Development of Hybrid Project-Based Learning Model for Multimedia Technology and Animation

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***Abstract*—Technological advancements, global initiatives, and digitization have led to a sustained demand for highly qualified engineers. However, the current state of engineering education has drifted apart from real-world requirements. Thus, it is crucial to identify the specific skills lacking in engineering graduates. Additionally, this research results can be useful for curriculum development, fostering collaboration between academic institutions and industry partners, and improving students' skills. This study aims to introduce a pioneering educational model that combines hybrid learning and Project-Based Learning (PBL) to address the needs and preferences of college students in the fields of multimedia technology and animation. The paper presents the development and implementation of the method, including an assessment of learner characteristics, expert assessments, peer evaluations, and limited tests. The experts involved as validators comprised three individuals from the fields of education, animation, and industry practitioners. The product testing was conducted in two classes: a control class with 20 students and a limited experimental class with 15 students. Based on the paired sample *t*-test, *p*-values of 0.001 for the multimedia technology course and 0.002 for the animation course were obtained at a significance level of 0.05. This suggests that there is a significant difference in the classes that implement the Hybrid Project-Based Learning (H-PBL) model. Additionally, instructional products were developed, including a model book, a learning materials book, a user guide for lecturers, a user guide for students, and teaching modules. Furthermore, this research also yielded an e-learning platform and online modules.**

***Keywords*—Project-Based Learning (PBL), multimedia technology, animation, hybrid learning**

I. Introduction

In recent years, the field of education has witnessed a paradigm shift towards innovative and effective teaching methodologies. One of such approaches that has gained immense popularity is hybrid learning, which combines traditional face-to-face instruction with online elements to enhance the learning experience [1–3]. Previous studies show a correlation between increased student engagement when learning with a hybrid learning model [4, 5]. According to the research paper of Johnson *et al.* [4], hybrid learning plays a role in enhancing the social engagement and computer literacy skills of students, particularly adult learners. Furthermore, Rini *et al.* [6] demonstrated that younger university students, meaning those from newer academic cohorts, exhibit higher positive responses to online-based learning compared to older cohorts. Hence, the development of hybrid learning models tailored to the needs of students becomes crucial.

Previous studies collectively provide evidence of the effectiveness of Project-Based Learning (PBL) and hybrid or blended learning models in enhancing various aspects of students' educational experiences [7–9]. These studies demonstrate the positive impact of a Hybrid Project-Based Learning (H-PBL) model on students' knowledge gain, satisfaction, behavioral intention to use, and academic achievement [10]. In addition, PBL has been shown to enhance students' creativity in product creation [11]. Furthermore, according to the research paper of Raval [12], in the context of H-PBL, enabling teams to choose real-world examples enhances their intrinsic motivation.

The study that evaluated the effectiveness of a H-PBL approach by Martin *et al.* [13] found support for the model's effectiveness. This suggests that the integration of PBL within a hybrid learning framework can effectively enhance students' understanding and satisfaction with the learning process. Another research developed a model that focused on enhancing students' behavioral intention to use and academic achievement in a blended-project-based learning approach [10]. The study revealed positive outcomes, indicating that the model succeeded in motivating students to engage actively in the learning process and improve their academic performance.

The report by Education Northwest emphasized the benefits of combining PBL with blended learning approach [14]. The report highlights that PBL successfully engages students in answering questions, solving problem, or addressing challenges for an extended period, and it can build skills, mindsets, and behaviors needed for success in the modern workplace. Moreover, a study exploring strategies to make PBL inclusive in a hybrid setting found that PBL provides a powerful platform for creating a shared learning space where all students' voices are valued, fostering an inclusive and collaborative learning environment [15].

Overall, previous studies collectively support the effectiveness of an H-PBL model in enhancing students' learning outcomes, satisfaction, and overall preparedness for success in their future careers. The model's emphasis on practical applications, real-world challenges, and collaborative learning aligns well with the demands of the modern job market and contributes to the development of essential skills and mindsets necessary for success in various fields.

This present study defines hybrid learning as the combination of in-person and online education, utilizing both traditional classrooms and internet methods to enhance the flexibility and effectiveness of learning. Additionally, this study adopts the definition of PBL from Kokotsaki *et al.* [16],

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which describes it as an engaging student-centered learning approach featuring student autonomy, constructive inquiries, goal-setting, collaboration, communication, and reflection within authentic real-world contexts.

In the context of multimedia technology and animation courses, this study introduces an innovative educational model that seeks to synergize the benefits of hybrid learning with PBL to equip students with practical skills [17, 18]. This model aims to transform learning by creating an interactive and stimulating environment that encourages students to actively engage in their education. This approach aims to smoothly integrate theory and practice, equipping graduates for success in their upcoming professional endeavors [19].

