final exam
Q4	1.034	Final exam
NCR1	1.204	Notebook
NCR2	0.553	Notebook
NCR3	1.477	Notebook
MCR1	−1.882	Model
MCR2	−1.479	Model
MCR3	0.093	Model
MCR4	−1.308	Model
TCR1	−1.201	Presentation
TCR2	−0.602	Presentation
TCR3	−0.281	Presentation
TCR4	−0.438	Presentation
TCR5	−0.359	Presentation
TCR6	−0.281	Presentation
PCR1	−1.308	Poster
PCR2	−0.438	Poster
PCR3	−0.644	Poster
PCR4	−0.644	Poster

Table 3. Logit value distribution of each student

STD#	Logit value	STD#	Logit value
1	0.822	22	2.709
2	1.708	23	0.223
3	0.518	24	0.822
4	0.885	25	1.209
5	0.638	26	1.559
6	0.578	27	1.415
7	1.143	28	0.518
8	0.948	29	0.638
9	0.518	30	−0.125
10	1.415	31	1.415
11	1.012	32	0.458
12	0.282	33	0.885
13	1.077	34	0.282
14	0.34	35	−0.416
15	0.885	36	2.03
16	1.277	37	0.458
17	2.116	38	0.282
18	1.143	39	0.885
19	1.708	40	0.107
20	2.116	41	0.638
21	0.458		

IV. Result and Discussion

The WINSTEPS software was used to analyze the 41 measured individuals. The study used a sample size of 41 students, considering how e-learning is changing, especially during the COVID-19 pandemic. Research is urgently needed to comprehend and maximize learning outcomes in this innovative educational paradigm because of the quick shift toward e-learning. This study aimed to offer an early and focused investigation into the efficacy of implication of practical tasks within this emerging educational framework, as the concept of e-learning gains prominence post-COVID-19. Additionally, we thoroughly investigated learning objectives thanks to a smaller, more focused sample that included every student enrolled in the target course. This allowed us to provide insightful information that could guide future research projects in this quickly developing field and enable a thorough analysis of learning outcomes that could be directly applied to the architectural curriculum, guaranteeing practical knowledge for educators in this field. A smaller sample allowed for a more in-depth and accurate analysis, as the Rasch model and WINSTEPS software require a close inspection of each response.

The WINSTEPS software analysis yielded summary statistics for the person and item categories of the course, which are displayed in Tables 4 and 5. This provides a thorough assessment of the measurement model's efficacy.

Table 4. Summary statistics for person and item

Categories	Data code	Total score	Count	Measure	Model S.E	In fit		Out fit	
						MNSQ	ZSTD	MNSQ	ZSTD
Person	Mean	89.9	25	0.92	0.26	1.00	−0.05	0.98	−0.12
	SEM	1.5	0	0.10	0	0.06	0.20	0.06	0.21
	P.SD	9.7	0	0.65	0.02	0.36	1.29	0.37	1.32
	S.SD	9.8	0	0.65	0.02	0.36	1.31	0.38	1.33
	Max.	113	25	2.71	0.34	2.05	3.15	2.21	3.53
	Min.	68	25	−0.42	0.24	0.38	−3.03	0.40	−2.92
Item	Mean	147.4	41	0	0.20	1.00	−0.22	0.98	−0.25
	SEM	5.2	0	0.20	0	0.09	0.42	0.08	0.38
	P.SD	25.5	0	0.99	0.02	0.43	2.04	0.40	1.88
	S.SD	26.1	0	1.01	0.02	0.44	2.08	0.41	1.92
	Max.	189	41	1.48	0.28	2.09	4.06	2.07	4.03
	Min.	107	41	−1.88	0.18	0.26	−5.03	0.26	−5.03

Note: S.E. of Person Mean= 0.10; Person Raw Score-to-Measure Correlation = 1.00; Cronbach Alpha (KR-20) Person Raw Score "Test"; Reliability = 0.83; SEM = 4.01; Standardized (50 Item) Reliability = 0.91
S.E. of Item Mean= 0.20; Item Raw Score-to-Measure Correlation = −1.00; UMEAN= 0.0000 USCALE = 1.0000

Table 5. Root Mean Square Error values (RMSE)

Categories	Data code	Total score	True SD	Separation	Item reliability
Person	Real RMSE	0.27	0.58	2.13	0.82
	Model RMSE	0.26	0.59	2.30	0.84
Item	Real RMSE	0.22	0.96	4.38	0.95
	Model RMSE	0.20	0.97	4.75	0.96

