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STEM-integrated physics digital teaching material to develop conceptual understanding and new literacy of students

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Abstract

Learning should be able to develop the students' literacy skills in the industrial revolution 4.0. However, the literacy of students related to this era was still low. The solution to solve the problem is to develop STEM-integrated physics digital teaching material (PDTM). The research objective was to investigate the effect of using PDTM on students' conceptual understanding and new literacy. The research method was quasi-experimental with a nonequivalent control group design. Instruments for collecting data consist of written tests and performance assessments. Data analysis used a comparison test of two independent groups: t-test and Mann-Whitney U test. The results of the data analysis state that the use of STEM-integrated PDTM has a positive effect on students' conceptual understanding and new literacy. The students' new literacy skills include data, technology, and human literacy. These results indicate that using STEM-integrated PDTM in physics learning effectively develops students' conceptual understanding and new literacy skills.

Keywords: digital teaching material, STEM, conceptual understanding, new literacy

INTRODUCTION

The industrial revolution 4.0 has had an impact on the world of education. Education in this era should be able to prepare human resources to adapt and compete globally (Lase, 2019). The teacher determines the quality of education to encourage students to have literacy skills in the industrial revolution 4.0 era. New literacy is the primary ability to handle various challenges in the industrial revolution, including data, technology, and human literacy (Graff, 2022; Hoerudin, 2021; Yurnetti et al., 2020). In learning, teachers must be able to prepare information and strengthen old literacy with new literacy (Lase, 2019). Students must acquire this new literacy to learn how to find and analyze data, comprehend and utilize technology for learning, and develop critical thinking, collaboration, and communication skills (Maya & Suseno, 2022). Therefore, teachers need to develop students' new literacy in learning to handle the challenges of education in the 4.0 industrial revolution era.

Technology to support learning becomes urgent in the 4.0 industrial revolution. Technology, in general, can be defined as a machine that can facilitate human work (Emery, 2016). Technology is an educational tool to support the implementation of learning (Prayudi et al., 2021). Examples of technology to help the learning process include electronic teaching materials, projectors, mobile phones, laptops, computers, and others (Abed, 2019; Baker et al., 2012). Teachers can utilize and master the technology to support learning (Champa et al., 2019; Ghavifekr & Rosdy, 2015). Students can also use this technology to find additional information and learn independently (Hashim, 2018). Thus, technology can be used in learning to improve students' abilities, especially literacy skills.

The reality found was contrary to the expected ideal conditions. First, the learning resources used in schools still use printed teaching materials. Zakiyah (2022) did the same thing in his research and showed that students only used electronic schoolbooks in PDF form. It implies that there is no use of technology in learning. The less use of technology to support learning causes online

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Contribution to the literature

- STEM activities in PDTM are able to develop students' ability to solve problems and understand concepts based on a topic of physics application in technology.
- STEM integration in PDTM is able to develop students' new literacy including data literacy, technology literacy and human literacy.
- The use of STEM-integrated PDTM in physics learning is effective for developing students' conceptual understanding and new literacy.

learning to be less effective (Dhawan, 2020; Ratnasari et al., 2021). Second, the teaching materials used in schools have yet to be able to integrate STEM. From the results of STEM integration analysis in physics teaching materials, the average value was still low, with an average value of 58.22. Integrating STEM in teaching materials can provide opportunities for students to create more meaningful learning (Margot & Kettler, 2019; Stehle & Peters-Burton, 2019). The reason is that STEM is close to students' real-life problems, so they experience and have the motivation to develop their new literacy skills (N et al., 2022; Yurnetti et al., 2020). This finding was supported by Niam and Asikin (2020), which state that teaching materials in schools do not contain real-life problems and do not yet link the concepts of science, technology, engineering, and mathematics with more detailed and in-depth discussion. Third, students' new literacy skills were still low. It obtained these results by assessing students' data, technology, and human literacy performance. Students' literacy had an average value of 43.41, which falls under the low category.