To successfully develop and implement this model, an extensive design and analysis process must be undertaken. In the design phase, educators collaborate to curate a comprehensive curriculum that blends multimedia technology and animation principles with hands-on project assignments [20]. Furthermore, an analysis process must be conducted to assess the efficacy of the H-PBL model. Researchers collect and analyze data related to student performance, engagement levels, and learning outcomes [21]. This iterative analysis allows for the identification of potential areas of improvement and ensures that the model remains relevant and adaptive to the evolving educational landscape and industry trends.

Previous studies have integrated hybrid learning and PBL into the learning process [22–25]. Some previous studies have also developed materials for multimedia and animation courses, including interactive multimedia-based animation [26, 27], interactive multimedia application [28, 29], interactive textbooks [30], 3D animation created using virtual reality technology [31], web-based multimedia [32], and digital books [33].

Nevertheless, there exists a gap in the current discourse on this topic, as existing studies do not comprehensively articulate the entire model for the learning process. Rather, they primarily concentrate on investigating effectiveness, performing component analysis, and developing learning materials as discrete studies. Therefore, this study addresses the existing gap in research concerning the integration of hybrid learning and PBL with a specific emphasis on the development of models and learning materials. The novelty of this study lies in its pioneering approach to educational enhancement, where the integration of hybrid learning and PBL is strategically employed to address the distinct needs of college students specializing in multimedia technology and animation. Hence, the objective is to create and assess the validity, practicality, and effectiveness of a H-PBL model, as well as to investigate its impact on student achievement.

II. Method

A. Research Design

This study employs a Research and Development (R&D) approach to design and evaluate a model, encompassing educational products such as modules and e-learning materials [34]. The research methodology aligns with the ASSURE model (Analyzing Learners, Stating Standards and Objectives, Selecting Strategies and Materials, Utilizing Technology, Requiring Learner Participation, and Evaluating and Revising) [35]. The ASSURE model was chosen for its explicit emphasis on integrating technology into the instructional design process. Additionally, the inherent flexibility of the ASSURE model allows for a tailored application that accommodates the unique needs and context of the study. However, this study did not follow the sequence exactly; instead, it modified the order and may have conducted iterations in certain steps.

B. Participants

Participants were divided into two categories: expert validators and students. Purposive sampling was utilized to select experts based on specific criteria. For an educator specialist, a minimum of ten years of experience in developing learning models and a minimum of a PhD are required. An animator must have a minimum of five years of experience in technology-based animation business management. Likewise, an industry practitioner should possess a minimum of five years of experience in technology-based animation business. This process resulted in the selection of three experts, each specialized in one of these fields. In selecting the student groups, the research employs a purposive sampling method, which includes two distinct segments: a control group consisting of 20 students and a limited experimental group consisting of 15 students.

C. Procedure

A preliminary study using a questionnaire was conducted to assess students' tech-savviness, preferences for interaction, and interest in practicality. The questionnaire consists of 15 items, with each aspect comprising 5 items. The Likert scale ranges from 1 (strongly disagree) to 5 (strongly agree) for each item. The reliability test results for this questionnaire instrument reveal a Cronbach's alpha value of 0.78, indicating good internal consistency reliability. Furthermore, in the Pearson validity test, all items demonstrate a significant positive correlation with the construct, as evidenced by r-values exceeding the critical r-table value (0.334) at a significance level of 0.05.

The results from the preliminary study and literature review regarding the components in the model were used to develop the H-PBL model. Subsequently, the initial development results underwent expert assessment. These steps were conducted iteratively until the model was suitable for use in the learning process. The testing of practicality and effectiveness is conducted thereafter by involving students.

D. Products

The research produced six products, including a model book, a learning materials book, a user guide for lecturers, a user guide for students, teaching modules, and an e-learning platform.

The content of the materials in multimedia technology and animation courses delves into topics such as digital media creation, graphic design principles, animation techniques, and the utilization of multimedia software tools. The concept section, explained in the teaching materials book, introduces abstract ideas and fundamental principles that serve as the bedrock of multimedia technology and animation. These conceptual elements include design principles, storytelling techniques, user experience considerations, and 3D modeling concepts. Meanwhile, the knowledge acquired in this course transcends the practical application of the developed video animation. Students develop hands-on skills, problem-solving abilities, and critical thinking within the process of video animation making.

