

Do problem-based learning and flipped classroom models integrated with Android applications based on biomechanical analysis enhance the learning outcomes of Pencak Silat?

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Abstract

This study aimed to determine the efficacy of problem-based learning and the flipped classroom model combined with an Android application based on biomechanical analysis to improve the learning outcome of pencak silat and focused on teaching students the movement of a single artistic category of pencak silat. The following three research questions were formulated to guide the purposes of this study. (1) What is the evidence of the reliability and validity of the learning outcomes of pencak silat single artistic instrument? (2) Is there any significant item difficulty functioning (DIF) detected on items based on gender? (3) Is problem-based learning or flipped classrooms more effective at improving the learning outcomes of pencak silat? This research included 76 physical education students from Universitas Islam 45 Bekasi in Indonesia (age: M=20.51, SD=0.49; gender: 59 males and 17 females). The test procedures were used to measure the learning outcome of pencak silat with 50 single artistic empty-hand moves. Rasch analysis was utilized to evaluate the validity and reliability and to check item difficulty functioning based on gender. An Independent t-test was used for hypothesis analysis. A video with biomechanical analysis of pencak silat in the Android application was created with the Kinovea application and the RAD Studio 10.3 software developer. Based on data and statistical analysis, there was a significant effect ($P \leq 0.05$) of the problem-based learning model integrated with the Android application based on higher biomechanical analysis for improving the learning outcomes of a single artistic category of pencak silat and item difficulty functioning (DIF) item based on gender. *Jurus* is a series of basic movements for the upper and lower body, which are used as a guide to mastering the use of advanced techniques of pencak silat when practiced individually or in pairs which included F8 of *jurus* 6, and G5, G10, and G11 of *jurus* 7. This learning design may be the right formula to improve student learning outcomes of pencak silat. Thus, by using problem-based learning models in learning, students will be able to learn more effectively.

Key Words: problem-based learning, flipped classroom, pencak silat, Android application, biomechanical analysis

Introduction

Pencak silat is a sport of martial arts native to Indonesia (J. Lubis, Fitrianto, et al., 2021; J. Lubis, Sukur, et al., 2021) that is provided from elementary school to college through formal and non-formal education. In pencak silat, the competition categories include fight (tanding), singles (tunggal), doubles (ganda), and team (regu). (J. Lubis et al., 2020). One of the skills that must be mastered in pencak silat course material is a single artistic skill (Haqiyah et al., 2017), which is a category of pencak silat competition in which an artist demonstrates his skills in a single artistic standard (baku) of jurus correctly, precisely, and steadily with full of soul using as many as 7 jurus with his empty hands, 3 jurus golok, and 4 jurus tongkat (Haqiyah, 2019; Lubis, 2014). Jurus are a series of basic movements for the upper and lower body, which are used as a guide to mastering the use of advanced techniques of pencak silat when practiced individually or in pairs (Wilson, 2002). The main value of a single artistic move is the correctness of the sequence of movements and the sequence of steps that are displayed. Therefore, appropriate learning and training designs are needed, including appropriate learning media. For learning outcomes to be carried out optimally, various models and teaching methods are needed based on student-centered learning (SCL), not teacher-centered learning (TCL). In making this SCL learning design, especially in choosing a learning model, it is necessary to pay attention to students, teaching materials or study materials, and learning facilities or media. The selection of learning forms and techniques is an attempt to determine the best strategy for students to meet their learning objectives by fostering active interactions between students, lecturers, and learning materials. Problem-based learning is one of the learning paradigms used (Suteja, J., & Cirebon, 2017) as well as a flipped classroom (Junaidi, 2020).

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Problem-based learning is a method of developing and teaching courses that employ problems as a stimulus and focuses on student participation (Boud & Feletti, 2013), and it has repeatedly demonstrated higher efficacy for long-term information retention and knowledge application (Yew & Goh, 2016). It also can link new information with the cognitive structures that students already have through group learning activities to develop problem-solving skills using various learning resources. Problem-based learning is a student-centered learning model that allows students to actively perform research, integrate theory and practice, and use knowledge and abilities by problem-solving. Through this learning model, it is hoped that students will be able to overcome movement difficulties when learning Pencak silat empty-handed single artistic moves.

