Penerbit Akademia Baru

International Journal of Advanced Research in Future Ready Learning and Education

https://www.akademiabaru.com/submit/index.php/frle/index
ISSN: 2462 - 1951

A Proposed Integration Model of Project Based Learning and Simulation to Improve the Learning Quality

Radhya Yusri[1], Anuar Mohd Yusof[2,*], Azlin Sharina[2]

[1] Faculty of Science and Technology, Universitas PGRI Sumatera Barat, Indonesia
[2] Faculty of Creative Technology and Heritage, Universiti Malaysia Kelantan, Malaysia

ABSTRACT

Although many studies have been conducted to improve the quality of the learning process at the higher education level, the need for an effective learning model that can develop students' skills remains a challenge that needs to be fully resolved. Considering and redeveloping the suitable learning model to use is very important. This study proposed a project-based learning and simulation model to develop students' skills and the quality of learning in higher education. The implementation stages of the model are also offered, applied, and analyzed, and the effectiveness of the model is also seen. The 4-D model design, including define, design, develop, and disseminate, was used in this study. The results show that the project-based learning and simulation model developed in the aspects of the rationale for the learning model, supporting theory of learning model, description of learning model syntax, implementation of the learning model, syntax interconnection in learning model, and support platform for learning model were in the highly valid category. Meanwhile, there is also a statistically significant difference in students' pre-test and post-test scores, which means that students' skills improved after implementing project-based learning and simulation model in learning. It is concluded that project-based learning and simulation models support improving learning quality in higher education.

Keywords:
Learning quality; project-based learning; skills; simulation

Received: 30 January 2024	Revised: 9 March 2024	Accepted: 18 March 2024	Published: 24 April 2024

1. Introduction

Education is one of the main pillars of sustainable community development [1-2]. Improving the quality of learning has become a pressing agenda for educators. Along with the rapid development of technology and transformation in various aspects of life, education must be able to adjust itself to remain relevant and effective in preparing future generations for the challenges of the future [3-4]. Not only to ensure an understanding of the subject matter, but it must also encourage the development of skills necessary for success in an increasingly complex and globally connected society [5-7]. Therefore, educators need to adopt innovative and adaptive learning approaches to meet the needs of students in this digital era [8]. This requires educators to update their teaching approach and ensure that students have relevant skills and can compete in the modern era [9]. In addition, there needs to be a gap that needs to be addressed between the learning development efforts made

* *Corresponding author.*
E-mail address: anuarmy@umk.edu.my

and the expected results, especially in the context of improving student skills. Despite various efforts to improve the quality of learning, such as the use of innovative teaching methods [10-11], the application of technology [12-16], and the development of relevant curriculum [17-22], but the results have not reached the expected expectations, especially in developing student skills. Results from the Program for International Student Assessment (PISA) show that Indonesian students tend to have low thinking skills. The study's results highlighted that the learning approach in science in Indonesia emphasizes understanding concepts alone, without integrating elements of student skills in learning [23]. The results of the PISA survey 2022 show that Indonesia's position in mathematics is still relatively low, as shown in Table 1. In 2022, Indonesia was ranked 366th out of 80 PISA-participating countries in the category of mathematical ability.

Table 1
Comparing countries' and performance in mathematics

		Math score 2022	Math score change from 2018			Math score 2022	Math score change from 2018
Above the OECD average	Singapore	575	6	Below the OECD average	*Ukrainian regions (18 of 27)*	441	N.A
	Macao (China)	552	-6		Serbia	440	-8
	Chinese Taipei	547	16		United Arab Emirates	431	-4
	*Hong Kong (China)**	540	-11		Greece	430	-21
	Japan	536	9		Romania	428	-2
	Korea	527	1		Kazakhstan	425	2
	Estonia	510	-13		Mongolia	425	N.A
	Switzerland	508	-7		Bulgaria	417	-19
	Canada*	497	-15		Moldova	414	-6
	Netherlands*	493	-27		Qatar	414	0
	Ireland*	492	-8		Chile	412	-6
	Belgium	489	-19		Uruguay	409	-9
	Denmark*	489	-20		Malaysia	409	-32
	United Kingdom*	489	-13		Montenegro	406	-24
	Poland	489	-27		*Baku (Azerbaijan)*	397	-23
	Austria	487	-12		Mexico	395	-14
	Australia*	487	-4		Thailand	394	-25
	Czech Republic	487	-12		Peru	391	-9
	Slovenia	485	-24		Georgia	390	-8
	Finland	484	-23		Saudi Arabia	389	16
	Latvia*	483	-13		North Macedonia	389	-6
	Sweden	482	-21		Costa Rica	385	-18
	New Zealand*	479	-15		Colombia	383	-8
No difference	Lithuania	475	-6		Brazil	379	-5
	Germany	475	-25		Argentina	378	-2
	France	474	-21		Jamaica*	377	N.A
	Spain	473	N.A		Albania	368	-69
	Hungary	473	-8		*Palestinian Authority*	366	N.A
	Portugal	472	-21		Indonesia	366	-13
	Italy	471	-15		Morocco	365	-3
	Viet Nam	469	N.A		Uzbekistan	364	N.A
	Norway	468	-33		Jordan	361	-39
	Malta	466	-6		Panama*	357	4
	United States*	465	-13		*Kosovo*	355	-11
Below	Slovak Republic	464	-22		Philippines	355	2
	Croatia	463	-1		Guatemala	344	10
	Iceland	459	-36		El Salvador	343	N.A
	Israel	458	-5		Dominican Republic	339	14
	Türkiye	453	0		Paraguay	338	11
	Brunei Darussalam	442	12		Cambodia	336	12

Source: OECD, PISA 2022 Database

With so many factors influencing the gap, it is necessary to take concrete steps to resolve this gap, such as increasing student participation in learning through active and collaborative learning and integrating relevant skill elements. Thus, it is hoped that the gap between learning development efforts and expected outcomes can be minimized so that students can gain the skills needed to succeed in the world of work.

