

Problem-based learning augmented reality based on local potential to improve student learning motivation

Zufahmi ⁽¹⁾ *, Fatchur Rohman ⁽²⁾, Dwi Listyorini ⁽²⁾

⁽¹⁾ Department of Biology Education, Faculty of Teacher Training and Education, Universitas Jabal Ghafur, Pidie, Aceh, Indonesia

⁽²⁾ Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, East Java, Indonesia

* Corresponding Author Email: zufahmibio@gmail.com

Article Information

Keyword:

problem based learning;
Augmented reality; Learning
motivation; Local potential;
Quasi-experimental design

Kata Kunci:

Pembelajaran berbasis masalah;
Realitas tertambah; Motivasi
belajar; Potensi lokal; Desain
kuasi-eksperimental

History:

Received : 07/01/2026
Revised : 23/01/2026
Accepted : 06/02/2026
Published : 10/02/2026

Abstract

Advances in technology and information have compelled the education sector to undergo continuous transformation. These developments present new challenges, as educational systems are required to equip students with the knowledge, skills, and attitudes necessary to respond to an increasingly dynamic world. Such competencies are strongly influenced by students' learning motivation; however, empirical evidence indicates that students' learning motivation remains relatively low. The present study seeks to examine the effectiveness of an augmented reality-assisted problem-based learning model integrated with local potential in enhancing students' learning motivation. A quasi-experimental design with a non-equivalent control group was employed. Data on learning motivation were collected using the Motivated Strategies for Learning Questionnaire. The results of the ANCOVA analysis revealed a significant effect on students' learning motivation ($p < 0.05$), indicating that the local potential-based AR-PBL model was effective in improving learning motivation. The Partial Eta Squared value of 0.605 indicates a large effect size, accounting for approximately 60% of the variance. Furthermore, the corrected mean score of learning motivation in the experimental group (87.93) was higher than that of the control group (80.64). These findings demonstrate that the local potential-based AR-PBL model is more effective in enhancing students' learning motivation than the PBL model alone.

Abstrak. Kemajuan teknologi dan informasi telah memaksa sektor pendidikan untuk mengalami transformasi berkelanjutan. Perkembangan ini menghadirkan tantangan baru, sebab sistem pendidikan diharuskan membekali siswa dengan pengetahuan, keterampilan, dan sikap yang diperlukan untuk merespons dunia yang semakin dinamis. Kompetensi tersebut sangat dipengaruhi oleh motivasi belajar siswa; namun, bukti empiris menunjukkan bahwa motivasi belajar siswa tetap relatif rendah. Penelitian ini bertujuan untuk menguji efektivitas model pembelajaran berbasis masalah yang didukung augmented reality dan terintegrasi dengan potensi lokal dalam meningkatkan motivasi belajar siswa. Desain kuasi-eksperimental dengan kelompok kontrol non-ekuivalen digunakan. Data tentang motivasi belajar dikumpulkan menggunakan Kuesioner Strategi Motivasi untuk Belajar. Hasil analisis ANCOVA menunjukkan efek signifikan pada motivasi belajar siswa ($p < 0.05$), menunjukkan bahwa model AR-PBL berbasis potensi lokal efektif dalam meningkatkan motivasi belajar. Nilai Partial Eta Squared sebesar 0.605 menunjukkan ukuran efek besar, menjelaskan sekitar 60% varians. Selain itu, skor rata-rata yang telah disesuaikan untuk motivasi belajar pada kelompok eksperimen (87,93) lebih tinggi dibandingkan dengan kelompok kontrol (80,64). Temuan ini menunjukkan bahwa model AR-PBL berbasis potensi lokal lebih efektif dalam meningkatkan motivasi belajar siswa dibandingkan dengan model PBL saja.

A. Introduction

The rapid advancement of technology and information has driven significant changes in the field of education. Technological progress has transformed the way people communicate, work, and think. Within the educational context, these transformations necessitate adjustments in curricula, teaching methods, and learning strategies to better equip students for future challenges (Kosimov et al., 2021). Learners are required to develop adequate knowledge, skills, and attitudes to compete and participate effectively in an increasingly complex and dynamic job market (Scott, 2015). Nevertheless, these goals can only be achieved if students possess a high level of learning motivation.

Learning motivation is a driving factor for students to actively engage (Chen, 2019; Filgona et al., 2020), a generator of desire to learn, and ensures the sustainability of the learning process (Chue & Nie, 2016; Ferreira et al., 2011; Filgona et al., 2020; Gopalan et al., 2017; Shabani, 2012). Students who lack learning motivation tend to be lazy in exploring new materials. Motivation can be a personality trait or an interest (Filgona et al., 2020). When students are highly motivated, the learning process becomes more enjoyable (Huang et al., 2019), and their understanding of creativity, productivity, and learning outcomes improve (Pintrich & De Groot, 2003; Saeed & Zyngier, 2012). Students who have low levels of motivation tend to experience frustration during the learning process (Ryan & Deci, 2000; Wood, 2019). Conversely, highly motivated students are more likely to participate in a wider range of learning activities (Legault et al., 2006; McDermott, 2001).