Several previous researchers have studied the impact of using teaching materials on students' literacy skills (Hikmawati et al., 2020; Indrasari et al., 2020; Rahmawati et al., 2021; Shofiyah et al., 2021). However, students' literacy skills are now highly developed, one of which is new literacy skills. Integrating STEM into teaching materials can support new literacy skills (N et al., 2022). Fourth, the school has low student learning outcomes, as indicated by the average value of the mid-semester exam of 51.90. The cause of expected student learning outcomes was a lack of interest and students' motivation to study physics because learning is boring (Nuriyani & Winarso, 2021). It aligns with the problems found by Niam et al. (2021), which show that students' interest in physics is low because learning problems are far from real-world issues. Students with a common interest in studying physics have expected student learning outcomes. Thus, these four problems are why the need to develop STEM-integrated digital teaching materials (DTMs) to improve students' conceptual understanding and new literacy skills.

Researchers have widely researched using DTMs to support the learning process and promote students' learning outcomes (A'yun et al., 2020; Asrizal et al., 2022; Suyatna et al., 2020; Zakiyah, 2022). However, these learning materials are not comprehensively implemented to improve students' conceptual understanding and new literacy skills. Previous research only examined the impact of using DTMs on students' concept understanding, scientific literacy, data literacy, and an aspect of 21st-century skills (A'yun et al., 2020; Melisa et al., 2021; Shofiyah et al., 2021; Suyatna et al., 2020; Zakiyah, 2022). This research can support and complement previous studies by integrating STEM into DTMs. STEM is related to problems in life and provides alternative solutions by using the latest technology and interpreting it in a mathematical formulation (Niam & Asikin, 2020; Niam et al., 2021). These teaching materials have various animations, images, videos, audio, and links that can make learning more fun and interactive (A'yun et al., 2020; Arista & Kuswanto, 2018; Asrizal et al., 2022). DTM also supports using technology such as cell phones and computers in learning (Asmiliyah et al., 2021; Sung et al., 2016). The teaching material is also supported by STEM activities, including experimental activities using a virtual laboratory that can encourage students' new literacy skills (A'yun et al., 2020; Asrizal et al., 2022). So, developing more exciting and interactive DTM needs to be developed.

There are at least four differences between this study and previous studies. First, the product developed is in the form of PDTM, utilizing technology in its application. Second, DTM in this research integrates STEM components in a physics topic in physics learning. Third, STEM-integrated PDTM aims to improve students' conceptual understanding and new literacy. Fourth, class XI high school students participated in field test activities to learn physics using this STEM-integrated DTM. This research carried out the use of STEM-integrated PDTM in field testing. Therefore, the purpose of this research was to determine the effects of STEM-integrated PDTM on students' conceptual understanding and new literacy.

THEORETICAL FRAMEWORK

The revolution era 4.0 requires students to have various literacy in this era. Literacy in this era is known as a new literacy. This new literacy consists of three types: data, technology, and human (Graff, 2022; Hoerudin, 2021; Yurnetti et al., 2020). Data literacy can be defined as a person's ability to read, analyze, and use information in the digital world (Kartika et al., 2021;

Rahmawati et al., 2021). Literacy skills can collect, read, analyze, and communicate data analysis results and make conclusions about data and information (Kartika et al., 2021; Rahmawati et al., 2021; Smolnikova, 2020; Yurnetti et al., 2020). Therefore, students must have data literacy skills so that they can understand data both quantitative and qualitative data and can master information obtained from the digital world.

Technology literacy is a person's ability to use technology. Technology literacy includes the ability to set technology, use modern tools such as laptops and mobile phones, utilize the Internet, and use electronic learning resources such as DTM (Ali et al., 2022; Asrizal et al., 2022; Baker et al., 2012; Yurnetti et al., 2020). So, by using technology literacy, students can understand technology well and expand their knowledge by getting information from various technologies.

Human literacy is literacy to develop a person's soft and hard skills. Human literacy leads a person to improve communication skills, mastery of design science, collaboration, critical thinking, creative thinking, and innovation (Azizah et al., 2020; Khoiri et al., 2021; Zakiyah, 2022). Therefore, students can improve their learning abilities by having human literacy skills to become functional human beings in their environment.

The new literacy abilities of students are closely related to STEM integration in learning. STEM combines science, technology, engineering, and mathematics (Erdogan & Ciftci, 2017; Gonzalez & Kuenzi, 2014; Krajcik & Delen, 2016). STEM is an approach in education that integrates the four aspects of STEM and focuses on solving problems in life (Widya et al., 2019). Schools can implement STEM into learning (Ramli & Talib, 2017). Thus, integrating STEM into learning can help students hone their abilities and multiply their knowledge in life.