E. Data Analysis

Data analysis was conducted qualitatively in the needs analysis phase by describing findings related to student characteristics and describing proposed learning models that are potentially suitable for student characteristics. Additionally, descriptive analysis was performed on expert assessment (validity), student assessment (practicality), and limited test results (effectiveness). The instruments grids used for this analysis were modified versions sourced from Wahyuni [36] for validity, Lestari *et al.* [37] for practicality, and Ipaubla and Maftuh [38] for effectiveness. The validity instrument employs a 1–5 scale, ranging from highly unsuitable to highly suitable. The practicality and effectiveness instruments also use a 1–5 scale, representing strongly disagree to strongly agree. Validity values in this study are determined using V coefficients, where a value exceeding 0.5 indicates good validity. Meanwhile, practicality and effectiveness values are determined using a percentage, where percentages above 75% indicate that the assessed aspects in the model are considered practical or effective.

Paired sample tests were conducted with normality and homogeneity prerequisite tests. Normality was determined through the Lilliefors test, where data is considered normal if the p-value is less than the critical value at a 0.05 significance level. Homogeneity was assessed by comparing the chi-square value to the critical value at a 0.05 significance level, indicating homogeneous variances if the chi-square value is smaller. Subsequently, paired sample tests were conducted on the pretest and posttest results for both groups, with the criterion that a significant difference exists between the test groups if the p-value is <0.05.

III. Findings

A. Analysis of Student Characteristics in the Initial Conditions

The results of the preliminary study conducted with 35 students are presented in Table 1. The highest score in the tech-savviness aspect was achieved by item 1, scoring 4.23, which reveals that students are comfortable using various digital technologies. Conversely, the lowest score in this aspect was obtained by item 2, addressing students' activity in exploring and adapting to new technologies and platforms, scoring 3.80. In the preference for interaction and interest in practicality aspects, it is indicated that the score differences between indicators are not significantly large. The conclusion regarding the results of these descriptive analysis is shown in Table 2. The results presented in Table 2 serve as the foundation for developing a model that supports the characteristics of students.

Table 1. Preliminary study descriptive analysis results

Item No.	Statements	Median	Mode	Mean	Standard Deviation
1	I am comfortable using various digital technologies.	4	5	4.23	7.18
2	I actively explore and adapt to new technological tools and platforms.	5	5	3.80	6.23
3	I consider myself tech-savvy and proficient in using modern digital tools.	4	5	4.23	7.18
4	I prefer using digital resources over traditional methods for academic tasks.	4	4	3.80	5.10
5	I feel confident navigating and utilizing a variety of software and applications.	4	4	4.11	6.67
6	I enjoy learning experiences that incorporate multimedia elements, such as videos and interactive quizzes.	4	4	4.17	7.75
7	When choosing academic resources, I prioritize those with interactive features.	4	4	4.20	8.22
8	I find gamified learning experiences engaging and effective for my understanding.	4	5	4.20	7.00
9	I prefer e-learning platforms that provide virtual simulations to enhance my learning.	4	4	3.94	7.91
10	Multimedia-rich content enhances my overall learning experience.	4	4	3.94	7.45
11	I actively seek out opportunities to apply theoretical concepts in real-world scenarios.	4	4	3.89	8.15
12	Practical applications and hands-on projects are important aspects of my learning.	4	4	3.97	7.48
13	I prefer learning technologies that offer simulation tools for practical experimentation.	4	4	4.06	7.38
14	Virtual labs are valuable to me as they allow for hands-on learning in a digital environment.	4	4	4.00	6.24
15	Coding environments that enable direct practice of acquired skills are important to my learning preferences.	4	4	3.89	6.44

Note: n = 35. Items 1–5 represent tech-savviness, items 6–10 represent preference for interaction, and items 11–15 represent interest in practicality.

Table 2. Summary of student characteristics analysis

Aspect Assessed	Findings
Tech-Savviness	Preliminary study indicate that the majority of students are tech-savvy and familiar with digital technologies.
Preference for Interaction	The students have a strong preference for interactive and multimedia-rich learning experiences. This preference is attributed to Generation Z. For example, when it comes to choosing software and applications for both academic and personal use, students often prioritize those that offer interactive and visually appealing features. They are drawn to e-learning platforms that provide gamified learning experiences, virtual simulations, and multimedia content like videos and interactive quizzes.
Interest in Practicality	The students' keen interest in practical applications and hands-on projects is evident. This indicates that students actively seek learning technologies that enable them to apply theoretical concepts in real-world scenarios. For instance, they show a preference for software and platforms that offer simulation tools, virtual labs, or coding environments where they can directly practice and experiment with the skills they are acquiring.

