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# Development of MATLAB-Based Physics Practical Media to Optimize Online Learning for Students on Sine Wave Material

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**ABSTRACT**

**Purpose of the study:** This study aims to develop MATLAB-based learning media as an interactive online practicum tool to understand the concept of sine waves.

**Methodology:** The research method uses the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model. The research subjects are physics education students at Jambi University, data collection techniques using questionnaires. MATLAB-based media is designed with interactive simulation features that allow students to manipulate sine wave parameters, such as frequency, amplitude, and phase, in real-time.

**Main Findings:** The test results showed that the majority of students responded positively to the use of this media, with 60% in the "Good" and "Very Good" categories. In addition, students' science process skills, such as data analysis and problem solving, also increased significantly, with an average score reaching 70.80. The results of the correlation test revealed a significant positive relationship ($r = 0.542$, $p = 0.001$) between students' responses to MATLAB development and science process skills. This interactive simulation provides a more intuitive learning experience than conventional methods, allowing students to understand abstract concepts visually and deeply. However, hardware and software limitations are challenges that need to be overcome for wider implementation.

**Novelty/Originality of this study:** This research provides significant contributions in the development of simulation-based learning media for online education, especially in improving the understanding of physics concepts and science process skills. In the future, web-based development or mobile applications are proposed to improve accessibility and efficiency of learning.



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## 1. INTRODUCTION

Since the COVID-19 pandemic hit, online learning has grown and been accepted as a primary method in global education. In some countries, such as Japan and South Korea, online learning in physics has widely used augmented reality (AR) or virtual reality (VR)-based media to enrich students' learning experiences [1]-[2].

Meanwhile, in Western countries, such as the United States, the use of Python or Unity-based simulation applications has become a popular alternative in teaching physics concepts interactively. However, in Indonesia, MATLAB-based simulation media has great potential to answer the challenges of online learning, especially because of its capabilities in data processing and in-depth mathematical visualization [3]-[6]. The use of MATLAB can be a more affordable and suitable solution for educational environments in Indonesia.

The development of interactive learning media based on MATLAB for the topic of sine waves provides an opportunity for physics students to gain a better understanding visually and practically [7]-[10]. Students can perform independent experiments through the user-friendly designed MATLAB interface, which will ultimately help them understand abstract concepts more intuitively [11]-[13]. In addition, interactive features in MATLAB allow students to test various physics scenarios without the need for expensive and difficult-to-access physical laboratory equipment.

However, the application of MATLAB-based media in online physics learning is not free from various challenges [14]-[15]. One of them is the limited access of students to computer devices or laptops with adequate specifications to run MATLAB simulations. In addition, some students may not be familiar with the MATLAB interface which can be considered complex, so additional training is needed to ensure that all students can make optimal use of this media [16]-[18]. Moreover, in the context of online learning, the limited stable internet network in several regions in Indonesia is also a separate obstacle that can affect the smooth use of this media.

The use of MATLAB in physics learning shows interesting variations across countries. In the ASEAN region, such as Singapore and Malaysia, MATLAB is widely used in universities to simulate real-time data-based physics experiments, especially on the topics of waves and fluid dynamics [8]. In Europe, countries such as Germany and the Netherlands are leveraging MATLAB not only for interactive simulations, but also for integration with laboratory hardware, so that students can study physics applications in a hybrid environment between virtual and physical laboratories [19]. Meanwhile, in Indonesia, the use of MATLAB is still focused on mathematical visualization and data processing in online learning, but currently various efforts are being made to develop MATLAB-based media to increase interactivity and accessibility in physics education [20]. This development aims to address local challenges, such as limited access to physical laboratories and the need for a more practical approach to online learning.

The use of MATLAB in physics learning is expected to provide significant short-term and long-term impacts for students. The short-term impacts are in the form of increased student engagement and motivation to learn abstract topics such as sine waves, as well as increased efficiency and understanding of the material through interactive visualization [21]-[24]. Meanwhile, the long-term impact is the development of deeper analytical abilities and problem-solving skills, which can support their success in careers in STEM fields, especially those requiring data modeling and analysis skills [25]-[27]. Students who are accustomed to using MATLAB will have a competitive advantage, both in academic and industrial contexts, so that the relevance of physics learning in the real world also increases.

Based on previous research conducted, where previous research focused on the development of audiovisual media based on the I-SETS approach, which integrates scientific, technological, environmental, social, and Islamic value aspects for basic physics practicums [28]. This study aims to improve understanding of practicums by linking physics concepts to real problems and instilling religious character. Meanwhile, this study focuses on the development of MATLAB-based media to understand the concept of sine waves. This media features interactive simulations that allow students to manipulate physics parameters in real-time, oriented towards conceptual understanding and visual science process skills.

The novelty of this research is to develop MATLAB-based learning media that is specifically designed to support online learning on sine wave material, by providing interactive simulations that allow students to manipulate important variables such as frequency, amplitude, and phase in real-time. This media is expected to improve students' conceptual understanding of the abstract topic of sine waves, while also training science process skills such as data analysis, independent experiments, and problem solving. This study also aims to evaluate the effectiveness of the media in improving learning outcomes, motivating students to learn independently, and overcoming the challenges of online learning, such as the limitations of physical laboratories and the need for intuitive interactive visualizations. Thus, the development of this media is expected to provide innovative solutions to improve the quality of online physics learning and prepare students to face the demands of the STEM-based education world in the digital era.

