

Development of an Application for Project-based Learning to Improve Hard and Soft Skills in 2D Animation Production

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Abstract—Project-Based Learning is widely regarded as an effective pedagogical approach for fostering both technical competencies (hard skills) and interpersonal competencies (soft skills) in higher education. The development of an application for Project-Based Learning in 2D Animation Production is proposed in this study to evaluate its potential effectiveness, compare learners' pre-test and post-test achievement scores following its utilization, and assess learners' hard skills and soft skills. The participants consisted of 51 undergraduate students, purposively sampled, majoring in Multimedia Technology, and enrolled in a 2D Animation Production course at Nakhon Pathom Rajabhat University (one-group pre-test–post-test design). The research instruments included the developed application, an expert-quality evaluation questionnaire, pre-test and post-test measures, and rubric-based performance assessments for hard skills and soft skills. Data were analyzed using descriptive statistics, paired-samples *t*-tests, and inter-rater reliability (Cohen's κ). The results showed that experts rated the overall quality of the application at the highest level (Mean = 4.67, SD = 0.48). The Meguigan's effectiveness index was 1.12 (>1.00), exceeding the acceptable criterion and suggesting the potential effectiveness of the application in this context. Learners' post-test achievement scores were significantly higher than their pre-test scores ($p < 0.001$), and they demonstrated high levels of hard skills and soft skills, with high inter-rater reliability. The findings suggest the potential effectiveness of the application in supporting the development of hard skills and soft skills in higher education within this context.

Keywords—application, project-based learning, hard skills, soft skills, 2D animation production, rubric assessment

I. INTRODUCTION

The Economic and Social Development Plan emphasizes the critical role played by higher education institutions in addressing learning deficits resulting from the COVID-19 pandemic. The plan also aims to align pedagogical practices with sustained professional development through personalized and inquiry-based learning [1]. In response to this national directive, the "Creative Integration" pedagogical framework has been developed to prioritize instructional design suited to the demands of disruptive technology, thereby suggesting potential improvements in the effectiveness of Thailand's educational system. This framework encourages learners to develop higher-order cognitive skills by integrating both hard skills and soft skills to address complex real-world problems and contribute to societal advancement. The approach is grounded in the principle of integration, defined as the systematic synthesis of multidisciplinary knowledge, to promote holistic understanding and support deep learning tailored to individual learner needs. Moreover, the framework provides a structured pathway for designing learning experiences that align technological competencies with authentic,

learner-centered problem-solving [2].

Curricula in graphic design and multimedia disciplines are predominantly practice-based, emphasizing experiential learning and the development of applied skills. However, traditional pedagogical approaches often encourage students to rely on established paradigms rather than develop independent critical thinking skills. These limitations may reduce creativity, decrease engagement, and lower students' motivation to participate. Similar challenges have been observed in the 2D Animation Production course, which is likewise practice-oriented. Such deficiencies may undermine students' professional readiness for internships and impede long-term career advancement in the industry. Therefore, developing effective learning models that foster multidimensional competencies is essential.

In accordance with Section 30 of the Education Act, educational institutions are mandated to cultivate robust teaching and learning processes while fostering educators' research capabilities to optimize learning strategies tailored to each educational level [3]. Teaching methodologies have increasingly shifted toward approaches that prioritize skill attainment over knowledge acquisition. Project-Based Learning (PBL) is subsequently regarded as a promising model for twenty-first-century education, facilitating hands-on activities aligned with students' individualized interests. To support sustainable learning outcomes and long-term impact, pedagogy should incorporate project-based tasks and collaborative inquiry [4], thereby fostering active engagement, collective knowledge construction, and authentic problem-solving through meaningful outputs. Empirical evidence from higher education research suggests that PBL may contribute to both cognitive and behavioral outcomes, including improved academic achievement, heightened engagement, and the refinement of professional competencies and interpersonal skills [5]. Consequently, PBL has been incorporated into instructional design to provide learners with meaningful opportunities for applied practice. This pedagogical approach is suggested to support the development of competencies relevant to the modern workforce, emphasizing the need for individuals to possess both hard skills and soft skills for effective collaboration. PBL principles are operationalized within the application by structuring the learning experience around an authentic project cycle, encompassing driving-question formulation, inquiry, collaboration, artifact development, and reflective refinement. This pedagogical architecture aligns with the fundamental PBL criteria of centrality, constructive investigation, learner autonomy, and realism [6].

Applications represent pervasive technologies in contemporary pedagogical contexts, serving as mechanisms

for learning support that address the evolving needs of modern learners. Supplementary instructional applications are designed to reinforce prior knowledge acquisition, often using remedial modules to enhance and consolidate learners' comprehension. Consequently, such applications are not intended to supersede educators' roles in the instructional process [7]. This integration is particularly pertinent to practice-oriented disciplines, notably 2D Animation Production, where learners are expected to develop technical competencies (e.g., design, animation tools, and production processes) alongside essential soft skills, such as teamwork, communication, and project management. Interactive multimedia is suggested to enhance learning outcomes in the 2D Animation Production course by facilitating immersive learning experiences and fostering active practice through systematically structured project-based tasks [8, 9].

The development of a Project-Based Learning application for the 2D Animation Production course is posited to facilitate autonomous learning while simultaneously supporting the enhancement of both hard skills and soft skills. By engaging in collaborative group work and applying project-based activities centered on authentic artifact creation, learners are expected to attain a deeper understanding, foster creativity, and refine their hard skills. Furthermore, collaborative interactions are suggested to support the development of planning, communication, and leadership competencies, thereby strengthening learners' soft skills. This pedagogical approach affords learners opportunities to cultivate both technical and interpersonal proficiencies, which are imperative within the contemporary workforce. Moreover, this methodology aligns with national mandates to equip learners with industry-relevant competencies while assisting higher education institutions in mitigating learning deficits resulting from the COVID-19 pandemic.

Despite extensive research underscoring the effectiveness of PBL and technological learning tools, empirical evidence on integrating PBL into an application to simultaneously support the development of hard skills and soft skills in animation education remains limited. Existing literature predominantly focuses on learning achievement or satisfaction, often using web-based platforms and relying on self-report measures rather than performance-based assessments. Furthermore, systematic rubric-based evaluation with inter-rater reliability analysis rarely assesses both technical and interpersonal competencies in authentic educational settings. This study addresses this gap by developing and evaluating an application-based, Project-Based Learning approach for a 2D Animation Production course, utilizing rubric-based assessments of hard skills and soft skills, and conducting an inter-rater reliability analysis. This study is expected to contribute empirical and methodological evidence on how application-supported PBL may enhance learning achievement and synergistic skill development in practice-oriented higher education.

The objectives of the study are as follows:

- (1) To develop an application for Project-Based Learning in 2D Animation Production.
- (2) To evaluate the potential effectiveness of the application within this context.
- (3) To compare learners' pre-test and post-test achievement

scores following the utilization of the application.

- (4) To assess learners' hard skills and soft skills following the utilization of the application.

The research questions of this study are as follows:

- (1) What is the experts' evaluation of the overall quality of the application for Project-Based Learning in 2D Animation Production?
- (2) What is the instructional effectiveness of the developed application according to Meguigan's index?
- (3) Is there a significant difference between learners' pre-test and post-test achievement scores?
- (4) What levels of hard skills and soft skills are evidenced among learners after utilizing the application?

The hypotheses of this study are as follows:

H₀: There is no statistically significant difference between learners' pre-test and post-test achievement scores.

H₁: Learners' post-test achievement scores are significantly higher than their pre-test scores.

II. LITERATURE REVIEW

A. Project-based Learning

Project-Based Learning (PBL) is a pedagogical approach that prioritizes learner-centered education through systematic inquiry frameworks, beginning with the stimulation of interest or the identification of problems, followed by the exploration of potential solutions [10]. Within this framework, learners acquire essential competencies by actively investigating context-specific problems and developing tangible artifacts or outcomes. Through sustained inquiry, collaboration, and reflection, learners apply concepts in real-world contexts, thereby constructing conceptual understanding and demonstrating their attainment through project completion [11]. Within this pedagogical framework, learners actively engage in the design, planning, and execution of projects that bridge disciplinary knowledge with real-world contexts, thereby supporting deeper understanding, collaboration, and higher-order thinking skills. Through sustained inquiry and the creation of tangible artifacts, PBL has the potential to assist learners in constructing knowledge, integrating theory with practice, and cultivating competencies relevant to both academic and professional contexts [12]. PBL entails systematically structured collaborative project planning, followed by implementation and the attainment of learning outcomes, culminating in the synthesis of conclusions regarding the subject matter [13].