Each STEM component is essential in improving students' new literacy skills. STEM connects the concept of physics with real life and supports virtual lab activities to encourage data, technology, and human literacy skills through its science component (Emery, 2016; Rahmawati et al., 2021). The technology component in STEM trains students to use technology and adds insight into the application of physics to technology (Abed, 2019; Arista & Kuswanto, 2018; McGee, 2020). The engineering component of STEM trains students to develop creative thinking skills, respect each other, and collaborate (Melisa et al., 2021; Suyatna et al., 2020; Zakiyah, 2022). The mathematical component of STEM can help students formulate equations related to physics concepts in life mathematically (Kartika et al., 2021; Smolnikova, 2020). Thus, STEM can encourage students' new literacy skills.

Integrating STEM with one of the digital learning materials, namely the STEM-integrated DTM, is necessary. Integrating STEM into teaching materials can enhance the quality of students (Niam et al., 2021; Nurramadhani et al., 2020). By integrating STEM into DTM, students can solve problems in life and understand the interrelationships of the four aspects of STEM (Phungsuk et al., 2017). STEM-integrated DTM can improve students' knowledge aspects and new literacy and skills. It aligns with previous research that DTM can support learning and improve student learning outcomes regarding knowledge and skills (A'yun et al., 2020; Asrizal et al., 2022; Paramita et al., 2021). Thus, STEM-integrated DTM can be the right solution to improve students' knowledge and new literacy skills.

DTM are teaching materials that are displayed in digital form and contain interactive learning (ElAdl & Musawi, 2020). These teaching materials can be accessed through developing technologies such as mobile phones, laptops, and computers (Handayani et al., 2021; Saleh, 2015). DTM consists of several supporting features that can arouse students' interest in learning and understanding physics material (Alshaya & Oyaid, 2017; Sriyanti et al., 2021). The use of DTM in learning is to make it easier for teachers to encourage the formation of knowledge and abilities of students (Nurhasnah et al., 2020). DTM can make learning effective and efficient (Azalia et al., 2020; Vina Serevina et al., 2018). Thus, DTM is very important to achieve successful student learning outcomes regarding knowledge and literacy skills.

METHODOLOGY

Method and Design Research

This research can be classified into quasi-experimental research methods. The research design used a nonequivalent control group type. This design produces two groups of samples obtained from a specific population. The two groups in this design were the experimental and control groups. The experimental group is the group that is given the treatment, the independent variable, while the control group is the group that was not given any treatment. The therapy in field testing was STEM-integrated PDTM. The experimental group was treated using STEM-integrated PDTM, and the control group used the usual teaching materials available at school. The type of research design can be described in **Table 1**.

Table 1. Design research

Groups	Treatment	Post-test
Experimental	X	T
Control	-	T

Note. X: Treatment of experimental group in STEM-integrated PDTM form & T: Tests were given to experimental & control groups

Sample

The research population included all students of class XI SMA 3 in Padang City. Using ANOVA test, obtained the sample by performing statistical analysis on the students' UTS scores. Four sample classes have the same ability from ANOVA test analysis results. The four classes were selected randomly and obtained two sample classes with an average value of each category of 65.60 and 64.60. Both sample groups were tested to determine the normality and homogeneity of the data. The test results found that the two groups of samples were normally distributed and homogeneous. To determine whether the student's prior knowledge in the two sample classes was the same, two independent group comparison tests were conducted using a t-test. The results of the data analysis prove that the two sample classes did not have a significant difference. This result indicated that both sample classes had the same initial abilities before the treatment was given. The determination of the experimental and control groups was not done randomly. The selected class XI MIPA 5 was the control group, and class XI MIPA 6 was the experimental group.

Research Implementation

This research implements STEM-integrated PDTM to improve students' conceptual understanding and new literacy skills. This STEM-integrated PDTM has been validated by a team of experts consisting of three lecturers of the master's study program of physics education at Padang State University. The validation results show that the STEM-integrated PDTM is valid with an average value of 0.94 Aiken's V with a good category. The expert team gave advice, and the STEM-integrated PDTM was revised accordingly. The integration of STEM in the product lies in the work activities section. The cover of the product describes the entire contents of the product. The components contained in the cover are the university logo and the motto of the Indonesian education system, author identity, product title, description of STEM integration, education level, semester, and agency. The colors used are contrasts between blue, yellow, and red. The cover sample of the STEM-integrated PDTM can be displayed in **Figure 1**.