## 2. RESEARCH METHOD

This study uses the ADDIE development model, which stands for five main stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was chosen because of its structured and systematic approach to developing learning media, which can ensure that each stage of the development process is designed to meet specific learning objectives [29]-[32]. In this study, the ADDIE model is applied to develop MATLAB-based practicum media that focuses on sine wave material, with the aim of increasing student involvement and understanding in online learning. Each stage is carried out with planned steps to achieve optimal final results. The steps of the ADDIE model in this study can be seen in Figure 1 below.


Figure 1. ADDIE method

In the analysis stage, learning needs and objectives were identified [33],[34]. Researchers collected initial data through surveys and interviews with physics students and lecturers to understand the difficulties faced in learning sine wave material online [35]. This data includes students' difficulties in understanding the concept of sine waves without adequate visualization assistance and the limitations of interactive learning media available online. From the results of this analysis, it was formulated that MATLAB-based practicum media is needed to provide interactive simulations that can help students understand the concepts of frequency, amplitude, and phase in sine waves independently.

The design stage aims to prepare a development plan for MATLAB-based practicum media [36]. At this stage, the features that will be developed in the media are determined, such as visual simulations of sine waves whose frequency, amplitude, and phase can be changed by the user [37]. The design also includes a sketch of a simple and intuitive user interface, so that students can easily access and use this media. In addition, an evaluation plan is also prepared to ensure that the media developed can meet learning needs and help students understand the material better [38]. In the development stage, researchers began to build practical media using MATLAB based on previously prepared designs [19]. MATLAB was chosen because of its superior capabilities in data processing and visualization, as well as its flexibility in creating interactive simulations [39],[40]. In this stage, programming was carried out to implement the planned features, including controls to set sine wave parameters, such as frequency, amplitude, and phase. Each feature was tested internally to ensure that the media functioned properly and in accordance with the specifications set in the design stage. The implementation stage involved testing the media on a group of physics students to see how the media was applied in learning [41]. Before being used widely, the media was tested in a test class to identify obstacles and receive input from users [42],[43]. This implementation was carried out in two stages: first, as a demonstration in lectures, and second, as an independent practice where students could access the media online for independent exploration. Each student was asked to use the media and fill out a questionnaire to provide feedback on the ease of use and effectiveness of the media in helping their understanding. The evaluation stage aims to assess the effectiveness and quality of the learning media that has been developed [44],[45]. The evaluation was conducted using data from the results of the questionnaire filled out by students, as well as the filling out of observation sheets by lecturers who observed the use of the media in learning. The data obtained was analyzed to determine whether this MATLAB-based practical media succeeded in increasing students' understanding of the concept of sine waves, and whether there were improvements that needed to be made to improve the students' learning experience. Based on the evaluation results, revisions were made to the media if necessary to ensure that the media met learning standards and could be applied effectively in online physics learning [46].

This study describes the development of MATLAB-based learning media to understand the concept of sine waves up to the evaluation stage. The process begins with a needs analysis through questionnaires and observations to identify students' difficulties in understanding the concept of sine waves online, which then becomes the basis for designing interactive media. At the design stage, interactive simulation features and an intuitive interface are designed, followed by the development stage, where the media is created using MATLAB and tested internally. The implementation stage is carried out by testing physics students to obtain feedback regarding the effectiveness of the media in supporting independent and interactive learning. This article also covers the evaluation stage, where student and lecturer responses are analyzed to assess the success of this media and provide recommendations for improvement before wider implementation.

The population in this study were 3rd semester physics education students at the University of Jambi. Purposive sampling, also known as judgment sampling, is a sampling technique by selecting samples from among the population according to what the researcher wants (objectives or problems in the study), so that the sample can represent the characteristics of the population that have been previously known. The sample criteria in this study were 3rd semester physics education students who took the optical wave course, specifically the sine wave material. So the sample in this study amounted to 50 3rd semester physics education students at Jambi University. The data collection technique in this study for matlab responses used a questionnaire sheet and for students' science process skills assessed through an observation sheet. The number of matlab response questionnaire items consists of 25 statement items. Then for the observation sheet for students' science process skills consists of 21 assessment items. The grid of the student Matlab response questionnaire is presented in Table 1 below:

Table 1. MATLAB Response Questionnaire Research Instrument Grid

| No | Matlab response indicators | Item Number | Number of Items |
|---|---|---|---|
| 1 | Understanding of Material | 1-5 | 5 |
| 2 | Utilization of Discussion | 6-10 | 5 |
| 3 | Utilization of Companions | 11-15 | 5 |
| 4 | Awareness of Understanding | 16-20 | 5 |
| 5 | Planning Experiments | 21-15 | 5 |
| | Number of Items | | 25 |

Next, the grid for the science process skills observation sheet can be seen in table 2.

Table 2. Science Process Skills Observation Sheet Grid

| No | Science Process Skills Indicators | Item Number | Number of Items |
|---|---|---|---|
| 1 | Observing | 1, 2, 3 | 3 |
| 2 | Classifying | 4, 5 | 2 |
| 3 | Communicating | 6, 7, 8, 9 | 4 |
| 4 | Measuring | 10, 11, 12 | 3 |
| 5 | Planning Experiments | 13 | 1 |
| 6 | Analyzing Experiments | 14 | 1 |
| 7 | Conducting Experiments | 15 | 1 |
| 8 | Collecting and Processing Data | 16 | 1 |
| 9 | Predicting | 17,18,19 | 3 |
| 10 | Creating Data Tables | 20 | 1 |
| 11 | Conclusions | 21 | 1 |
| | Total | | 21 |

The categories for each variable are as follows in table 3:

Table 3. MATLAB Response Categories and Students' Science Process Skills

| Matlab Response | | Science Process Skills | |
|---|---|---|---|
| Score Range | Category | Score Range | Category |
| 85 - 100 | Very Good | 110 - 132 | Very Good |
| 70 - 84 | Good | 88 - 109 | Good |
| 55 - 69 | Quite Good | 66 - 87 | Quite Good |
| 40 - 54 | Poor | 44 - 65 | Poor |
| < 40 | Very Poor | < 44 | Very Poor |

Data analysis techniques in this study use descriptive and inferential statistics. Descriptive statistics in the form of frequency tables that include frequency, percentage, mean, median, min and max [47],[48] Then inferential statistics in the form of assumption and hypothesis tests, namely the normality and linearity prerequisite tests. Data is normally distributed and linear, so it meets the requirements to be able to conduct a correlation hypothesis test. Data is said to be normal and linear if the significance value obtained is more than 0.05. For hypothesis testing, data is said to have a significant relationship if the significance value found is less than 0.05. In data collection, the first thing to do is to determine the research subjects to be studied based on predetermined criteria, then distribute research instruments in the form of sheets for matlab responses and for students' science process skills assessed through observation sheets. For the questionnaire sheet and observation sheet, this was given to 50 students in the 3rd semester of Physics Education at Jambia University. Where this data collection is to analyze the influence of matlab development on the basic science process skills of physics education students at Jambi University. The data that has been obtained will be analyzed using the SPSS application with descriptive statistical tests. From this test a conclusion will be obtained.

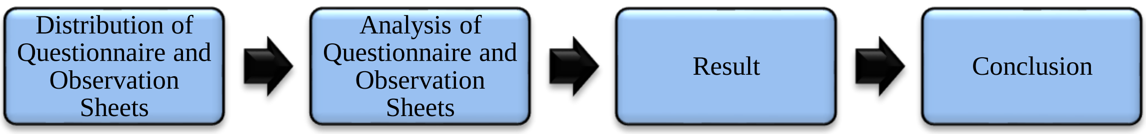


Figure 2. Research Procedure

## 3. RESULTS AND DISCUSSION

### 3.1. Result

The following is a table of descriptive statistical results of this study which includes frequency, percentage, mean, median, minimum, and maximum for the matlab response variables and science process skills.

Table 4. Descriptive Statistics of Matlab Response and Science Process Skills

| Variable | Interval | Category | f | % | Mean | Med | Min | Max |
|---|---|---|---|---|---|---|---|---|
| Matlab Response | 85 - 100 | Very Good | 10 | 20.0 | 72.50 | 74 | 60 | 85 |
| | 70 - 84 | Good | 20 | 40.0 | | | | |
| | 55 - 69 | Quite Good | 15 | 30.0 | | | | |
| | 40 - 54 | Poor | 5 | 10.0 | | | | |
| | < 40 | Very Poor | 0 | 0.0 | | | | |
| Total | | | 50 | 100.0 | | | | |
| Science Process Skills | 110 - 132 | Very Good | 8 | 16.0 | 70.80 | 71 | 55 | 82 |
| | 88 - 109 | Good | 22 | 44.0 | | | | |
| | 66 - 87 | Quite Good | 15 | 30.0 | | | | |
| | 44 - 65 | Poor | 5 | 10.0 | | | | |
| | < 44 | Very Poor | 0 | 0.0 | | | | |
| Total | | | 50 | 100.0 | | | | |

Based on the data on matlab development responses, the frequency distribution shows that 20.0% of students fall into the "Very Good" category, 40.0% fall into the "Good" category, and 30.0% fall into the "Quite Good" category. Only 10.0% of students fall into the "Less Good" category, while none fall into the "Very Poor" category. The mean score for matlab development responses is 72.50 with a median of 74, a minimum score of 60, and a maximum of 85, indicating a fairly wide variation in matlab development responses.

For science process skills, 16.0% of students fall into the "Very Good" category, while the majority (44.0%) fall into the "Good" category. A total of 30.0% of students fall into the "Quite Good" category, and 10.0% fall into the "Less Good" category, with no students falling into the "Very Poor" category. The mean score of science process skills is 70.80 with a median of 71, a minimum score of 55, and a maximum of 82, indicating that although many students showed good results, there were some students who were below average.

This table shows the results of the data normality test for both variables using the Kolmogorov-Smirnov test.

Table 5. Data Normality Test

| Variable | Normality Test | Sig. (p-value) | Description |
|---|---|---|---|
| Matlab Response | Kolmogorov-Smirnov | 0.078 | Normal |
| Science Process Skills | Kolmogorov-Smirnov | 0.065 | Normal |

Based on the results of the normality test, the p-value for the matlab development response is 0.078 and the p-value for science process skills is 0.065, both of which are greater than 0.05. This indicates that the data on both variables, namely the matlab development response and science process skills, are normally distributed. This normal distribution indicates that the distribution of the matlab response data and students' science process skills follows a balanced distribution pattern, with the majority of data around the average.This table shows the results of the linearity test between the matlab response and science process skills.

Table 6. Linearity Tests

| Independent Variable | Dependent Variable | Sig. (p-value) | Description |
|---|---|---|---|
| Matlab Response | Science Process Skills | 0.072 | Linear |

The results of the linearity test show a significance value of 0.072, which is greater than the commonly used significance level of 0.05. This indicates that there is a significant linear relationship between the matlab development response and science process skills. Although the significance value is higher than the threshold of 0.05, which usually indicates insignificance in the context of a linear relationship, these results indicate that there is still a linear relationship pattern between the two variables.