Preliminary research results in 2022 on high school students in Pidie Regency, Aceh Province, show that student learning motivation in the value component is fairly high in intrinsic goal orientation (61%), but low in extrinsic goal orientation (57%) and task value (56.9%). In the expectancy component, learning motivation was classified as adequate in terms of belief control for learning (61.1%), but low in terms of self-efficacy for learning (57.6%). Meanwhile, the affective component was classified as low in terms of anxiety test (55.7%). Overall, the results of the study show that student learning motivation is still low. Low student motivation is closely related to the implementation of learning in the classroom.

Students' learning motivation is strongly shaped by the role of teachers in the instructional process (Ryan & Deci, 2000; Trigueros et al., 2020; Wood, 2019). As educators, teachers need to understand students' needs, goals, and attitudes in order to effectively foster their motivation to learn (Gibbens, 2019; Trigueros et al., 2020). Moreover, teachers can enhance students' motivation by delivering learning activities in engaging and appealing ways (Fredricks et al., 2004; Tymms & Bolden, 2008). However, most teachers have not presented learning in an interesting way. The learning

methods used are limited to discussions, practical work, and observation. In addition, many teachers have not developed teaching materials according to the needs of students. As a result, learning becomes less meaningful and fails to foster values, expectations, and comfort in learning in students. The learning models currently implemented have not been effective in linking instructional content to real-life contexts, which results in lower levels of students' active learning motivation.

Learning motivation can be developed through the application of the Problem-Based Learning (PBL) model (Setyani et al., 2021). The PBL model has several key characteristics, namely that it is based on real, open-ended, and unstructured problems; problem identification and solving serve as a catalyst for acquiring knowledge and skills in achieving learning objectives; and learning is independent, team-based, and collaborative (Hung, 2013; Tortorella & Cauchick-Miguel, 2017); teachers as facilitators in the learning process; contextual learning; as well as reflective, continuous interaction, knowledge construction, and self-assessment (Rådberg et al., 2020; Tortorella & Cauchick-Miguel, 2017). The PBL model is an appropriate approach in science learning because it has been proven effective in improving students' understanding of science concepts, problem-solving abilities, critical thinking skills (Loyens et al., 2011; Savery, 2006), and increasing student motivation to learn (Arief & Sudin, 2016; Dayeni et al., 2017).

The PBL model will be more interesting if integrated with Augmented Reality (AR) technology. AR is one of the technologies that helps reduce challenges in science learning (Cai et al., 2017; Cheng & Tsai, 2013). Augmented Reality (AR) functions to stimulate and facilitate interaction between users and real-world objects as well as visual elements through the use of a camera accessible on computers or smartphones (D'Orazi, 2021). This technology offers considerable potential for educators to design learning experiences that are more engaging, exploratory (Sudarmilah & Wibowo, 2016), enjoyable (Tomi & Rambli, 2013), and efficient without diminishing the core learning content (Lee & Wong, 2019; López et al., 2019). The implementation of AR has also been shown to enhance students' learning motivation (Anuar et al., 2021), as it can enrich learning activities and improve overall instructional effectiveness (Clayton et al., 2010).

The development of a PBL model integrated with AR will be more meaningful if it incorporates local potential. Every individual constantly interacts with their environment, which is a source of knowledge to be learned. Utilizing the environment in the development of teaching materials allows for the presentation of material that is relevant to everyday life and serves as a solution to problems (Susilo, 2018). The Grand Forest Park provides information about

local potential, in the form of endemic animals and plants. This information can be integrated into learning through various forms of teaching materials. Based on the above issues, the purpose of this study is to determine the effectiveness of the Augmented Reality Problem-Based Learning model based on local potential in increasing student learning motivation.

B. Method

This research employed a quasi-experimental design using a non-equivalent control group approach (Table 1). The participants comprised 96 senior high school students from Aceh Province, Indonesia, with 49 students assigned to the control group (PBL) and 47 students to the experimental group (PBL+AR). The participants were selected using intact class sampling. Two senior high schools in Aceh Province were purposively chosen based on similar academic characteristics and curriculum implementation. In each participating school, one intact class was allocated to serve as either the experimental group or the control group. Baseline equivalence between groups was examined using pretest learning motivation scores prior to the intervention.

The intervention was conducted over six instructional sessions, each lasting 90 minutes. Both groups studied ecosystem components, environmental change, and conservation topics. Teachers involved in the study received prior orientation to ensure consistent implementation of instructional procedures. The experimental group was taught using a problem-based learning model assisted by an augmented reality e-module based on local potential. The control group received the same problem-based learning syntax without augmented reality support, using textbooks and internet resources.

The learning motivation instrument used in this study was the Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich and De Groot (2003). The questionnaire consisted of 31 items covering six motivation indicators: intrinsic goal orientation, extrinsic goal orientation, task value,

control of learning beliefs, self-efficacy for learning and performance, and test anxiety. Responses were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The MSLQ has been widely validated and demonstrated strong reliability in educational research contexts. Previous studies reported Cronbach's alpha coefficients ranging from 0.70 to 0.90 for the motivation subscales, indicating good internal consistency (Pintrich & De Groot, 2003). Therefore, the instrument was considered valid and reliable for measuring students' learning motivation in this study.

Augmented Reality (AR) was integrated into the learning process at several stages of the Problem-Based Learning (PBL) model. AR was implemented using an Android-based AR e-module containing local potential content from Tahura Pocut Meurah Intan, including three-dimensional visualizations of endemic plants and animals.