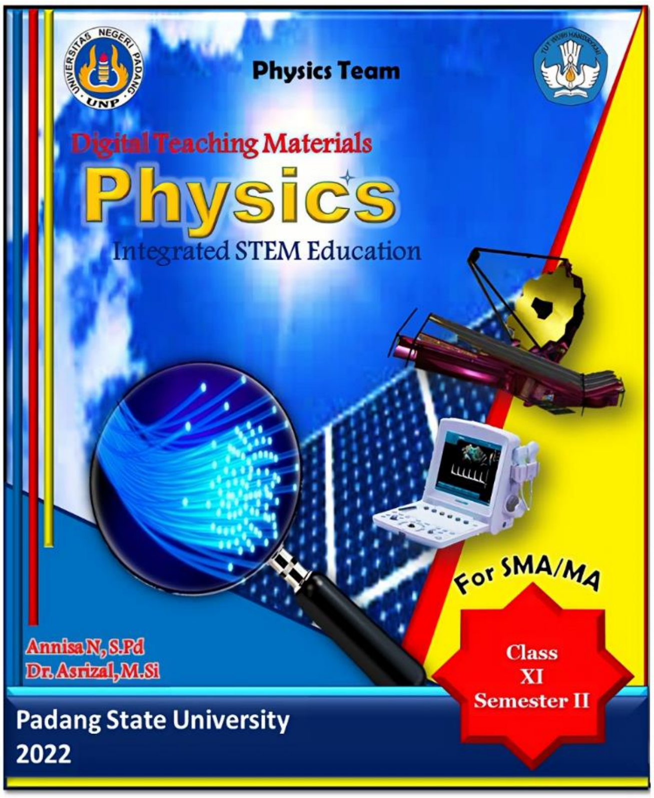

Figure 1. STEM-integrated PDTM cover (Source: Authors' own elaboration)

They briefly carried out the research implementation in three stages. The first stage is in the form of a preparatory stage to prepare everything related to research. The second stage implemented a scientific learning approach in both sample groups and provided treatment in the form of STEM-integrated PDTM in the experimental group. The third stage is a closing activity in making a research report.

The research procedure carried out consisted of two parts. They first tested the effect of using STEM-integrated PDTM on students' conceptual understanding of physics. The instrument to test conceptual understanding was a written test. This testing was done by giving post-test questions to the two sample groups. The written test was made in multiple choice with 25 questions. The questions used have been tested first with several valid questions, as many as 25 out of 40, and have a reliability of 0.72 with a reliable category. The test results show that the questions are feasible for the post-test. Second, they tested the effect of using STEM-integrated PDTM on students' new literacy skills. Performance assessments measured students' new literacy skills in data, technology, and human literacy. The new literacy skills of students were assessed in the physics learning process using STEM-integrated PDTM. Data literacy is assessed from reports of experimental activities. Data literacy is assessed using technology such as internet handphones to find and analyze information, and human literacy is assessed from processes and reports of the student's problem-solving.

Data Collection and Instrument

The data obtained in this research is on the effectiveness of using STEM-integrated PDTM. The instrument used consisted of test questions and student performance assessment sheets. Test questions are used to measure the effectiveness of using STEM-integrated PDTM on students' conceptual understanding. On the other hand, performance assessment sheets were used to measure the effects of STEM-integrated PDTM on