This table presents the results of the correlation test between matlab respin and science process skills.

Table 7. Correlation Test

| Independent Variable | Independent Variable | Dependent Variable | Correlation Coefficient (r) | Sig. (p-value) | Description |
|---|---|---|---|---|---|
| Matlab Response | Matlab Response | Science Process Skills | 0.542 | 0.001 | Significant Positive Correlation |

The results of the correlation test revealed that the correlation coefficient (r) between the matlab development response and science process skills was 0.542, with a p-value of 0.001. A p-value smaller than 0.05 indicates a significant positive influence between student responses related to matlab development and science process skills, indicating that development in matlab tends to be related to an increase in their science process skills. The correlation coefficient of 0.542 indicates that this relationship is moderate, meaning that student responses related to the development of online practicums in matlab have a higher tendency to show better science process skills.

This MATLAB-based practicum media has succeeded in providing an interactive learning experience for students in studying sine wave material [49]. Based on the trial results, students can understand the concept of sine waves more deeply through interactive simulations provided by this media. The simulation allows students to directly observe the influence of key variables such as frequency and amplitude on waveforms, which were previously difficult to understand through conventional methods. Through this feature, students can explore various wave parameters by changing certain values and see the results visually [50]. This gives a more intuitive understanding of the characteristics of a sine wave than just learning it through theory and static images.

Here is the result in Matlab, where the first plot shows a half-sine wave, showing only the positive portion of the wave. The second plot shows a discrete signal that is repeated to match the period length of the half-sine wave. The third plot shows the result of a convolution, which combines information from both signals above.

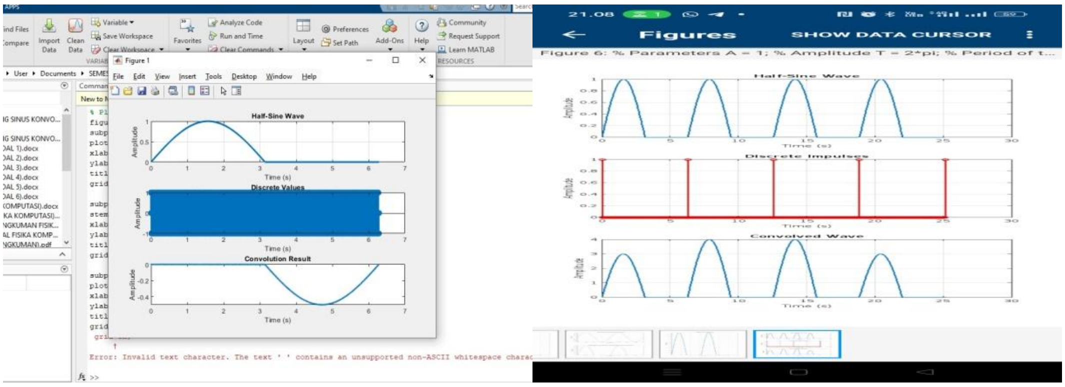


Figure 3. Resulting Waveform

## 3.2. Discussions

The development of this media follows the ADDIE model, which has been widely used in the creation of technology-based learning media because of its systematic and structured approach [51],[52]. The stages in the ADDIE model, such as needs analysis, feature design, software development, implementation, and evaluation, provide clear guidance to achieve the desired results. This method also allows researchers to identify student needs at the analysis stage and evaluate the effectiveness of the media at the final stage [53],[54]. The application of ADDIE helps create media that suits students' learning needs, which in this case is the ability to understand the concept of sine waves better through interactive simulations. Thus, the ADDIE model ensures that this media can meet learning objectives.

The results of the statistical analysis showed that the majority of students had a positive response to the development of Matlab, with 60% in the "Good" and "Very Good" categories. The average student response score was 72.50, reflecting the variation in the level of acceptance of this development. In addition, students' science process skills were also in the good category, with an average score of 70.80, indicating a positive tendency in mastering these skills. The results of the correlation test revealed a significant positive relationship ($r = 0.542$, $p = 0.001$) between students' responses to Matlab development and science process skills, indicating that increased responses to Matlab can contribute to better science skills [55]-[56]. With normal data distribution and significant linear relationships, these findings indicate that Matlab development as a learning tool can effectively support the strengthening of students' science process skills.

This study has a gap with previous studies that mostly focus on the use of simulations in face-to-face learning environments. For example, research by [57] emphasizes simulations as a tool in physical classes, not for online learning. In addition, studies by [58] show that application-based simulations in physics subjects are generally limited to static visualizations that only provide visual guidance without interaction. In this study, MATLAB-based media are developed specifically for online learning, where interaction and learning independence are very important. Thus, this study provides a new approach to the use of simulations for fully online physics learning.

The use of MATLAB as a learning medium has developed in various countries, with various approaches to improving students' science process skills. From previous research found in the ASEAN region, for example, Singapore has implemented MATLAB for physics teaching through interactive simulations that strengthen students' data analysis and virtual experimentation skills [59]. In Europe, Germany and the Netherlands utilize this software in digital-based laboratory practicums, which emphasize collaboration and application of theory in real contexts, thereby improving critical thinking and problem-solving skills [60]. Meanwhile, in Indonesia, the development of MATLAB-based media has begun to be integrated into online learning, especially in complex materials such as sine waves, to optimize conceptual understanding and train science process skills such as observation, experimentation, and independent evaluation of results among students [61].