B. Selection of Methodology, Media, and Materials

The selection of teaching methods, media, and development materials for the learning model is based on the results of the student characteristic analysis in the previous subsection, learning objectives to be achieved, and literature review. This selection process yields several components as listed in Table 3. These components include hybrid learning, PBL, multimedia resources, interactive lectures, and industry-relevant case studies. These components are suggested to support students with a high level of technological skill, a preference for interactive learning, and an interest in practical applications. In addition, they are designed to help achieve the learning objectives, specifically the mastery of multimedia technology and animation course materials.

Table 3. Summary of model components and their contributions

Model Components	Contributions
Hybrid Learning	The role of hybrid learning in the H-PBL model is expected to accommodate students' tech-savviness and provided flexibility by integrating online elements [39].
Project-Based Learning	In PBL, students are presented with opportunities to apply theoretical knowledge to real-world scenarios through industry-relevant case studies and hands-on projects [40, 41]. This experiential learning approach enabled them to cultivate valuable competencies such as problem-solving skills, critical thinking abilities, and adaptability [42–46]—qualities highly sought after in the job market.
Multimedia Resources	Multimedia resources serve as diverse and comprehensive learning materials with engaging and dynamic content. The integration of multimedia elements aided students in grasping complex concepts, facilitating a deeper understanding of the course content [47]. This enriched learning content significantly contributed to the model's effectiveness in equipping students with both theoretical knowledge and practical skills.
Interactive Lectures	The combination of in-person instruction (lectures) and online elements enabled students to access multimedia resources and course materials at their own pace, accommodating individual learning preferences.
Industry-Relevant Case Studies	Industry-relevant case studies are a crucial component in the PBL process [48]. The emphasis on case studies relevant to the industry provides students with opportunities to apply theoretical knowledge in real-world contexts. Industry-relevant case studies can include project development, client interactions, problem-solving, industry trends, and success stories.

C. Expert Assessment Results

Table 4 displays the assessment results from experts regarding the validity of the components of the developed model, as indicated by V coefficient values. All aspects demonstrate V coefficient values exceeding 0.50, indicating the validity of all components for use in the model. The highest score was obtained for the hybrid learning with PBL component, with a score of 0.92. Meanwhile, the lowest score of 0.87 was obtained for the interactive lectures component, suggesting that this aspect may benefit from some improvement compared to the other components. This indicates that the interactive lectures developed in this model do not quite represent the role of a lecturer as expected by the experts. Nevertheless, the obtained values comply with the standard of validity assessment. The high validity indicates that the chosen method, media, and materials in the H-PBL model are well-matched to fulfill the specific characteristics and learning objectives of college students.

Table 4. Expert assessment results

Aspect Assessed	Average of V Coefficients
Hybrid Learning with Project-Based Learning	0.92
Multimedia Resources	0.88
Interactive Lectures	0.87
Industry-Relevant Case Studies	0.90

Note: The values presented for each assessed aspect are the averages of V coefficients across all items. In this study, all items within each aspect surpass a V coefficient of 0.50.

D. Peer Assessment (Model Practicality Test)

Table 5 shows the results of peer assessment in the experimental group that received H-PBL model instruction. The results indicate that the "application of theoretical knowledge" received the highest score, 91%, while the lowest score was obtained for the "problem-solving skills" aspect (85%). The results show practicality and feasibility because they indicate that the various aspects and skills being assessed. In other words, the model is shown to be practical because it aligns well with the practical needs and requirements of the situations it is designed for.

Table 5. Peer assessment results

Aspect Assessed	Percentage Success
Collaborative Teamwork	88%
Application of Theoretical Knowledge	91%
Problem-Solving Skills	85%

E. Limited Group Test (Effectiveness Test)

An analysis of effectiveness was conducted after the experimental group received instruction using H-PBL model. Table 6 shows the results of the test students' responses to the model. The results generally indicate a positive response, with the highest obtained in the aspect of PBL experience where students feel that the experience with the projects presented by the model is highly beneficial in learning.

Table 6. Limited group test results

Aspects Assessed	Positive Responses (%)	Neutral Responses (%)	Negative Responses (%)
Engagement with Multimedia Resources	93%	6%	1%
Practical Skill Development	91%	7%	2%
Project-Based Learning Experience	95%	4%	1%
Overall Satisfaction with the Model	92%	6%	2%

F. Paired Sample Test

A paired sample *t*-test was conducted to determine the difference in learning outcomes achieved by the experimental and control groups. Prerequisite tests should be conducted before performing the test. The results of the preliminary tests of normality and homogeneity are shown in Tables 7 and 8, respectively. Table 7 indicates that based on the normality test, it is concluded that all test groups have normally distributed data (L-value < L-table). Meanwhile, the results of the homogeneity test in Table 8 show that the data has homogeneous variances (chi-square < critical value). Since the prerequisite tests have been met, the further test, namely the paired sample *t*-test, can be conducted.