In this research, innovative learning, such as Project-based Learning (PJBL) and simulation, is the focus of attention as an approach capable of improving skills and learning quality. PJBL is relatively seldom implemented in the context of mathematics education. To advance theory and practice in mathematics, learning PJBL is essential, as has been done by Palatnik [24]. PJBL emphasizes project-centered learning, where students learn through practical experience and collaboration in completing authentic project tasks. PJBL is a learning model with theoretical roots in constructivism and views learning as a meaningful process formed from interaction, reflection of ideas, and authentic experiences. PJBL develops from the work of influential constructivists Jean Piaget and Vygotsky. Constructivist learning philosophy is the foundation of PJBL. PJBL has evolved as a learning model that integrates various skills in solving real-world problems. It emphasizes individual and group higher-order thinking through interaction and collaboration. The interaction and collaboration that happen in the learning process will positively impact the implementation of the learning process. This is in line with research findings that PJBL affects increasing students' knowledge [25], motivation, and attitude toward learning.

Meanwhile, simulation offers learning that allows students to interact with specific situations. Simulation is an effective learning model inside and outside the classroom [26]. It allows students to repeatedly practice skills until they develop a sense of mastery to learn at their rate and are free to make mistakes. Learning simulation is a collection of learning techniques and strategies that involve individuals in real-life scenarios through role play, games, and reflection to develop and strengthen the knowledge and skills learned in the classroom [27]. Simulation creates a natural context that allows students to recognize various realities and problems [28]. Thus, simulation becomes an essential part of the learning process and is an excellent learning tool that offers hands-on experience to students [29]. Simulation learning focuses on the student's learning process. Students are given very high autonomy and independence and are more empowered to make decisions in solving existing problems [30]. Furthermore, learning simulations can improve interest, motivation, active participation, intensive learning, and academic achievement and develop skills such as decision-making ability [31].

Conceptual challenge can be overcome with simulations that embed abstract material concepts through active student participation [32]. In simulation activities, they are directly involved in developing an understanding of the material being studied. However, many of it has yet to be designed to provide opportunities to articulate the material or expand on emerging ideas. Masson suggests that simulations can support learning [33]. These simulations can support them in integrating instructed knowledge with conceptual knowledge [32]. Simulation is a learning method that can encourage the application of learned decision analysis concepts [34]. This approach provides an opportunity for students to combine knowledge and practice. Simulation practice has proven very effective for training students in the classroom environment and the field [34]. By involving them in accurate and relevant experiences, simulations allow students to hone their skills in facing complex and dynamic decision situations.

However, using these two approaches separately may not reach their full potential. A theory-focused approach results in a deep understanding of fundamental concepts, while a practice-based approach can develop the practical skills required to apply those concepts in real-world situations. By integrating both approaches, it is possible to create a learning environment that simultaneously supports theoretical concept understanding and practical skill development. Thus, students can benefit from both approaches simultaneously, which in turn can optimize their learning. The findings of this study can provide a strong foundation for developing innovative and effective learning models in higher education, especially in developing skills that students need now and for the future.

2. Methodology
2.1 Research Design

The development model used in this research is the 4D model developed by Thiagarajan [35]. This model consists of four interrelated and sequential stages. The first stage is Define, also known as the needs analysis stage. At this stage, in-depth identification and analysis of the needs and problems to be solved are carried out. The second stage is Design, where the conceptual framework of the model is systematically organized. This design process includes selecting models, methods, strategies, or learning techniques that match the needs identified previously. After that, the third stage is Develop, which is the actual development stage. At this stage, the learning model that has been designed is tested for validity through expert validation. This evaluation aims to ensure that the model developed meets the predetermined objectives and can provide the desired benefits. The last stage is dissemination, the model that has been developed is implemented on the target research subjects. At this stage, the results and findings of the research are disseminated through the application of the model in the learning process to determine the impact of its implementation.

2.2 Research Subject

The subjects of this study were all students of the mathematics education study program in the academic year 2023. In developing the learning model, this research subject has a vital role as the primary recipient and user of the developed model. The involvement of all students in this research makes it possible to get various points of view and input on developing learning models that are more effective and relevant to their needs. By involving all students, it is expected that the results of this research can significantly contribute to improving the quality of learning.

2.3 Research Data

The data obtained in this study consisted of two types, namely quantitative and qualitative data. Quantitative data was obtained through scores generated from expert validation sheets and response questionnaires given by respondents. The validation sheet is used to measure the validity of the learning model developed, while the response questionnaire provides an overview of how respondents react and perceive the learning model. On the other hand, qualitative data are obtained through notes, suggestions, or comments given by experts based on the results of their assessment of the proposed learning model. This qualitative data provide an overview of the strengths and weaknesses of the learning model and provides direction for necessary improvements.

2.4 Research Instruments

The research instrument includes several sections designed to measure various aspects of the developed learning model. First, a validation sheet was used to determine the validity of the learning model. This validation sheet is designed to assess the extent to which the learning model is by applicable principles and relevant to the specified learning outcomes. In addition, pre-test and post-test questions were used to measure the learning model's effectiveness on learning outcomes. The pre-test questions are given before applying the learning model to measure students' initial understanding of the material being taught. After that, the learning model was applied in the learning process, and in the end, post-test questions were given to students to measure the improvement of their understanding after participating in learning using the model. The comparison between pre-test and post-test scores is used to evaluate the effectiveness of the learning model in improving students' understanding of the learning material.

