23 (2), 2022, 1069-1082

Jurnal Pendidikan MIPA

e-ISSN: 2550-1313 | p-ISSN: 2087-9849
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Autonomy-Based STEM Learning: An Innovative Solution to Improve Students' Digital Literacy

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Abstract: In the current era of technology and information, digital literacy is a critical factor for life and career success, but it has received less attention in schools. Therefore, this study aims to analyze the effectiveness of Autonomy-Based STEM learning (A-STEM learning) in improving students' digital literacy. This research uses the ADDIE development model. The implementation test used a one-group pre-test post-test design on 29 students in class XI MIPA in one of the high schools in Banjarmasin, South Kalimantan, Indonesia. Data collection used a digital literacy questionnaire that emphasized indicators of the intensity of application and utilization of digital literacy in learning activities; the number and variety of teaching materials and digital-based teaching aids; the frequency of accessing digital teaching materials; having operational skills in using ICT for learning and learning outcomes tests. The results obtained the n-gain value of digital literacy and learning outcomes of 0.74 and 0.85, respectively, with a high criteria. Thus, the developed A-STEM learning effectively improves students' digital literacy in physics.

Keywords: Autonomy-based STEM learning, digital literacy, learning outcomes.

Abstrak: *Di era teknologi dan informasi saat ini, literasi digital menjadi faktor kunci bagi kesuksesan hidup dan berkarir, namun literasi tersebut kurang mendapatkan perhatian di sekolah. Oleh karena itu, tujuan penelitian ini adalah menganalisis keefektifan autonomy-based STEM learning (A-STEM learning) dalam meningkatkan literasi digital siswa. Penelitian ini menggunakan model pengembangan ADDIE. Uji implementasi menggunakan one-group pre-test post-test design pada 29 siswa kelas XI MIPA di salah satu sekolah menengah atas di Banjarmasin, Kalimantan Selatan, Indonesia. Pengumpulan data menggunakan angket literasi digital yang ditekankan pada indikator intensitas penerapan dan pemanfaatan literasi digital dalam kegiatan pembelajaran; jumlah dan variasi materi ajar serta alat peraga berbasis digital; frekuensi pengaksesan materi ajar digital; memiliki keterampilan operasional dalam menggunakan TIK untuk belajar serta tes hasil belajar. Hasil penelitian memperoleh nilai n-gain literasi digital dan hasil belajar masing-masing sebesar 0,74 dan 0,85 dengan kategori tinggi. Dengan demikian, A-STEM learning yang dikembangkan efektif dalam meningkatkan literasi digital siswa pada pembelajaran fisika.*

Kata kunci: *Autonomy-based STEM learning, literasi digital, hasil belajar.*

▪ INTRODUCTION

In industrial 4.0, technology and information products have coloured all human life activities, including education (Anwar et al., 2021; Belbase et al., 2021; Mulyani, 2019). Education is the main thing humans need to prepare themselves in the face of an ever-evolving world (Callaway-Cole & Kimble, 2021; Hamalainen et al., 2021; Winarto, Asnawati, & Wijaya, 2018). The quality of education is a benchmark for the progress of a nation. Therefore, the world of education is trying to integrate the latest technology and information products to improve the quality of learning, which is expected to positively impact the quality of graduates (Mardiyanti & Jatmiko, 2022). In

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DOI: http://dx.doi.org/10.23960/jpmipa/v23i3.pp1069-1081
Received: 20 August 2022
Accepted: 16 September 2022
Published: 18 September 2022

this case, educators must master various skills using technology, media, and information that support the learning process at school (Karakose, Polat, & Papadakis, 2021; Rahman & Nuryana, 2019). Educators can create or use technology-based learning tools that are innovative, creative, effective, fun, and student-oriented (Dahlan & Wibisono, 2021; Maulana & Sari, 2018; Putri, Fahmi, & Wahyuningsih, 2021). In this case, the STEM approach can be an alternative solution that supports 21st-century learning (Miguel, Tambe, & da Costa, 2022; Putra, Deffinika, & Islam, 2021; Vidakovich, 2021). Through the STEM approach, students are familiarized with technology literacy and apply 4C skills (critical thinking, communication, collaboration, and creativity) in learning (Chusni, Saputro, & Rahardjo, 2021; Muzana et al., 2021; Weng et al., 2022). Students are accustomed to solving real-life problems individually or in groups, so it impacts increasing students' digital literacy (Prihadi, 2018; Sahidillah & Miftahurrisqi, 2019; Setiawan, Mahanal, & Zubaidah, 2021).