At the problem orientation stage, students in the experimental class accessed AR-based learning materials to observe contextual problems related to ecosystem components and environmental conservation. During the investigation stage, AR was used to support information exploration by allowing students to interact directly with virtual representations of local biodiversity. This facilitated deeper understanding of abstract concepts through visual and interactive experiences. At the development and presentation stage, AR-supported materials served as references for students in designing posters or videos proposing solutions to environmental problems. Through these stages, AR functioned as a cognitive and motivational support tool integrated into the PBL framework.

The increase in student learning motivation was measured using the N-Gain criteria (Table 2). Test the normality of the data using the Kolmogorov-Smirnov Test. Test the homogeneity of the data using Levene's Test. The data are considered normally distributed and homogeneous when the significance value exceeds 0.05.

Table 1 Quasi-experimental non-equivalent control group design

Pretest	Treatment	Posttest
O1	PBL + AR	O2
O3	PBL	O4

Description: PBL + AR = PBL +AR learning model class (experimental); PBL = PBL learning model class (control); O1, O3 = pretest motivation scores; and O2, O4 = posttest motivation scores

Table 2 Criteria for N-Gain assessment improvement

Scores	Category
> 0,7	High
> 0,3 dan < 0,7	Moderate
< 0,3	Low

(Source: Hake, 1999)

Data analysis was conducted using SPSS version 20. Statistical significance was determined at an alpha level of 0.05. Effect size was interpreted using Partial Eta Squared values. The ANCOVA test is used to determine the effectiveness of the local potential-based PBL AR model on student learning motivation in the control and experimental classes. If the p-value is <0.05, then the local potential-based PBL AR model is effective in increasing student learning motivation in the control and experimental classes. If the p-value is >0.05, then the local potential-based PBL AR model is not effective in increasing student learning motivation in the control and experimental classes.

C. Results and discussion

The results of this study indicate that the problem-based learning (PBL) model assisted by augmented reality (AR) and integrated with local potential is more effective in enhancing students' learning motivation than the PBL model alone. This finding is supported by the ANCOVA results (Tabel 3), which revealed a significant difference between the experimental and control groups with a large effect size. These results suggest that the integration of AR and local contextual

content within the PBL framework plays an important role in strengthening students' motivational engagement during learning. The corrected mean score of learning motivation in the experimental group was higher than that of the control group, indicating stronger motivational engagement among students exposed to AR-supported learning (Table 4).

An increase in learning motivation was observed across all motivation indicators, including intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety (Table 5 and Figure 1).

An increase in learning motivation was observed across all motivation indicators, including intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety. However, the magnitude of improvement varied among indicators, indicating that the AR-assisted PBL model influenced specific motivational dimensions differently. In particular, indicators related to task value and self-efficacy showed substantial improvement in the experimental group.

Table 3 Summary of ANCOVA test results for learning motivation

Tests of between-subjects effects			
Dependent variable: Posttest			
Source	Type III sum of squares	Mean square	Partial eta squared
Corrected Model	3257,624 ^a	628,812	0,797
Intercept	1158,073	158,073	0,583
Pre	2214,260	214,260	0,728
Group	1268,905	268,905	0,605
Error	828,209	8,905	
Total	684826		
Corrected Total	4085,833		
a. R Squared = .797 (Adjusted R Squared = .793)			

Table 4 Estimated marginal means

Group				
Dependent variable: Posttest				
Class	Mean	Std. error	95% confidence interval	
			Lower bound	Upper bound
PBL+AR	87.90 ^a	.436	87.065	88.796
PBL	80.64 ^a	.427	79.791	81.486
a. Covariates appearing in the model are evaluated at the following values: Pretest = 72.25.				

Table 5 Results of the N-Gain test of learning motivation in the control and experimental classes

Learning motivation indicators	Control (PBL)		Experimental (PBL + AR)	
	N-Gain score	Category	N-Gain score	Category
Intrinsic goal orientation	0,26	Low	0,58	Moderate
Extrinsic goal orientation	0,24	Low	0,57	Moderate
Task value	0,24	Low	0,58	Moderate
Control belief	0,30	Low	0,57	Moderate
Self-Efficacy for Learning and performance	0,30	Low	0,55	Moderate
Task Anxiety	0,35	Moderate	0,55	Moderate
Average	0,28	Low	0,57	Moderate

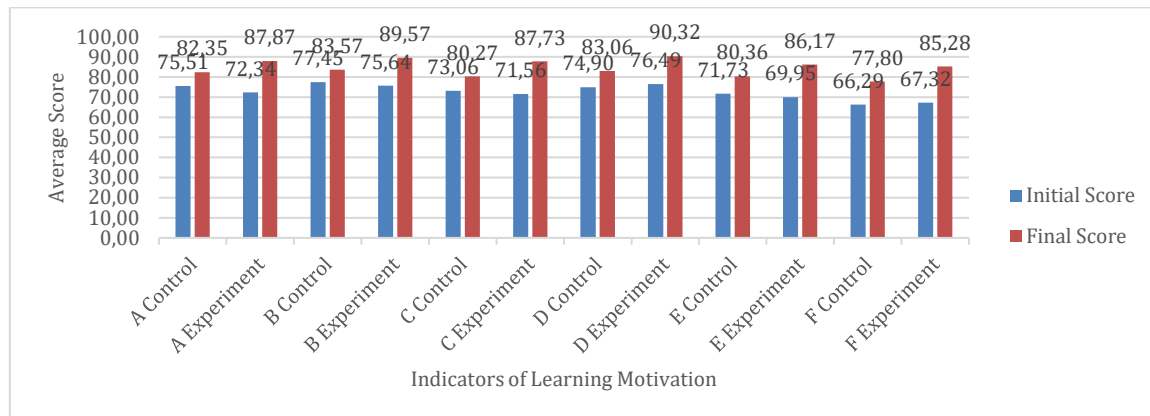


Figure 1

Initial and final values of learning motivation in control and experimental class students: a. intrinsic value; b. extrinsic value; c. task value; d. control belief for learning; e. belief for learning and achievement; and F. anxiety test.