2.5 Data Analysis

The data analysis conducted in this study included two approaches: qualitative descriptive analysis and descriptive statistical analysis. First, qualitative descriptive analysis was used to parse and understand descriptive data, such as notes, suggestions, or comments given by experts based on the assessment results on the validation sheet. Second, descriptive statistical analysis processes quantitative data, such as validation result scores and pre-test and post-test learning outcome test scores. This descriptive statistical analysis involves using statistical methods that aim to summarize and describe the main characteristics of the data.

3. Results

The development of the project-based learning and simulation (PJBLS) model in this study was conducted through a series of processes, starting from in-depth identification and analysis of the needs and problems to be solved. The design process was conducted by considering the relationship between the steps of the learning model; the model was developed and tested for validity by experts, and then the implementation of the model to determine the impact of its implementation. The PJBLS stages in this study adopted the research steps Doppelt [36], as shown in Table 2.

Table 2
Activity steps of project-based learning and simulation model

No.	Syntax	Lecturer activities	Student activities
		PRELIMINARY ACTIVITIES	
		a. The lecturer provides motivation and apperception to students by connecting the learning material being studied. b. The lecturer presents the learning objectives to be achieved and explains the learning steps conducted during the learning process with project-based learning and simulation.	a. Students listen and pay attention to what the lecturer says. b. The students listening and paying attention to what the lecturer says.
		CORE ACTIVITIES	
1	Formulating the project	a. The lecturer asks students to open the e-learning platform and understand the problems or project activities conducted according to the topic of the material being studied.	a. The students open the e-learning platform and understand the problem.
2	Designing a project	a. The lecturer observes and ensures students can design and plan activities according to the problems set.	a. The students attempt to design and plan project activities to solve the problem (Project objectives, plan, and steps to solve the problem).

3	Simulation	a. The lecturer observes and ensures that students can solve problems according to the plans and solution steps they have set.	a. The students try to solve the problem according to the plan and solution steps they have set and their respective roles.
4	Monitoring students and project progress	a. The lecturer monitor the project activities conducted by students. b. The lecturer asks about the development or progress of the projects conducted by students.	a. The students conduct project activities based on the problems given and document each activity conducted. b. The students answer according to the question given by the lecturer.
5	Evaluation	a. The lecturer observes the activities that students are doing	a. The students evaluate the problems solved by checking back, analyzing the results, and comparing them with the data or solutions they obtained using existing resources (computers, androids, etc.).
6	Reflection and presentation	a. The lecturer gives feedback to students on the presentation that has been done. b. The lecturer asks about students' experiences during project activities.	a. The students present the results of the project activities from the problems they have solved to the class. b. The students reflect on their experience during the project activities.
		FINAL ACTIVITY	
		a. The lecturer gives a reflection on the learning process that has been done.	a. The students listen and understand the explanation delivered

After the model is developed, the next step is self-evaluation, which is a stage to ensure the quality of the developed model. Self-evaluation involves a thorough review of all model components, including learning project design, simulation, and model integration with the utilization of learning support platforms. The results of this self-evaluation can provide input to improve and refine the model to suit the needs and characteristics of students better. Expert validation is the next stage, where the PJBLS model is evaluated by experts in the field of mathematics education, technology experts, and linguists. The results of model validation by experts can be seen in Table 3. Suartama et al., stated that the expert validation process can involve several stages, such as content expert validation and design expert validation [37]. The results of expert validation showing that the PJBLS model has obtained validity and feasibility signify a significant achievement in learning development. The validity of this model ensures that each element in PJBLS, starting from the design of the learning project and simulation, has gone through in-depth evaluation and assessment by experts. Leow et al., emphasized that learning tools that have passed expert validation can be considered feasible to use theoretically and empirically [38]. His research showed a positive correlation with expert validation of the PJBL model. This ensures that the model developed is theoretically tested through expert validation and has empirical relevance based on previous research.

Table 3
Validation results for project-based learning and simulation models

Variable	No. Item	Validator 1	Validator 2	Validator 3	V (per-aspect)	Validity	V (per-variable
Rationale for the learning model	1	4	4	5	0.8333	High	0,8889
	2	5	4	5	0.9167	High	
	3	5	5	4	0.9167	High	
Supporting Theory of Learning Model	4	4	4	4	0.7500	Medium	**0.7500**
	5	4	3	4	0.6667	Medium	
	6	4	4	5	0.8333	High	
Description of Learning Model Syntax	7	4	4	5	0.8333	High	0.8542
	8	5	4	5	0.9167	High	
	9	4	5	4	0.8333	High	
	10	4	5	4	0.8333	High	
Implementation of the Learning Model	11	4	4	5	0.8333	High	0.8056
	12	5	4	4	0.8333	High	
	13	4	4	4	0.7500	Medium	
Syntax Interconnection in Learning Model	14	5	5	4	0.9167	High	**0.9167**
	15	5	4	5	0.9167	High	
Support platform (e-learning) for Learning Model	16	4	5	4	0.8333	High	0.8611
	17	5	4	4	0.8333	High	
	18	5	4	5	0.9167	High	
Category					**0.8426**	**High**	

Table 3 shows that the Aiken index of the validity test of the project-based learning and simulation models is 0.8426. This value shows a fairly high level of validity. This means that the learning model received a positive assessment from the expert. In particular, the Syntax Interconnection in the Learning Model aspect achieved the highest Aiken's index of 0.9167, indicating that the model was declared highly valid. This shows that the syntax relationship in the learning model is very good. Meanwhile, in the Supporting Theory of Learning Model aspect, Aiken's lowest index was 0.7500 with sufficient validity criteria. Although it reaches an adequate level of validity, further improvement may be needed to ensure that the theory supporting the learning model is truly structured and relevant.