Table 9 displays the results of paired sample *t*-test on pretest and posttest scores for both courses, along with their respective significance levels (*p*-values). The results show a statistically significant improvement in average pretest and posttest scores for both courses, with *p*-values of 0.001 for multimedia technology and 0.002 for animation at a significance level of 0.05. This indicates a positive impact of H-PBL model on students' learning outcomes.

Table 7. Normality test results

Group	Dataset	L-value ($L_{calculated}$)	L-table (alpha = 0.05)	Normality Assessment
Experimental class	Pretest score of multimedia technology course	0.181	0.220	Normal
	Posttest score of multimedia technology course	0.212	0.220	Normal
	Pretest score of animation course	0.135	0.220	Normal
	Posttest score of animation course	0.211	0.220	Normal
Control class	Pretest score of multimedia technology course	0.181	0.220	Normal
	Posttest score of multimedia technology course	0.212	0.220	Normal
	Pretest score of animation course	0.072	0.190	Normal
	Posttest score of animation course	0.078	0.190	Normal

Note: Lilliefors (K-S) test was used for assessing normality.

Table 8. Homogeneity test results

Dataset	Chi-Square	Critical Value (alpha = 0.05)	Homogeneity Assessment
Multimedia technology course	7.086	85.965	Variance Homogenous
Animation course	30.553	85.965	Variance Homogenous

Note: Bartlett test was used to assess homogeneity.

Table 9. Paired sample *t*-test (2-tailed)

Test Type	Significance (*p*-value)
Multimedia Technology Course	0.001*
Animation Course	0.002*

Note: $*p < 0.05$.

G. Visual Presentation of the Model Products

The development of H-PBL model resulted in six products, namely a model book, a learning materials book, user guides for lecturers and students, teaching modules, and an e-learning platform with online modules to support H-PBL model. The model book contains explanations about H-PBL model, its foundations, the development process, and how to implement it. On the other hand, the teaching module includes comprehensive content for 16 learning sessions, each with materials, videos, projects, and tests accessible through the university domain-based e-learning platform. The printed products include the model book, learning materials book, and teaching modules, while other products are available in digital form as e-learning materials. However, the products of this development cannot be accessed by the public, except for the model book and teaching modules. Other resources can be obtained through reasonable requests.

Before use in the classroom, the lecturer studies the model book, learning materials book, and user guide for lecturers. In class, students are provided with a user guide and learning materials book. The e-learning platform is used as a teaching medium in every session and as a guide for students' project information. Additionally, the lecturer also utilizes the e-learning platform for the assessment of student assignments and evaluations.

Fig. 1 displays the cover of the model book and teaching module. In addition, Fig. 2 presents the online modules accessible by lecturers and students, which contain learning materials. Fig. 3 showcases the content of the first session, while Fig. 4 illustrates the content of sessions 3, 4, and 16. Additionally, Figs. 5 and 6 feature the e-learning platform's home screen and the class session grid view.

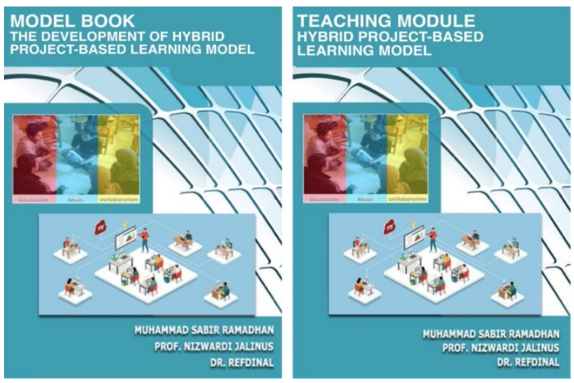

Fig. 1. Cover page of model book (left) and teaching module (right).

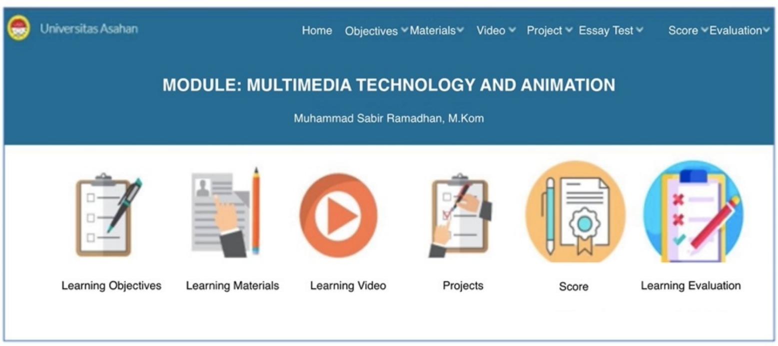

Fig. 2. Online module home page.

