ISSN : 2549-2764 (ONLINE)
ISSN : 2337-604X (PRINT)
BERKALA ILMIAH PENDIDIKAN FISIKA
https://ppjp.ulm.ac.id/journal/index.php/bipf

Development of E-Learning with an Educational Platform Based on Problem-Based Learning to Train High School Students' Understanding of Concepts

Juli Pratiwi[*1], Ayu Sundari[1,2], Nadiatul Husna[1], Talia Ananda[1,3], and M. Rahmad[1*]
[1]Master of Physics Education, Universitas Riau, Indonesia
[2]SMAN 8 Pekanbaru, Riau, Indonesia
[3]SMAN 1 Kampar Kiri, Riau, Indonesia
*m.rahmad@lecturer.unri.ac.id

DOI:10.20527/bipf.v12i3.19681

Received: 28 May 2024 Accepted: 12 October 2024 Published: 19 October 2024

Abstract

E-learning is a system carried out via electronic media, such as computers, tablets, or smartphones. E-learning platforms provide greater flexibility and accessibility for students to access learning materials anytime and anywhere. Based on the analysis conducted, 85.9% of students felt happy with e-learning, and 88.5% of students felt comfortable with e-learning-based learning because the features contained in e-learning helped students understand the material and were easy to use. This research expects to develop and test the validity and practicality of the PBL-based Edukati platform in increasing students' valid and practical understanding of concepts. This research is development research carried out using the ADDIE-type instructional design model. This research was completed only up to the development stage, namely at the validity and practicality stage. In view of the aftereffects of the validity test, the result was 3.30. Based on the results of the teacher's practicality test, the result was 3.88 and the students' practicality was 3.43, so it tends to be expressed that e-learning with an issue-based learning instructive stage to prepare comprehension understudies might interpret ideas in impulse and momentum material is in the valid and very practical category. Based on the results of the validity and practicality that have been carried out, e-learning with an educational platform based on problem-based learning to train understanding of concepts is suitable for use.

Keywords: e-learning; education; PBL; momentum and impulse; understanding concepts

How to cite: Pratiwi, J., Sundari, A., Husna, N., Ananda, T., & Rahmad, M. (2024). Development of e-learning with an educational platform based on problem based learning to train high school students' understanding of concepts. *Berkala Ilmiah Pendidikan Fisika*, *12*(3), 446-457.

INTRODUCTION

Education plays a crucial role in improving people's quality of life. Technology has made a significant contribution to elevating the standard of education in the digital age (Shiddiqi et al., 2021; Yang & Haiyu, 2024). Education is encountering significant changes, especially with the advancement of data and correspondence innovation (Li, 2024). One of the effects of mechanical improvements in

schooling is the introduction of E-learning (Cheng, 2024; Yiping & Jiajun, 2024).

One of education's recent innovations is e-learning (Hua, 2024). E-learning is a system carried out via electronic media, such as computers, tablets or smartphones (Carmi, 2024; Lim et al., 2023). E-learning stages give more noteworthy adaptability and openness to understudies in getting to learning materials whenever and anywhere (Setiaji & Dinata, 2020). The e-learning developed is based on problem-based learning, where the development of e-learning follows the indicators of the problem-based learning model. Each indicator aims to achieve the intended learning objectives. For example, in e-learning, there is a learning orientation where students will get a condition or problem regarding the learning topic. Students are directed in such a way as to understand the work steps of how to solve the problem. Then, students are allowed to conduct experiments using the learner worksheet media contained in e-learning. In the end, students will be tested on the concepts and solutions found from the problems studied by answering questions on formative and summative tests available on e-learning. Therefore, using the problem-based learning model, the developed e-learning can improve the achievement of learning objectives and the students' success in understanding the lesson concepts. The utilization of E-Learning in learning enjoys the benefits of learning freedom, interactivity, and training in the use of technological media (Setiaji & Dinata, 2020; Winata et al., 2021). E-learning can be accessed using several platforms, including LMS Edukati. LMS Edukati is an e-learning platform developed based on Moodle. Edukati is here to help run e-learning with features that make teaching and learning activities easier, such as monitoring progress, accessing materials, giving assignments, assessments, and other activities related to learning (Arifah et al., 2024).