This pedagogical approach incorporates a diverse set of skills, including research, effective communication, creative thinking, and teamwork. These competencies are embedded within the PBL framework, potentially contributing to constructive educational outcomes. Essentially, PBL represents a multifaceted educational approach that integrates diverse pedagogical perspectives. The framework enables educators to adopt versatile instructional methods, suggesting the potential for enhancing creative thinking. Utilizing both group and individual formats, PBL aligns with learner-centered principles, offering learners opportunities to enhance their competencies in accordance with individual interests and aptitudes [14, 15]. This methodological approach entails learners working collaboratively on

project-based tasks that incorporate systematic exploration, observation, and the selection of topics relevant to their specific interests. Participants collaboratively structure the project, synthesize relevant information, and execute tasks in accordance with the established framework. This systematic approach is expected to facilitate the emergence of new discoveries or pedagogical innovations. Learners subsequently document their findings, disseminate their work through presentations, and synthesize data. These projects and experiences constitute a basis for discussion, knowledge exchange, and reflection, thereby supporting the formulation of conclusions from their learning experiences [10, 16]. PBL conventionally entails a structured pedagogical process comprising five core phases: (1) driving questions, (2) planning and inquiry, (3) collaboration, (4) artifact creation, and (5) reflection and presentation. The integration of these elements suggests the potential for enhancing learners' active engagement alongside both cognitive and social competencies [17, 18].

B. Hard Skills and Soft Skills

Instructional design in the era of disruptive technology requires learners to cultivate higher-order thinking skills and integrate both hard skills and soft skills to generate innovations that address complex problems and contribute to societal development. Integrating diverse concepts poses significant challenges for educators, as it requires the coherent synthesis of multiple frameworks to align instructional design with active learning methodologies. Pedagogical practices must be adapted to address learners' needs and the complex contexts inherent in the educational process. The role of the educator is shifting from knowledge dissemination to facilitation, thereby enabling learners to access knowledge independently. This transition may foster deeper learning and support the development of innovation-related skills. These competencies are considered essential in contemporary educational contexts. This process comprises five systematic stages: (1) learners establish individual learning goals, (2) learners plan their learning activities, (3) learners execute their learning plans, (4) learners conduct self-assessment, and (5) the educator provides constructive feedback [2].

Hard skills and soft skills are complementary components

that collectively contribute to effective performance. Hard skills represent quantifiable competencies, whereas soft skills emphasize interpersonal dynamics and attitudinal attributes rather than technical aspects. Although hard skills and soft skills are often viewed separately, integrating them is suggested to enhance professional performance in practical work settings [19]. Recent measurement-oriented studies emphasize the necessity of validated instruments and psychometric evidence (e.g., factor structure and reliability) when operationalizing soft skills within educational research frameworks. A methodological study conducted in Thailand developed and validated a twenty-first-century Skills Assessment Scale based on the P21 framework. This study identifies a multidimensional structure that includes creativity and innovation, critical thinking and problem-solving, communication and collaboration, as well as initiative and self-direction [20].

In practice-oriented courses, such as the 2D Animation Production course, effective learning outcomes require the integration of technical mastery (hard skills) with transferable competencies (soft skills) to support authentic performance. However, soft skills assessment remains challenging due to its latent and context-dependent nature, thereby necessitating the development of validated measurement tools. Recent literature introduces rigorous frameworks and psychometrically validated instruments for evaluating transferable competencies in educational settings. Accordingly, this study utilizes a multi-method assessment framework that combines rubric-based evaluation of animation outputs with standardized measures of soft skills to support learners' planning, problem-solving, collaboration, and iterative improvement [20, 21]. Prior research indicates that hard skills relate to professional competencies, whereas soft skills are often associated with individual personality traits. Hard skills are quantifiable and can be assessed in concrete, objective ways, making them more clearly defined than soft skills. The application of hard skills typically involves a more linear mode of execution across contexts, whereas the utilization of soft skills requires contextual understanding and adaptive responses to situational demands [22]. The comparison of prior studies is summarized in Table 1.

Table 1. Conceptual comparison of prior studies and research positioning

Conceptual	Prior Research	Limitations in Prior Research	Present Study
Project-Based Learning (PBL) in Higher Education [5, 6, 16, 23, 24]	PBL enhances academic achievement, engagement, and higher-order learning outcomes	Limited empirical evidence in practice-oriented animation courses with integrated skill assessment	Implementation of PBL within the 2D Animation Production course integrated with a multidimensional assessment of hard and soft skills
Integration of Digital Technology with PBL [8, 25, 26]	Digital and multimedia-supported PBL improves learner achievement and engagement	Most studies on 2D animation rely on web-based media rather than application platforms or employ applications that primarily use video-based content	Developed and evaluated an application designed to facilitate PBL activities and incorporate multimedia-based learning content
Hard skills and soft skills as Integrated Competencies [8, 19, 21]	Hard and soft skills should be developed and applied in an integrated manner	Lack of operationalized assessment models in an authentic classroom	Operationalization of integrated hard skills and soft skills through rubric-based performance assessment
Instructional Design for a Project-Based Learning (PBL) Application [25, 27–29]	The ADDIE model supports systematic and iterative development of digital learning tools	Limited explanation of how application features align with pedagogical models such as PBL	Mapping of ADDIE-based application development onto PBL learning processes

C. Concept of the Application

Applications serve as software tools that facilitate user

activities on portable communication devices, including smartphones, tablets, and other mobile devices. These applications are designed to operate across diverse operating

systems. Given the proliferation and enhanced capabilities of applications, mobile device users increasingly depend on software programs to facilitate daily activities, access information, and engage in multimodal digital media consumption. In application development, it is essential to prioritize the project timeline, production costs, and the application's functional requirements [30]. In educational and technology-enhanced contexts, applications are often designed to facilitate user interaction, content delivery, and structured task completion, thereby supporting learners in accessing resources and engaging in activities via mobile or computer-based platforms [31].

Among various methodologies for application development, a prominent approach is grounded in the instructional design process for computer-based learning, synthesized from systematic methodologies. This approach has evolved to incorporate multiple design perspectives, with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model recognized as one of the most widely adopted frameworks [28]. The ADDIE development process consists of five stages: (1) analysis of instructional content, (2) design of instructional materials, (3) development of learning materials, (4) implementation, and (5) evaluation of instructional outcomes [32]. In digital learning design, the ADDIE model supports the integration of effective teaching practices, such as multimedia presentations, interactive activities, and feedback mechanisms. These components are suggested to enhance learner engagement and improve learning effectiveness in online environments [27, 29].

D. 2D Animation Production

Two-Dimensional (2D) animation is the process of sequentially displaying still images or graphics at a predetermined frame rate to create the illusion of motion or persistence of vision. Animation software and tools facilitate the controlled display of these images at a defined speed, thereby generating the visual illusion of movement [33]. In 2D animation, motion is constructed through the sequential presentation of flat, hand-drawn, or digitally generated images on a two-dimensional plane. Within this framework, movement is achieved through incremental frame-by-frame modifications to visual elements (e.g., characters, objects, or scenes), thereby supporting visual storytelling and dynamic communication without relying on volumetric depth. Within educational contexts, 2D animation is conventionally used as a form of multimedia instruction, as it has the potential to present complex information in an engaging and comprehensible manner, which may help maintain attention and motivation [34]. At present, animation is primarily developed using computer-based tools, comprising a wide range of software designed to support diverse animation techniques. Animation may be executed in both 2D and 3D formats, including drawn animation, stop-motion (model) animation, and computer-generated animation [35].

As illustrated in Fig. 1, this study is grounded in Project-Based Learning (PBL), which prioritizes learner-centered instruction, collaboration, and project development. The framework also emphasizes the integration of hard skills and soft skills (e.g., teamwork, communication, and leadership), as these competencies are essential for

real-world performance. Furthermore, the application facilitates learning in 2D Animation Production through structured digital activities and motion graphics instruction, suggesting the potential to enhance learners' understanding, achievement, and competency development. In this study, the independent variable comprises an application integrating PBL to enhance learners' hard skills and soft skills in the context of 2D Animation Production. The dependent variables include learners' academic achievement, along with their demonstrated hard skills and soft skills. The selection of the ADDIE model is due to its systematic, iterative nature, which is well-suited to developing and refining an educational module prior to large-scale implementation. The development process comprised five phases: Analysis, Design, Development, Implementation, and Evaluation.