Fig. 3. The content of the first session.

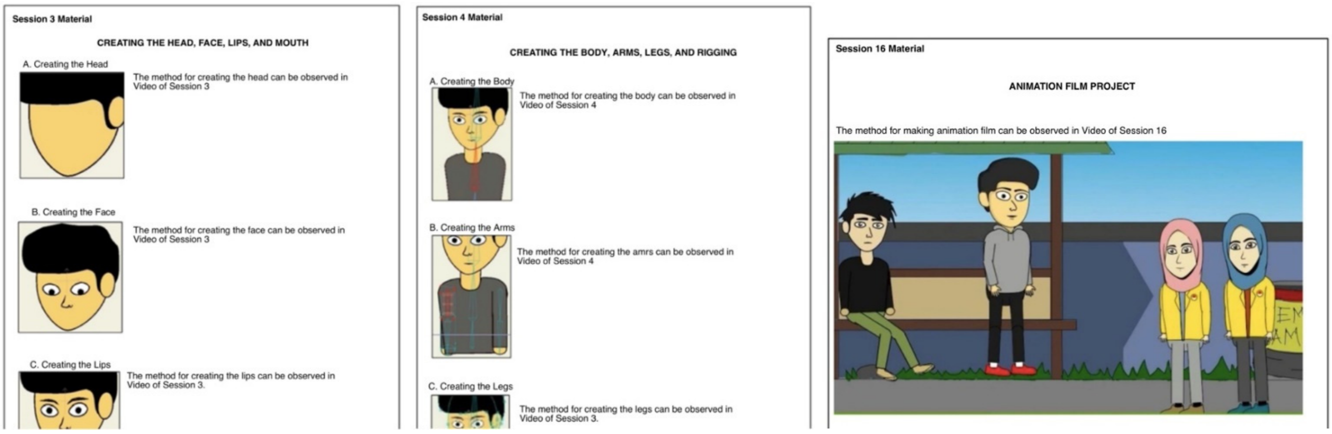

Fig. 4. The content of the third, fourth, and sixteenth sessions.

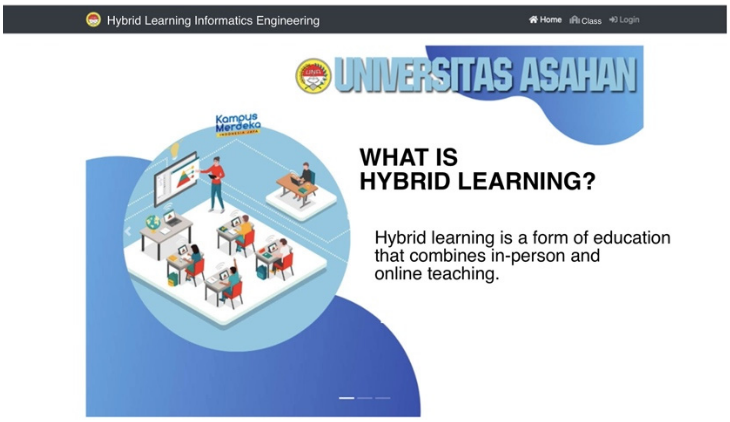

Fig. 5. E-learning platform's home screen.

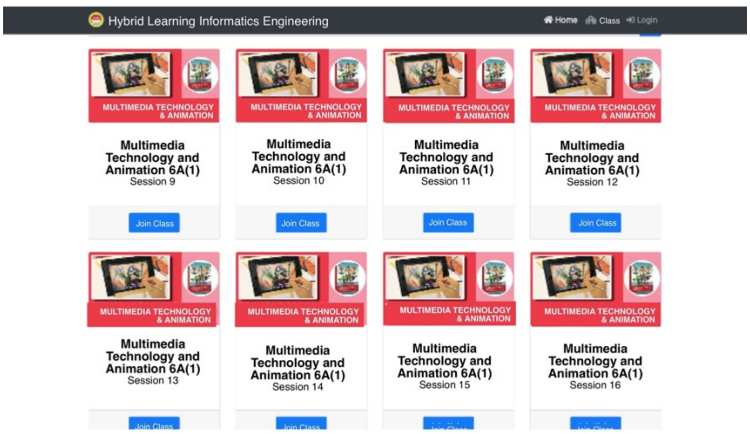

Fig. 6. Class session grid view.