The learning model that could be implemented in higher education (Gough, DeJong, et al., 2017) is a flipped classroom (Gough, Dejong, et al., 2017; Khan & Abdou, 2020; Milman, 2012; Yurniwati & Utomo, 2020). Materials that require teacher feedback are used in class, while material concepts are studied at home as homework (Arnold-Garza, 2014; Bergmann & Sams, 2012; Milman, 2012; Wallace, 2014). Teachers can utilize problem-based learning and flipped classrooms to efficiently allocate current school learning time so that they can develop subjects in the classroom. These developments have resulted in the flipped classroom technique in which information is taught outside of the classroom using media, challenge, and group work. Flipped learning, a popular instructional paradigm at Universitas Islam 45 in Indonesia, flips the traditional format by practice (Brewer & Movahedazarhouli, 2018).

In an effort to provide material for a single artistic move in the learning process, the right media is needed, so that skills are still mastered even in limited situations (Haqiyah et al., 2021). Previous researchers have used a multimedia Android app (Marwan, 2018) and computer-based training (CBT) (Marwan, 2014). However, in this study, an Android application was developed, which displays divisional steps, slow motion, and is equipped with biomechanical analysis. This is novel because until now no other researchers have developed it. Previous martial arts research tends to focus on movement descriptions rather than biomechanical considerations (Kuragano & Yokokura, 2008). The Android application was developed by using the RAD Studio 10.3 software developer with the content steps of 1 to 7 for the pencak silat single artistic empty-hand category with slow-motion video and biomechanics analysis using Kinovea software (Kinovea, 2014). Biomechanics is a branch of science that studies the function of the musculoskeletal system and provides advice on how to improve it (Arus & Ingber, 2017). The advantages of this learning media are that it may be easier for students or athletes to follow the movement and perceive the trajectory of motion with the help of the angle of motion and proper sequence; thus, it is expected to help athletes and students in learning empty-hand single artistic moves of pencak silat.

Three research questions were formulated to guide the purposes of this study. (1) What is the evidence of the reliability and validity of the learning outcome of the pencak silat single artistic instrument? (2) Is there any significant DIF detected on items based on gender? (3) Is problem-based or flipped classroom learning more effective in improving the learning outcomes of pencak silat?

Materials and Methods

Study participants

The participants included 76 undergraduate students in the physical education, sport, and recreation study program at Universitas Islam 45, Indonesia who were 19–21 years of age (age: $M=20.51$, $SD=0.49$), and the majority were male (Table 1).

Table 1. Crosstab Participants

		Gender		Total
		Male	Female	
Age	19	5	0	5
	20	50	15	65
	21	4	2	6
Total		59	17	76

Study organization

Before attending live classes, students watched instructional videos of pencak silat online. Kinovea software created a video with biomechanical analysis (Kinovea, 2014) and evaluated (Guzmán-Valdivia et al., 2013) slow-motion videos and studied the athletes' techniques, as well as used the RAD Studio 10.3 software developer. The Rapid Application Development (RAD) approach was used to create this application (Salamah et al., 2019) using technical advancements. This application could be accessed online or offline in an Android phone during the data transmission procedure. This program informs the user while it is in use. Media is created to provide content in the form of visuals, audio, and video in an attempt to help stimulate students' interest and focus throughout the autonomous learning process (Mohamed et al., 2018). An example display of the step movement in the Android application is shown.