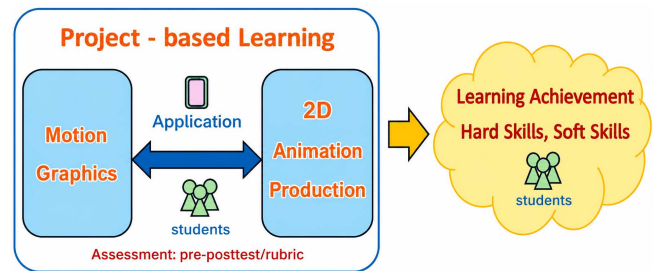


Fig. 1. Conceptual framework.

III. MATERIALS AND METHODS

The research procedures commenced with obtaining ethical approval from the Ethics Review Committee for Research Involving Human Subjects at Nakhon Pathom Rajabhat University. The study was officially approved under Certificate No. 022/2567. Informed consent was formally obtained from all participants prior to the commencement of data collection. The research methodology was executed according to the following stages:

A. Research Design

This study utilized a one-group pre-test–post-test quasi-experimental design, necessitated by curricular and ethical constraints that precluded withholding the instructional intervention from a control group. Given that the application was designed to facilitate learning outcomes and constituted an integral component of the 2D Animation Production course, withholding access from a control group was considered ethically inappropriate. Therefore, all participants received equal opportunities to engage in the pedagogical activities facilitated by the application. However, this design has inherent limitations for causal inference; consequently, the findings should be interpreted as indicative rather than definitive.

To mitigate potential threats to internal validity, the study employed several strategies, including repeated measures (pre-test, post-test, and re-test), performance-based assessment facilitated by structured rubrics, and inter-rater reliability analysis. These methodological features are expected to enhance the credibility of the findings by permitting the examination of learning gains, retention effects, and consistency in competency assessment. Nonetheless, despite these procedural measures, it is acknowledged that residual threats to internal validity cannot be entirely eliminated.

This study utilized a multi-stage research design, the procedural components of which are outlined in the following sections.

- (1) To evaluate the potential effectiveness of the application and to compare learners' pre-test and post-test achievement scores following the utilization of the application, a one-group pre-test-post-test quasi-experimental design was utilized, as illustrated in Table 2 [35].

Table 2. One-group pre-test-post-test research design

Sample	Pre-test	Experimental	Post-test
E	O ₁	X	O ₂

The instructional effectiveness of the application was assessed using Meguigan's effectiveness index, derived from pre-test and post-test scores. Index values exceeding 1.00 are considered to indicate an acceptable level of instructional effectiveness (see Eq. (1)) [36, 37].

$$\frac{M_2 - M_1}{P - M_1} + \frac{M_2 - M_1}{P} \quad (1)$$

Within the context of this study, M_1 denotes the mean post-test score, M_2 denotes the mean pre-test score, and P represents the full score.

- (2) To assess learners' hard skills and soft skills following the utilization of the application, a one-group post-test-only research design was utilized, as illustrated in Table 3 [35].

Table 3. One-group post-test-only research design

Sample	Experimental	Post-test
E	X	O ₁

As shown in Table 3, a one-group post-test-only research design was used to assess learners' hard skills and soft skills following the utilization of the application.

B. Participants

A panel of experts evaluated the content validity using the Item-Objective Congruence (IOC) index and assessed the quality of the application. These experts were instructors in computer-related fields or instructional technology, each holding a doctoral degree or possessing at least three years' instructional experience in computer-related courses.

The research sample comprised 51 undergraduate students majoring in Multimedia Technology at Nakhon Pathom Rajabhat University, all of whom were enrolled in the 2D Animation Production course during the first semester of the 2024 academic year. The participants were selected using a purposive sampling technique to ensure alignment with the instructional objectives.

C. Development

1) Pre-test and post-test measures

The research procedures were executed according to the following stages:

- The instructional content and behavioral objectives were analyzed, resulting in the identification of five specific behavioral objectives.
- A draft achievement test was developed in alignment with the established behavioral objectives, and the assessment instrument was structured as a four-option,

multiple-choice test comprising 40 items.

- A panel of three experts evaluated the congruence between the test items and behavioral objectives using the Item-Objective Congruence (IOC) index, and the mean IOC value was reported as 1.00, suggesting satisfactory content validity.
- The revised assessment instrument was administered to a pilot group of 30 students who had previously completed the relevant coursework but were not part of the actual study sample, and the resulting data were used to evaluate the psychometric quality of the instrument by calculating the item difficulty index (P) and the discrimination index (D) for each item.
- Items were selected in accordance with the following criteria: an item difficulty index (P) ranging from 0.20 to 0.80 and a discrimination index (D) of at least 0.20. Although 29 items met these criteria, 20 were ultimately selected for the final version of the instrument.
- The reliability of the assessment was evaluated using the Kuder-Richardson Formula 20 (KR-20), and the analysis yielded an internal consistency coefficient of 0.80.
- The final version of the instrument served as both the pre-test and post-test.

2) Assessment form for hard skills and soft skills

The assessment instrument was developed and validated in accordance with the following procedural steps:

- The relevant evaluation criteria and instructional objectives were thoroughly reviewed.
- The assessment was designed using analytic scoring rubrics, encompassing (1) hard skills assessment and (2) soft skills assessment.
- The hard skills assessment comprised three criteria, as illustrated in Table 4.
 - Knowledge of 2D animation
 - Ability to create 2D animation
 - Creativity in 2D animation production.
- The soft skills assessment comprised five criteria, as detailed in Table 5.
 - Work planning
 - Ability to collaborate with others
 - Ability to express opinions and accept others' opinions
 - Leadership ability
 - Presentation skills.
- Learners' hard skills and soft skills were evaluated using a four-level analytic rubric (4-point Likert-type scale), as detailed in Tables 4 and 5.
 - 4 = Excellent
 - 3 = Good
 - 2 = Fair
 - 1 = Needs Improvement.
- The scoring rubric was subjected to expert review by a panel of three specialists using the Item-Objective Congruence (IOC) index. The experts assessed the validity of both the hard skills and soft skills instruments, and the evaluation yielded a mean IOC value of 1.00, suggesting satisfactory content validity. Subsequently, the rubric was refined based on expert feedback before being finalized for implementation.
- The scoring rubric was used to evaluate learners' performance across both individual and collaborative tasks.

Table 4. Assessment criteria for hard skills

Assessment Items	Assessment Criteria			
	Excellent	Good	Fair	Needs Improvement
1. Knowledge of 2D animation	Post-test score > 80%	Post-test score > 70%	Post-test score > 50%	Post-test score < 50%
2. Ability to create 2D animation	- Attractive colors - Appropriate composition - Meets the design brief (100%)	- Attractive colors - Composition still insufficient - Meets the design brief (>80%)	- Colors are still insufficient - Composition still insufficient - Meets the design brief (>50%)	- Lacks color - Composition still insufficient - Does not meet the design brief
3. Creativity in 2D animation production	- Exceeds the given task requirements - Uses techniques beyond those specified - Realistic and engaging	- Exceeds the given task requirements - Uses techniques beyond those specified	- Meets the given task requirements (100%) - Uses techniques beyond those specified	Does not meet the given task requirements

Table 5. Assessment criteria for soft skills

Assessment Items	Assessment Criteria			
	Excellent	Good	Fair	Needs Improvement
1. Work planning	- Plans work systematically, step-by-step - Written in a clear format - Performs duties according to responsibilities	- Plans work step-by-step - Written in a clear format	- Plans work, but not step-by-step - Not written in a clear format	No work planning
2. Ability to collaborate with others	Always cooperates well with others	Cooperates well with others	Cooperates with others sometimes	No cooperation with others
3. Ability to express opinions and accept others' opinions	- Able to express opinions - Accepts others' opinions - Listens and accepts others' opinions well	- Expresses opinions - Accepts others' opinions	- Expresses opinions - Does not accept others' opinions	- Does not express opinions - Does not accept others' opinions - Opposes others' opinions
4. Leadership ability	Always demonstrates leadership	Demonstrates good leadership	Shows leadership occasionally	Lacks leadership
5. Presentation skills	- Voice is loud and clear - Concise and to the point - Good personality and confident	- Voice is loud and clear - To the point - Good personality	- Voice is loud and clear - To the point - Personality needs improvement	- Soft voice - Not to the point - Lacks personality

3) Description of the application

The ADDIE model was prioritized over other instructional design methodologies due to its systematic and iterative nature, as well as its demonstrated adaptability to technology-enhanced learning environments. Unlike alternative models that emphasize linear or content-centric strategies, the ADDIE model provides a comprehensive and cyclical process that may facilitate alignment with the requirements of iterative application development. This structured approach suggests that each phase of the study, from the development of research instruments to the execution of data analysis, may be conducted in a rigorous and systematic manner [28].