In the person measurement summary, the average errors between the measured and observed data are represented by the Root Mean Square Error (RMSE) values, which are low (Real: 0.27, Model: 0.26), suggesting a good fit. The actual Standard Deviation (SD): (0.58 real, 0.59 model) demonstrates good variability and discrimination. Real: 2.13; model: 2.30; separation values are reasonably good. It is reasonably accurate to divide the student performance into two groups based on how they answered the measured items. Person reliability is high, highlighting accuracy and consistency (Real: 0.82, Model: 0.84). The low (0.10) Standard Error (S.E.) of Person Mean indicates high accuracy in estimating mean person measures. A perfect Person Raw Score-to-Measure Correlation of 1.00 shows a strong correlation. Test for Cronbach Alpha (KR-20) Individual Raw Score Good reliability (0.83) indicates internal consistency. Strong reliability across items is confirmed by the high (0.91) standardized (50-item) reliability. The analysis validates the measurement model by showing a firm fit, precision, and reliability. Standard Error Measurement (SEM) (4.01) is relatively high, but the overall model reliability may still be high (0.83). This could be influenced by several things, such as the type of data, how the scores are distributed, or the features of the measuring tool.

Low RMSE values (Real: 0.22, Model: 0.20) highlight reliability in the item measurement summary. Genuine SD for items indicates consistent measurement (Real: 0.95, Model: 0.96) and high reliability (Real: 0.96, Model: 0.97). Effective discrimination is indicated by item separation values (Real: 4.38, Model: 4.75), which means that the task difficulty level is distributed over a reasonable range. The item means S.E. (0.20) indicates high precision. The differences between the practical and theoretical tasks may have influenced unexpected patterns, as indicated by the perfect Item Raw Score-to-Measure Correlation (−1.00). These findings demonstrate the measurement model's robustness and consistency for individuals and items.

The study only measured how well students performed on theoretical and practical tasks and how complex the theoretical tasks were compared to their practical counterparts. This gives rise to some preliminary readings about the impact of application-based learning theory in an online theoretical course. The study did not concentrate on specific causes to account for students' academic performance. Its goal was not to investigate the suitability of assignments, tests, or student performance.

Based on these limitations, the WINSTEPS software utilized a dataset consisting of 41 students to compute the corresponding outcomes. The software generated the Person-Item Distribution Map (PIDM) upon processing the provided data, as illustrated in (Fig. 4). This map depicts the placement of each student (Person) and task (Item) regarding task distribution. Based on the principles of Latent Trait Theory, the PIDM effectively represents the distribution of individuals and tasks on a unified logit scale.

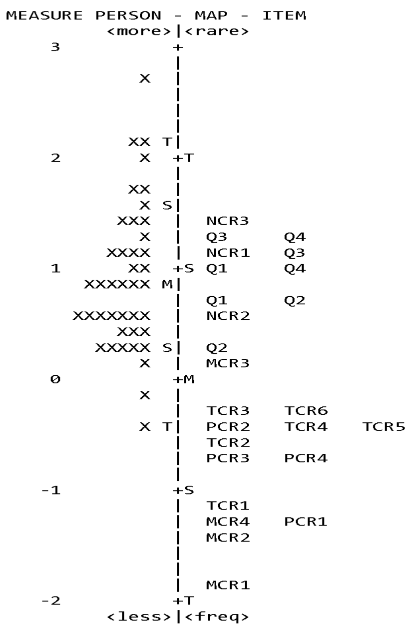

Fig. 4. Person-item distribution map.

The PIDM determines a person's ability (βv) concerning task difficulty (δi). It indicates the item's position on the same latent trait: if n is more significant than I, the person is more likely to respond correctly to the task [33]. Similarly, the distance between the item and the person's location on the map signifies the person's ability. A greater distance implies a higher likelihood of the person responding correctly to the given task.

Conversely, the difficulty of a task is determined by its positioning on a scale. For instance, tasks located further away from the Mean $_{item}$ exhibit higher complexity than those closer. Thus, in this dataset, the Mean $_{item}$ is assigned a value of zero, acting as the threshold for the logit scale.