Table 2. Components, indicators, & descriptions of new literacy instrument

Literacy component	Indicator	Description
Data literacy	Reading data	Reading measured values Reading units from measured values
	Collecting data	Collecting data in tables Determining data source accuracy Selecting dependent variable & independent variable on data
	Analyzing data	Analyzing data according to concept of physics Analyzing data using formulation of physics
	Concluding data analysis result	Summarizing data in graphical form Formulating conclusions in form of data interpretation & mathematics (Kartika et al., 2021; Rahmawati et al., 2021; Smolnikova, 2020)
Technology literacy	Using a virtual laboratory/ experimental set	Opening & closing virtual laboratories Setting up an experiment Determining independent & dependent variables
	Using modern tools	Using cellphone Using a laptop/computer Using experimental tools such as lasers
	Using the Internet	Using the Internet to open a virtual laboratory Using the Internet to find other references Using the Internet to open DTM
	Using electronic learning resources	Using DTM Using crocodile physics software Using sound generator software (Abed, 2019; Arista & Kuswanto, 2018; Asrizal et al., 2022; Baker et al., 2012)
Human literacy	Communicating in writing	Using capital letters correctly Using punctuation correctly Using conjunctions correctly Connecting data in language, physics symbols & formulas, & graphs correctly
	Collaborating	Work together in groups Responsible Flexible Respect opinions of others
	Critical thinking	Asking question Answer question Looking for alternative solutions Finding reason
	Creative thinking	Proposing lots of ideas Asking many questions Asking for many answers Propose many ways (Azizah et al., 2020; Ennis, 2011; Khoiri et al., 2021; Reaves, 2019; Zakiyah, 2022)

students' new literacy skills, including data, technology, and human literacy.

The instrument of this performance appraisal sheet consists of an assessment of data, technology, and human literacy. This new literacy instrument was developed based on a literature review of various articles. From the literature review, indicators of each literacy were obtained. An instrument lattice and assessment rubric was compiled to form an instrument for assessing new literacy abilities. Experts have validated this instrument. The grid of new literacy instruments can be seen in **Table 2**.

Data Analysis Technique

The data analysis technique used in this research consisted of two parts, namely conceptual understanding and new literacy skills. Determining the effect of STEM-integrated PDTM on students' mastery of concepts can be done through several stages. In the first stage, the data that has been obtained were tested for normality first. The normality test used was the Lilliefors test. In the second stage, the data groups were tested to determine whether the data came from a homogeneous sample or not using the homogeneity test (F-test). Finally, hypothesis testing was carried out to determine the effects of using STEM-integrated PDTM for regular and homogeneous data using the mean test of two independent groups (t-test). Meanwhile, the U Mann-Whitney (Z) test was used to test the hypothesis for the standard distribution data. The hypothesis testing stage of the new literacy skill was the same as the hypothesis testing of students' conceptual understanding.

Table 3. Analysis of student's conceptual understanding

Statistical parameters	Experiment group	Control group
Average value	82.60	73.80
Standard deviation	10.53	13.13
Variance	110.84	172.33
L_o value test for normality	0.1045	0.1385
L_t value test for normality	0.1401	0.1401
Lo homogeneity test	1.538	
Lo homogeneity test	1.705	
t-test value	3.34	
t-table value	1.99	

RESULTS

Effects of the STEM-Integrated PDTM on Conceptual Understanding

The result of the first analysis related to the effects of STEM-integrated PDTM on conceptual understanding aspect. It aims to investigate the effect of STEM-integrated PDTM in the two sample groups on aspects of conceptual understanding. The difference in the mean value and standard deviation were determined based on data on students' conceptual understanding of the experimental group using STEM-integrated PDTM, and control group the control group did not use this teaching material. The analysis results of differences in students' conceptual understanding between the experimental group and control group on student conceptual understanding can be summarized in **Table 3**.

From the data in **Table 3**, the difference in the value of conceptual understanding in the experimental and control groups can be described. The average value of students in the two classes is 82.60 and 73.80. From the average value, it is known that there is a difference in the value of students' conceptual understanding between the experimental and control group. The results of this difference have not described the significant effects of STEM-integrated PDTM on students' conceptual understanding. For this reason, it is necessary to test the mean of two independent groups. Before that, the normality and homogeneity tests were carried out first, based on the results of data analysis, which obtained a value of $L_0<L_t$, which means that the concept of understanding the value of students in both groups came from a normally distributed population. From the homogeneity test data, it was found that the value of Fc<Ft. This means that the conceptual understanding data of both the experimental group and control group have homogeneous variances. Because the data are typically distributed and come from a homogeneous population, the two independent groups' mean difference test is used to test the hypothesis. The result of the data analysis shows that the value of this is outside the area of acceptance of the null hypothesis. This result indicates that STEM-integrated use significantly affects students' conceptual understanding of physics teaching.