The novelty of this study lies in the use of MATLAB-based simulations that allow students to manipulate variables in the sine wave concept independently. Unlike other simulation media that only offer static visualizations, this media provides an opportunity for students to change the frequency, amplitude, and phase values directly, and see the changes that occur in the waveform. This interactive simulation provides a deeper and more intuitive understanding, which is difficult to achieve with conventional learning media [62]-[ 63]. In addition, the ability to access this media online allows flexibility of time and place, so that students can learn according to their needs and convenience. This study has significant implications for the development of simulation-based learning media for distance education, especially in courses that require visual understanding such as physics and measuring science process skills.

Through this media, students can learn more flexibly and independently, which is very important in online learning [64]. However, this study also has limitations, including limited access for students who do not have MATLAB software or supporting hardware. In the future, the development of this media can be improved by creating a web-based version or mobile application to reach more users. In addition, further research is needed to test the effectiveness of this media on various groups of students in various geographic locations in order to obtain more general and comprehensive results.

This study has several limitations that need to be considered. The use of simulation-based learning media that requires MATLAB software and certain hardware is an obstacle to access for students who do not have these facilities, so that its benefits are not evenly distributed. In addition, the limited sample coverage to a group of students from a certain geographic location means that the results of the study cannot be generalized to groups of students with more diverse backgrounds. The effectiveness of this media has also not been tested in the long term, so its impact on continuous learning and mastery of science process skills in depth is still not fully known. On the other hand, the implementation of this media requires additional training for students and lecturers, which requires more time and resources, thus adding complexity to its implementation.

## 4. CONCLUSION

This study concludes that the development of MATLAB-based practicum media is effective in improving students' understanding of the concept of sine waves and science process skills. The results of statistical tests revealed a significant positive relationship between the use of this media and the improvement of science process skills, with the majority of students giving good to very good responses. This media offers advantages through interactive simulations that allow real-time parameter manipulation, providing a more intuitive learning experience than conventional methods. However, access to adequate hardware and software is a challenge in wider implementation. In the future, web-based or mobile development can be a solution to increase the reach and sustainability of the use of this media. To improve the quality and scope of research, it is recommended that this simulation-based learning media be developed into a web-based version or mobile application to increase accessibility and reduce dependence on certain software such as MATLAB. Future research should also involve student populations from various geographic locations and educational backgrounds to obtain more general and representative results, while evaluating the effectiveness of the media in different contexts. In addition, longitudinal studies are needed to understand the long-term impact of using this media on students' mastery of science process skills and learning outcomes. The development of more user-friendly media and training for students and lecturers are also priorities to minimize implementation barriers and encourage wider adoption. This study recommends that further research should involve interdisciplinary collaboration, such as with educational technology experts or software developers, to create more efficient innovative solutions. Equally important, the development of comprehensive evaluation indicators is needed to measure the effectiveness of this media in detail, covering aspects of science process skills, material understanding, and user satisfaction.