However, the challenge faced in implementing e-learning is ensuring that students truly understand the concepts being taught, not just memorize the material. In this manner, the utilization of E-Learning is likewise joined by great learning strategies. Problem-Based Learning or PBL for short, is one strategy that has the potential to enhance students' conceptual comprehension. PBL is a learning model that can work on understudies' capacity to understand the concepts and material being studied. PBL is a learning model that focuses on problem solving (Baena-Luna et al., 2024; Papkiadeh et al., 2024). In this model, students are directed to solve problems related to the material being studied. Using PBL, students can gain direct experience in solving problems and improve their understanding of concepts (Kurniawan et al., 2020; Pimdee et al., 2024).

The e-learning developed is based on problem-based learning, where the development of e-learning follows the indicators of the problem-based learning model. Each indicator aims to achieve the intended learning objectives. For example, in e-learning, there is a learning orientation where students will get a condition or problem regarding the learning topic. Students are directed in such a way as to understand the work steps of how to solve the problem. Then, students are allowed to conduct experiments using the learner worksheet media contained in e-learning. In the end, students will be tested on the concepts and solutions found from the problems studied by answering questions on formative and summative tests available on e-learning. Therefore, using the problem-based learning model, the developed e-learning can improve the achievement of learning objectives and the students' success in understanding the lesson concepts.

In view of the consequences of research conducted by Budiarti et al. (2018), it is stated that the level of student misconceptions regarding momentum and impulse material is still high. Several factors contribute to this high misperception, such as students' limited access to learning materials or resources and extremely difficult-to-understand momentum and impulse materials. One way to overcome this problem is to develop learning resources that can be accessed quickly, such as technology-based learning resources, namely e-learning. E-learning is an alternative method of delivering material that is not limited by distance (Albanyan, 2024; Moussa, 2023; O'Connor et al., 2023).

Previous studies show that implementing PBL in e-learning can increase students' learning motivation and understanding of learning material (Hermanto et al., 2023; Junaid et al., 2021). PBL is implemented in e-modules and worksheets developed in e-learning. E-modules and worksheets are presented completely with PBL learning syntax, starting from problem orientation to the evaluation stage, which requires strong analysis before developing and implementing e-learning with the aim that the PBL syntax implemented is right on target and according to needs. Therefore, it is recommended that further research be able to conduct interviews with students to obtain more in-depth information about the role of each stage of learning in training students' understanding of concepts. Based on the analysis, 85.9% of students felt happy with e-learning, and 88.5% of students felt comfortable with e-learning-based learning because the features contained in e-learning helped students understand the material and were easy to use. In addition, this is bolstered by students' readily available internet access and devices. Therefore, the development of PBL-based e-learning with the Edukati platform can be an effective solution in training students' understanding of concepts. This research expects to develop and test the validity and practicality of PBL-based e-learning education in increasing the conceptual understanding of Class XI high school students.

METHOD

This type of research is development research, using the ADDIE instructional design model, which has five stages: Analyze, Design, Development, Implementation, and Evaluation. (Stephanie et al., 2023; Yu et al., 2021). This exploration was completed exclusively up to the Development stage, namely the practicality stage. The steps in the ADDIE development model are shown in Figure 1.

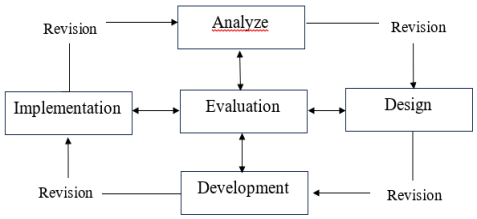

Figure 1 The steps in the ADDIE development model

The grid of validation items and practicalities tested is shown in Table 1.