Logit values are generated to assess each student's task achievement in the PIDM, and the probability of each student achieving each task is calculated using logit equations inserted into Excel. The person and item measurements show the logit value position for each student and task. According to the PIDM, the cohort $Mean_{person}$ (0.92) is greater than the threshold value, $Mean_{item}$, indicating that students have high abilities on a given task. Only two students (4.8%) scored below the $Mean_{item}$. These two students can complete most of the practical tasks assigned during the course but need help to complete the remaining theoretical tasks, as shown in Fig. 4. Out of the 25 tasks, NCR3 from the notebook task (logit 1.48) appeared to be the most difficult, followed by questions; Q3 in the final exam and Q4 in the mid-exam (logit 1.34, logit 1.31). The most difficult tasks are the theoretical ones, as questions from midterm and final exams and individual tasks. Students must memorize the facts to answer the questions during the examination. As a result, students may need to consult books or notes to answer the questions. This is consistent with the findings of Ahmad *et al.* [33]. Furthermore, Salama *et al.* [14, 15], Bonwell [18], Coulshed [19], and Felder [20] concur that listening to lectures and extracting knowledge from them may become more complex, particularly in distance learning settings.

This could explain why theoretical tasks have a higher logit value than practical task value results. The most accessible item revealed in the PIDM, for example, is MCR1 (project model), which has a logit value of −1.88. Table 2 shows the distribution of items ascending from easiest to most difficult, indicating that practical tasks are concentrated on the easiest and theoretical tasks are focused on the most difficult according to the logit value for each task. This could suggest that practical tasks in cooperative groups increase student engagement and exert more effort in completing the project. The significance of this was highlighted by the research conducted by Stiggins [8], Delahunty *et al.* [22], and Farrell and Brunton [23].

Analyzing each person's correlation to each item by computing each student's task achievement probability and, as a result, learning outcomes and competency. Achievement probability was calculated using Eq. (1) inserted into Excel. It can be calculated manually for STD22, which had a logit value of 2.709, as shown in Table 3, to the achievement of NCR3 item; the logit value is 1.477, as an example as follows:

$$\beta v - \delta i = 2.709 - 1.477 = 1.232$$

$$Pr = \frac{\exp 1.232}{1 + \exp 1.232} = 0.77$$

Similarly, the probability of each student achieving each task of CLOs was calculated and then coded from high to low, as shown in Fig. 5.