Here are examples of projects undertaken by students after the 16th meeting. This project is called Project 16 (Final Exam), which requires students to create a short animated video with the following specifications:

- A minimum of 2 characters.
- A minimum film duration of 2 minutes.
- Different voices must be included.
- A film storyboard script must be provided.
- This project is an individual assignment.
- Submit the link to your animation film on your e-learning channel (learningti.una.web.id) in the TMA6AUAS class.
- Reference link for the storyboard: https://youtu.be/VF3aNRDUOQc
- Reference link for creating animation videos: https://youtu.be/ygP6CwMiu80

H. H-PBL Model

The model that has been developed is supported by the products that have been showcased in the previous subsection. The syntax of this model is presented in Table 10.

The learning sessions are conducted for a total of 16 meetings, implementing the previously structured syntax. The instructor utilizes teaching modules and model books to assist in understanding the objectives and activities of each session. Throughout the semester, students undertake a phased assignment of creating animated videos, with progress reported every week in the subsequent meeting. Online learning processes are conducted once a month, specifically in the fourth, eighth, and twelfth meetings, while the final meeting, the 16th, is held in-person. Table 11 illustrates the learning objectives for each session.

Table 10. H-PBL model syntax

Stage	Syntax
1	Creating essential questions that determine the direction of the activities to be carried out.
2	Articulating the learning objectives in a more concrete form that can serve as a reference for students in designing a project.
3	Creating a schedule of activities within the designed project.
4	Coordinating and monitoring students' work and the progress of the project.
5	Conducting assessments to measure the standards of achieving project milestones.
6	Evaluating the activities and outcomes of the completed project.

Table 11. Learning objectives

Session	Learning Objectives
1	Students are able to explain the history and development of animation, skills and careers in the field of animation, as well as the principles of animation production.
2	Students can understand the use of tools and drawing techniques in *Moho Pro 13*.
3	Students can create a learning video about crafting head, face, lips, and mouth.
4	Students can make a learning video project on developing the body, hands, legs, and rigging.
5	Students can produce a learning video project featuring moving characters.
6	Students can produce a learning video project showcasing characters walking.
7	Students can create a learning video project focusing on talking characters.
8	Students can make a learning video project of characters walking and talking.
9	Students can create a learning video project illustrating running characters.
10	Students can make a learning video project demonstrating characters interacting with objects.
11	Students can produce a learning video project about background and camera settings.
12	Students can create a learning video project about scene creation and replacement.
13	Students can make a learning video project on audio insertion, recording, and lipsync.
14	Students can create a learning video project demonstrating masking effects.
15	Students can make a learning video project illustrating the creation of storyboards.
16	Students can produce a learning video project explaining the creation of an animated film project.

In online meetings, students access the provided e-learning platform, and learning takes place through *Zoom* or *Google Meet*. Each project milestone is evaluated in the subsequent meeting, with a one-week interval for each meeting, allowing students one week to complete the milestone tasks for each session. The assessment of student projects takes place in the 16th meeting or the final session.

IV. Discussion

The findings from the development of the H-PBL model for multimedia technology and animation courses demonstrate its high effectiveness. This aligns with the preferences of students who favor interactive and practical learning experiences. Furthermore, the positive outcomes of the expert assessment, peer assessment, and limited test responses further validate the model's success. Additionally, the statistically significant improvement in pretest and posttest scores indicates that the model positively influenced students' knowledge and understanding in both the multimedia and animation courses. The results are supported by Alamri [10], who revealed that the improvement in learning achievement is one of the aspects indicating the success of the H-PBL model.

This research emphasizes the importance of developing a learning model that suits students' needs, specifically H-PBL model. A suitable model will lead to effective learning. In the fields of multimedia and animation, where students often require a combination of technical skills and creative application, aligning the model with their preferences contributes to more effective learning outcomes. Alfaro *et al*. [25] endorse this perspective, asserting that an adaptive e-learning system model employing the PBL approach results in satisfaction levels comparable to or even surpassing those achieved by other studies utilizing varied methodologies.

The results showcase a comprehensive set of projects that can facilitate students in practicing their skills. In this research, these projects are assigned milestones that make it easier for instructors to monitor the progress of student projects. With projects organized in such a manner, the learning objectives will be achieved effectively. Furthermore, Chen and Yang [49] emphasizes that the success of PBL also needs to be supported by the lecturer's proficiency in mastering technology.

Several theories support the learning process within this model, specifically constructivism and experiential learning theory. In learning with this model, students actively constructing their own knowledge through experience and reflection aligns with PBL [50]. Additionally, this learning demonstrates that David Kolb's experiential learning theory directly supports the idea of learning through concrete experiences, reflective observation, abstract conceptualization, and active experimentation.