Table 1 Validation Sheet Grid

No	Indicator	Number of Items
Pedagogical Aspects		
1	Presentation	6
2	PBL model	3
3	Concept Understanding	5
Media Aspect		
4	Appearance	7
5	Program	5
Material Aspects		
6	Material Suitability	8
7	Accuracy of Material	2
8	Update of Material	1
9	Language	1

Adapted from Hikmah & Nasrudin (2023); Septiani (2021).

The grid for the student's practical worksheet is shown in Table 2.

Table 2 Student practicality sheet grid

No	Indicator	Number of Items
Pedagogical Aspects		
1	Presentation	2
2	PBL model	3
3	Concept Understanding	3
Media Aspect		
4	Appearance	5
5	Program	5

Adapted from Septiani (2021)

The Teacher's Practical Sheet is listed in Table 3.

Table 3 Teacher practicality sheet grid

No	Indicator	Number of Items
Pedagogical Aspects		
1	Presentation	6
2	PBL model	3
3	Concept Understanding	5
Media Aspect		
4	Appearance	7
5	Program	5
Material Aspects		
6	Material Suitability	8
7	Accuracy of Material	2
8	Update of Material	1
9	Language	1

Adapted from Hikmah & Nasrudin (2023); Septiani (2021)

The research and development procedure is shown in Figure 2.

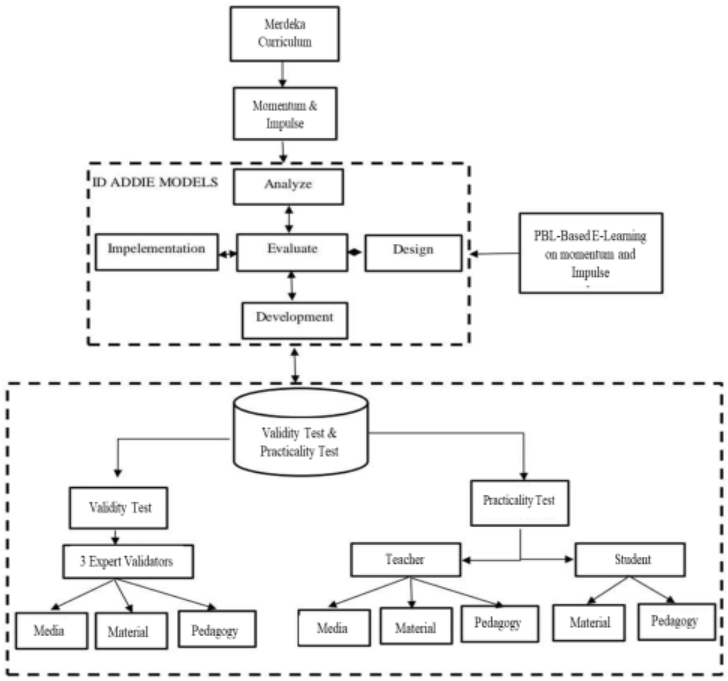

Figure 2 E-learning development procedure

The validity of the E-Learning created can be seen from the results of descriptive analysis, namely by describing quantitative data in the form of questionnaires filled out by experts. The validity test assessment questionnaire is prepared based on a Likert scale, which measures attitudes, opinions, and perceptions of a person or group (Budiaji et al., 2013; Riduwan (2013).

The validity category was determined from the average score of each item based on the Likert scale in Table 4.

Table 4 Validation index

Validation Index	Category
$3.50 < \underline{x} < 4.00$	Very Valid
$3.00 < \underline{x} < 3.50$	Valid
$1.00 < \underline{x} < 3.00$	Invalid

Adapted from Septiani (2021)

The e-learning component is declared valid if each validation assessment component has a minimum score of 3.00. If one of the assessment indicators is < 3.00, then the category is declared invalid, and the indicator must be corrected or revised, which is then validated again until it is valid.

Furthermore, the practicality test in this research uses descriptive analysis techniques, namely describing quantitative data in the form of scores from the practicality sheet of e-learning learning media by teachers and students. The steps taken for descriptive analysis are adding the values for each indicator on the practicality sheet. Then it is integrated into equation 1. E-learning is declared practical if the average assessment is in the practical and very practical categories, as in Table 5.