The results of this study indicate that learning through the PBL model assisted by AR based on local potential has a better effect on student learning motivation than the PBL model alone. This is because the PBL model was developed with modern technology and contains content based on local potential. The AR technology used in this model provides an engaging visual experience of abstract concepts (Albayrak & Yilmaz, 2021; Santi et al., 2021) in the experimental class, while students in the control class understand the material through textbooks and the internet. It has been proven to increase learning motivation. In addition, the AR e-module-assisted PBL model, which contains local content in the form of endemic animals and plants, makes learning more relevant to students' lives, especially since the content is presented with three-dimensional (3D) animated images. All of this makes learning more interesting and interactive (Akçayır & Akçayır, 2017; Kok et al., 2022; Buchner & Kerres, 2023) so that students are motivated to learn (Wu et al., 2013; Wen et al., 2023).

The increase in student learning motivation in the experimental class was significantly higher than in the control class. This was evident throughout the entire learning syntax. At the initial stage of learning, both classes were directed to watch videos of problems relevant to students' lives. Students in the experimental class had the opportunity to watch repeatedly through the AR e-module based on local potential developed in this study, so that students had plenty of time to understand the concepts anytime and anywhere. This flexibility gave students the autonomy to learn independently, thereby motivating them (Jen and Yong, 2013; Legault, 2016; Gopalan et al., 2017; Yardimci et al., 2017). Students can enjoy learning, understand the material well, and be more confident (Gopalan et al., 2017; Torres, 2020; Trigueros et al., 2020). In contrast, students in the control class were

directed to watch the problem-solving video together on a monitor screen at the front of the classroom. Students had only one opportunity to watch the video. This activity caused commotion, reduced concentration, and decreased the desire to learn. The less conducive classroom conditions made it difficult for students to grasp and understand the material. Weak mastery of the material concepts reduced students' confidence and made them anxious in following the learning process (Filgona et al., 2020).

The next step is to organize students to learn using AR. Students are directed in groups to create concept maps. Students in the experimental class were more active and enthusiastic in searching for and finding important points relevant to the learning material through the AR e-module based on local potential. The material needed by students is available in this e-module, which has been proven to increase motivation as reported by Legault (2016), Yardimci et al. (2017), and Filgona et al. (2020). AR provided convenience to students in the experimental class due to the availability of teaching materials, making it easier for students to complete tasks and produce appropriate concept maps. In contrast, students in the control class searched for material through various learning resources, such as textbooks and the internet. In this study, there were no guidelines regarding website selection, which resulted in students having difficulty determining the appropriate ones. When students feel challenged, they become less active and their motivation to learn decreases (Olatoye, 2009; Silaj et al., 2021; Fr  chette-Simard et al., 2022). Students in the control class seemed to have difficulty determining these important points, while students in the experimental class found it easy to determine the important points because they were available in the AR e-module based on local potential. Based on these conditions, it was proven that the PBL model assisted

by an AR e-module based on local potential provided more convenience in learning for students in the experimental class compared to the control class, which only used the PBL model. After the concept map was well organized, students were directed to elaborate on the important points through information search activities about the concepts on the concept map that had been created.

Next, students conduct group investigations using AR. Students must find information relevant to endemic animals and plants. Students in the experimental class can easily and quickly find local information relevant to the learning material through the AR e-module. The speed and ease of accessing information increases students' confidence (Taylor et al., 2014) and belief in completing tasks on time (Wormington & Linnenbrink, 2017; Bae & Debusk, 2018). In contrast, students in the control class explored information through various sources. This caused students to take a long time to obtain the information they needed. As a result, students felt anxious (Torres, 2020) because they were afraid of obtaining incorrect information. This caused students to delay completing their tasks (Filgona et al., 2020).

After the investigation is complete, students develop their work in the form of posters or videos. In this case, students may choose posters or videos that contain information to protect the ecosystem in Tahura Pocut Meurah Intan. At this stage, students are encouraged to determine solutions to the problem. Students in the control and experimental classes are given the freedom to develop their ideas and present proposed solutions in the form of posters or videos. This freedom provides students with the opportunity to explore creative ideas (Vansteenkiste et al., 2018; Howard et al., 2021) in designing products. Students in the experimental class not only used AR based on local potential, but also used various sources of information. The use of diverse sources of information helped students to obtain ideas in developing their work (Fauziah et al., 2019). This activity increases students' motivation to learn and their enthusiasm for exploring ideas, as also reported by Cascales-Martínez et al. (2017) and Hsu et al. (2017). The designs produced by students in the control and experimental classes did not show significant differences. During the learning process, students in the control and experimental classes had the same opportunities, enabling them to develop their work well.