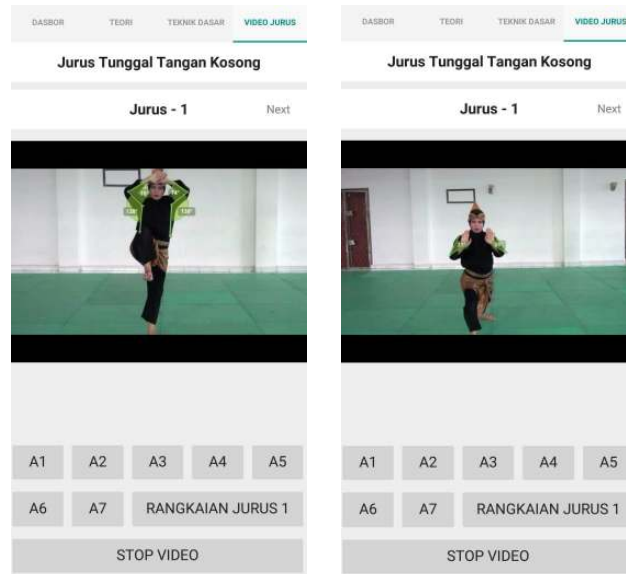


Figure 1. Android app display

Motion details are shown in the Android app based on the learning outcome for the pencak silat single artistic instrument (Table 2). The test procedures were used to measure the learning outcomes of pencak silat with a single artistic performance of 50 empty hand moves. The element of truth of motion is the focus of the evaluation.

Table 2. Instruments of learning outcomes for pencak silat empty-handed single artistic movements

Dimensions	Number of Moves	Movement Details Code by Alphabetically
<i>Jurus 1</i>	7	A1, A2, A3, A4, A5, A6, A7
<i>Jurus 2</i>	6	B1, B2, B3, B4, B5, B6
<i>Jurus 3</i>	5	C1, C2, C3, C4, C5
<i>Jurus 4</i>	7	D1, D2, D3, D4, D5, D6, D7
<i>Jurus 5</i>	6	E1, E2, E3, E4, E5, E6
<i>Jurus 6</i>	8	F1, F2, F3, F4, F5, F6, F7, F8
<i>Jurus 7</i>	11	G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G11
TOTAL	50	

Statistical analysis

To perform descriptive statistics, SPSS version 25 (IBM Corp, 2017) was used. In performing participant demographic profiles, the validity independent sample t-test was utilized with a confidence level of $\alpha < 0.05$ (Muhamad, Memet; Hanif, Achmad Sofyan; Haqiyah, 2021). WINSTEPS version 5.2.5.1 software (Linacre, 2022) for Rasch analysis was used to evaluate the validity and reliability instruments, and the differential item functioning (DIF) analysis was performed based on gender to confirm bias interaction for each moves.

Results

Validity and reliability instrument

To ensure the fit validity at the item level, the item measure and fit criteria results are shown in Table 3. In this study, the item measures ranged from -0.80 logits to 0.51 logits, and Outfit MNSQ values ranged from 0.76 logits to 1.68 logits. This result confirmed that the learning outcome of pencak silat with 50 moves of single artistic empty-hand is valid for all items in this studies.

Table 3. Validity and reliability instrument

Attribute	Value
Number of Items	50
Mean	
Item outfit MNSQ	1.18
Item infit MNSQ	1.36

Person outfit MNSQ	0.79
Person infit MNSQ	0.70
Item separation	3.59
Person separation	3.23
Item reliability	0.93
Cronbach's alpha	0.99

The item reliability criteria were evaluated based on item reliability and Cronbach's alpha (α). For whole items in the learning outcome of pencak silat with 50 single artistic empty hand moves, the item reliability value was 0.99, confirming the reliability achieved for both studies (Fisher, 2007). The Cronbach's alpha (α) ranged from 0.82 to 0.94 where the minimum value for Cronbach's alpha was 0.6 (Taber, 2018). This result confirms that reliability was also achieved based on Cronbach's alpha values.

DIF analysis based on gender

DIF analysis was utilized to confirm whether there were items with bias regarding gender (female and male) that affected the learning outcome of pencak silat. DIF analysis can identify participant bias based on subgroups or background variables for each item in the used questionnaire (Boone et al., 2014; Khine, 2020). DIF was determined following two categories: significant probability ($p < 0.05$) and DIF contrast. Three DIF contrast classifications according to Zwick et al. (1999) were negligible, slight to moderate ($|DIF| \geq 0.43$ logits), and moderate to large ($|DIF| \geq 0.64$ logits). Figure 3 reveals that several items in both studies indicated DIF based on significant probability. However, no items showed a DIF contrast of more than 0.46 logits. Thus, we can conclude that those items showed negligible DIF, which indicates that the instrument is free of bias issues. The item difficulty functioning based on gender involved F8, G5, G10, and G11 *jurus* in pencak silat single artistic empty-hand moves. *Jurus* IS a series of basic movements for the upper and lower body, which are used as a guide to mastering the use of advanced techniques of pencak silat when practiced individually or in pairs.