Many schools have implemented digital-based learning, but the learning process is still teacher-centered. Teachers only occasionally apply it in class to have less impact on students' digital literacy (Rahayu & Mayasari, 2018; Setiani, Ngazizah, & Kurniawan, 2016). Educators must facilitate students' digital literacy during learning. This is useful in supporting student success in the academic field, learning to be professional and adapting to the all-digital era of the industrial revolution 4.0 so that they are ready to face the modern world of work (Alakrash & Abdul-Razak, 2021; Khasanah & Herina, 2019). To support digital literacy in schools, the government launched a school literacy movement through the ministry of education and culture in collaboration with the ministry of communication and information. Learning is directed to be electronic-based or e-learning familiar to students (Pratama, Hartini, & Misbah, 2019). Educators can implement STEM learning which is believed to be able to improve students' digital literacy. Through STEM learning, students are accustomed to solving problems and thinking critically about various aspects of life, including issues that exist in cyberspace (Belbase et al., 2021; Handayani, 2020). In learning with the STEM 4.0 approach, there are activities to understand the concept of learning materials (sains) by integrating the phenomena of daily life (mathematics) supported by learning media (technology) and followed by the practice of solving a problem in groups (engineering) (Hamalainen et al., 2021; Loliyana et al., 2022; Muzana et al., 2021). To implement STEM learning more effective and efficient, educators need to consider the level of student autonomy, known as Autonomy Based STEM learning (A-STEM learning) (Suyidno, Mahtari, & Siswanto, 2021). Implementing A-STEM learning is believed to facilitate students' development and apply various 21st-century knowledge and skills (Dare et al., 2021; Mulyani, 2019).

Based on the 2018 PISA study (Arthur et al., 2021' Rahmadani, 2020; Zulifah & Masfuah, 2021), Indonesia's digital literacy skills are low and below average because they are ranked 6th from the bottom with an average score of 371. The teacher dominates learning in the classroom, and inappropriate learning models or approaches make students less interested in understanding learning more deeply (Agusty, Alifteria, & Anggaryani, 2021; Nazifah, Amir, & Hidayatullah, 2022; Zheng, 2021). In addition, the use of digital media in Indonesia's teaching and learning process is minimal. Whereas in the industrial era 4.0, every educational institution must be responsive to the development of technology, information and communication (Belbase et al., 2021;

Setyaningsih et al., 2019). This is in line with the results of the researcher's initial study that students are less active in learning physics because learning is still centered on educators, printed books dominate learning resources, there are no reference sources such as digital teaching materials, and rarely do virtual lab-based experiments, learning models have not varied and have not been combined with STEM. In addition, digital literacy-based learning habits receive less attention in the classroom. Based on a digital literacy questionnaire given to 112 students in class XI MIPA, the average score was 40.00, a poor criteria. The score of students who read scientific journals or e-books to expand their knowledge is 37.50, often open the school website to keep up with the development of information at school is 40.00, and read seven books a week is 35.25.

An innovative alternative to cultivating digital literacy in schools is that education can implement A-STEM learning, a learning approach that integrates S-T-E-M and considers the level of student autonomy or independence (Pratama, Hartini, & Misbah, 2019; Suyidno, Mahtari, & Siswanto, 2021). This is in line with (Afriyanti & Suyatna, 2021; Nenchi, Budi, & Rustana, 2021; Wibowo, 2019) that using e-learning with a STEM approach can improve scientific skills and positive student responses to physics learning. In addition, STEM-based teaching materials can contain characteristics that cover concepts, are rich in material, and can improve students' science and technology literacy (including digital literacy) (Belbase et al., 2021; Rusyati, Permanasari, & Ardianto, 2019; Toto, Yulisma, & Amam, 2021). Students' response to learning with the STEM approach is very good and can increase the average technological literacy of students from 41.93 to 80.99 (Satriana, 2021). Applying STEM learning can improve students' critical thinking skills on sound wave material in moderate criteria (Khoiriyah, Abdurrahman, & Wahyudi, 2018). Some previous studies have examined A-STEM learning but have not emphasized the development of students' digital literacy. Therefore, this study aims to analyze the effectiveness of A-STEM learning in improving students' digital literacy. Implementing A-STEM learning is believed to enhance students' creativity, personality, and independence in 21st-century education.

▪ METHOD

This research and development type is adapted from the ADDIE development model (Tegeh, Jampel, & Pudjawan, 2015). The independent variable was the A-STEM learning tool, while the dependent variables were digital literacy and learning outcomes. The research subjects were 29 students of class XI MIPA at one of the high schools in Banjarmasin, Indonesia. The research was conducted from January to June 2022.