Previous studies in the field of PBL have established a substantial foundation that underpins the development of the H-PBL model in our study. For example, Syahril *et al.* [51] emphasized the development of instructional media for a mechanical drawing course, underscoring the validity, practicality, and effectiveness of PBL. This aligns with our study's focus on creating a diverse range of instructional products, but with an expanded scope that encompasses multimedia technology and animation, integrated within a hybrid learning framework. Similarly, Febrianti *et al.* [52] demonstrated the effectiveness of PBL in enhancing critical thinking skills within creative product and entrepreneurship subjects. Their use of a quasi-experimental method in a specialized subject area reinforces the capacity of PBL to develop essential skills, a foundational concept that is integral to our comprehensive H-PBL model. Furthermore, Le *et al.* [53] contributed a theoretical perspective by analyzing competencies necessary for the 21st century in technical and vocational training, thereby highlighting the significance of contemporary teaching methods such as PBL. Our study not only reflects these competencies but also brings them into practice through the deployment of various instructional products and an e-learning platform. Together, these previous studies emphasize the importance and need for innovative teaching methods in modern education, particularly in specialized domains like multimedia technology and animation. This collectively validates the approach and outcomes of our study, showcasing its contribution to the advancement of PBL.

This study demonstrates strength in several key aspects. The acknowledgment of the prevailing gap between engineering education and industry demands highlights its relevance to the current challenges faced by educational institutions. Additionally, the study's commitment to practical implementation, as evidenced by the inclusion of control and experimental classes, further strengthens its validity. The study's focus on multimedia technology and animation suggests potential transferability to other engineering disciplines, indicating scalability that contributes to its broader impact.

However, the study has several weaknesses or limitations that should be considered in interpreting its findings. The generalizability of the results may be limited, as the research focused exclusively on college students in the fields of multimedia technology and animation. The relatively small sample sizes in the control and experimental classes, along with the absence of diversity representation, further restrict the external validity of the findings. The study's duration, confined to one semester, raises concerns about capturing the long-term impact of the H-PBL model on student outcomes, retention, and professional development. Additionally, potential variability in the implementation of the H-PBL model across different instructors or institutions may influence the results.

Methodologically, the study primarily relies on paired sample *t*-tests, neglecting a more diverse range of assessment methods such as qualitative analyses and interviews. The expert validation process, though valuable, may introduce bias, and a more diverse panel of experts, including student perspectives, would enhance the study's credibility. Furthermore, the study lacks comparisons with alternative pedagogical approaches, hindering a comprehensive understanding of the relative effectiveness of the proposed model.

V. Conclusion

Based on the results of the development of the H-PBL model for multimedia technology and animation courses, it has been found that this model is highly effective. The integration of multimedia resources, interactive lectures, and industry-relevant case studies through a digital platform has significantly enhanced students' understanding and practical application of concepts. The positive outcomes from expert assessments, peer evaluations, and limited tests further validate the model's effectiveness.

H-PBL model has the potential to enhance the educational experience of college students in the fields of multimedia technology and animation. This is because this model is supported by comprehensive resources and is capable of creating an environment that supports PBL. This is done by providing independent learning time as well as suitable project completion time. This ensures that students not only gain theoretical knowledge but also have ample opportunity to apply it in practical, hands-on projects.

Furthermore, the model provides a valuable contribution to engineering education. For instance, students gain insights into the effectiveness of the H-PBL model in addressing real-world requirements in the fields of multimedia technology and animation. Additionally, students can learn about the significance of collaboration between academic institutions and industry partners.

There are several recommendations for educators and colleges. Educators should consider customizing learning models to match their students' preferences and needs, similar to what H-PBL model has effectively achieved. In an era where technology play a pivotal role in education, educators should emphasize the integration of advanced digital platforms, multimedia resources, and interactive content to craft dynamic and engaging learning experiences. Colleges and educational institutions should keep up-to-date with the latest trends and technologies in their respective fields to ensure that their teaching methods stay pertinent to the demands of modern education.

As we move forward, future research endeavors should explore the broader applicability of the H-PBL model across different disciplines and educational settings. Investigating its effectiveness in diverse learning environments and its potential to meet the needs of a wider range of student demographics would provide valuable insights. Additionally, long-term studies should examine the lasting impact of the H-PBL model on students' academic and professional development.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

MSR developed the methodology, conducted investigations, and wrote the original manuscript; NJ supervised the study, provided resources, and contributed to writing the original manuscript; R analyzed data, revised the manuscript, and created visualizations; NM conducted investigations, wrote the original manuscript, and analyzed data; MA provided resources, contributed to writing the original manuscript, and created visualizations; all authors approved the final version of the manuscript.

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