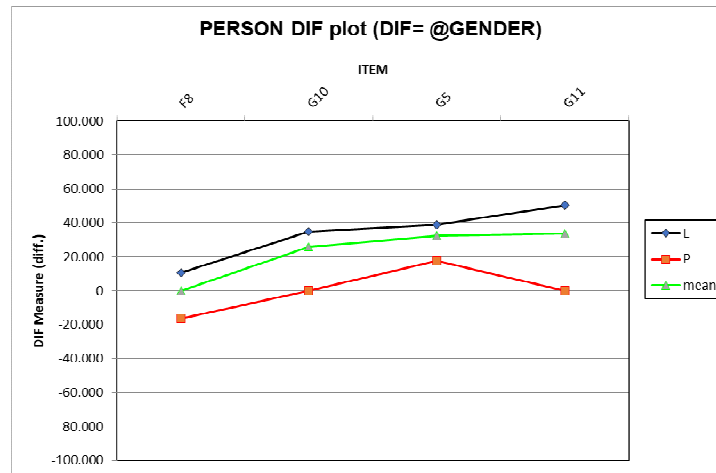


Figure 2. DIF analysis based on gender

Hypothesis test result

The results of descriptive statistical tests show that there was an increase in learning outcome in which the problem-based learning mean was 41.8421 and the flipped classroom mean was 38.4474 (Table 4 and Figure 3). This means descriptively that the problem-based learning group had a higher value than the flipped classroom group. The hypothesis analysis showed that problem-based learning models more effectively for physical education students ($t = 2.452, p = 0.018$) (see Table 4).

Table 4. Descriptive statistics

Learning Model	N	Mean	Std. Deviation
Problem-based learning	38	41.8421	3.38140
Flipped classroom	38	38.4474	7.83512

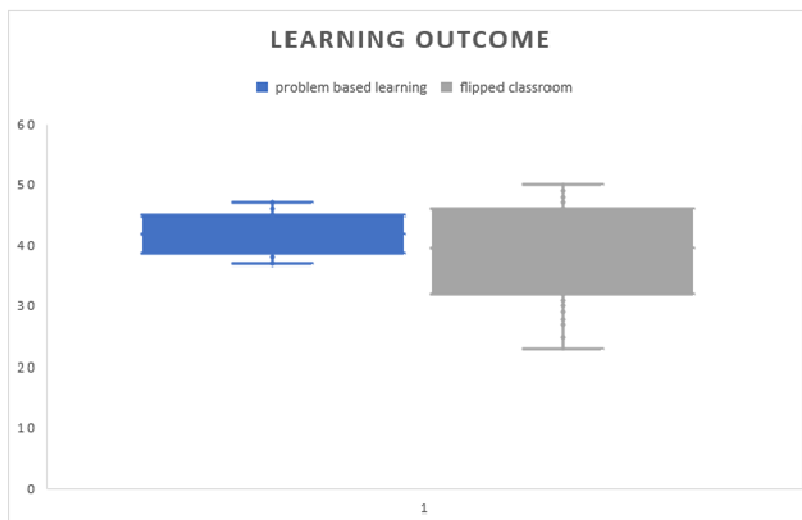


Figure 3. Learning outcomes

Table 5. Hypothesis test results

Levene's Test for Equality of Variances			t-test for Equality of Means			
F	Sig.		t	df	Sig. (2-tailed)	Mean Difference
39.159	0.000		2.452	74	.017	3.39474

Learning outcomes of pencak silat single artistic moves obtained by students were significant, and learning was carried out using the problem-based learning model. The mean difference was 3.39474. The Android application was made using Kinovea and the software developer RAD Studio 10.3, which had the intention to make learning the movements of a single category of pencak silat easier for students. The precision of movement is the most important aspect of assessment; thus, students must memorize the movements and sequences completely.