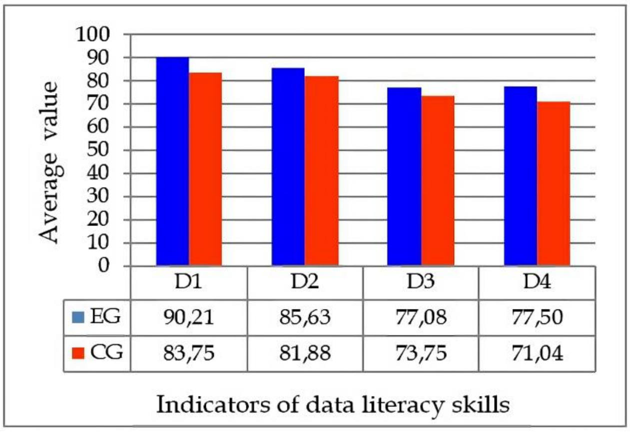

Figure 2. Analysis results of data literacy skills (Source: Authors' own elaboration)

Effects of the STEM-Integrated PDTM on New Literacy Skills

The results of the second analysis relate to the effects of STEM-integrated PDTM on students' new literacy. The new literacy is analyzed in three aspects, namely, data literacy, technology literacy, and human literacy. The result of the analysis of the first new literacy skills is data literacy skills. Analysis of data literacy skills consists of four indicators. The four indicators of data literacy are collecting data (D1), reading data (D2), analyzing data (D3), and concluding the results of data analysis (D4). The results of data literacy skills analysis in the experimental and control group can be shown in **Figure 2**.

Data analysis in **Figure 2** can describe the average value of each indicator of the data literacy skills of students in the experimental and control groups. The results of the data analysis showed that the value of students' data literacy skills in the experimental group was higher than the value of the control group of students. The average value of the overall data literacy skills of the experimental and control groups is 82.60 and 77.55, respectively. It shows a difference in the value of students' new literacy skills in the experimental and control groups using STEM-integrated PDTM. The results of the analysis of differences in student data literacy skills in the two sample groups can be summarized in **Table 4**.

The data analysis in **Table 4** can be used to describe the differences in the values of data literacy skills of students. The results of descriptive statistical analysis showed that there are differences in the data literacy skills of students. Data from both experimental groups were tested for normality. The normality test results obtained the value of $L_0<L_t$, which means that the two data literacy values in the two sample groups are expected. The value of students' data literacy skills must also be tested for homogeneity. From the homogeneity test data, it was found that the value of $F_c<F_t$. It means

Table 4. Analysis of student's data literacy skills

Statistical parameters	Experiment group	Control group
Average value	82.60	77.55
Standard deviation	5.73	6.84
Variance	32.84	46.85
L_o value test for normality	0.1081	0.1002
L_t value test for normality	0.1401	0.1401
Lo homogeneity test	1.409	
Lo homogeneity test	1.705	
t-test value	3.61	
t-table value	1.99	

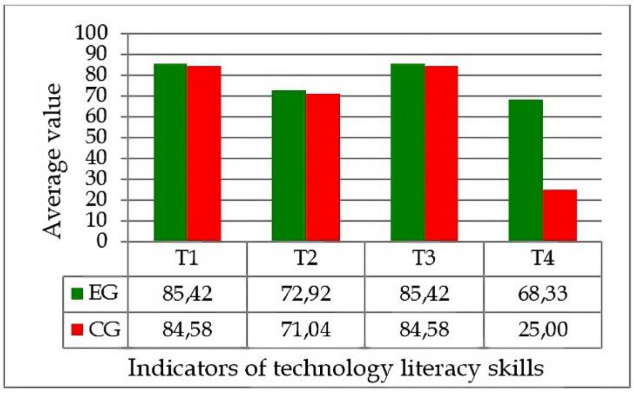

Figure 3. Analysis results of technology literacy skills (Source: Authors' own elaboration)

that the two data literacy value of experimental and control groups of students have homogeneous variances. Because the data are typically distributed and come from a homogeneous population, the hypothesis test uses the two independent groups' mean difference test. Data analysis shows that the value of the t-test is outside the area of acceptance of the null hypothesis, so this hypothesis is rejected. The result of this hypothesis test shows that using STEM-integrated PDTM significantly affects on students' data literacy skills.

The second result of the analysis of new literacy related to technology literacy skills. Analysis of technology literacy skills consists of four indicators. The four indicators of technology literacy are using a virtual laboratory or experimental set (T1), using modern tools (T2), using the Internet (T3), and using electronic learning resources (T4). The results of the analysis of technology literacy skills in the sample groups can be shown in **Figure 3**.