The application was designed for smartphone integration using the ADDIE model, which comprises the following phases. Each consecutive phase informed the subsequent design and development of the application.

Phase 1: Analysis. This initial phase involved a comprehensive examination of the instructional content, behavioral objectives, and relevant technologies illustrated in Fig. 2.

The application's functional structure was developed to operationalize the core processes of PBL within a systematic and sequential framework. As shown in Table 6, each module of the application is aligned with a specific PBL phase, suggesting a mechanism that may facilitate learners' engagement in the associated pedagogical activities.

As shown in Table 6, the Content Module aligns with the

driving question, planning, and inquiry phases by providing course orientation, instructional materials, and guided learning activities that support learners in comprehending the problem context and planning their work strategically.

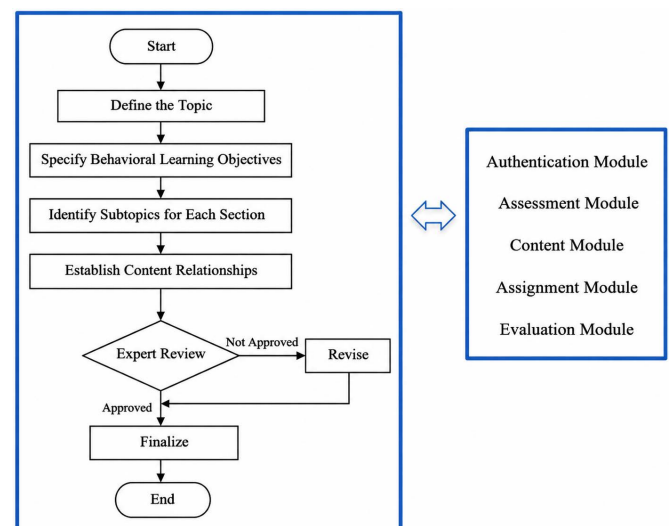


Fig. 2. Analysis phase.

The Assignment Module facilitates collaboration and artifact creation by enabling learners to work together through group worksheets, engage in team discussions, and produce 2D animation outputs as project artifacts.

The Assessment Module supports the reflection and presentation phases by providing opportunities for learners to

present their findings, receive constructive feedback, and reflect on their learning outcomes.

Table 6. Application and PBL integration analysis

PBL Principle	Application Feature	Learning Activity
Driving Question	Content Module	Course orientation session
Planning and Inquiry	Content Module	Planning, inquiry, and learning
Collaboration	Assignment Module: Group Worksheet	Team planning and discussion
Artifact Creation	Assignment Module: Individual Worksheet	Create 2D animation
Reflection and Presentation	Assessment Module	Presentation of the group worksheet

Through this structured alignment, the application serves as a digital environment that supports the consistent implementation of PBL processes and provides a framework that guides learners through each stage of PBL.

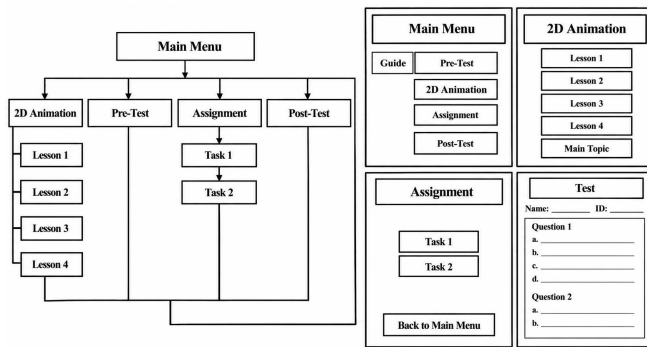


Fig. 3. User interface designs.

Phase 3: Development. The development phase involved the production of instructional content, with Adobe Animate CC used to generate 2D animation sequences. Adobe Premiere was used to synchronize the animated files with multimedia elements, including text, narration, sound effects, and background music, as illustrated in Fig. 5. The application was developed for cross-platform functionality on both iOS and Android, using the Flutter framework.

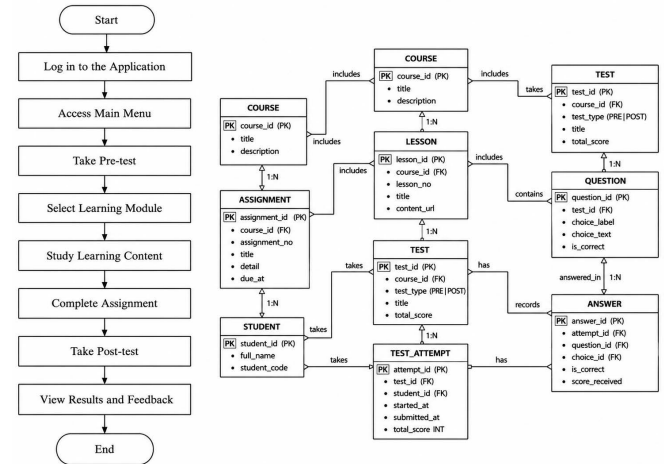


Fig. 4. Workflow diagrams.

Phase 2: Design. Workflow diagrams and user-interface designs were developed in the design phase, as illustrated in Figs. 3 and 4.

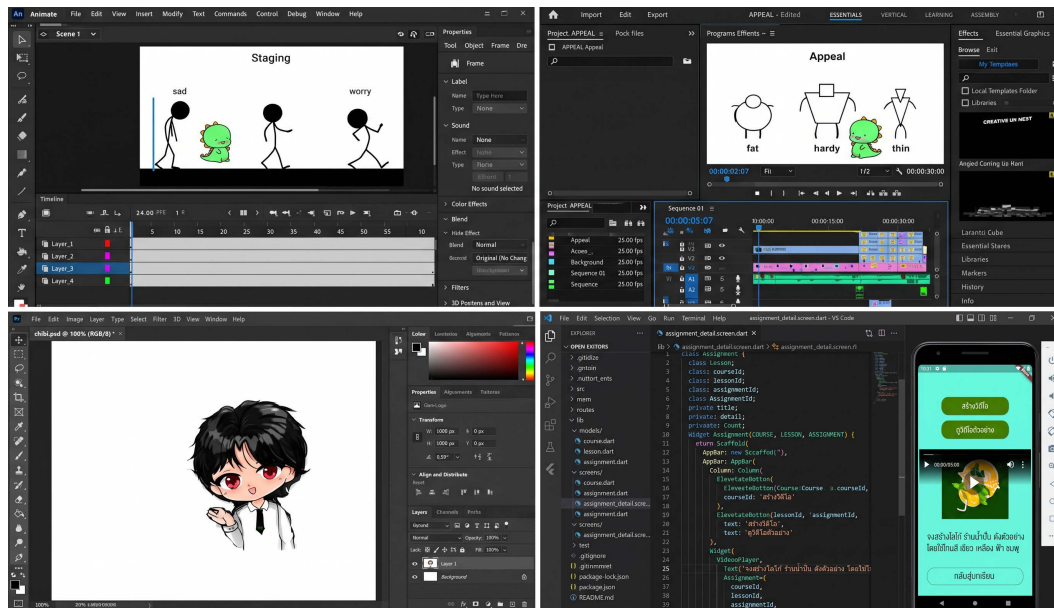


Fig. 5. Development phase.

Phase 4: Implementation. An expert-based evaluation of the application was conducted to identify potential technical issues and pedagogical challenges.

This initial trial used structured observation and interviews to elicit comprehensive feedback regarding issues encountered during the evaluation process. The qualitative insights obtained were subsequently used to refine the functionality and interface of the application, as illustrated in Fig. 6. Expert feedback primarily addressed system usability, technical functionality, and instructional clarity.