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**REFERENCES**

[1] J. Gibson and S. Olivia, “Direct and indirect effects of covid-19 on life expectancy and poverty in Indonesia,” *Bull. Indones. Econ. Stud.*, vol. 56, no. 3, pp. 325–344, 2020, doi: 10.1080/00074918.2020.1847244.
[2] J. Hall and S. McLaren, “teaching and researching Japan through the pandemic and beyond,” *Japanese Stud.*, vol. 43, no. 3, pp. 215–219, 2023, doi: 10.1080/10371397.2023.2281137.
[3] M. V. Mawn, P. Carrico, K. Charuk, K. S. Stote, and B. Lawrence, “Hands-on and online: scientific explorations through distance learning,” *Open Learn.*, vol. 26, no. 2, pp. 135–146, 2011, doi: 10.1080/02680513.2011.567464.
[4] A. Alam and A. Mohanty, “Educational technology: exploring the convergence of technology and pedagogy through mobility, interactivity, AI, and learning tools,” *Cogent Eng.*, vol. 10, no. 2, p. 2283282, 2023, doi: https://doi.org/10.1080/23311916.2023.2283282.
[5] J. Liu, F. Yu, B. He, and T. Yan, “Hydrodynamic numerical simulation and prediction of bionic fish based on computational fluid dynamics and multilayer perceptron,” *Eng. Appl. Comput. Fluid Mech.*, vol. 16, no. 1, pp. 858–878, 2022, doi: 10.1080/19942060.2022.2052355.
[6] K. Iuchi *et al.*, “Questioning the hazard map-based rebuilding process: learning from the 2018 Sulawesi earthquake in Indonesia,” *Coast. Eng. J.*, vol. 65, no. 1, pp. 126–148, 2023, doi: 10.1080/21664250.2023.2165430.
[7] V. Garneli and K. Chorianopoulos, “Programming video games and simulations in science education: exploring computational thinking through code analysis,” *Interact. Learn. Environ.*, vol. 26, no. 3, pp. 386–401, 2018, doi: 10.1080/10494820.2017.1337036.
[8] T. Zito, C. Park, and B. Jeong, “Life cycle assessment and economic benefits of a solar assisted short route ferry operating in the Strait of Messina,” *J. Int. Marit. Safety, Environ. Aff. Shipp.*, vol. 6, no. 1, pp. 24–38, 2022, doi: 10.1080/25725084.2021.1968664.
[9] Z. A. Huneiti, W. Balachandran, Y. Balarabe, and M. Abdul Majid, “Matlab As a Teaching and Learning Tool for Mathematics: a Literature Review,” *Int. J. Arts Sci.*, vol. 2, no. 3, pp. 1–23, 2023.
[10] M. A. Lala, Z. O. Olomowewe, A. T. Adeniyi, and A. Giwa, “Maize cob-derived activated carbon as an adsorbent for the removal of nickel (II) cation from aqueous solution: optimization and kinetic studies,” *Arab J. Basic Appl. Sci.*, vol. 30, no. 1, pp. 573–582, 2023, doi: 10.1080/25765299.2023.2266230.
[11] K. Perkins, “Transforming STEM Learning at Scale: PhET Interactive Simulations,” *Child. Educ.*, vol. 96, no. 4, pp. 42–49, 2020, doi: 10.1080/00094056.2020.1796451.
[12] R. P. Tripathi, A. K. Singh, P. Gangwar, and R. K. Verma, “Sensorless speed control of DC motor using EKF estimator and TSK fuzzy logic controller,” *Automatika*, vol. 63, no. 2, pp. 338–348, 2022, doi: 10.1080/00051144.2022.2039990.
[13] M. Gedefaw, “Analysis of the trends of climate variability over two different eco-regions of Ethiopia,” *Cogent Eng.*, vol. 10, no. 2, pp. 1–13, 2023, doi: 10.1080/23311916.2023.2283337.
[14] J. R. Smith *et al.*, “A Smartphone-based virtual reality plotting system for STEM education,” *Primus*, vol. 33, no. 1, pp. 1–15, 2023, doi: 10.1080/10511970.2021.2006378.
[15] A. Shirvani, M. Nili-Ahmadabadi, and M. Y. Ha, “Machine learning-accelerated aerodynamic inverse design,” *Eng. Appl. Comput. Fluid Mech.*, vol. 17, no. 1, pp. 1–31, 2023, doi: 10.1080/19942060.2023.2237611.
[16] P. C. Campbell, “Modifying ADDIE: Incorporating New Technologies in Library Instruction,” *Public Serv. Q.*, vol. 10, no. 2, pp. 138–149, 2014, doi: 10.1080/15228959.2014.904214.
[17] A. Razzaque, L. Nahar, M. Akter Khanam, and P. Kim Streatfield, “Socio-demographic differentials of adult health indicators in Matlab, Bangladesh: self-rated health, health state, quality of life and disability level,” *Glob. Health Action*, vol. 3, no. 1, p. 4618, 2010, doi: 10.3402/gha.v3i0.4618.
[18] N. Alam, H. R. Chowdhury, A. Ahmed, M. Rahman, and P. Kim Streatfield, “Distribution of cause of death in rural Bangladesh during 2003-2010: Evidence from two rural areas within matlab health and demographic surveillance site,” *Glob. Health Action*, vol. 7, no. 1, 2014, doi: 10.3402/gha.v7.25510.
[19] M. M. Y. B. Elshabasy, M. A. Al-Moghazy, and H. A. El Gamal, “Investigation of the enhancement of microelectromechanical capacitive pressure sensor performance using the genetic algorithm optimization technique,” *Eng. Optim.*, vol. 53, no. 1, pp. 1–17, 2021, doi: 10.1080/0305215X.2019.1694673.
[20] Z. Zuhrohtun, M. Z. Salim, K. Sunaryo, and S. Astuti, “Returns co-movement and interconnectedness: Evidence from Indonesia banking system,” *Cogent Econ. Financ.*, vol. 11, no. 2, pp. 1–33, 2023, doi: 10.1080/23322039.2023.2226903.
[21] P. T. Nugroho, D. P. Dewi, S. Fuada, H. E. Putri, F. R. Jannah, and F. W. Zanah, “Teaching sine wave concept through simulation for elementary school students,” *J. Phys. Conf. Ser.*, vol. 1987, no. 1, 2021, doi: 10.1088/1742-6596/1987/1/012044.
[22] J. B. Jarrett, K. L. Goliak, S. T. Haines, E. Trolli, and A. Schwartz, “Development of an entrustment-supervision assessment tool for pharmacy experiential education using stakeholder focus groups,” *Am. J. Pharm. Educ.*, vol. 86, no. 1, pp. 15–20, 2022, doi: 10.5688/ajpe8523.
[23] J. A. Bawalsah *et al.*, “Students with and without handwriting difficulties,” vol. 17, no. 7, pp. 2447–2461, 2022.
[24] S. Parent *et al.*, “Development and initial factor validation of the Violence Toward Athletes Questionnaire (VTAQ) in a sample of young athletes,” *Loisir Soc.*, vol. 42, no. 3, pp. 471–486, 2019, doi: 10.1080/07053436.2019.1682262.
[25] Y. Ramma, A. Bholoa, M. Watts, and P. S. Nadal, “Teaching and learning physics using technology: Making a case for the affective domain,” *Educ. Inq.*, vol. 9, no. 2, pp. 210–236, 2018, doi: 10.1080/20004508.2017.1343606.
[26] M. Adula, Z. A. Birbirsa, and S. Kant, “The effect of interpersonal, problem solving and technical training skills on performance of Ethiopia textile industry: Continuance, normative and affective commitment as mediators,” *Cogent Bus. Manag.*, vol. 10, no. 3, pp. 1–16, 2023, doi: 10.1080/23311975.2023.2286672.

[27] P. O. Dierks, T. N. Höffler, J. S. Blankenburg, H. Peters, and I. Parchmann, "Interest in science: a RIASEC-based analysis of students' interests," *Int. J. Sci. Educ.*, vol. 38, no. 2, pp. 238–258, 2016, doi: 10.1080/09500693.2016.1138337.