The final stage of learning involves analyzing and evaluating the results of the work. Students present and discuss the results of their work. At this stage, there is a significant difference between students in the experimental class and the control class. Students in the experimental class are more confident that the tasks they have completed are in accordance with the instructions. Students are more confident when presenting their work and are ready to receive feedback from other groups. This confidence

facilitates students in decision-making (Acosta & Ramirez, 2021) related to determining solutions and producing work. AR based on local potential contains structured material descriptions that are relevant to the local context. Students have structured guidelines that make it easier for them to understand the material and complete tasks (Trilestari & Almunawaroh, 2021; Amrilizia et al., 2022). In contrast, in the control class without the AR, students were unsure of their work because they did not have clear guidance to understand the tasks given. This caused anxiety and embarrassment in making decisions (Kim & Hodges, 2012; Butz et al., 2015) so students lacked confidence when presenting their work and were less prepared to receive feedback from other groups.

Overall, PBL learning assisted by AR e-modules based on local potential proved to be more effective in increasing student learning motivation compared to the use of PBL alone. The combination of PBL and AR based on local potential provides a more interactive and relevant learning experience, thereby influencing various indicators of student learning motivation. AR technology allows students to interact directly with the local context through digital devices. This activity makes learning more interesting and enjoyable, thereby encouraging students to be more active in learning (Khan et al., 2019; Kirikkaya & Başgöl, 2019). This study proves that students who use the PBL model assisted by AR e-modules based on local potential are more motivated to learn and understand complex concepts more easily, resulting in better understanding, greater confidence, and motivation to actively engage in the learning process.

This study provides both practical and theoretical contributions to the field of education. Practically, the findings demonstrate that the integration of an augmented reality-assisted problem-based learning (AR-PBL) model based on local potential can effectively enhance students' learning motivation in senior high school biology classes. The use of AR-supported local content enables schools to implement innovative learning without relying solely on generic or externally produced learning resources, thereby strengthening contextual and meaningful learning experiences.

From a theoretical perspective, this study contributes to the literature by extending research on learning motivation through the integration of problem-based learning, augmented reality, and local potential. Unlike previous studies that examined AR or PBL independently, this research demonstrates how the synergy between AR technology and local-context-based PBL can positively influence multiple dimensions of learning motivation, including intrinsic and extrinsic goal orientation, task value, self-efficacy, and anxiety reduction. These findings enrich existing motivational learning theories by highlighting the importance of contextualized digital learning environments.

The findings of this study have important implications for educational practice and policy. For teachers, the AR-assisted PBL model based on local potential can serve as an alternative instructional strategy to increase student motivation through interactive and contextual learning experiences. For schools, the development of AR-based teaching materials utilizing local potential supports the implementation of innovative learning while preserving local environmental knowledge. From a broader educational perspective, this study highlights the potential of integrating digital technology with local context to support student-centered learning. Policymakers and curriculum developers may consider incorporating AR-based contextual learning into science education curricula to foster motivation, engagement, and environmental awareness among students.

Several limitations should be acknowledged. This study did not explicitly measure treatment fidelity or teacher effect control. In addition, assumptions related to covariate linearity were not examined in depth. These limitations do not invalidate the findings but should be considered in future studies.

D. Conclusion

This study demonstrates that a problem-based learning model assisted by augmented reality and integrated with local potential is more effective in enhancing students' learning motivation than problem-based learning alone. The integration of digital technology with local contextual content provides meaningful, engaging, and student-centered learning experiences. This study highlights the potential of contextual augmented reality as an instructional support to improve motivation in biology learning.

E. Acknowledgement

This research was funded by the Education Fund Management Agency (LPDP) of the Ministry of Finance and the Centre for Education Financing Services (PUSLAPDIK) of the Ministry of Education.