After the validation process, the new framework in this study was designed by adopting the framework proposed by Ramlee *et al.*, [39]. They proposed that lecturers and students obtain knowledge about the learning model before the project or assignment is given. So that, they get the concept and technical implementation of the model in the learning process. The findings show that there are several inhibiting factors in implementing the model. These inhibiting factors include insufficient time, high cost, and lack of collaboration in the group. The causes are students' negative attitudes, lack of communication, inadequate facilities, and uncreative products.

To reduce these inhibiting factors, the new framework needs to include new skills so that projects or tasks can be done well and optimally, namely skills that allow students to face various challenges or problems in the future. The reason for adding these skills is based on a literature review of previous studies [40-43] because of the demands of an increasingly advanced digital Era. To develop those skills, a new framework in this research is designed and illustrated in Figure 1. This new framework is adopted from the framework [39] and significantly contributes to this research.

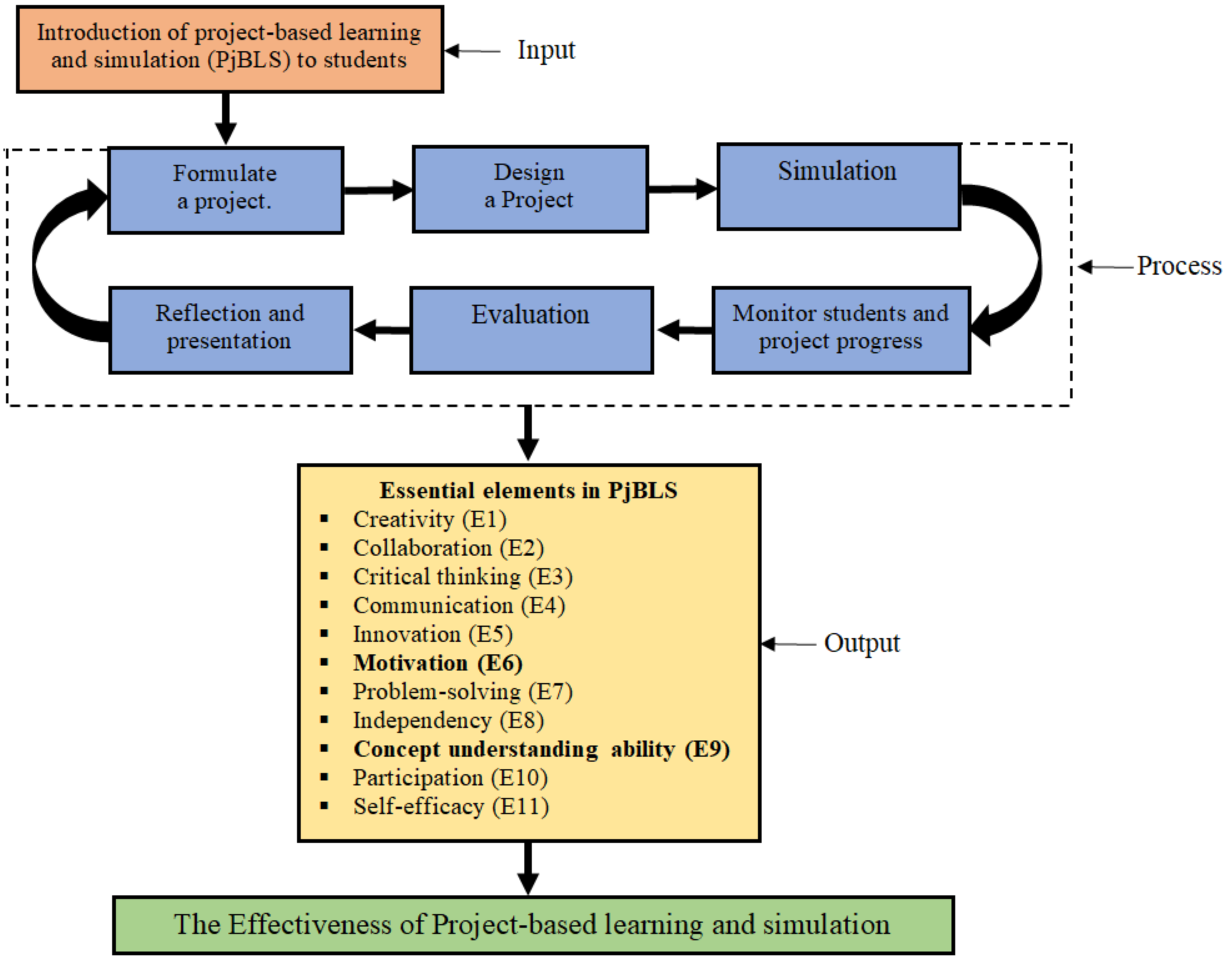

Fig. 1. PJBLS framework

The new framework combines two learning approaches, namely project-based learning (PJBL) and simulation (S), which focus on three main domains: input, process, and output. Based on the proposed framework, lecturers should explain the theory and technical application of PJBLS to students before starting the project. After the knowledge is obtained, proceed to implement PJBLS with predetermined steps. In this case, simulation is included in the PJBL stage. Simulation in PJBL plays a role in providing in-depth and contextual learning experiences to students. Simulation can give students practical experience in real situations that they can apply directly to the projects they work on. For example, students can design a specific project or task by utilizing information technology to design, model, and test the project before physically building it. Simulations can help students explore complex or abstract problems, such as building spaces. In addition, simulations can encourage collaboration and cooperation in groups. They can work together to find solutions, share knowledge, and integrate different knowledge and skills.