[28] F. Alatas and D. Solehat, "Pengembangan media audiovisual praktikum fisika dasar berbasis I-SETS (Islamic-Science, Environment,Tecnology, Society) sebagai solusi praktikum saat new normal," *J. Penelit. Pembelajaran Fis.*, vol. 13, no. 1, pp. 103–116, 2022, doi: 10.26877/jp2f.v13i1.11401.

[29] V. Batdı, Y. Doğan, and T. Talan, "Effectiveness of online learning: a multi-complementary approach research with responses from the COVID-19 pandemic period," *Interact. Learn. Environ.*, vol. 31, no. 7, pp. 4113–4146, 2023, doi: 10.1080/10494820.2021.1954035.

[30] Y. Zhou *et al.*, "Rayleigh–Taylor and Richtmyer–Meshkov instabilities: A journey through scales," *Phys. D Nonlinear Phenom.*, vol. 423, 2021, doi: 10.1016/j.physd.2020.132838.

[31] Y. O. Hunter-Johnson and R. B. Closson, "Learners' educational orientation as a design tool for human resource development professionals in law enforcement: A caribbean context," *Hum. Resour. Dev. Int.*, vol. 15, no. 2, pp. 193–208, 2012, doi: 10.1080/13678868.2011.647462.

[32] Matsun, V. S. Andrini, T. W. Maduretno, and A. C. Yusro, "Development of physics learning e-module based on local culture wisdom in Pontianak,West Kalimantan," *J. Phys. Conf. Ser.*, vol. 1381, no. 1, 2019, doi: 10.1088/1742-6596/1381/1/012045.

[33] M. Pøhl *et al.*, "Keratin 34betaE12/keratin7 expression is a prognostic factor of cancer-specific and overall survival in patients with early stage non-small cell lung cancer," *Acta Oncol. (Madr).*, vol. 55, no. 2, pp. 167–177, 2016, doi: 10.3109/0284186X.2015.1049291.

[34] C. Harms, J. A. Pooley, and L. Cohen, "The protective factors for resilience scale (PFRS): development of the scale," *Cogent Psychol.*, vol. 4, no. 1, pp. 1–17, 2017, doi: 10.1080/23311908.2017.1400415.

[35] P. Kumar *et al.*, "Using empirical science education in schools to improve climate change literacy," *Renew. Sustain. Energy Rev.*, vol. 178, no. May 2022, p. 113232, 2023, doi: 10.1016/j.rser.2023.113232.

[36] J. Marsot and L. Claudon, "Design and ergonomics. methods for integrating ergonomics at hand tool design stage," *Int. J. Occup. Saf. Ergon.*, vol. 10, no. 1, pp. 13–23, 2004, doi: 10.1080/10803548.2004.11076591.

[37] J. Bakunowicz and T. Kopecki, "Global analysis of the aircraft structure and its application to the preliminary design stage," *Aviation*, vol. 9, no. 3, pp. 29–35, 2005, doi: 10.1080/16487788.2005.9635908.

[38] A. S. Fathi and W. O'Brien, "A simulation-based approach for evaluating indoor environmental quality at the early design stage," *Sci. Technol. Built Environ.*, vol. 29, no. 4, pp. 457–471, 2023, doi: 10.1080/23744731.2023.2187611.

[39] J. G. Djokoto, P. Pomeyie, and C. A. Wongnaa, "Foreign direct investment in food manufacturing and stages of human development," *Cogent Econ. Financ.*, vol. 11, no. 2, 2023, doi: 10.1080/23322039.2023.2267738.

[40] J. Huang and L. S. J. Tsaih, "Exploring potential impacts for early involvement of interior design in the early land development stage - Studying Taiwan Cosmos Group's hotel development," *J. Asian Archit. Build. Eng.*, vol. 22, no. 2, pp. 452–460, 2023, doi: 10.1080/13467581.2022.2046588.

[41] E. Mantzourani, R. Deslandes, K. Hodson, A. Evans, L. Taylor, and C. Lucas, "Community pharmacists' views on the early stages of implementation of a national pilot independent prescribing service in wales: a qualitative study," *Integr. Pharm. Res. Pract.*, vol. 12, no. 1, pp. 11–23, 2023, doi: 10.2147/iprp.s395322.

[42] W. Hu and X. Guo, "Toward the development of key competencies: a conceptual framework for the STEM curriculum design and a case study," in *Frontiers in Education*, Frontiers Media SA, 2021, p. 684265.

[43] M. A. Durand, M. Bannier, M. A. Aim, and J. Mancini, "Adaptation and implementation of pictorial conversation aids for early-stage breast cancer surgery and reconstruction: a quality improvement study," *Patient Prefer. Adherence*, vol. 17, no. 11, pp. 2463–2474, 2023, doi: 10.2147/PPA.S421695.

[44] S. Hamid, S. Naveed, H. Ayub, and S. Akhtar, "Academic leadership during the time of crisis: Success story of implementation success from traditional to online mode of education in a low-resource context," *Cogent Soc. Sci.*, vol. 9, no. 1, pp. 1–15, 2023, doi: 10.1080/23311886.2023.2197302.

[45] S. Sharma, T. Singh, and A. Dvivedi, "Developments in tandem micro-machining processes to mitigate the machining issues at micron level: a systematic review, challenges and future opportunities," *Mach. Sci. Technol.*, vol. 26, no. 4, pp. 515–570, 2022, doi: 10.1080/10910344.2022.2129991.

[46] A. Ghadge, M. Bourlakis, S. Kamble, and S. Seuring, "Blockchain implementation in pharmaceutical supply chains: A review and conceptual framework," *Int. J. Prod. Res.*, vol. 61, no. 19, pp. 6633–6651, 2023, doi: 10.1080/00207543.2022.2125595.