Table 5 Practicality criteria

Average Score	Category
$3.25 < \underline{x} < 4.00$	Very Practical
$2.50 < \underline{x} < 3.25$	Practical
$1.75 < \underline{x} < 2.50$	Impractical
$1.00 < \underline{x} < 1.75$	Very Impractical

Adapted from Sugiyono (2015)

RESULTS AND DISCUSSION

The procedure for developing E-Learning learning media using the Edukati Platform in the physics subject Momentum and Impulse material applies the ADDIE development model. Based on the development stages of the ADDIE model, there are five stages carried out in the development of e-learning with a problem-based learning educational platform to train students' conceptual understanding of impulse and momentum material, namely the analysis, design, development, implementation and evaluation stages. In this research, e-learning development was only carried out to the practicality stage. Testing of e-learning media is carried out using validity tests and practicality tests where validity tests are carried out involving experts, including material experts, media experts and learning design experts (pedagogy), while practicality tests are carried out using individual trials, small group trials, and field trials to test the responses of teachers and students. Presentations related to research and testing results are explained according to the ADDIE stages:

Needs Analysis

Researchers distributed questionnaires when making initial observations to analyze students' characteristics. Based on the questionnaire distributed to 78 respondents, results were obtained, as shown in Figure 3.

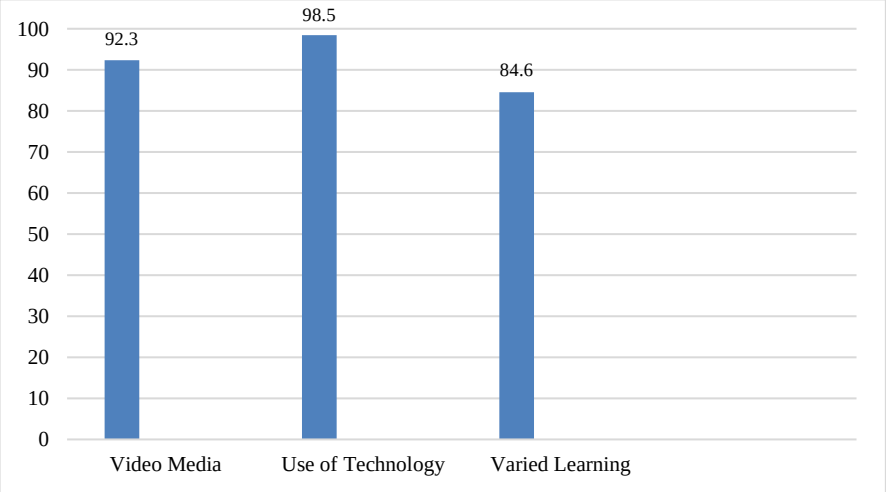

Figure 3 Results of the needs analysis

Based on a questionnaire distributed to 78 respondents, the results showed that 92.3% of students preferred learning if there were pictures or videos, and 98.5% felt comfortable with learning using technology. Meanwhile, based on the results of learning analysis in physics subjects based on the results of questionnaires, it is said that students feel bored with teachers' teaching methods, which always use conventional methods. Learning using conventional methods takes place classically and is teacher-centred; 84.6% of students are motivated to learn with varied activities and assignments.

Design

At the design stage, this is done by designing the learning media content uploaded to the e-learning being developed. The content design stage of e-learning learning media is carried out by designing teaching materials for momentum and impulse material for class activities. The learning content design stage is focused on creating learning content through e-modules, e-LKPD, videos, quizzes and evaluation questions.

Figure 4 Class menu display

At the e-learning media design stage, researchers developed media using the Educati platform. The researchers designed a menu structure for the flow of learning process activities by designing the features used in e-learning. The menu structure in e-learning using the education platform consists of three main menus: login, home, and class. The results of designing the menu structure in e-learning media designed using the educational platform can be seen in Figure 4. Figure 4 is a display of the e-learning class menu developed using education software.