This research began with the analysis stage, where researchers analyzed the curriculum, student characteristics, and teaching materials so that the problem's urgency was found about the importance of developing A-STEM Learning tools to improve students' digital literacy. Researchers designed lesson plans, teaching materials, student worksheets, digital literacy questionnaires, and learning outcomes tests in the design stage. At the development stage, researchers made A-STEM learning devices. They then conducted validation tests by three physics learning experts and obtained validity values (0-4 value range) and reliability (0-1 value range) for lesson plans (3.77, 0.90); teaching materials (3.65, 0.83), student worksheets (3.70, 0.81), digital literacy questionnaires (3.78, 0.75), and learning outcomes tests (3.66, 0.87). Thus, these tools have met the validity and reliability criteria and can be used in this study.

The implementation stage used a one-group pre-test and post-test design (O1 x O2). The study began by measuring students' digital literacy skills, so students were given a pre-test (O1) in the form of a digital literacy questionnaire containing 14 statements on the indicators of digital literacy achievement. In addition to being given a digital literacy questionnaire, students were also given seven items of essay questions combined with STEM and the learning objectives that had been prepared previously. During the learning activities (X), students were directed to learn in groups in two meetings and individually for one session. The learning process applied the A-STEM learning tool in three meetings.

In the first meeting, the discussion of characteristics, propagation speed, and classification of sound waves. The teacher applied to learn based on the structured inquiry learning model combined with STEM, where students were formed into six study groups in the second meeting to discuss the symptoms of sound waves and resonance on strings. The teacher applies to learning based on the direct teaching-learning model combined with STEM; in this meeting, students do not form study groups. The third meeting discussed resonance in organ pipes, intensity levels, and sound wave applications. The teacher applied to learn based on the cooperative learning model combined with STEM. In this meeting, students were formed into six study groups. The purpose of creating this study group is to familiarize students with working together to solve problems contained in the worksheet activities. Still, there is one meeting where students do not form study groups. This is done so that the teacher can determine individual students' abilities and make improvements for the next meeting. In addition to being familiarized with STEM blended learning, students are also trained with the four indicators of digital literacy. At the last meeting, students were given a post-test (O2) in the form of a digital literacy questionnaire and essay questions combined with STEM that had been answered previously. Still, the order of questions or statements differed from the pre-test. Finally, at the evaluation stage, the weaknesses found in this study were taken into consideration in revising the device to make it of higher quality.

Digital literacy data was obtained by filling out a digital literacy questionnaire to measure the intensity of application and utilization of digital literacy in learning activities, the number and variety of teaching materials and digital-based teaching aids, the frequency of accessing digital-based teaching materials and having operational skills in using ICT for learning. The rating scale used is 1 to 4, wherein positive statements the value 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree while in negative statements the value 1 = strongly agree, 2 = agree, 3 = disagree, and 4 = strongly disagree. While the learning outcomes test contains STEM-based essay questions and corresponds to the learning objectives compiled previously, the assessment scale is from 0-100, depending on the answers given by students. The digital literacy score will be calculated and then adjusted to the criteria in Table 1.

Table 1. Criteria for digital literacy achievement

Score	Criteria
$X > 80$	Very good
$60 < X \leq 80$	Good
$40 < X \leq 60$	Enough

$20 < X \leq 40$	Poor
$X \leq 20$	Very poor

Furthermore, the effectiveness of A-STEM learning will be reviewed from the results of data analysis of digital literacy and learning outcomes using the n-gain equation. The calculation results are then adjusted to the criteria: high ≥ 0.7; 0.7 > medium ≥ 0.3, and 0.3 > low (Hake, 1998).

▪ RESULT AND DISSCUSSION

In the industry 4.0 era, digital literacy is critical to familiarize students at school. The results of students' digital literacy achievement are contained in Table 2.

Table 2. Results of student digital literacy analysis

Digital Literacy Indicator	The Obtained Result			
	Before		After	
	Score	Criteria	Score	Criteria
The intensity of the application and utilization of digital literacy in learning activities	49.14	Enough	88.79	Very good
The number and variety of teaching materials and digital-based teaching aids	56.25	Enough	88.79	Very good
The frequency of accessing digital teaching materials	52.30	Enough	90.80	Very good
Having operational skills in using ICT for learning	58.05	Enough	84.20	Very good
N-gain	0.74 (high criteria)			

Based on Table 2, four indicators of students' digital literacy achievement are contained in the digital literacy questionnaire. Before students were given treatment, all digital literacy indicators were assessed in enough criteria. Meanwhile, all digital literacy indicators were obtained in the very good criteria after treatment. In addition, there is also the acquisition of n-gain, categorized as high. The test results that students carried out before and after receiving treatment are in Table 3, Figure 1 and Figure 2.