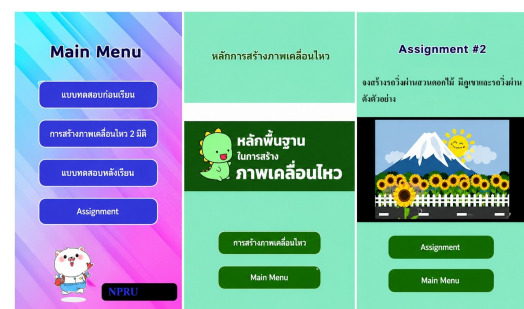


Fig. 6. Refined application interface based on expert evaluation.

Phase 5: Evaluation. A standardized quality-assessment instrument was employed to evaluate the application across two primary domains: content accuracy and instructional-media production.

D. Data Collection

Week 1:

- (1) Course Orientation: Participants were briefed on the 2D Animation Production course, including administrative rules, learning procedures, instructional methods, and assessment criteria. The instructor used a detailed scoring guide, supplemented with exemplar artifacts, to help minimize scoring subjectivity.
- (2) Instructional Format Clarification: The instructor elaborated on the structure and pedagogical format of the instructional activities.
- (3) Pre-test Administration and Student Grouping: Prior to the instructional intervention, students completed a pre-test to assess their foundational knowledge. Each student was assigned a dedicated workstation. The assessment comprised 20 multiple-choice items, each containing four alternatives, with automated randomization applied to both items and distractors.

The examination was limited to 20 min. Based on the resultant scores, students were grouped into triads. Each group comprised one high-performing, one average-performing, and one low-performing student to achieve a heterogeneous composition. This grouping strategy was designed to facilitate peer learning and promote equitable team collaboration.

Week 2:

- (1) Provision of Structured Learning Resources: The instructor provided access to instructional content and application-based materials.
- (2) Instructional Session: Learners interacted with the prescribed learning content for a duration of two hours.
- (3) Collaborative Task Performance: Participants were required to complete two distinct types of worksheets. Initially, each triad collaboratively completed a group worksheet related to the lesson topic within a two-hour timeframe.
- (4) Performance Assessment: Two instructors evaluated students' soft-skills-related behaviors using an observation checklist during the instructional activities. The final composite score reflected the mean value derived from the two raters.

This methodological approach was employed to enhance inter-rater reliability and help reduce subjectivity in soft skills assessment.

Week 3:

- (1) Individual Task Performance: Each student completed an individual worksheet within a 90-minute timeframe.
- (2) Performance Assessment: Two instructors evaluated students' project work related to hard skills. The final score reflected the mean value derived from the two raters.
- (3) Post-test Administration: Following the instructional intervention, students completed a post-test under conditions identical to those of the pre-test. Each student used a dedicated workstation to complete a 20-item multiple-choice assessment, with automated

randomization applied to both items and distractors. The examination was limited to 20 min.

Week 6:

1) Retention test (Re-test)

- (1) Each student independently completed an individual worksheet within a 90-minute timeframe. Students' project work (hard skills) was assessed based on the mean value derived from two raters.
- (2) Each group collaboratively completed a group worksheet related to the lesson topic within a two-hour period. Students' soft skills behaviors were evaluated using an observation checklist, with final scores reflecting the mean value derived from two raters.
- (3) Students then completed a re-test under conditions identical to those of the pre-test and post-test. The examination was limited to 20 min.

2) Data Compilation

Results obtained from the pre-test, post-test, re-test, and performance assessments were systematically compiled and prepared for subsequent statistical analysis.

E. Data Analysis

The quality of the application was evaluated using descriptive statistics, specifically the Mean (M) and Standard Deviation (SD). Learners' achievement was analyzed using the mean, SD, and a paired-samples t-test to examine significant differences.

Knowledge retention was examined using a one-way repeated-measures ANOVA, with a significance level of 0.05, to assess the long-term impact of the application. Furthermore, learners' hard skills and soft skills were evaluated using the mean, SD, and inter-rater reliability (measured via Cohen's kappa coefficient).

This analytical approach helped ensure that performance evaluation within the 2D Animation Production course met the required standards of objectivity and consistency.

The interpretation of the mean scores followed the interval criteria established for the Likert-type scale [38, 39].

3.26–4.00	highest level
2.51–3.25	high level
1.76–2.50	low level
1.00–1.75	lowest level.

Inter-rater reliability was evaluated using Cohen's kappa coefficient, calculated according to Eq. (2) [40].

$$\kappa = \frac{P_o - P_e}{1 - P_e} \quad (2)$$

where:

κ denotes Cohen's kappa coefficient;

P_o represents the observed proportion of agreement between the independent raters;

P_e signifies the expected proportion of agreement occurring by chance.

The interpretation of Cohen's kappa (κ) was conducted in accordance with the benchmarks proposed by Landis and Koch (1977) [40].

$\kappa < 0.00$	Poor agreement
0.00–0.20	Slight agreement
0.21–0.40	Fair agreement
0.41–0.60	Moderate agreement

- 0.61–0.80 Substantial agreement
0.81–1.00 Almost perfect agreement.

IV. RESULTS AND DISCUSSION

A. Results

The results derived from the expert-based evaluation of the application for Project-Based Learning in 2D Animation

Production are summarized in Table 7.

The assessment of content quality and media-production techniques by three experts suggested that the application's overall quality was at the highest level, with a mean score of 4.67 (SD = 0.48).

Such empirical data suggest that the application met established quality standards, as indicated by expert consensus.

Table 7. Expert evaluation of the application

Evaluation Items	Evaluation Criteria	M	SD	Quality Level
Content Quality	1. Alignment of content with learning objectives	5.00	0.00	Highest
	2. Accuracy and completeness of content	4.67	0.58	Highest
	3. Clarity and comprehensibility of language	4.33	0.58	High
	4. Clarity of content organization	4.33	0.58	High
	5. Appropriateness of content length	5.00	0.00	Highest
Media Production Technique	1. Accessibility and ease of use of the application	4.33	0.58	High
	2. Ease of use of the menu interface	5.00	0.00	Highest
	3. Aesthetic quality of the menu design	5.00	0.00	Highest
	4. Appropriateness of lesson illustrations	4.67	0.58	Highest
	5. Clarity and readability of the lesson text	5.00	0.00	Highest
	6. Aesthetic appeal and visual engagement of characters	4.67	0.58	Highest
	7. Animation quality of characters and illustrations	4.33	0.58	High
	8. Suitability of the voice narration	4.33	0.58	High
	9. Appropriateness of background music	4.67	0.58	Highest
	10. Overall attractiveness of the application	4.67	0.58	Highest
Overall		4.67	0.48	Highest

The results regarding the application's potential effectiveness are presented as follows.

Table 8. Results of the application's instructional effectiveness ($N = 51$)

Test Phase	Full Score	M	SD	Effectiveness Index
Pre-Test	20	7.06	2.12	1.12
Post-Test	20	15.82	2.70	

*Meguigan's effectiveness index criterion >1.00

As illustrated in Table 8, the mean achievement score increased from 7.06 (pre-test) to 15.82 (post-test). Meguigan's effectiveness index was 1.12, exceeding the criterion of 1.00 and suggesting an acceptable level of instructional effectiveness within this specific context.

The comparative results for learners' pre-test and post-test achievement scores following the utilization of the application are summarized in Table 9.

Table 9. Comparison of pre-test and post-test achievement scores ($N = 51$)

Test Phase	Full Score	M	SD	<i>t</i>	<i>df</i>	<i>p</i>
Pre-Test	20	7.06	2.12	25.40	50	< 0.001
Post-Test	20	15.82	2.70			

*sig = 0.05, Hedges' $g = 3.50$, 95% CI [2.77, 4.24].

As indicated in Table 9, the learners' post-test achievement scores following the utilization of the application were significantly higher than their pre-test scores at the 0.05 significance level. The effect size, estimated using Hedges' g , was 3.50 (95% CI [2.77, 4.24]), suggesting a large effect size and practical significance within this educational context.

However, given the limitations of the one-group pre-test-post-test design, these findings suggest the application's potential to facilitate improvements in academic achievement rather than providing evidence of definitive causal relationships.