Development

The product development stage is the stage where it is developed in the form of an e-learning website. The product

development process is divided into several stages, namely the database implementation stage, system implementation, which includes preparation and programming, and finally, the interface implementation stage. The implementation stage must be in accordance with the previously planned design stage and also in accordance with needs. After e-learning had been developed, the validity and practicality tests were carried out. Based on the validity and practicality tests carried out, the following results were obtained:

Expert validity

Validity test e-learning with an educational platform based on problem-based learning to train students' understanding of concepts in impulse and momentum material carried out by three experts, including material experts, media experts and pedagogy experts (van Haastrecht et al., 2024). Based on the validation carried out, the results obtained are as in Table 6.

Table 6 Expert validity test results

No	Indicator	Number of Items
Pedagogical Aspects		
1	Presentation	3.3
2	PBL model	3.3
3	Concept Understanding	3.6
Media Aspect		
4	Appearance	3.3
5	Program	3,2
Material Aspects		
6	Material Suitability	3.5
7	Accuracy of Material	3.5
8	Update of Material	3.0
9	Language	3.0

Based on validity tests carried out by media experts, material experts and pedagogy experts, it was found that the practicality value for each aspect tested was in the range 3.0-3.6. Based on the validity index criteria in Table 5, each aspect tested was in the valid category. If integrated into equation 1, it is obtained that the expert validation index value for e-learning with a problem-based learning educational platform to train students' understanding of concepts in impulse and momentum material is 3.3. Based on Table 6, the validation index for e-learning with a problem-based learning educational platform to train students' understanding of concepts in impulse and momentum material is in the valid category. This is in line with research studies conducted by Putri et al. (2021) and Chelsiyanti et al. (2022), which stated that e-learning is suitable for use in the learning process, with a very good category seen from the expert validation assessment.

Teacher Practicality

Three physics subject teachers carried out practicality test-learning with an educational platform based on problem-based learning to train students' understanding of concepts in impulse and momentum material. The teacher's practicality test results were obtained, as shown in Table 7.

Table 7 Teacher practicality test results

No	Indicator	Practicality Score		
		G1	G2	G3
Pedagogical Aspects				
1	Presentation	4.0	3.8	3.8
2	PBL model	3.6	3.3	3.6
3	Concept Understanding	3.8	3.8	3.8
Media Aspect				
4	Appearance	4.0	3.8	4.0
5	Program	4.0	3.8	4.0
Material Aspects				
6	Material Suitability	3.8	4.0	4.0
7	Accuracy of Material	4.0	4.0	4.0
8	Update of Material	4.0	4.0	4.0
9	Language	4.0	4.0	4.0

Based on the teacher's practicality test, it was found that the practicality value for each aspect tested was in the range of 3.3-

4.0. Every aspect tested is in the very practical category. If integrated into equation 1, it is found that the teacher's practicality value for e-learning with a problem-based learning educational platform to train students' understanding of concepts in impulse and momentum material is 3.88. Based on Table 6, the practicality of e-learning with an educational platform based on problem-based learning to train students' understanding of concepts in impulse and momentum material is in the very practical category. E-learning based on Problem-Based Learning (PBL) has emerged to enhance students' conceptual understanding of various subjects. Inquiries demonstrate that PBL fosters deeper learning and basic consideration and advances communication abilities, as it locks students into understanding real-world issues and requires them to take an interest in the preparation of their learning effectively. Previous research has also proven that technology-enhanced PBL highlights how this approach makes a difference in creating higher-order reasoning abilities, such as intelligent decision-making and judgment. These abilities are particularly important in disciplines that require problem-solving and explanatory skills. By coordinating e-learning tools, teachers can create intelligent scenarios that recreate real-life challenges, allowing students to apply concepts better and reflect on their learning outcomes. This strategy is very beneficial in advancing basic thinking and problem-solving among substitute students (Singh et al., 2024). This is in accordance with research directed by Putra (2022), which expresses that e-learning development using Moodle is practical. Practicality is related to the ease of use of e-learning.