F. References

- Acosta, G. E., & Ramirez, A. (2021). The influence of motivation, emotions, cognition, and metacognition on students' learning performance: A comparative study in higher education in blended and traditional contexts. *SAGE Open*, 11(2), 1–4. DOI: <https://doi.org/10.1177/21582440211027561>
- Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20, 1–11. DOI: <https://doi.org/10.1016/j.edurev.2016.11.002>
- Albayrak, S., & Yilmaz, R. M. (2021). An investigation of preschool children's interactions with augmented reality applications. *International Journal of Human-Computer Interaction*, 38(2), 165–184. DOI: <https://doi.org/10.1080/10447318.2021.1926761>
- Amrilizia, N., Habiddin, H., & Marsuki, M. F. (2022). Improving students' critical thinking skills using e-modules contextual teaching and learning (CTL) on the interaction of living organisms with their environment. *Journal of Disruptive Learning Innovation (JODLI)*, 3(2), 65–82. DOI: <http://dx.doi.org/10.17977/um072v3i22022p%25p>
- Anuar, S., Nizar, N., & Ismail, M. A. (2021). The impact of using augmented reality as teaching material on students. *Asian Journal of Vocational Education and Humanities*, 2(1), 1–8. DOI: <https://doi.org/10.53797/ajvah.v2i1.1.2021>
- Arief, H. S., & Sudin, A. (2016). Meningkatkan motivasi belajar melalui pendekatan problem-based learning (PBL). *Jurnal Pena Ilmiah*, 1(1), 141–150. DOI: <https://doi.org/10.23819/pi.v1i1.2945>
- Bae, C. L., & Debusk, L. M. (2018). Motivation belief profiles in science: Links to classroom goal structures and achievement. *Learning and Individual Differences*, 67, 91–104. DOI: <https://doi.org/10.1016/j.lindif.2018.08.003>
- Buchner, J., & Kerres, M. (2023). Media comparison studies dominate comparative research on augmented reality in education. *Computers & Education*, 195, 104711. DOI: <https://doi.org/10.1016/j.compedu.2022.104711>
- Butz, N. T., Stupnisky, R. H., & Pekrun, R. (2015). Students' emotions for achievement and technology use in synchronous hybrid graduate programmes: A control-value approach. *Research in Learning Technology*, 23, 26097. DOI: <https://doi.org/10.3402/rlt.v23.26097>
- Cai, S., Chiang, F. K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interactive Learning Environments*, 25(6), 778–791. DOI: <https://doi.org/10.1080/10494820.2016.1181094>
- Cascales, M. A., Martínez-Segura, M. J., Pérez-López, D., & Contero, M. (2017). Using an augmented reality enhanced tabletop system to promote learning of mathematics: A case study with students with special educational needs. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(2), 355–380. DOI: <https://doi.org/10.12973/eurasia.2017.00621a>
- Chen, Y. C. (2019). Effect of mobile augmented reality on learning performance, motivation, and math anxiety in a math course. *Journal of Educational Computing Research*, 57(7), 1695–1722. DOI: <https://doi.org/10.1177/0735633119854036>
- Cheng, K. H., & Tsai, C. C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of Science Education and Technology*, 22(4), 449–462. DOI: <https://doi.org/>

- 10.1007/s10956-012-9405-9
- Chue, K. L., & Nie, Y. (2016). International students' motivation and learning approach: A comparison with local students. *Journal of International Students*, 6(3), 678–699. DOI: <https://doi.org/10.32674/jis.v6i3.349>
- Clayton, K., Blumberg, F., & Auld, D. P. (2010). The relationship between motivation, learning strategies and choice of environment whether traditional or including an online component. *British Journal of Educational Technology*, 41(3), 349–364. DOI: <https://doi.org/10.1111/j.1467-8535.2009.00993.x>
- D'Orazi, G. (2021). Recent advances in P53. *Biomolecules*, 11(2), 1–4. DOI: <https://doi.org/10.3390/biom11020211>
- Dayeni, F., Irawati, S., & Yennita, Y. (2017). Upaya meningkatkan motivasi dan hasil belajar siswa melalui model problem based learning. *Diklabio: Jurnal Pendidikan dan Pembelajaran Biologi*, 1(1), 28–35. DOI: <https://doi.org/10.33369/diklabio.1.1.28-35>
- Fauziah, N., Hakim, A., & Andayani, Y. (2019). Improving student science literacy through problem-based learning. [Accepted manuscript].
- Ferreira, M., Cardoso, A. P., & Abrantes, J. L. (2011). Motivation and relationship of the student with the school as factors involved in the perceived learning. *Procedia - Social and Behavioral Sciences*, 29, 1707–1714. DOI: <https://doi.org/10.1016/j.sbspro.2011.11.416>
- Filgona, J., Sakiyo, J., Gwany, D. M., & Okoronka, A. U. (2020). Motivation in learning. *Asian Journal of Education and Social Studies*, 10(4), 16–37. DOI: <https://doi.org/10.9734/ajess/2020/v10i430273>
- Fr chet te, S. C., Plante, I., Duchesne, S., & Chaffee, K. E. (2022). The mediating role of test anxiety in the evolution of motivation and achievement of students transitioning from elementary to high school. *Contemporary Educational Psychology*, 71, 102116. DOI: <https://doi.org/10.1016/j.cedpsych.2022.102116>
- Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, 74(1), 59–109. DOI: <https://doi.org/10.3102/00346543074001059>
- Gibbens, B. (2019). Measuring student motivation in an introductory biology class. *The American Biology Teacher*, 81(1), 20–26. DOI: <https://doi.org/10.1525/abt.2019.81.1.20>
- Gopalan, V., Bakar, J. A. A., Zulkifli, A. N., Alwi, A., & Mat, R. C. (2017). A review of the motivation theories in learning. *AIP Conference Proceedings*, 1891, 020043. DOI: <https://doi.org/10.1063/1.5005376>
- Hake, R. R. (1999). Analyzing change/gain scores. Indiana University, Department of Physics.
- Howard, J. L., Bureau, J., Guay, F., Chong, J. X. Y., & Ryan, R. M. (2021). Student motivation and associated outcomes: A meta-analysis from self-determination theory. *Perspectives on Psychological Science*, 16(6), 1300–1323. DOI: <https://doi.org/10.1177/1745691620966789>
- Hsu, Y. S., Lin, Y. H., & Yang, B. (2017). Impact of augmented reality lessons on students' STEM interest. *Research and Practice in Technology Enhanced Learning*, 12(1). DOI: <https://doi.org/10.1186/s41039-016-0039-z>
- Huang, F., Teo, T., & Zhou, M. (2019). Factors affecting Chinese English as a foreign language teachers' technology acceptance: A qualitative study. *Journal of Educational Computing Research*, 57(1), 83–105. DOI: <https://doi.org/10.1177/0735633117746168>
- Hung, W. (2013). Problem-based learning: A learning environment for enhancing learning transfer. *New Directions for Adult and Continuing Education*, 2013(137), 27–38. DOI: <https://doi.org/10.1002/ace.20042>
- Jen, & Yong, B. C. S. (2013). Secondary school students' motivation and achievement combined science. *US-China Education Review B*, 3(4), 213–228. Retrieved from <https://files.eric.ed.gov/fulltext/ED542966.pdf>
- Khan, T., Johnston, K., & Ophoff, J. (2019). The impact of an augmented reality application on learning motivation of students. *Education Research International*, 2019, 7208494. DOI: <https://doi.org/10.1155/2019/7208494>
- Kim, C. M., & Hodges, C. B. (2012). Effects of an emotion control treatment on academic emotions, motivation and achievement in an online mathematics course. *Instructional Science*, 40(1), 173–192. DOI: <https://doi.org/10.1007/s11251-011-9165-6>
- Kirikkaya, E. B., & Ba  g  l, M.   . (2019). The effect of the use of augmented reality applications on the academic success and motivation of 7th grade students. *Journal of Baltic Science Education*, 18(3), 362–378. DOI: <https://doi.org/10.33225/jbse/19.18.362>
- Kok, D. L., Dushyanthen, S., Peters, G., Sapkaroski, D., Barrett, M., Sim, J., & Eriksen, J. G. (2022). Virtual reality and augmented reality in radiation oncology education: A review and expert commentary. *Technical Innovations and Patient Support in Radiation Oncology*, 24, 25–31. DOI: <https://doi.org/10.1016/j.tipsro.2022.08.007>
- Kosimov, S. U., Rafiqova, M. R., & Murodova, M. I. (2021). Implementation of the technological competence of future specialists. *Creative Education*, 12(3), 666–677. DOI: <https://doi.org/10.4236/ce.2021.123046>
- Lee, C., & Wong, G. K. C. (2019). Virtual reality and augmented reality in the management of intracranial tumors: A review. *Journal of Clinical Neuroscience*, 62, 14–20. DOI: <https://doi.org/10.1016/j.jocn.2018.12.036>