The results of the one-way repeated-measures ANOVA, comparing academic achievement across the pre-test,

post-test, and re-test phases, are summarized in Table 10. Specifically, the analysis revealed statistically significant differences across the three assessment phases ($F(2, 100) = 703.64$, $p < 0.001$). Both post-test and re-test scores were significantly higher than those for the initial pre-test, suggesting that the instructional intervention utilizing the application may have facilitated improvements in learners' academic achievement while supporting knowledge retention, as reflected in the re-test phase.

Table 10. Repeated-measures ANOVA (pre-test, post-test, re-test) ($N = 51$)

Test Phase	Full Score	M	SD	<i>F</i>	<i>df</i>	<i>p</i>
Pre-Test	20	7.06	2.12	703.64	2, 100	<0.001
Post-Test	20	15.82	2.70			
Re-Test	20	16.18	2.38			

*sig = 0.05

In light of the findings presented in Table 10, these results should be interpreted with caution, particularly given the absence of a control group within the experimental framework.

The results regarding learners' hard skills following the utilization of the application, as assessed by two independent raters, are summarized in Table 11.

Table 11. Hard skills results following the application's utilization ($N = 51$)

Assessment Items	M	SD	Quality Level
1. Knowledge of 2D animation	3.43	0.85	Highest
2. Ability to create 2D animation	3.14	0.78	High
3. Creativity in 2D animation production	3.05	0.80	High
Overall	3.21	0.84	High

As illustrated in Table 11, learners demonstrated a high level of hard skills following the intervention. Regarding specific dimensions, knowledge of 2D animation had a mean score of 3.43 (SD = 0.85), classified as the highest level. The ability to create 2D animation received a mean score of 3.14

(SD = 0.78), indicating a high level. Similarly, creativity in 2D animation production exhibited a mean score of 3.05 (SD = 0.80), indicating a high level.

Considering all dimensions collectively, the overall mean score was 3.21 (SD = 0.84), suggesting that learners' hard skills following the utilization of the application were at a

high level. These findings were derived from rubric-based performance assessments conducted by two independent raters.

The results regarding learners' hard skills and the associated inter-rater reliability following the utilization of the application are summarized in Table 12.

Table 12. Hard skills results and inter-rater reliability following the application's utilization ($N = 51$)

Assessment Items	M (SD)		% Agreement		Cohen's κ	
	Post-Test	Re-Test	Post-Test	Re-Test	Post-Test	Re-Test
1. Knowledge of 2D animation	3.43 (0.85)	3.51 (0.73)	100*	100*	1.00*	1.00*
2. Ability to create 2D animation	3.14 (0.78)	3.23 (0.80)	80.39	82.35	0.70	0.73
3. Creativity in 2D animation production	3.05 (0.80)	3.30 (0.79)	82.35	82.35	0.74	0.72
Overall	3.21 (0.84)	3.35 (0.80)	87.58	88.24	0.81	0.81

*post-test score, **Interpretation of Cohen's κ : 0.61–0.80 = Substantial; 0.81–1.00 = Almost perfect.

Table 12 presents the assessment results for the learners' hard skills following the utilization of the application, comparing the post-test and re-test phases. The findings suggest that learners demonstrated high levels of performance, while the inter-rater reliability of the assessments was consistently high. In the post-test phase, the overall mean score was 3.21 (SD = 0.84). The percentage of agreement between raters was 87.58%, and Cohen's kappa coefficient was 0.81, suggesting an almost perfect level of agreement. These results suggest a high level of inter-rater consistency in assessing learners' hard skills.

At the individual assessment level, knowledge of 2D animation revealed a Cohen's kappa coefficient of 1.00 in the post-test, suggesting almost perfect agreement. In contrast, the dimensions of ability to create 2D animation and creativity in 2D animation production exhibited Cohen's kappa values of 0.70 and 0.74, respectively, suggesting substantial agreement.

In the re-test phase, the overall mean score was 3.35 (SD = 0.80). The percentage of agreement increased slightly to 88.24%, while Cohen's kappa coefficient remained at 0.81, suggesting an almost perfect level of agreement. This suggests that inter-rater reliability remained high following the utilization of the application. When examined by individual dimensions in the re-test phase, Cohen's kappa coefficients ranged from 0.72 to 1.00, suggesting substantial to almost perfect agreement across all assessed hard skills domains.

These findings suggest that the assessment criteria were clearly defined and consistently applied by the two independent raters across both evaluation phases. These results suggest the reliability and temporal stability of the rubric-based assessment within the 2D Animation Production course, indicating a sufficiently structured framework for stable and replicable outcomes.

The results regarding learners' soft skills following the utilization of the application, as assessed by two independent raters, are summarized in Table 13.

Table 13. Soft skills results following the application's utilization ($N = 51$)

Assessment Items	M	SD	Quality Level
1. Work planning	3.25	0.80	High
2. Ability to collaborate with others	3.16	0.85	High
3. Ability to express opinions and accept others' opinions	3.38	0.71	Highest
4. Leadership ability	3.31	0.76	Highest
5. Presentation skills	3.01	0.80	High
Overall	3.22	0.81	High

As illustrated in Table 13, the overall findings suggest that learners demonstrated a high level of soft skills following the utilization of the application, derived from the mean scores of two independent raters. At the individual dimension level, work planning had a mean score of 3.25 (SD = 0.80), suggesting a high level. The ability to collaborate with others received a mean score of 3.16 (SD = 0.85), reflecting a high level. The ability to express opinions and accept others' opinions exhibited the highest mean score of 3.38 (SD = 0.71), suggesting the highest level. Furthermore, leadership ability had a mean score of 3.31 (SD = 0.76), indicating the highest level. Finally, presentation skills yielded a mean score of 3.01 (SD = 0.80), indicating a high level.

Collectively, the overall composite mean score was 3.22 (SD = 0.81), suggesting that learners' soft skills following the utilization of the application reached a high level. These findings further suggest that learners demonstrated strong performance across the various dimensions of soft skills.

The results regarding learners' soft skills and the associated inter-rater reliability following the utilization of the application are summarized in Table 14.

Table 14. Soft skills results and inter-rater reliability following the application's utilization ($N = 51$)

Assessment Items	M (SD)		% Agreement		Cohen's κ	
	Post-Test	Re-Test	Post-Test	Re-Test	Post-Test	Re-Test
1. Work planning	3.25 (0.80)	3.41 (0.65)	82.35	84.31	0.73	0.73
2. Ability to collaborate with others	3.16 (0.85)	3.23 (0.88)	88.24	86.27	0.82	0.79
3. Ability to express opinions and accept others' opinion	3.38 (0.71)	3.33 (0.79)	86.27	88.24	0.77	0.81
4. Leadership ability	3.31 (0.76)	3.17 (0.85)	84.31	90.20	0.74	0.85
5. Presentation skills	3.01 (0.80)	3.31 (0.68)	82.35	84.31	0.72	0.74
Overall	3.22 (0.81)	3.29 (0.79)	84.71	86.67	0.76	0.81

**Interpretation of Cohen's κ : 0.61–0.80 = Substantial; 0.81–1.00 = Almost perfect.

Table 14 presents assessment results for the learners' soft skills following the utilization of the application, comparing

the post-test and re-test phases. The overall findings suggest that learners demonstrated high levels of soft skills, and the

inter-rater reliability was high across both phases. In the post-test phase, the overall mean score was 3.22 (SD = 0.81). The percentage of agreement between raters was 84.71%, and Cohen's kappa coefficient was 0.76, suggesting substantial agreement. These results suggest a high level of inter-rater consistency in assessing learners' soft skills.

At the individual skill level, work planning, the ability to express opinions and accept others' opinions, leadership ability, and presentation skills exhibited Cohen's kappa coefficients ranging from 0.72 to 0.77, suggesting substantial agreement. The ability to collaborate with others showed a higher level of agreement, with a Cohen's kappa coefficient of 0.82, suggesting almost perfect agreement.

In the re-test phase, the overall mean score was 3.29 (SD = 0.79). The percentage of agreement was 86.67%, and Cohen's kappa coefficient was 0.81, suggesting almost perfect agreement. This indicates that assessment reliability remained high following the intervention.

When examined by individual dimensions in the re-test phase, Cohen's kappa coefficients ranged from 0.73 to 0.85, suggesting substantial to almost perfect agreement across all soft skills domains. Notably, the ability to express opinions and accept others' opinions and leadership ability exhibited Cohen's kappa values of 0.81 and 0.85, respectively, suggesting almost perfect agreement.