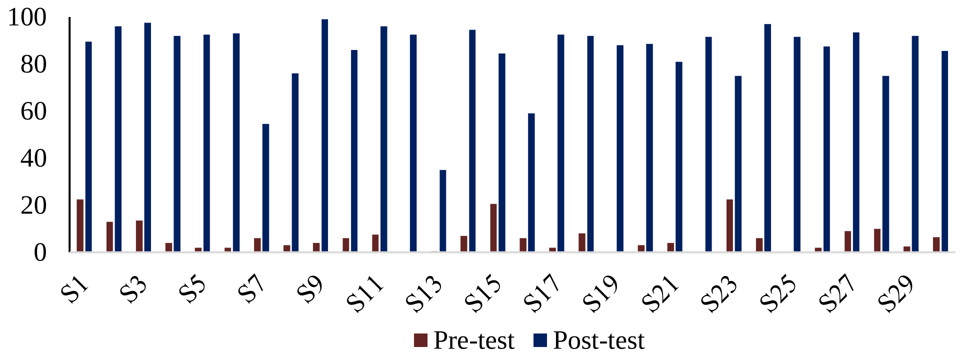

Table 3. Analysis of pre-test and post-test scores of student learning outcomes

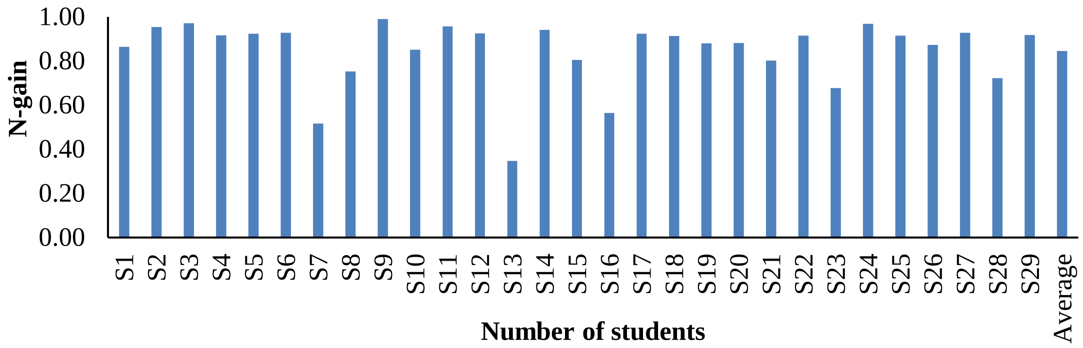

Figure 1. Analysis of improvement in student learning outcomes

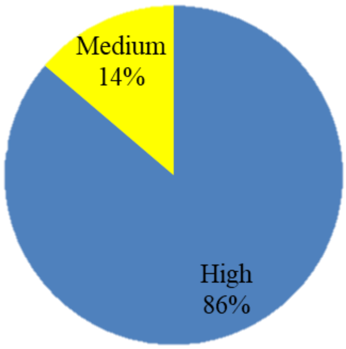

Figure 2. Percentage increase in student learning outcomes

Based on Figure 1, the increase in student learning outcomes can be seen from the n-gain value. The lowest n-gain value for student S13 was 0.35 with moderate criteria, the highest n-gain value for student S9 was 0.99 with high criteria, and the average n-gain score of 0.85 with high criteria. This is reinforced by Figure 2 that implementing A-STEM Learning can improve student learning outcomes in moderate (14%) and high (86%) criteria. In other words, no students improved their learning outcomes in the low criteria (0%).

Effectiveness is the suitability between the person carrying out the task and the intended goal or target where there is an influence and the results obtained from the implementation of the study are by the specified target or goal. In contrast, the effectiveness of learning devices means an educational quality standard measured by looking at the achievement of a learning objective derived from a learning outcome test (Rohmawati, 2015). Analysis of the device's effectiveness is obtained by comparing learning test results (n-gain score) in the form of pre-test and post-test (Rifansyah, Mastuang, & Salam, 2017). The effectiveness of the device reviewed in this study is the n-gain of digital literacy and student learning outcomes. The transfer of knowledge from educators to students can be said to be ineffective if the student does not have the desire to understand, process, and build the knowledge that has been conveyed by the educator (Dewantara, Safitri, & Susilowati, 2022) so that the resulting learning outcomes will get poor results (Rahmatullah et al., 2022).