Discussions

The difficulties of students for learning a single artistic move of pencak silat can be overcome by applying an effective learning model that includes strategy, use of media, and evaluation. The implemented problem-based learning model and the flipped classroom model provide different learning outcomes for the single artistic pencak silat empty-handed material. There is an increase in the mastery of the single artistic category that could be achieved through the application of a problem-based learning model (Ramdhani, 2016).

Students actively solve problems in the problem-based learning model (Sarifudin; Hanif, 2020) and overcome movement difficulties when learning pencak silat, assisted by this Android application based on biomechanical analysis. The application of computerized video technology for biomechanical research helped identify the particularities of vital components of the technique (Potop et al., 2022).

The problem-based learning model increases the capacity of classroom learning activities and increases interaction between students, teachers, and their environments. Students that are able to support the learning content can access learning media, and it can be taught or implemented in a variety of ways through the use of interactive multimedia with the goal of developing student-centered learning to increase learning quality (Ozdamli & Asiksoy, 2016).

One of the most important advantages is that students can view material via the Android application or other media to prepare for class (Mok, 2014). As a result, it enables students to have access to previously generated knowledge by lecturers (Isidori, E., Chiva-Bartoll, O., Fazio, A., & Sandor, 2018). The problem-based learning model can help to develop critical thinking skills and provide time to accommodate individual student requirements (Nouri, 2016; Østerlie, 2018). This model can also raise student interest in learning (Blair et al., 2016).

Conclusions

Based on the analysis data, We showed that the instrument of learning outcomes for single artistic moves in empty-hand categories in pencak silat are valid and reliable for all items in these studies. The items were categorized as negligible DIF, which indicates the instrument is free of bias issues. The item difficulty functioning (DIF) based on gender included F8 of *jurus* 6, and G5, G7, G10 and G11 of *jurus* 7 in pencak silat single artistic empty-handed moves. The best formula for increasing learning outcome in pencak silat is a

problem-based learning model combined with an Android application based on biomechanical analysis. This Android application for pencak silat with biomechanical analysis was created using Kinova software and RAD Studio 10.3, which aims to make learning an empty-hand single artistic category of pencak silat easier for students. It is concluded that by using the problem-based learning model integrated with Android applications based on biomechanical analysis enhances the learning outcomes of pencak silat.

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Conflicts of Interest

We state that there were no conflicts of interest in this study.