Overall, the findings indicate that learners demonstrated high levels of proficiency in both hard skills and soft skills following their utilization of the application, while the assessments yielded high to very high inter-rater reliability coefficients across both evaluation phases. These results further suggest the consistency and temporal reliability of the rubric-based assessment across both assessment intervals.

B. Discussion

These findings suggest that the developed Project-Based Learning (PBL) application may have contributed to improvements in learners' achievement within the 2D Animation Production course. The substantial increase in post-test scores, supported by a large effect size (Hedges' $g = 3.50$, 95% CI [2.77, 4.24]) and Meguigan's effectiveness index of 1.12, indicates that the intervention may have had a meaningful practical impact on participants' learning outcomes. These results are consistent with the characteristics of effective PBL, which emphasize active engagement and the application of knowledge in authentic contexts. However, despite the overall positive trend, a closer examination of the results suggests several pedagogical considerations that should be acknowledged to avoid overgeneralized conclusions.

The significant increase in post-test and re-test scores compared to pre-test scores suggests that the developed application may have supported learners' conceptual understanding and knowledge retention. This finding is consistent with previous studies reporting that PBL may promote deeper learning through sustained inquiry, learner autonomy, and the creation of meaningful artifacts [5, 11]. In technology-enhanced environments, PBL has been reported to facilitate active engagement and knowledge construction by allowing learners to apply theoretical concepts to authentic tasks [12]. These findings align with prior literature, suggesting that PBL, particularly when facilitated through the

application, may promote active engagement and foster the development of applied competencies in practice-oriented disciplines.

However, the findings of this study indicate that the significant pre-test–post-test difference, together with a large effect size and an effectiveness index exceeding the acceptable threshold, may indicate a meaningful practical impact within this specific instructional context. The findings should also be interpreted in accordance with the study's methodological limitations. The use of a one-group pre-test–post-test design without a comparison group limits the ability to draw causal inferences. Observed enhancements in learning outcomes suggest that the results could be influenced by extraneous variables, such as prior knowledge, learner motivation, or familiarity with assessment formats. Furthermore, the relatively large effect size may reflect specific instructional conditions, including the short-term, intensive nature of the intervention and the novelty of the application.

From an assessment perspective, this study provides methodological evidence supporting the integration of rubric-based performance assessment with inter-rater reliability analysis to evaluate combined hard skills and soft skills [20]. Although soft skills are often considered difficult to measure due to their latent and context-dependent nature, the substantial to almost perfect Cohen's kappa values observed in this study suggest that well-structured rubrics, when aligned with learning objectives and supported by clear performance descriptors, may yield reliable assessments of complex competencies. These findings help address common concerns regarding subjectivity in soft skills assessment and support the use of rubric-based approaches in applied learning contexts. This contrasts with prior studies examining learners' satisfaction as the sole outcome measure or focused on learners' achievement [25, 26].

Regarding hard skills, the rubric-based performance assessment indicated that learners demonstrated a relatively high level of technical competence in 2D animation, including knowledge, production skills, and creativity. These findings are consistent with prior studies by Untari [8] and Ramadhan [9], who reported that multimedia-supported PBL may improve learners' technical performance and creative output in animation-related courses. The application facilitated structured learning resources, visual demonstrations, and iterative project tasks, and this framework suggests its potential to support the transition of conceptual knowledge into practical competencies. Importantly, the high to very high inter-rater reliability observed across test and re-test phases suggests that the assessment criteria were clearly defined and consistently interpreted, thereby helping to address a common methodological concern in performance-based evaluation [40].

In terms of soft skills, learners demonstrated a relatively high level of performance across all evaluated dimensions, including work planning, collaboration, communication, leadership, and presentation skills. These results indicate that PBL environments may be particularly effective in cultivating transferable competencies through collaborative problem-solving and shared responsibility [19]. These results align with the extant literature, suggesting that the

development of soft skills requires authentic social interaction and contextualized practice, both of which are core attributes of PBL [21].

While overall scores were high, a slight decline was observed in certain soft skills dimensions during the re-test phase, particularly in leadership ability (from 3.31 to 3.17) and the capacity to express opinions and accept others' opinions (from 3.38 to 3.33). This downward trend suggests that as projects progressed toward completion, increased pressure and technical complexity may have contributed to challenges in group dynamics, making it more difficult to maintain consensus and leadership. Furthermore, technical competencies such as creativity in 2D animation production (3.05) were consistently lower than those demonstrated in procedural tasks, such as work planning, indicating a potential variation in skill mastery. This disparity suggests that, while a PBL framework supported through the application may effectively support learning workflows, fostering deep creativity and high-level interpersonal skills remains a complex challenge, potentially requiring longer-term intervention and more direct faculty mentorship.

Additionally, the exceptionally high effect size should be interpreted with caution, given the limitations of the one-group design. In the absence of a control group, the findings should also be interpreted in light of the study's methodological limitations. The adoption of a one-group pre-test–post-test design lacking a comparison group suggests that the ability to derive causal inferences may be constrained. The observed enhancements in learning outcomes indicate that the results could be influenced by extraneous variables, such as prior knowledge, learner motivation, or familiarity with assessment formats. Moreover, the relatively large effect size may reflect specific instructional conditions—encompassing the short-term, intensive nature of the intervention and the novelty of the application—potentially influencing the findings.

Collectively, these findings suggest that the developed application may serve as a supportive instrument for implementing PBL within practice-oriented courses, such as 2D Animation Production. However, the potential effectiveness of the application should be interpreted as context-dependent rather than universally generalizable. It is suggested that future research expand the empirical evidence base by employing more rigorous experimental or quasi-experimental designs. Specifically, incorporating comparison groups and extending the intervention's duration may facilitate longitudinal analyses of knowledge retention and the sustained development of soft skills within the 2D Animation Production course.

C. Limitations and Threats to Validity

The findings of this study should be interpreted with caution due to several limitations. The adoption of a one-group pre-test–post-test design lacking a comparison group suggests that caution is warranted regarding causal inferences, as observed improvements may have been influenced by extraneous factors such as prior knowledge, learner motivation, or testing effects rather than the intervention exclusively. The sample was derived from a single cohort within a localized institutional context, and this focus suggests that the generalizability of the findings to

diverse educational environments may be constrained. Although a rubric-based assessment with inter-rater reliability was employed, the evaluation of complex competencies, particularly soft skills, suggests that some subjective interpretation may persist. In addition, the relatively short duration of the intervention limits conclusions regarding long-term retention and sustained skill development. The large effect size should be interpreted with caution, as it may reflect specific instructional conditions rather than a precise estimate of the application's potential effectiveness. Overall, these findings suggest preliminary indications, and further research utilizing more robust methodologies and longer durations is needed to validate and generalize the outcomes within the context of the 2D Animation Production course.

V. CONCLUSION

The present study examined the development and potential effectiveness of a PBL application intended to enhance hard skills and soft skills in a 2D Animation Production course. Analysis of learners' achievement revealed that post-test scores were significantly higher than pre-test scores, suggesting the application's potential to support knowledge acquisition. The findings suggest an acceptable level of instructional effectiveness, as evidenced by improvements in learners' achievement following the intervention.

Furthermore, learners demonstrated high proficiency in both hard skills and soft skills, including knowledge, technical ability, creativity in 2D animation production, work planning, collaboration, communication, leadership, and presentation. These outcomes were supported by consistent inter-rater reliability in rubric-based assessments. Overall, these results suggest that the application may serve as a valuable tool to facilitate PBL in practice-oriented courses.