After the new framework was successfully created, the PJBLS model was applied to the learning process. Evaluation of the impact of the model implementation on student learning outcomes was conducted through pre-test and post-test scores to measure students' mathematical concept abilities. First, the pre-test was given before applying the learning model to assess students' initial understanding of the studied mathematical concepts. After the learning model was applied, the post-test was given to evaluate the improvement of students' understanding after participating in learning using the model. The difference between the pre-test and post-test scores was used to evaluate the effectiveness of the learning model in improving students' understanding of mathematical concepts.

Based on the data analysis results, students' ability to apply the project-based learning and simulation (PJBLS) model showed statistically significant results. The results of the hypothesis test analysis of students' mathematical concept ability data using the SPSS 16.0 program are presented in Table 4 below.

Table 4
Results of hypotheses testing for mathematical concept ability

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	31970.417[a]	1	31970.417	78.877	.000
Intercept	226812.017	1	226812.017	559.587	.000
Nilai	31970.417	1	31970.417	78.877	.000
Error	23508.567	58	405.320		
Total	282291.000	60			
Corrected Total	55478.983	59			

a. R Squared = ,576 (Adjusted R Squared = ,569)

Based on the analysis results, using the Two-way ANOVA test, the Sig. Value is smaller than α = 0.05, which is 0.000. This result shows a significant difference in the average value of students' mathematics ability based on the variable factor (pre-test and post-test). This conclusion proves that the PJBLS model improved students' mathematics learning outcomes. This finding provides concrete evidence of the successful implementation of the PJBLS model in improving learning effectiveness. The results of the analysis that showed significant differences in students' mathematical concept skills made it clear that the PJBLS model positively contributed to the learning process.

The combination of project-based learning (PJBL) and simulation in the learning process can significantly increase students' understanding of concepts. This is based on previous research findings, which show that PJBL is method that can help students develop their understanding of the material studied [44-45]. Students can reflect on their knowledge and apply it to relevant projects. Thus, they can explore their knowledge and experience more deeply in carrying out the assigned tasks. This aligns with the statement Anazifa and Djukri that PJBL is an effective learning method in stimulating concept understanding and acts as a catalyst to improve learning outcomes [46]. This is supported by the results of research [47-48}, which showed that this model proved effective in improving cognitive learning outcomes and learning quality. Through projects relevant to the learning material, students can develop their understanding of the concepts taught. Through PJBL, students can apply their knowledge in a real-world context and strengthen their knowledge transfer.

PJBL changes learning dynamics by emphasizing projects as the core of students' learning experience [49]. By integrating science concepts into relevant and engaging projects, students gain an understanding of the subject matter and develop their skills. The findings from their research indicate that PJBL is not just an alternative learning method but also an approach that can optimize students' science success through contextual, collaborative, and project-centred approaches. The researcher's findings reflect the statement of Ergül and Kargın that Project-based learning and simulation effectively improve students' mathematical concepts and skills.

PJBLS creates a powerful approach to learning where theory and practice come together to solve real-world problems. PJBLS brings a project element to learning, allowing students to engage in tasks that reflect real situations and require the application of theoretical concepts. On the other hand, Simulation presents an environment that allows students to experience and experiment with situations that may be difficult in the real world [50]. This aligns with previous research, which states that simulations based on real cases provide opportunities for students to relate abstract theories to real-world contexts that can strengthen their understanding [51]. By involving in simulations, students can see how concepts learned in class are applied in real situations to gain a deeper understanding.

Through PJBLS, students can design and implement projects that require the application of theory in a practical context. This process involves decision-making, problem-solving, group collaboration, and creating a contextualized learning experience. Meanwhile, simulations allow students to test their knowledge and skills. PJBLS creates an approach that allows students to hone practical skills while understanding the theoretical foundation. Thus, combining PJBL and simulation becomes an effective learning method in preparing students to face real-world challenges by synergistically integrating theory and practice. This aligns with the statement [52-53] that PJBL helps students integrate and apply theoretical principles in practice to solve real-world problems. However, students used to traditional learning may needed help to control their time, gather information, and solve project problems effectively [54]. Students' learning outcomes and skills can improve due to group discussion learning.

The application of this model plays a role in optimizing student skills through the group work process. Regarding this, [55] stated that PJBL is an effective method to help students develop critical thinking and problem-solving skills. Students do not just receive information, but they are actively involved in challenging problems. This process builds students' ability to construct arguments, evaluate information, and investigate concepts [56]. In addition, students are given challenges to face real-world problems, stimulating critical thinking in finding solutions to solve problems. This process stimulates problem-solving skills [57}, where students learn to face challenges together and investigate solutions creatively. Research has shown that student involvement in project activities promotes the development of creative thinking skills in problem-solving [58]. In this context, creativity is defined as the ability to generate new ideas and the ability to view problems from multiple perspectives and develop solutions.

Other research also shows that students can develop their creative skills through active participation in learning activities [59]. Students are not only focused on understanding concepts but also tested in their ability to apply that knowledge in creating products. This process challenges students creatively and provides concrete results that can add to their understanding of the learning material. PJBL provides space for students to participate actively in the learning process. Project tasks in PJBL encourage significant learning, where students understand concepts in depth and develop problem-solving skills [60]. The challenges faced together encourage students to think critically to deal with complexity and explore various solutions.

4. Conclusions

Based on the research results, the project-based learning and simulation (PJBLS) model received a very valid assessment in each aspect observed. First, on the aspect of Rationale for the learning model, which highlights the clarity of the selection of the learning model; second, Supporting Theory of Learning Model, which shows that there is a solid theoretical basis to support the application of the learning model; third, Description of Learning Model Syntax, which assesses the clarity and accuracy in explaining the structure and steps of the learning model; fourth, Implementation of the Learning Model, which shows the ability to implement the learning model well in learning; fifth, Syntax Interconnection in Learning Model, which highlights the alignment between various elements in the learning model; and finally, Support Platform, which assesses the availability and ease of access to platforms that support the implementation of the learning model. This research also shows that PJBLS contributes to developing effective and sustainable learning methods. The statistically significant difference between the pre-test and post-test scores indicates that implementing the PJBLS model in learning contributes positively to improving students' abilities and skills. Thus, applying the PJBLS model improves the quality of learning in higher education. The findings empirically confirm the model's effectiveness in improving students' academic achievement and provide a basis for developing more innovative and skill-oriented learning practices. In light of this research, it is essential to continue to encourage the integration of learning models into the higher education curriculum to ensure a more immersive and relevant learning experience for students.