References

- Arnold-Garza, S. (2014). The flipped classroom teaching model and its use for information literacy instruction. *Communications in Information Literacy* 8 (1), 9. <https://doi.org/10.15760/comminfolit.2014.8.1.161>
- Arus, E., & Ingber, L. (2017). *Biomechanics of human motion: Applications in the martial arts: Second edition. Biomechanics of Human Motion: Applications in the Martial Arts: Second Edition*. USA: Human Kinetics <https://doi.org/10.1201/b22446>
- Bergmann, J., & Sams, A. (2012). *Flip Your Classroom: Reach Every Student in Every Class Every Day*. Washington, D. C & Virginia: iste & ASCD.
- Blair, E., Maharaj, C., & Primus, S. (2016). Performance and perception in the flipped classroom. *Education and Information Technologies*, 21(6), 1465–1482. <https://doi.org/10.1007/s10639-015-9393-5>
- Boone, W. J., Staver, J. R., & Yale, M. S. (2014). *Rasch Analysis in the Human Sciences*. Springer.
- Boud, D., & Feletti, G. I. (2013). *The challenge of problem-based learning. The Challenge of Problem-based Learning*. Psychology Press. <https://doi.org/10.4324/9781315042039>
- Brewer, R., & Movahedazarhouligh, S. (2018). Successful stories and conflicts: A literature review on the effectiveness of flipped learning in higher education. *Journal of Computer Assisted Learning*, 34(4), 409–416. <https://doi.org/10.1111/jcal.12250>
- Fisher, W. P. J. (2007). Rating Scale Instrument Quality Criteria. *Rasch Measurement Transactions*, 21(1), 1095.
- Gough, E., Dejong, D., Grundmeyer, T., & Baron, M. (2017). K-12 Teacher Perceptions Regarding the Flipped Classroom Model for Teaching and Learning. *Journal of Educational Technology*, 45(3), 390–423. <https://doi.org/10.1177/0047239516658444>
- Gough, E., DeJong, D., Grundmeyer, T., & Baron, M. (2017). K-12 Teacher Perceptions Regarding the Flipped Classroom Model for Teaching and Learning. *Journal of Educational Technology Systems*, 45(3), 390–423. <https://doi.org/10.1177/0047239516658444>
- Guzmán-Valdivia, C. H., Blanco-Ortega, A., Oliver-Salazar, M. A., & Carrera-Escobedo, J. L. (2013). Therapeutic motion analysis of lower limbs using Kinovea. *International Journal of Soft Computing and Engineering*.
- Haqiyah, A. (2019a). *Pencak Silat*. Jakarta: PT. Rajagrafindo Persada.
- Haqiyah, A., Lubis, J., Tangkudung, J., Muhamad, M., Kusumawati, M., Lanos, M. E., & Riyadi, D. N. (2021). Flipped classroom model integrated with the online learning platform and video biomechanic analysis to enhance learning outcome of Pencak silat during the Covid-19 pandemic. *Turkish Journal of Computer and Mathematics Education*, 12(11), 1489–1494.
- Haqiyah, A., Mulyana, M., Widiastuti, W., & Riyadi, D. N. (2017). The Effect of Intelligence, Leg Muscle Strength, and Balance Towards The Learning Outcomes of Pencak Silat with Empty-Handed Single Artistic. *JETL (Journal Of Education, Teaching and Learning)*, 2(2), 211. <https://doi.org/10.26737/jetl.v2i2.288>
- Isidori, E., Chiva-Bartoll, O., Fazio, A., & Sandor, I. (2018). Flipped classroom in physical education: pedagogical models and possible implementation through Web 2.0. *In The International Scientific Conference ELearning and Software for Education*, 3, 274–279.
- Junaidi, A. dkk. (2020). *Guidelines for preparing a higher education curriculum*. Direktorat Pendidikan Tinggi, Kementerian Pendidikan dan Kebudayaan
- Khan, M. S. H., & Abdou, B. (2020). Flipped Classroom: How Institutions of Higher Education (HEIs) of Bangladesh Could Move Forward During Covid-19 Pandemic. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3615400>
- Khine, M. S. (2020). Rasch Measurement. *In Rasch Measurement*. <https://doi.org/10.1007/978-981-15-1800-3>
- Kinovea, O. (2014). *Kinovea*. Motion Analysis Tool.
- Kuragano, T., & Yokokura, S. (2008). Experimental Analysis of Japanese Martial Art. *Journal of Research - Japanese Martial Art Nihon-Kempo*, 7(1), 40–45.