The indicators of digital literacy achievement contained in Table 2 were adopted from several sources and adapted to the research objectives, then applied in 14 statements in the questionnaire distributed before and after treatment (Rahayu & Mayasari, 2018; Pratama, Hartini, & Misbah, 2019). Based on Table 2, it is known that in all digital literacy indicators before being given treatment, namely the intensity of application and utilization of digital literacy in learning activities; the number and variety of teaching materials and digital-based teaching aids; the frequency of accessing digital teaching materials; and having operational skills in using ICT for learning are included in the good criteria. This is in line with the findings in research (Pratama, Hartini, & Misbah, 2019), where students' digital literacy skills scored in the very poor criteria. In addition, this result also corresponds with the initial observation data where the level of digital literacy of XI MIPA students is in the insufficient criteria. In contrast, the students' digital literacy post-test data (Table 2) shows that the indicators of the intensity of application and utilization of digital literacy in learning activities; the number and variety of teaching materials and digital-based teaching aids; the frequency of accessing digital teaching materials; and having operational skills in using ICT for learning are included in the very good criteria. This means that applying A-STEM learning tools can improve students' digital literacy. This data is supported by the acquisition of digital literacy n-gain, which is included in the high criteria. This indicates that STEM blended learning can improve students' digital literacy because its innovative education supports students' readiness to face the digital era and creates meaningful science learning (Dare et al., 2021; Karakose, Polat, & Papadakis, 2021; Nurcahyo & Setyowati, 2021). This is in line with (Dahlan & Wibisono, 2021; Muzana et al., 2021; Taufan et al., 2022) that ICT supports the learning process because it increases students' understanding of what the teacher is teaching.

In addition to looking at the acquisition of digital literacy n-gain, student learning outcomes can support the effectiveness of the device developed (Rifansyah et al., 2017). This study's student learning outcomes test contains seven essay questions combined with STEM. The pre-test data of student learning outcomes (Table 3) shows that after applying A-STEM learning, the lowest score of students has increased. Student learning outcomes can be improved in medium and high criteria (Figure 2, Figure 3). This is in line with research (Mulyana, Abdurrahman, & Rosidin, 2018), where the acquisition of pre-test scores will increase after being given treatment, namely learning with a STEM approach; this is evident in the purchase of the post-test obtained by students. In addition, based on the Minimum Completeness Criteria of 73, which applies to physics lessons at senior high school in Banjarmasin, it is known that the number of students who are complete after the application of A-STEM learning has increased. This increase can occur because the existing facilities and infrastructure support students' digital literacy skills, and education prioritizes student independence in learning (A-STEM) so that students will experience an increase in critical and creative thinking (Nurlina, Nurfadilah, & Bahri, 2021; Suyidno, Mahtari, & Siswanto, 2021). The advantage of A-STEM in the learning that has been applied is to build students' basic science and math concepts and then coordinate them to use them in product engineering and technology in groups and individually (Dare et al., 2021; Muzana et al., 2021; Suyidno, Mahtari, & Siswanto, 2021; Vidakovich, 2021). This means that A-STEM corresponds to the learning theory of cognitivism and constructivism because learning prioritizes the learning process and makes students active in building new ideas or concepts based on the knowledge or experience they already have. In other words building knowledge little by little (Nurlina, Nurfadilah, & Bahri, 2021).

A-STEM learning can improve the effectiveness of the learning process because the teaching materials familiarize students with digital literacy; in the digital teaching materials, several links or QR codes support digital literacy, and examples and practice questions train students' ability to solve problems combined with STEM and familiarize students with working on difficulties combined with STEM. This is in line with Suyatna, Viyanti, & Sari (2020) that digital learning resources combined with STEM familiarize students with independent learning and stimulate them to think at a higher level.

▪ CONCLUSION

Implementing A-STEM learning is effective as an alternative solution to improve students' digital literacy in schools. Students are accustomed to applying and utilizing digital literacy in the learning process, using various digital-based teaching materials and teaching aids, accessing digital-based teaching materials, and skillfully using ICT for physics learning. A-STEM learning is believed to be an innovative alternative to cultivating the digital literacy movement in schools. The limitation of the research is that it only examines levels one and two of A-STEM learning, so it is not known what students' digital literacy achievements will be if they apply autonomy three of A-STEM learning. The following research is the STEM approach can be integrated into problem-based learning, projects, or creative responsibility.

▪ ACKNOWLEDGEMENTS

The author would like to thank Universitas Lambung Mangkurat (ULM) for funding this research, the Department of Physics Education ULM and SMAN 5 Banjarmasin for supporting and facilitating this research activity.

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