TASK		MID EXAM				FINAL EXAM				NOTEBOOK PORTFOLIO			MODEL				POSTER				PRESENTATION					
PARAMETER		P3,P7	P1,P2,P5	P4, P7	P1,P6, P7	P3,P7	P1,P2,P5	P4, P7	P1,P5, P6, P7	P3	P4	P7	P7	P4	P3	P8	P2	P4	P5, P6	P7	P1	P3	P4	P8	P5, P6	P7
	ITEMS	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	NCR1	NCR2	NCR3	MCR1	MCR2	MCR3	MCR4	PCR1	PCR2	PCR3	PCR4	TCR1	TCR2	TCR3	TCR4	TCR5	TCR6
STD#	STD	0.726	0.237	1.136	1.306	1	0.76	1.34	1.034	1.204	0.553	1.477	-1.882	-1.479	0.093	-1.308	-1.308	-0.438	-0.644	-0.644	-1.201	-0.602	-0.281	-0.438	-0.359	-0.281
35	-0.416	24	34	17	15	20	24	15	19	17	28	13	81	74	38	71	71	51	56	56	69	55	47	51	49	47
30	-0.125	30	41	22	19	25	29	19	24	21	34	17	85	79	45	77	77	58	63	63	75	62	54	58	56	54
40	0.107	35	47	26	23	29	34	23	28	25	39	20	88	83	50	80	80	63	68	68	79	67	60	63	61	60
23	0.223	38	50	29	25	31	37	25	31	27	42	22	89	85	53	82	82	66	70	70	81	70	62	66	64	62
12	0.282	39	51	30	26	33	38	26	32	28	43	23	90	85	55	83	83	67	72	72	82	71	64	67	65	64
34	0.282	39	51	30	26	33	38	26	32	28	43	23	90	85	55	83	83	67	72	72	82	71	64	67	65	64
38	0.282	39	51	30	26	33	38	26	32	28	43	23	90	85	55	83	83	67	72	72	82	71	64	67	65	64
14	0.34	40	53	31	28	34	40	27	33	30	45	24	90	86	56	84	84	69	73	73	82	72	65	69	67	65
21	0.458	43	56	34	30	37	43	29	36	32	48	27	91	87	59	85	85	71	75	75	84	74	68	71	69	68
32	0.458	43	56	34	30	37	43	29	36	32	48	27	91	87	59	85	85	71	75	75	84	74	68	71	69	68
37	0.458	43	56	34	30	37	43	29	36	32	48	27	91	87	59	85	85	71	75	75	84	74	68	71	69	68
3	0.518	45	57	35	31	38	44	31	37	33	49	28	92	88	60	86	86	72	76	76	85	75	69	72	71	69
9	0.518	45	57	35	31	38	44	31	37	33	49	28	92	88	60	86	86	72	76	76	85	75	69	72	71	69
28	0.518	45	57	35	31	38	44	31	37	33	49	28	92	88	60	86	86	72	76	76	85	75	69	72	71	69
6	0.578	46	58	36	33	40	45	32	39	35	51	29	92	89	62	87	87	73	77	77	86	76	70	73	72	70
5	0.638	48	60	38	34	41	47	33	40	36	52	30	93	89	63	88	88	75	78	78	86	78	71	75	73	71
29	0.638	48	60	38	34	41	47	33	40	36	52	30	93	89	63	88	88	75	78	78	86	78	71	75	73	71
41	0.638	48	60	38	34	41	47	33	40	36	52	30	93	89	63	88	88	75	78	78	86	78	71	75	73	71
1	0.822	52	64	42	38	46	52	37	45	41	57	34	94	91	67	89	89	78	81	81	88	81	75	78	77	75
24	0.822	52	64	42	38	46	52	37	45	41	57	34	94	91	67	89	89	78	81	81	88	81	75	78	77	75
4	0.885	54	66	44	40	47	53	39	46	42	58	36	94	91	69	90	90	79	82	82	89	82	76	79	78	76
15	0.885	54	66	44	40	47	53	39	46	42	58	36	94	91	69	90	90	79	82	82	89	82	76	79	78	76
33	0.885	54	66	44	40	47	53	39	46	42	58	36	94	91	69	90	90	79	82	82	89	82	76	79	78	76
39	0.885	54	66	44	40	47	53	39	46	42	58	36	94	91	69	90	90	79	82	82	89	82	76	79	78	76
8	0.948	56	67	45	41	49	55	40	48	44	60	37	94	92	70	91	91	80	83	83	90	82	77	80	79	77
11	1.012	57	68	47	43	50	56	42	49	45	61	39	95	92	71	91	91	81	84	84	90	83	78	81	80	78
13	1.077	59	70	49	44	52	58	43	51	47	63	40	95	93	73	92	92	82	85	85	91	84	80	82	81	80
7	1.143	60	71	50	46	54	59	45	53	48	64	42	95	93	74	92	92	83	86	86	91	85	81	83	82	81
18	1.143	60	71	50	46	54	59	45	53	48	64	42	95	93	74	92	92	83	86	86	91	85	81	83	82	81
25	1.209	62	73	52	48	55	61	47	54	50	66	43	96	94	75	93	93	84	86	86	92	86	82	84	83	82
16	1.277	63	74	54	49	57	63	48	56	52	67	45	96	94	77	93	93	85	87	87	92	87	83	85	84	83
10	1.415	67	76	57	53	60	66	52	59	55	70	48	96	95	79	94	94	86	89	89	93	88	85	86	85	85
27	1.415	67	76	57	53	60	66	52	59	55	70	48	96	95	79	94	94	86	89	89	93	88	85	86	85	85
31	1.415	67	76	57	53	60	66	52	59	55	70	48	96	95	79	94	94	86	89	89	93	88	85	86	85	85
26	1.559	70	79	60	56	64	69	55	63	59	73	52	97	95	81	95	95	88	90	90	94	90	86	88	87	86
2	1.708	73	81	64	60	67	72	59	66	62	76	56	97	96	83	95	95	90	91	91	95	91	88	90	89	88
19	1.708	73	81	64	60	67	72	59	66	62	76	56	97	96	83	95	95	90	91	91	95	91	88	90	89	88
36	2.03	79	86	71	67	74	78	67	73	70	81	63	98	97	87	97	97	92	94	94	96	93	91	92	92	91
17	2.116	80	87	73	69	75	80	68	75	71	83	65	98	97	88	97	97	93	94	94	97	94	92	93	92	92
20	2.116	80	87	73	69	75	80	68	75	71	83	65	98	97	88	97	97	93	94	94	97	94	92	93	92	92
22	2.709	88	92	83	80	85	88	80	84	82	90	77	99	99	93	98	98	96	97	97	98	96	95	96	96	95

P≥90	90>P≥80	80>P≥70	70>P≥60	60>P≥50	<50

Fig. 5. Probability of each student achieving each Task of CLOs.