[47] H. Tjaraka, W. Hidayat, and R. Rusdiyanto, "The role of earning management as a mediator of the effect of the facial width to height ratio CEOs on leverage," *Cogent Bus. Manag.*, vol. 9, no. 1, 2022, doi: 10.1080/23311975.2022.2115733.

[48] I. Ikhsan and A. Amri, "Exploration of macroeconomic effects on criminality in Indonesia," *Cogent Soc. Sci.*, vol. 9, no. 1, 2023, doi: 10.1080/23311886.2023.2206678.

[49] S. Demir, "Comparison of normality tests in terms of sample sizes under different skewness and kurtosis coefficients," *Int. J. Assess. Tools Educ.*, vol. 9, no. 2, pp. 397–409, 2022, doi: 10.21449/ijate.1101295.

[50] D. Darmaji, A. Astalini, D. A. Kurniawan, and E. Triani, "The effect of science process skills of students argumentation skills," *J. Inov. Pendidik. IPA*, vol. 8, no. 1, pp. 78–88, 2022, doi: 10.21831/jipi.v8i1.49224.

[51] J. P. D. Addie, R. Keil, and K. Olds, "Beyond town and gown: Universities, territoriality and the mobilization of new urban structures in Canada," *Territ. Polit. Gov.*, vol. 3, no. 1, pp. 27–50, 2015, doi: 10.1080/21622671.2014.924875.

[52] S. N. F. Ramly, N. J. Ahmad, and H. Mohd Said, "The development of innovation and chemical entrepreneurship module for pre-university students: an analysis phase of ADDIE model," *J. Nat. Sci. Integr.*, vol. 5, no. 1, p. 96, 2022, doi: 10.24014/jnsi.v5i1.16751.

[53] T. Trust and E. Pektas, "Using the ADDIE model and universal design for learning principles to develop an open online course for teacher professional development," *J. Digit. Learn. Teach. Educ.*, vol. 34, no. 4, pp. 219–233, Oct. 2018, doi: 10.1080/21532974.2018.1494521.

[54] N. Jannah Berutu, D. Aurora, R. Amalia, R. Amelza, T. Adinda Siregar, and N. Azizah Lubis, "Analisis Standardisasi laboratorium dalam proses pembelajaran fisika (studi kasus di SMA 4 langsa)," *J. Ris. Pendidik. dan Bhs.*, vol. 2, no. 3, pp. 75–83, 2023.
[55] O. Chernikova, N. Heitzmann, M. Stadler, D. Holzberger, T. Seidel, and F. Fischer, "Simulation-based learning in higher education: a meta-analysis," *Rev. Educ. Res.*, vol. 90, no. 4, pp. 499–541, 2020, doi: 10.3102/0034654320933544.
[56] T. Hunegnaw and S. Melesse, "An evaluative study of the experimental tasks of the Ethiopian grade 12 chemistry textbook considering developing 'science process skills,'" *Cogent Educ.*, vol. 10, no. 1, 2023, doi: 10.1080/2331186X.2023.2208944.
[57] J. S. McKinney, "Teacher as client therapy (TACT): a model for simulated learning for traditional and online delivery models," *J. Teach. Soc. Work*, vol. 39, no. 4–5, pp. 429–439, 2019, doi: 10.1080/08841233.2019.1640339.
[58] N. Rutten, W. R. Van Joolingen, and J. T. Van Der Veen, "The learning effects of computer simulations in science education," *Comput. Educ.*, vol. 58, no. 1, pp. 136–153, 2012, doi: 10.1016/j.compedu.2011.07.017.
[59] T. N. A. Nguyen, T. H. H. Pham, and T. Vallée, "Similarity in trade structure: evidence from ASEAN + 3," *J. Int. Trade Econ. Dev.*, vol. 26, no. 8, pp. 1000–1024, 2017, doi: 10.1080/09638199.2017.1331372.
[60] M. Y. Al-Hamad and I. S. Qamber, "TVA generating unit modeling using MATLAB," *J. Assoc. Arab Univ. Basic Appl. Sci.*, vol. 17, pp. 73–81, 2015, doi: 10.1016/j.jaubas.2014.05.003.
[61] I. Rosyida, T. S. N. Asih, S. B. Waluya, and Sugiyanto, "Fuzzy shortest path approach for determining public bus route (Case study : Route planning for 'Trans Bantul bus' in Yogyakarta, Indonesia)," *J. Discret. Math. Sci. Cryptogr.*, vol. 24, no. 2, pp. 557–577, 2021, doi: 10.1080/09720529.2021.1891692.
[62] N. Tytova, "Digital literacy of future teachers in the realities of large-scale military aggression (Ukrainian experience)," *Futur. Educ.*, vol. 2, pp. 43–54, 2022, doi: 10.57125/fed/2022.10.11.33.
[63] N. Neupärtl, F. Tatai, and C. A. Rothkopf, "Naturalistic embodied interactions elicit intuitive physical behaviour in accordance with Newtonian physics," *Cogn. Neuropsychol.*, vol. 38, no. 7–8, pp. 440–454, 2021, doi: 10.1080/02643294.2021.2008890.
[64] F. Rosi, A. Abdurrahman, and W. Wahyuni, "the hybrid learning model; a teacher strategies in learning management during pandemic," *EDURELIGIA J. Pendidik. Agama Islam*, vol. 6, no. 1, pp. 76–88, 2022, doi: 10.33650/edureligia.v6i1.3651.