- Linacre, J. M. (2022). *Winsteps® (Version 5.2.2) [Computer Software]*. (5.2.2). Winsteps.com. <https://www.winsteps.com/>
- Lubis, J., Fitrianto, E. J., Sukiri, Haqiyah, A., Setiakarnawijaya, Y., Robianto, A., Sukriadi, S., Nurulfa, R., Irawan, A. A., & Sumartiningsih, S. (2021). Does aerobic interval training induce a decrease in body weight in pencak silat elite athletes? *Journal of Physical Education and Sport*, 21(4), 2372–2380. <https://doi.org/10.7752/jpes.2021.s4318>
- Lubis, J. H. W. (2014). *Pencak Silat Edisi Kedua*. Jakarta: Rajagrafindo.
- Lubis, J., Sukur, A., Fitrianto, E. J., Suliyanthini, D., Irawan, A. A., Robianto, A., Haqiyah, A., & Oktafiranda, N. D. (2021). Wearing a fibrous protein (cv-f) cooling vest to reduce fatigue among Indonesian pencak silat athletes: Is it effective? *Journal of Engineering Science and Technology*.
- Lubis, J., Thongdaeng, N., Haqiyah, A., Sukur, A., Abidin, D., Irawan, A. A., & Sumartiningsih, S. (2020). The Effect of Five-Week Aerobic Interval Training on The Body Composition of Pencak Silat Elite Athletes. *International Journal of Kinesiology and Sports Science*, 10(2), 16–24.
- Marwan, I. (2014). Learning single stance pencak silat through Computer Based Training (CBT). *Asian Social Science*, 10(5), 35–43. <https://doi.org/10.5539/ass.v10n5p35>
- Marwan, I. (2018). Development of an Android Application-Based Pencak Silat Movement Learning Model. *Jurnal Pendidikan Jasmani Dan Olahraga*, 3(2), 153–160. <https://ejournal.upi.edu/index.php/penjas/article/view/1832-008>
- Milman, N. B. (2012). The Flipped Classroom Strategy: What is it and how can it best be used? *Distance Learning*, 9(3), 85–88.
- Mohamed, H. I., Eaganathan, U., Medi, I., & Sabri, N. A. (2018). Condominium visitors registration and tracking system. *Journal of Advanced Research in Dynamical and Control Systems* 2(1), 23 - 32.
- Mok, H. N. (2014). Teaching tip: The flipped classroom. *Journal of Information Systems Education*, 25(1), 7.
- Muhamad, Memet; Hanif, Achmad Sofyan; Haqiyah, A. (2021). *Statistika dalam pendidikan dan olahraga*. PT. Rajagrafindo Persada.
- Nouri, J. (2016). The flipped classroom: for active, effective and increased learning – especially for low achievers. *International Journal of Educational Technology in Higher Education*, 13(1), 1-10. <https://doi.org/10.1186/s41239-016-0032-z>
- Østerlie, O. (2018). Can flipped learning enhance adolescents' motivation in physical education? An intervention study. *Journal for Research in Arts and Sports Education*, 2(1), 1–15. <https://doi.org/10.23865/jased.v2.916>
- Ozdamli, F., & Asiksoy, G. (2016a). Flipped Classroom Approach. *World Journal on Educational Technology*, 8(2), 98–105. <https://doi.org/10.18844/wjet.v8i2.640>
- Potop, V., Cîmpeanu, M., Moga, C., Jurat, V., Manole, C., & Eshtaev, A. (2022). Particularities of the biomechanical characteristics of learning the acrobatic exercises on balance beam in Junior III category (aged 9-10 years). *Journal of Physical Education and Sport*, 22(8), 1848–1853. <https://doi.org/10.7752/jpes.2022.08232>
- Ramdhani, R. (2016). *The Effect of Problem-based Learning Model on Mastery of Pencak Silat Learning Movements*. Universitas Pendidikan Indonesia.
- Salamah, I., Lindawati, L., & Sitompul, H. Y. (2019). Final Assignment Guidance Application Using Android-Based Notifications. *Jurnal Media Informatika Budidarma*. <https://doi.org/10.30865/mib.v3i3.1216>
- Suteja, J., & Cirebon, I. S. N. (2017). Learning models in the competency-based curriculum KKN di perguruan tinggi. *Jurnal Edueksos*, 6(1), 81–100.
- Taber, K. S. (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Research in Science Education*, 48(6), 1273–1296. <https://doi.org/10.1007/s11165-016-9602-2>
- Wallace, A. (2014). Social Learning Platforms and the Flipped Classroom. *International Journal of Information and Education Technology*, 4(4), 293–296. <https://doi.org/10.7763/IJNET.2014.V4.416>
- Wilson, I. D. (2002). *The politics of inner power: The practice of pencak silat in West Java* (Doctoral dissertation, Murdoch University).
- Yew, E. H. J., & Goh, K. (2016). Problem-Based Learning: An Overview of its Process and Impact on Learning. *Health Professions Education*. <https://doi.org/10.1016/j.hpe.2016.01.004>
- Yurniwati, Y., & Utomo, E. (2020). Problem-based learning flipped classroom design for developing higher-order thinking skills during the COVID-19 pandemic in geometry domain. *Journal of Physics: Conference Series*. <https://doi.org/10.1088/1742-6596/1663/1/012057>
- Zwick, R., Thayer, D. T., & Lewis, C. (1999). An empirical Bayes approach to Mantel-Haenszel DIF analysis. *Journal of Educational Measurement*, 36(1), 1–28.