- Legault, L. (2016). *Encyclopedia of personality and individual differences*. Springer International Publishing. DOI: <https://doi.org/10.1007/978-3-319-28099-8>
- Legault, L., Green-Demers, I., & Pelletier, L. (2006). Why do high school students lack motivation in the classroom? Toward an understanding of academic amotivation and the role of social support. *Journal of Educational Psychology*, 98(3), 567–582. DOI: <https://doi.org/10.1037/0022-0663.98.3.567>
- López, W. O. C., Navarro, P. A., & Crispin, S. (2019). Intraoperative clinical application of augmented reality in neurosurgery: A systematic review. *Clinical Neurology and Neurosurgery*, 177, 6–11. DOI: <https://doi.org/10.1016/j.clineuro.2018.11.018>
- Loyens, S. M., Kirschner, P., & Paas, F. (2011). Students' approaches to university instruction: Motivating learning, deep processing, and reflective thinking. *University of Wollongong Research Online*. Retrieved from <https://ro.uow.edu.au/edupapers/1235>
- McDermott, L. C. (2001). Oersted medal lecture 2001: Physics education research—The key to student learning. *American Journal of Physics*, 69(11), 1127–1137. DOI: <https://doi.org/10.1119/1.1389280>
- Susilo, A. B. (2012). Pengembangan model pembelajaran IPA berbasis masalah untuk meningkatkan motivasi belajar dan berpikir kritis siswa SMP. *Journal of Primary Education*, 1(1), 13–20. DOI: <https://doi.org/10.15294/jpe.v1i1.58>
- Olatoye, R. A. (2009). Students' test anxiety, motivation for examinations and science achievement in junior secondary schools in Ogun State, Nigeria. *International Journal of Psychology and Counselling*, 1(10), 194–198.
- Pintrich, P. R., & De Groot, E. V. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology*, 95(4), 667–686. DOI: <https://doi.org/10.1037/0022-0663.95.4.667>
- Radberg, K. K., Lundqvist, U., Malmqvist, J., & Hagvall Svensson, O. (2020). From CDIO to challenge-based learning experiences: Expanding student learning as well as societal impact. *European Journal of Engineering Education*, 45(1), 22–37. DOI: <https://doi.org/10.1080/03043797.2018.1441265>
- Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, 25(1), 54–67. DOI: <https://doi.org/10.1006/ceps.1999.1020>
- Saeed, S., & Zyngier, D. (2012). How motivation influences student engagement: A qualitative case study. *Journal of Education and Learning*, 1(2), 252–267. DOI: <https://doi.org/10.5539/jel.v1n2p252>
- Santi, G. M., Ceruti, A., Liverani, A., & Osti, F. (2021). Augmented reality in Industry 4.0 and future innovation programs. *Technologies*, 9(2), 33. DOI: <https://doi.org/10.3390/technologies9020033>
- Savery, J. (2006). Overview of problem-based learning: Definition and distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 1(1), 9–20. DOI: <https://doi.org/10.7771/1541-5015.1002>
- Scott, C. L. (2015). *The futures of learning 2: What kind of learning for the 21st century?* Education Research and Foresight Working Papers No. 14. UNESCO. Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000242996>
- Setyani, N. S., Susilowati, L., & Sholihah, Q. (2021). Application of electronic problem-based learning (e-PBL) during the COVID-19 pandemic in entrepreneurial attitude. *Eurasian Journal of Educational Research*, 95, 156–175. DOI: <https://doi.org/10.14689/ejer.2021.95.9>
- Shabani, K. (2012). Dynamic assessment of L2 learners' reading comprehension processes: A Vygotskian perspective. *Procedia - Social and Behavioral Sciences*, 32, 321–328. DOI: <https://doi.org/10.1016/j.sbspro.2012.01.047>
- Silaj, K. M., Schwartz, S. T., Siegel, A. L. M., & Castel, A. D. (2021). Test anxiety and metacognitive performance in the classroom. *Educational Psychology Review*, 33(4), 1809–1834. DOI: <https://doi.org/10.1007/s10648-021-09598-6>
- Sudarmilah, E., & Wibowo, P. A. (2016). Aplikasi augmented reality game edukasi untuk pengenalan organ tubuh manusia. *Khazanah Informatika: Jurnal Ilmu Komputer dan Informatika*, 2(1), 20. DOI: <https://doi.org/10.23917/khif.v2i1.1945>
- Susilo, M. J. (2018). Analisis potensi lingkungan sekitar sebagai sumber belajar biologi yang berdayaguna. *Proceeding Biology Education Conference*, 15(1), 541–546. Retrieved from <https://jurnal.uns.ac.id/prosbi/article/view/32606>
- Taylor, G., Jungert, T., Mageau, G. A., Schattke, K., Dedic, H., Rosenfield, S., & Koestner, R. (2014). A self-determination theory approach to predicting school achievement over time: The unique role of intrinsic motivation. *Contemporary Educational Psychology*, 39(4), 342–358. DOI: <https://doi.org/10.1016/j.cedpsych.2014.08.002>
- Tomi, A. B., & Rambli, D. R. A. (2013). An interactive mobile augmented reality magical playbook: Learning number with the thirsty crow. *Procedia Computer Science*, 25, 123–130. DOI: <https://doi.org/10.1016/j.procs.2013.11.015>
- Torres, M. A. (2020). Learning motivation-achievement theory utilizing deductive approach. *International Journal of Formal Sciences: Current and Future Research Trends*, 7(1), 7–18. Retrieved from https://ijfscfjournal.isrra.org/index.php/Formal_Sciences_Journal/article/view/568
- Tortorella, G., & Cauchick-Miguel, P. A. (2017). An initiative for integrating problem-based learning into a lean manufacturing course of an industrial engineering graduate program. *Production*, 27, 1–14. DOI: <https://doi.org/10.1590/0103-6513.224716>