Acknowledgement

Great thanks to the Rector of Universitas PGRI Sumatera Barat for the permission and support that has been given to implement this research. Appreciation to the students, who have enthusiastically participated in this research. Their contribution is significant in this research, and the results can be interpreted well so that they can provide sustainable benefits for learning development and become a valuable contribution to the understanding and practice of learning at the higher education level more generally.

References

[1] King, Norman Adamson Sigalla, and Jane Edward King. "Education As a Pillar for Sustainable Development in Tanzania." *OIDA International Journal of Sustainable Development* 12, no. 07 (2019): 53-58.

[2] Quiroz-Niño, Catalina, and María Ángeles Murga-Menoyo. "Social and solidarity economy, sustainable development goals, and community development: The mission of adult education & training." *Sustainability* 9, no. 12 (2017): 2164. https://doi.org/10.3390/su9122164

[3] Pucciarelli, Francesca, and Andreas Kaplan. "Competition and strategy in higher education: Managing complexity and uncertainty." *Business horizons* 59, no. 3 (2016): 311-320. https://doi.org/10.1016/j.bushor.2016.01.003

[4] Redeker, Christine, Miriam Leis, Matthijs Leendertse, Yves Punie, Govert Gijsbers, Paul A. Kirschner, Slavi Stoyanov, and Bert Hoogveld. "The future of learning: Preparing for change." (2012). https://doi.org/10.2791/64117

[5] Martinez, Corinne. "Developing 21st century teaching skills: A case study of teaching and learning through project-based curriculum." *Cogent Education* 9, no. 1 (2022): 2024936. https://doi.org/10.1080/2331186X.2021.2024936

[6] Malik, Ranbir Singh. "Educational challenges in 21st century and sustainable development." *Journal of Sustainable Development Education and Research* 2, no. 1 (2018): 9-20. https://doi.org/10.17509/jsder.v2i1.12266

[7] Van Laar, Ester, Alexander JAM Van Deursen, Jan AGM Van Dijk, and Jos De Haan. "The relation between 21st-century skills and digital skills: A systematic literature review." *Computers in human behavior* 72 (2017): 577-588.https://doi.org/10.1016/j.chb.2017.03.010

[8] Soulé, Helen, and Tatyana Warrick. "Defining 21st century readiness for all students: What we know and how to get there." *Psychology of Aesthetics, Creativity, and the Arts* 9, no. 2 (2015): 178. https://doi.org/10.1037/aca0000017

[9] Oddone, Kay, Hilary Hughes, and Mandy Lupton. "Teachers as connected professionals: A model to support professional learning through personal learning networks." *International Review of Research in Open and Distributed Learning* 20, no. 3 (2019). https://doi.org/10.19173/irrodl.v20i4.4082

[10] Caena, Francesca, and Christine Redecker. "Aligning teacher competence frameworks to 21st century challenges:

The case for the European Digital Competence Framework for Educators (Digcompedu)." *European journal of education* 54, no. 3 (2019): 356-369. https://doi.org/10.1111/ejed.12345
[11] Shahroom, Aida Aryani, and Norhayati Hussin. "Industrial revolution 4.0 and education." *International Journal of Academic Research in Business and Social Sciences* 8, no. 9 (2018): 314-319. https://doi.org/10.6007/IJARBSS/v8-i9/4593
[12] Winter, Eileen, Aisling Costello, Moya O'Brien, and Grainne Hickey. "Teachers' use of technology and the impact of Covid-19." *Irish educational studies* 40, no. 2 (2021): 235-246. https://doi.org/10.1080/03323315.2021.1916559
[13] Chen, Lijia, Pingping Chen, and Zhijian Lin. "Artificial intelligence in education: A review." *Ieee Access* 8 (2020): 75264-75278. https://doi.org/10.1109/ACCESS.2020.2988510
[14] Lawrence, Japhet E., and Usman A. Tar. "Factors that influence teachers' adoption and integration of ICT in teaching/learning process." *Educational Media International* 55, no. 1 (2018): 79-105. https://doi.org/10.1080/09523987.2018.1439712
[15] Ratheeswari, K. "Information communication technology in education." *Journal of Applied and Advanced research* 3, no. 1 (2018): 45-47. https://doi.org/10.21839/jaar.2018.v3iS1.169
[16] Hamidi, Hodjat, and Amir Chavoshi. "Analysis of the essential factors for the adoption of mobile learning in higher education: A case study of students of the University of Technology." *Telematics and Informatics* 35, no. 4 (2018): 1053-1070. https://doi.org/10.1016/j.tele.2017.09.016
[17] Hays, Jay, and Hayo Reinders. " Hamidi, Hodjat, and Amir Chavoshi. "Analysis of the essential factors for the adoption of mobile learning in higher education: A case study of students of the University of Technology." *Telematics and Informatics* 35, no. 4 (2018): 1053-1070." International Review of Education 66, no. 1 (2020): 29-52. https://doi.org/10.1007/s11159-020-09820-7
[18] Darling-Hammond, Linda, Lisa Flook, Channa Cook-Harvey, Brigid Barron, and David Osher. "Implications for educational practice of the science of learning and development." *Applied developmental science* 24, no. 2 (2020): 97-140. https://doi.org/10.1080/10888691.2018.1537791
[19] Wijngaards-de Meij, Leoniek, and Sigrid Merx. "Improving curriculum alignment and achieving learning goals by making the curriculum visible." *International Journal for Academic Development* 23, no. 3 (2018): 219-231. https://doi.org/10.1080/1360144X.2018.1462187
[20] Albrecht, Jeffrey R., and Stuart A. Karabenick. "Relevance for learning and motivation in education." *The Journal of Experimental Education* 86, no. 1 (2018): 1-10. https://doi.org/10.1080/00220973.2017.1380593
[21] Ali, Liaqat. "The Design of Curriculum, Assessment and Evaluation in Higher Education with Constructive Alignment." *Journal of Education and e-learning Research* 5, no. 1 (2018): 72-78. https://doi.org/10.20448/journal.509.2018.51.72.78
[22] Voogt, Joke M., Jules M. Pieters, and Adam Handelzalts. "Teacher collaboration in curriculum design teams: Effects, mechanisms, and conditions." In *Teacher Learning Through Teacher Teams*, pp. 7-26. Routledge, 2018. https://doi.org/10.4324/9781315123431-2
[23] Sumarni, W., and S. Kadarwati. "Ethno-stem project-based learning: Its impact to critical and creative thinking skills." *Jurnal Pendidikan IPA Indonesia* 9, no. 1 (2020): 11-21. https://doi.org/10.15294/jpii.v9i1.21754
[24] Palatnik, Alik. "Didactic situations in project-based learning: The case of numerical patterns and sequences." *The Journal of Mathematical Behavior* 66 (2022): 100956. https://doi.org/10.1016/j.jmathb.2022.100956
[25] Al-Balushi, Sulaiman M., and Shamsa S. Al-Aamri. "The effect of environmental science projects on students' environmental knowledge and science attitudes." *International Research in Geographical and Environmental Education* 23, no. 3 (2014): 213-227. https://doi.org/10.1080/10382046.2014.927167
[26] Jayanti, Ratna Dwi, S. Keb, Wahyul Anis, and S. Keb, eds. *Simulasi dalam Pendidikan Kebidanan*. Airlangga University Press, 2021.
[27] Seel, Norbert M., and Patrick Blumschein. "Modeling and simulation in learning and instruction: A theoretical perspective." In *Model-based approaches to learning*, pp. 2-14. Brill, 2009.https://doi.org/10.1163/9789087907112_003
[28] Angelini, M. Laura. "Integration of the pedagogical models "simulation" and "flipped classroom" in teacher instruction." *Sage Open* 6, no. 1 (2016): 2158244016636430. https://doi.org/10.1177/2158244016636430
[29] Zapalska, Alina, and Dallas Brozik. "A model for developing and evaluating games and simulations in business and economic education." *Zbornik radova Ekonomskog fakulteta u Rijeci, časopis za ekonomsku teoriju i praksu-Proceedings of Rijeka Faculty of Economics, Journal of Economics and Business* 26, no. 2 (2008): 345-368.
[30] Beckem, John M., and Michael Watkins. "Bringing life to learning: Immersive experiential learning simulations for online and blended courses." *Journal of Asynchronous Learning Networks* 16, no. 5 (2012): 61-70. https://doi.org/10.24059/olj.v16i5.287
[31] Klassen, Kenneth J., and Keith A. Willoughby. "In-class simulation games: Assessing student learning." *Journal of*