From these results, 7 of 41 achieve all CLOs by 17% in theoretical tasks, 39 of 41 earn all CLOs by 95% in practical tasks, and all students can complete practical tasks more efficiently than theoretical ones. The integration of action and critical thinking is highlighted by a high probability of achieving an applicable task score. It allows students to demonstrate their knowledge within the independently created applied work framework. This finding is supported by the studies of Salama [16], Wrenn [17], and Ceglie [24].

The virtual learning environment did not hinder completing the practical tasks. Instead, one could argue that each benefitted from the other. For instance, practical assignments enhanced student interaction, while technology and simultaneous communication increased students' integration into groups. Numerous prior studies, such as those by Davies [25] and Kumar [35], have supported the idea that this interaction catalyzes students to build their knowledge in a social context.

The model's performance can be improved by integrating soft computing strategies into the proposed model through additional research and experimentation. The model's robustness and adaptability in managing intricate and dynamic situations will be improved by incorporating these strategies. Investigate how to optimize specific model parameters by combining genetic algorithms, as suggested by Bhaskaran *et al.* [28] and Marappan *et al.* [36]. This strategic integration will significantly improve the overall performance of the proposed model and is in line with current trends in intelligent systems and recommender algorithms.

V. Conclusion

The study's results indicate a general enhancement in students' performance when engaging in group work-based tasks. On the other hand, the research findings also reveal that students' indicators of learning ability exhibited more significant improvement when involved in applied tasks. This underscores the notable influence of incorporating Applied-Based Learning (ABL) within theoretical online courses.

Comprehensive insights into the efficacy of the measurement model have been obtained from the WINSTEPS software analysis, which has proven the model's consistency, accuracy, and dependability at the person and item levels. The Person Raw Score-to-Measure Correlation of 1.00 indicates a strong correlation at the person level, and the reliability of the Test for Cronbach Alpha (KR-20) is 0.83, meaning internal consistency and the separation values (2.30) are reasonably good. Similarly, the item-level analysis highlights the measurement model's high reliability (0.96) and separation values (4.75), indicating that the task difficulty level is spread over a reasonable range. It has been possible to represent the distribution of people and tasks on a single logit scale using a Person-Item Distribution Map (PIDM). Students' high aptitude for practical tasks is highlighted by the PIDM analysis, as evidenced by a Mean person value (0.92) that is higher than the Mean item threshold. A thorough analysis of task complexities are also made possible by logit values obtained from the PIDM, which show that 95% of students have a high probability of completing practical tasks. In comparison, only 17% of students have a probability of completing theoretical tasks. These findings provide a nuanced understanding of student abilities and task difficulty.

The findings challenge the belief that theoretical courses primarily aim for knowledge acquisition. They contend that gaining valuable practical skills can supplement theoretical knowledge and contribute to a more comprehensive education. As a result, the study supports the idea of the pedagogical approach, which combines theoretical knowledge with applied tasks to support deep learning and skill development in applied fields like architecture. To bridge the theory-practice gap, theoretical courses are advised to include applied assignments. This is in line with contemporary theories of experiential learning, which emphasize the importance of practical experience in enhancing learning outcomes. The study also clarifies the feasibility of distance learning in applied disciplines. It demonstrates how distance education can still provide experiential learning opportunities, even when students are not physically present in a traditional classroom. The findings should help teachers and curriculum designers reconsider the organization and subject matter of theoretical courses by including additional applied tasks and projects. The study emphasizes how beneficial group projects and applied tasks are to students' performance. By using this method, educators can create more interesting and meaningful assessments that are more in line with real-world expectations and better prepare students for their future careers. Moving forward, it is crucial to continue exploring innovative ways to enhance the integration of theoretical constructs in e-learning environments. Future studies and research can be presented to investigate the integration and development of the pillars of (ABL) theory for the success of re-bridging between practice and theory, such as bridging theory and practice in the other direction.

Conflict of Interest

The authors declare no conflict of interest.

Authors Contributions

Muhsen wrote the first draft, and Al Rabay revised and edited it. They framed the research statement, significance, and the study's design. Muhsen gathered and examined the quantitative data. Both authors have approved the final draft.

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