- Trigueros, R., Padilla, A., Aguilar-Parra, J. M., & Lirola, J. (2020). The influence of teachers on motivation and academic stress and their effect on the learning strategies of university students. *International Journal of Environmental Research and Public Health*, 17(23), 9089. DOI: <https://doi.org/10.3390/ijerph17239089>
- Trilestari, K., & Almunawaroh, N. F. (2021). E-module as a solution for young learners to study at home. In *Proceedings of the 4th Annual Seminar on English Language and Teaching (ASSEHR)* (Vol. 513, pp. 364–369). DOI: <https://doi.org/10.2991/assehr.k.201230.132>
- Tymms, P., & Bolden, D. S. (2008). Science in English primary schools: Trends in attainment, attitudes and approaches. *Perspectives on Education: Primary Science*, 1, 19–42. Retrieved from <https://durham-repository.worktribe.com/output/1553099>
- Vansteenkiste, M., Aelterman, N., De Muynck, G. J., Haerens, L., Patall, E., & Reeve, J. (2018). Fostering personal meaning and self-relevance: A self-determination theory perspective on internalization. *Journal of Experimental Education*, 86(1), 30–49. DOI: <https://doi.org/10.1080/00220973.2017.1381067>
- Wen, Y., Wu, L., He, S., Ng, N. H. E., Teo, B. C., Looi, C. K., & Cai, Y. (2023). Integrating augmented reality into inquiry-based learning approach in primary science classrooms. *Educational Technology Research and Development*. DOI: <https://doi.org/10.1007/s11423-023-10235-y>
- Wood, R. (2019). Students' motivation to engage with science learning activities through the lens of self-determination theory: Results from a single-case school-based study. *Eurasia Journal of Mathematics, Science and Technology Education*, 15(7), 1–13. DOI: <https://doi.org/10.29333/ejmste/106110>
- Wormington, S. V., & Linnenbrink-Garcia, L. (2017). A new look at multiple goal pursuit: The promise of a person-centered approach. *Educational Psychology Review*, 29(3), 407–445. DOI: <https://doi.org/10.1007/s10648-016-9358-2>
- Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, 62, 41–49. DOI: <https://doi.org/10.1016/j.compedu.2012.10.024>
- Yardimci, F., Bektaş, M., Ozkutuk, N., Muslu, G. K., Gerceker, G. O., & Basbakkal, Z. (2017). A study of the relationship between the study process, motivation resources, and motivation problems of nursing students in different educational systems. *Nurse Education Today*, 48, 1–18. DOI: <https://doi.org/10.1016/j.nedt.2016.09.017>