Student practicality

Practicality learning with an educational platform based on problem-based learning to train students' understanding of concepts in impulse and momentum material was carried out by 10 high school students. Students can access e-learning by logging in using an account that the researcher has developed. In e-learning, students can access e-modules, worksheets, quizzes, and learning videos, where e-modules and worksheets are developed according to the problem-based learning steps. Based on practicality tests carried out by students, results were obtained as seen in Table 8.

Table 8 Student practicality test results

No	Indicator	Practicality Score
Pedagogical Aspects		
1	Presentation	3.55
2	PBL model	3.40
3	Concept Understanding	3.43
Media Aspect		
4	Appearance	3.42
5	Program	3.42

The practicality score of the e-learning developed is in the range of 3.40-3.55. Based on the practical criteria, each aspect of e-learning is in the very practical category. Suppose the results of student practicality are integrated into equation 1. In that case, the results of the practicality of e-learning with a problem-based learning educational platform to prepare comprehension understudies might interpret ideas in impulse and momentum material are obtained 3.43. Problem-based learning and e-learning are both practical educational platforms to train students' understanding of concepts in momentum, and impulse material is in the very practical category. This is in accordance with research led by Putra (2022), Hanifati et al. (2019) and Chelsiyanti et al. (2022), which expressed that e-learning development using Moodle is practical to use. Practicality is related to the ease of using e-learning.

This e-learning-based platform is very adaptive to the development of current technology in the field of

education. With this platform, students can quickly adapt to rapid technological developments; they become accustomed to digital computerized learning. This e-learning can be adjusted to achieve the desired abilities by adjusting the learning materials and indicators according to needs. This study can reference other schools that want to develop an e-learning-based learning system. Teachers or other users who want to use e-learning in learning can develop e-learning according to their needs by following the development steps in this study.

CONCLUSION

In view of the consequences of the media master validity test, the material and teaching method expressed that e-learning created is in the valid category. Based on the results of teacher and student practicality tests, it was found that the e-learning created was in the exceptionally very practical category. Based on the consequences of the validity and practicality of this research, e-learning with an educational platform based on problem-based learning to train students' understanding of concepts in momentum and impulse material is valid and very practical. Thus, the e-learning developed is suitable for implementation on momentum and impulse material in High School Class XI.

REFERENCES

Albanyan, A, M. (2024). The quality of distance learning during COVID-19: Perspectives of Saudi university students. *Heliyon*, *10*(13), e33731. https://doi.org/10.1016/j.heliyon.2024.e33731

Arifah, Z. N., Chaniago, S. M., & Kusmayati, N. B. (2024). Mengembangkan bahan ajar berbasis lms edukati untuk membaca kritis teks editorial. *Komposisi*, *25*(1), 22–39.

Baena-Luna, P., Sánchez-Torné, I., García-Río, E., & Pérez-Suárez, M. (2024). Influence of the problem-based learning methodology on the intrapreneurial intentions of university students. *International Journal of Management Education*, *22*(3). https://doi.org/10.1016/j.ijme.2024.101024

Budiaji, W., Fakultas, D., Universitas, P., Tirtayasa, A., Raya, J., Km, J., & Serang Banten, P. (2013). Skala pengukuran dan jumlah respon skala likert (The Measurement Scale and The Number of Responses in Likert Scale). *Jurnal Ilmu Pertanian Dan Perikanan Desember*, *2*(2), 127–133. http://umbidharma.org/jipp

Budiarti, A., Rusnayati, H., Siahaan, P., & Wijaya, A. F. C. (2018). Profil hambatan balajar epistimologis siswa pada materi momentum dan impuls kelas x sma berbasis analisis tes kemampuan responden. *WaPFi (Wahana Pendidikan Fisika)*, *3*(1), 35. https://doi.org/10.17509/wapfi.v3i1.10936