Information Technology Education: Research 2, no. 1 (2003): 1-13. https://doi.org/10.28945/306
[32] National Research Council. *Learning science through computer games and simulations*. 2010.
[33] Masson, Michael EJ, Daniel N. Bub, and Christopher E. Lalonde. "Video-game training and naïve reasoning about object motion." *Applied Cognitive Psychology* 25, no. 1 (2011): 166-173. https://doi.org/https://doi.org/10.1002/acp.1658
[34] Nusi, Ahmad, Azwar Ananda, Agusti Efi, and Piki Setri Pernantah. "Using Simulation on Project Based Learning in Minangkabau Culture Subject." *International Journal of Instruction* 15, no. 1 (2022): 311-326. https://doi.org/10.29333/iji.2022.15118a
[35] Maydiantoro, Albet. "Research model development: Brief literature review." *Jurnal Pengembangan Profesi Pendidik Indonesia* 1, no. 2 (2021): 29-35.
[36] Doppelt, Yaron. "Assessment of project-based learning in a mechatronics context." (2005). https://doi.org/10.21061/jte.v16i2.a.1
[37] Suartama, I. Kadek, Punaji Setyosari, and Saida Ulfa. "Development of an instructional design model for mobile blended learning in higher education." *International Journal of Emerging Technologies in Learning* 14, no. 16 (2019).https://doi.org/10.3991/ijet.v14i16.10633
[38] Leow, Fui-Theng, and Mai Neo. "Redesigning the classroom environment to enhance students' collaborative learning activities." In *Emerging Issues in Smart Learning*, pp. 267-274. Springer Berlin Heidelberg, 2015.https://doi.org/10.1007/978-3-662-44188-6_37
[39] Mustapha, Ramlee, Irdayanti Mat Nashir, Mohamed Nor Azhari bin Azman, and Khairul Anuar Hasnan. "Assessing the Implementation of the Project-Based Learning (PJBL) in the Department of Mechanical Engineering at a Malaysian Polytechnic." *Journal of Technical Education and Training* 12, no. 1 (2020). https://doi.org/10.30880/jtet.2020.12.01.011
[40] Pan, Ai-Jou, Chin-Feng Lai, and Hsu-Chan Kuo. "Investigating the impact of a possibility-thinking integrated project-based learning history course on high school students' creativity, learning motivation, and history knowledge." *Thinking Skills and Creativity* 47 (2023): 101214. https://doi.org/10.1016/j.tsc.2022.101214
[41] Barak, Miri, and Shiran Yuan. "A cultural perspective to project-based learning and the cultivation of innovative thinking." *Thinking Skills and Creativity* 39 (2021): 100766. doi: 10.1016/j.tsc.2020.100766. https://doi.org/10.1016/j.tsc.2020.100766
[42] Wu, Ting-Ting, and Yu-Tzu Wu. "Applying project-based learning and SCAMPER teaching strategies in engineering education to explore the influence of creativity on cognition, personal motivation, and personality traits." *Thinking Skills and Creativity* 35 (2020): 100631. https://doi.org/10.1016/j.tsc.2020.100631
[43] Williams, Simon. "Investigating the allocation and corroboration of individual grades for project-based learning." *Studies in Educational Evaluation* 53 (2017): 1-9. https://doi.org/10.1016/j.stueduc.2016.10.009
[44] Yusri, R., N. Nurmi, and H. Delyana. "Development of ICT integrated project based learning student worksheet." In *Journal of Physics: Conference Series*, vol. 1157, no. 3, p. 032127. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1157/3/032127
[45] Delyana, H., R. Yusri, and A. Yunita. "The effectiveness of student worksheets based on project and integrated information technology in geometry space subject." *International Journal of Scientific and Research Publications* 8, no. 9 (2018): 682-685. https://doi.org/10.29322/IJSRP.8.9.2018.p8192
[46] Anazifa, Risqa D., and Djukri Djukri. "Project-based learning and problem-based learning: Are they effective to improve student's thinking skills?." *Jurnal Pendidikan IPA Indonesia* 6, no. 2 (2017): 346-355.https://doi.org/10.15294/jpii.v6i2.11100
[47] Lasauskiene, Jolanta, and Asta Rauduvaite. "Project-based learning at university: Teaching experiences of lecturers." *Procedia-Social and Behavioral Sciences* 197 (2015): 788-792. https://doi.org/10.1016/j.sbspro.2015.07.182
[48] Chu, Samuel Kai Wah, Shek Kam Tse, Elizabeth Ka Yee Loh, and Ken Chow. "Collaborative inquiry project-based learning: Effects on reading ability and interests." *Library & Information Science Research* 33, no. 3 (2011): 236-243. https://doi.org/10.1016/j.lisr.2010.09.008
[49] Ergül, N. Remziye, and Elif Keskin Kargın. "The effect of project based learning on students' science success." *Procedia-Social and Behavioral Sciences* 136 (2014): 537-541. https://doi.org/10.1016/j.sbspro.2014.05.371
[50] Rutten, Nico, Wouter R. Van Joolingen, and Jan T. Van Der Veen. "The learning effects of computer simulations in science education." *Computers & education* 58, no. 1 (2012): 136-153. https://doi.org/10.1016/j.compedu.2011.07.017
[51] Langfield, Danielle. "Reality imagined: The choice to use a real-world case in a simulation." *Journal of Political Science Education* 12, no. 4 (2016): 403-419. https://doi.org/10.1080/15512169.2016.1147963
[52] Kuppuswamy, Ramesh, and Duncan Mhakure. "Project-based learning in an engineering-design course–

developing mechanical-engineering graduates for the world of work." *Procedia CIRP* 91 (2020): 565-570. https://doi.org/10.1016/j.procir.2020.02.215
[53] Sharma, Aashish, Himanish Dutt, Ch Naveen Venkat Sai, and Santosh Madeva Naik. "Impact of project based learning methodology in engineering." *Procedia Computer Science* 172 (2020): 922-926.https://doi.org/10.1016/j.procs.2020.05.133
[54] Chen, Cheng-Huan, and Yong-Cih Yang. "Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators." *Educational Research Review* 26 (2019): 71-81. https://doi.org/10.1016/j.edurev.2018.11.001
[55] Rakshith, P., Shobha Shankar, N. Gowtham, G. K. Savyasachi, and R. Avinash. "Effective implementation of project based learning in microcontroller course." *Journal of Engineering Education Transformations* 36, no. Special Issue 2 (2023). https://doi.org/10.16920/jeet/2023/v36is2/23045
[56] Almulla, Mohammed Abdullatif. "The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning." *Sage Open* 10, no. 3 (2020): 2158244020938702. https://doi.org/10.1177/2158244020938702
[57] Nurmi, N., Hafizah Delyana, Radhya Yusri, and Alfi Yunita. "EFFECT OF STUDENT WORKSHEETS BASED ON PROJECTS THAT INTEGRATE INFORMATION TECHNOLOGY ON PROBLEM-SOLVING ACHIEVEMENT IN GEOMETRY SPACE SUBJECT." *European Journal of Education Studies* (2018). https://doi.org/10.5281/zenodo.1489188
[58] Usmeldi, Usmeldi, and Risda Amini. "Creative project-based learning model to increase creativity of vocational high school students." *International Journal of Evaluation and Research in Education (IJERE)* 11, no. 4 (2022): 2155-2164. https://doi.org/10.11591/ijere.v11i4.21214
[59] Sumarni, Woro, Syeli Wardani, S. Sudarmin, and D. N. Gupitasari. "Project based learning (PBL) to improve psychomotoric skills: A classroom action research." *Jurnal Pendidikan IPA Indonesia* 5, no. 2 (2016): 157-163. https://doi.org/10.15294/jpii.v5i2.4402
[60] García, Consuelo. "Project-based learning in virtual groups-collaboration and learning outcomes in a virtual training course for teachers." *Procedia-Social and Behavioral Sciences* 228 (2016): 100-105.https://doi.org/10.1016/j.sbspro.2016.07.015