However, given the study's methodological limitations, these results should be considered preliminary and context-specific rather than definitive. Further research employing more rigorous methodologies and extended study durations is recommended to strengthen the evidence base and explore potential longitudinal effects.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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REFERENCES

- [1] Ratchakitcha, The Thirteenth National Economic and Social Development Plan 2023-2027, Office of The Prime Minister, 2022.
- [2] V. Wongyai and M. Phatpon, *Creative Integration*, 1st ed. Innovative Leaders Centre of Curriculum and Learning, 2019.
- [3] Ministry of Education, *National Education Act B.E. 2542(2) (B.E. 2545)*, 2nd ed. Express Transportation Organization of Thailand, 2002.
- [4] V. Panich, *The Way to Create Learning for Students in the 21st Century*, 1st ed. Sodsri-siriwong foundation, 2012.
- [5] P. Guo *et al.*, "A review of project-based learning in higher education: Student outcomes and measurement instruments," *International Journal of Educational Research*, vol. 102, 101586, May 2020. doi: 10.1016/j.ijer.2020.101586

- [6] J. W. Thomas. (2000). *A Review of Research on Project-Based Learning*. The Autodesk Foundation. [Online]. Available: https://tecfa.unige.ch/proj/eteachnet/Thomas_researchreview_PBL.pdf?utm_source=chatgpt.com
- [7] P. Tiranathanakul, P. Kiattikomol, and S. Yampinij, *Design and Producing Computer Instruction Package for E-Learning*, 1st ed. Bangkok: Media Center of Bangkok. 2003.
- [8] R. S. Untari *et al.*, "The development and application of interactive multimedia in project-based learning to enhance students' achievement for 2D animation making," *International Journal of Emerging Technologies in Learning.*, vol. 15, no. 16, pp. 4–16, August 2020. doi: 10.3991/ijet.v15i16.16521
- [9] S. M. Ramadnan and H. Harmayani, "Development of the project-based learning model in making teaching modules for courses multimedia technology and animation," *Journal of Computer Networks Architecture and High Performance Computing.*, vol. 6, no. 1, pp. 449–460, February 2024. doi: 10.47709/cnahpc.v6i1.3519
- [10] T. Khammanee, *Teaching Sciences*, 23th ed. Chulalongkorn University publishing house, 2019.
- [11] A. M. Almula, "The effectiveness of the Project-Based Learning (PBL) approach as a way to engage students in learning," *SAGE Open.*, vol. 10, no. 3, pp. 1–15, July 2020. doi: 10.1177/2158244020938702
- [12] R. S. Garcia and S. R. Cozar, "Enhancing project-based learning: A framework for sustainable education," *Sustainability.*, vol. 17, no. 11, 4978, May 2025. doi: 10.3390/su17114978
- [13] D. Yoelao, *PBL Learning Management from the Construction Project Knowledge Set to Enhance the Skills of the 21st Century of Children and Youth: from the Success Experience of Thai Schools*, 2nd ed. Bangkok, Thippayawisut LP, 2014.
- [14] A. Panmanee, *Training to Think Creatively*, 1st ed. Chulalongkorn University Publishing House, 2014.
- [15] M. Saimon *et al.*, "Enhancing the 4Cs among college students of a communication skills course in Tanzania through a project-based learning model," *Education and Information Technologies.*, vol. 28, pp. 6269–6285, November 2022. doi: 10.1007/s10639-022-11406-9
- [16] J. Petchamé *et al.*, "Student perceptions of project-based learning when studying 'information systems' in an ICT engineering program: Taking advantage of active learning," *Education Sciences.*, vol. 14, no. 11, 1148, October 2024. doi: 10.3390/educsci14111148
- [17] S. Bell, "Project-based learning for the 21st century: Skills for the future," *The Clearing House: A Journal of Educational Strategies, Issues and Ideas.*, vol. 83, no. 2, pp. 39–43, July 2010. doi: 10.1080/00098650903505415
- [18] C. H. Chen and Y. C. Yang, "Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators," *Educational Research Review.*, vol. 26, pp. 71–81, February 2019. doi: 10.1016/j.edurev.2018.11.001
- [19] J. Lamri and T. Lubart, "Reconciling hard skills and soft skills in a common framework: The generic skills component approach," *Journal of Intelligence.*, vol. 11, no. 6, pp. 1–19, June 2023. doi: 10.3390/jintelligence11060107
- [20] S. Panthumas, K. Zaw, and W. Kittipichai, "Validation of the 21st century skills assessment scale for public health students in Thailand: A methodological study," *Journal of Educational Evaluation for Health Professions.* vol. 21, no. 37, pp. 1–9, December 2024. doi: 10.3352/jeehp.2024.21.37
- [21] Á. E. Gascón *et al.*, "How to measure soft skills in the educational context: The SKILLS-in-ONE," *Evaluation and Program Planning.* vol. 74, pp. 1–14, September 2022. doi: 10.1016/j.evalprogplan.2022.102168
- [22] T. Theerathean. (2021). Hard skills + soft skills 7 trend in education. Starfish Academy. [Online]. Available: <https://www.starfishlabz.com/blog/48-hard-skills-soft-skills>
- [23] B. M. Mutanga, "Students' perspectives and experiences in project-based learning: A qualitative study," *Trends in Higher Education.*, vol. 3, no. 4, pp. 903–911, October 2024. doi: 10.3390/higheredu3040052
- [24] A. Saad, "The effectiveness of project based learning with computational thinking techniques in a software engineering project course," *Journal of Contemporary Issues and Thought.*, vol. 12, no. 1, pp. 65–79, January 2022. doi: 10.37134/jcit.vol12.1.6.2022
- [25] I. G. P. Sindu and A. A. J. Permana, "Developing E-learning-based collaborative learning models to improve learning outcomes of multimedia technology courses," in *Proc. International Conference on Vocational Education and Technology 2021*, Bali, Indonesia, November 27, 2021. doi: 10.4108/eai.27-11-2021.2315629
- [26] N. F. Jumaat and Z. Tasir, "Integrating project based learning environment into the de-sign and development of mobile apps for learning 2D-animation," *Procedia—Social and Behavioral Sciences.*, vol. 103, pp. 526–533, November 2013. doi: 10.1016/j.sbspro.2013.10.369
- [27] A. I. Pratiwi *et al.*, "Development and effectiveness of multimedia interactive learning Scratch Wabimendu (World Indonesian Cultural Heritage)," *Frontiers in Education.*, vol. 10, pp. 1–13, October 2025. doi: 10.3389/educ.2025.1628412
- [28] N. I. Prasetya and N. Saurina, "Game-based learning in programming courses: A platform development for enhanced learning engagement," *International Journal of Information and Education Technology.*, vol. 15, no. 12, pp. 2593–2602, December 2025. doi: 10.18178/ijiet.2025.15.12.2455
- [29] G. A. Spatioti and M. Flood, "A comparative study of the ADDIE instructional design model in distance education," *Information.*, vol. 13, no. 9, 402, August 2022. doi: 10.3390/info13090402
- [30] J. G. Buddhini *et al.*, "Development of mobile applications through design-based research," *Asian Association of Open Universities Journal.*, vol. 13, no. 2, pp. 145–168, September 2018. doi: 10.1108/AAOUJ-02-2018-0013
- [31] T. Xie and Y. Song, "Analysis of computer application software automation development technology," *Advances in Computer and Communication.*, vol. 5, no. 1, pp. 20–25, April 2024. doi: 10.26855/acc.2024.02.003
- [32] M. Tiantong, *Courseware Design and Development for CAI*, 3rd ed. King Mongkut's University of Technology North Bangkok, 2011.
- [33] S. Pariyawatee, *2D Animation*, 1st ed. Bangkok, SE-EDUCATION Public Company Limited, 2022.
- [34] C. J. Ejimonye *et al.*, "Effectiveness of two-dimensional animation technique in enhancing students' motivation in quantitative economics concepts," *International Journal of Future Generation Communication and Networking.*, vol. 13, no. 1, pp. 27–38, March 2020. doi: 10.33832/ijfgcn.2020.13.1.03
- [35] T. C. Fitz-Gibbon and L. L. Morris, *How to Design a Program Evaluation*, Beverly Hills, CA: Sage, 1987.
- [36] S. Sikkhabhandit, *Educational Technology*, 1st ed. King Mongkut's University of Technology North Bangkok, 1985.
- [37] W. Hiranrat *et al.*, "The results of using online interactive learning to enhance English in daily life towards ASEAN for lower secondary students with hearing impairment: A case study of deaf school in surin province," *Information Technology Journal.*, vol. 19, no. 2, pp. 53–67, December 2023. doi: 10.14416/j.it.2023.v2.005
- [38] H. N. Boone and D. A. Boone, "Analyzing Likert data," *Journal of Extension.*, vol. 50, no. 2, pp. 1–5, April 2012. doi: 10.34068/joe.50.02.02
- [39] A. Joshi *et al.*, "Likert scale: Explored and explained," *British Journal of Applied Science & Technology.*, vol. 7, no. 4, pp. 396–403, January 2015. doi: 10.9734/BJAST/2015/14975
- [40] R. J. Landis and G. G. Koch, "The measurement of observer agreement for categorical data," *Biometrics.*, vol. 33, no. 1, pp. 159–174, March 1977. doi: 10.2307/2529310

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