Carmi, G. (2024). E-Learning using zoom: A study of students' attitude and learning effectiveness in higher education. *Heliyon*, *10*(11), e30229. https://doi.org/10.1016/j.heliyon.2024.e30229

Chelsiyanti, M., Silitonga, H. T. M., & Hamdani, H. (2022). Pengembangan media pembelajaran berbasis moodle untuk materi momentum dan impuls di kelas x sma. *Variabel*, *5*(2), 75. https://doi.org/10.26737/var.v5i2.3639

Cheng, C. (2024). Entertainment social media based on deep learning and interactive experience application in English e-learning teaching systemNo Title. *Entertainment Computing*. https://doi.org/https://doi.org/10.1016/j.entcom.2024.100846

Hanifati, H. N., Budiharti, R., & Ekawati, E. Y. (2019). Pengembangan modul pembelajaran berbasis learning content development system (lcds)

tentang momentum dan impuls. *Jurnal Materi Dan Pembelajaran Fisika (JMPF)*, *9*(2), 96–102. https://jurnal.uns.ac.id/jmpf/article/view/38620

Heni Putri, D. A., Ardi, A., Alberida, H., & Yogica, R. (2021). Validitas media pembelajaran e-learning berbasis edmodo pada materi sel untuk peserta didik kelas xi sma/ma. *Journal for Lesson and Learning Studies*, *4*(2), 230–237. https://doi.org/10.23887/jlls.v4i2.34443

Hermanto, I. M., Nurhayati, Tahir, I., & Yunus, M. (2023). Penerapan model guided context-and problem-based learning untuk meningkatkan pemahaman konsep pada materi gelombang bunyi. *JPF (Jurnal Pendidikan Fisika) Universitas Islam Negeri Alauddin Makassar*, *11*(1), 151–162. https://doi.org/10.24252/jpf.v11i1.36233

Hikmah, S. I., & Nasrudin, H. (2023). Validity of student worksheets based on model argument driven inquiry integrated by stem to train students ' argumentation ability and self-efficacy in chemical equilibrium material. *IJORER: International Journal of Recent Educational Research*, *4*(4), 416–433.

Hua, C. (2024). Application of E-Learning entertainment learning based on intelligent interactive experience in English reading assistance mode. *Entertainment Computing*. https://doi.org/https://doi.org/10.1016/j.entcom.2024.100762

Junaid, M., Salahudin, S., & Anggraini, R. (2021). Pengaruh model pembelajaran problem based learning terhadap pemahaman konsep ipa siswa di smpn 17 tebo. *Physics and Science Education Journal (PSEJ)*, *1*(April), 16. https://doi.org/10.30631/psej.v1i1.709

Kurniawan, I. K., Parmiti, D., & Kusmariyatni, N. (2020). Pembelajaran ipa dengan model problem based learning berbantuan media audio visual meningkatkan pemahaman konsep siswa. *Jurnal Edutech Undiksha*, *8*(2), 80. https://doi.org/10.23887/jeu.v8i2.28959

Li, T. (2024). Research on digital entertainment media in English writing e-learning system based on interactive game learning method. *Entertainment Computing*, *52*.

Lim, C., Martin, Adnyana, M. A., Achmad, S., & Sutoyo, R. (2023). Online learning platform analysis during covid- 19 pandemic in indonesia. *Procedia Computer Science*, *227*, 606–613. https://doi.org/10.1016/j.procs.2023.10.564

Moussa, N. M. (2023). Conceptualizing the future of e-Learning: examining students ' readiness , satisfaction , and intention to continue employing remote learning in higher education landscape. *Journal of e-Learning and Knowledge Society*, *19*(2), 1–11.

O'Connor, S., Wang, Y., Cooke, S., Ali, A., Kennedy, S., Lee, J. J., & Booth, R. G. (2023). Designing and delivering digital learning (e-Learning) interventions in nursing and midwifery education: A systematic review of theories. *Nurse Education in Practice*, *69*(April), 103635. https://doi.org/10.1016/j.nepr.2023.103635

Papkiadeh, S. R., Taheri-Ezbarami, Z., Taklimi, M. M., Leili, E. K., & Razaghpoor, A. (2024). Comparing the effects of problem-and task-based learning on knowledge and clinical decision-making of nursing students concerning the use of transfusion medicine in pediatric nursing: An educational quasi-experimental study

in Iran. *Heliyon*, *10*(14). https://doi.org/10.1016/j.heliyon.2024.e34521

Pimdee, P., Sukkamart, A., Nantha, C., Kantathanawat, T., & Leekitchwatana, P. (2024). Enhancing thai student-teacher problem-solving skills and academic achievement through a blended problem-based learning approach in online flipped classrooms. *Heliyon*, *10*(7), e29172. https://doi.org/10.1016/j.heliyon.2024.e29172

Putra, F. (2022). Membangun e-learning menggunakan moodle sebagai alat bantu pembelajaran pada masa pandemi covid-19 di fakultas ilmu komputer universitas dharmas indonesia. *Jurnal SIMTIKA*, *5*(1), 35–41.

Riduwan. (2013). *Skala pengukuran variabel-variabel penelitian*. Alfabeta.

Septiani, Y., Misdalina., L. (2021). Development of e-learning based on flipped classroom assisted with blog on momentum and impuls materials physics in class x high schools. *Jurnal Geliga*, *Developmen*.

Setiaji, B., & Dinata, P. A. C. (2020). Analisis kesiapan mahasiswa jurusan pendidikan fisika menggunakan e-learning dalam situasi pandemi Covid-19. *Jurnal Inovasi Pendidikan IPA*, *6*(1), 59–70. https://doi.org/10.21831/jipi.v6i1.31562

Shiddiqi, A. M., Ijtihadie, R. M., Ahmad, T., Wibisono, W., Anggoro, R., & Santoso, B. J. (2021). Penggunaan internet dan teknologi iot untuk meningkatkan kualitas pendidikan. *Sewagati*, *4*(3), 235. https://doi.org/10.12962/j26139960.v4i3.7980

Singh, R., Singh, S. K., & Mishra, N. (2024). Influence of e-learning on the students' of higher education in the digital era: A systematic literature review. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-12604-3

Stephanie, C., Julie, Y., & Clinton, S. (2023). A systematic characterization of food safety training interventions using the analyze, design, develop, implement, evaluate (ADDIE) instructional design framework. *Food Control*, *145*.

Sugiyono. (2015). Metode penelitian kuantitatif, kualitatif, dan R&D. In *Alfabeta*.

van Haastrecht, M., Haas, M., Brinkhuis, M., & Spruit, M. (2024). Understanding validity criteria in technology-enhanced learning: A systematic literature review. *Computers and Education*, *220*(February), 105128. https://doi.org/10.1016/j.compedu.2024.105128

Winata, R., Friantini, R. N., & Sukirno, S. (2021). E-learning: Kemandirian belajar terhadap pemahaman konsep matematika pada pembelajaran dengan google classroom. *Faktor: Jurnal Ilmiah Kependidikan*, *8*(2), 148–157.

Yang, L., & Haiyu, Z. (2024). Big data technology for teaching quality monitoring and improvement in higher education - joint k-means clustering algorithm and apriori algorithm. *Systems and Soft Computing*, 200125. https://doi.org/10.1016/j.sasc.2024.200125

Yiping, T., & Jiajun, L. (2024). Research on digital entertainment technology and gaming methods based on hidden Markov models in English e-learning classroom mode. *Entertainment Computing*, *52*. https://doi.org/https://doi.org/10.1016/j.entcom.2024.100856

Yu, S. J., Hsueh, Y. L., Sun, J. C. Y., & Liu, H. Z. (2021). Developing an intelligent virtual reality interactive

system based on the ADDIE model for learning pour-over coffee brewing. *Computers and Education: Artificial Intelligence*, *2*, 100030. https://doi.org/10.1016/j.caeai.2021.100030