Data analysis in **Figure 3** can explain the average value of each student's technology literacy skill indicator. The results of the data analysis showed that the value of students' technology literacy skills in the experimental group was higher than that of the control group of students. The average value of the overall technology literacy skills of the experimental and control groups is 78.02 and 66.30, respectively. This shows a significant difference in the value of students' new literacy skills in the experimental and control groups using STEM-integrated PDTM. The results of the analysis of differences in students' technology literacy skills in the two sample groups can be summarized in **Table 5**.

Table 5. Analysis of student's technology literacy skills

Statistical parameters	Experiment group	Control group
Average value	78.02	66.30
Standard deviation	6.65	6.93
Variance	44.28	48.05
L_o value test for normality	0.1032	0.0722
L_t value test for normality	0.1401	0.1401
Lo homogeneity test	1.109	
Lo homogeneity test	1.705	
t-test value	7.67	
t-table value	1.99	

From the data analysis in **Table 5**, it can be seen that there are differences in the value of students' technology literacy skills in the two sample groups. The results of the data analysis showed that there were differences in students' technology literacy skills in the two sample groups. However, the results of this descriptive statistical analysis have not been able to describe the significant effects of STEM-integrated PDTM on the technology literacy skills of students. For this reason, data from the two experimental groups need to be tested for normality first. From the results of the analysis of the normality test, the value of $L_0<L_t$ was obtained, which means that the two data values of technology literacy skills in the two sample groups came from a normally distributed population. The value of students' technology literacy skills must also be tested for homogeneity. From the homogeneity test data, it was found that the value of $F_c<F_t$. This means that the two data values of technology literacy ability of experimental and control groups students have a homogeneous variance. Because the data are regular and homogeneous, the two independent groups' mean difference test is used. Data analysis indicates that the value of the t-test is in the area of rejection of the null hypothesis. It shows that using STEM-integrated PDTM significantly affects students' technology literacy skills.

The third result of the analysis of new literacy related to the human literacy skills of students. The human literacy skills measured in this research consist of four indicators. However, the communication indicator is only limited to written communication indicators. The indicators of human literacy are communicating in writing (C1), collaborating (C2), critical thinking (C3), and creative thinking (C4). The results of the analysis of human literacy abilities in the experimental and control group can be shown in **Figure 4**.

The results of data analysis in **Figure 4** described the comparison of the average scores for each indicator of students' human literacy skills in the two sample groups. The results of the data analysis showed that the experimental group of students' human literacy skills were superior to the control group of students, as seen

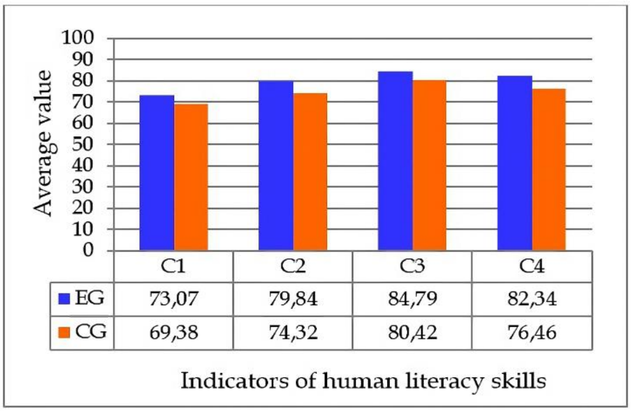

Figure 4. Analysis results of human literacy skills (Source: Authors' own elaboration)

Table 6. Analysis of student's human literacy skills

Statistical parameters	Experiment group	Control group
Average value	80.26	75.09
Standard deviation	4.61	5.83
Variance	21.23	34.03
L_o value test for normality	0.1576	0.1647
L_t value test for normality	0.1401	0.1401
Lo homogeneity test	1.725	
Lo homogeneity test	1.705	
t-test value	-3.71	
t-table value	1.64	

from the difference in the value of each indicator. The average value of students' human literacy skills from the two sample groups was 75.09 and 80.26. There are differences in the value of students' human literacy skills from this value in the two sample groups using STEM-integrated PDTM. The results of the analysis of differences in students' human literacy skills in the two sample groups can be summarized in **Table 6**.

The results of the data analysis in **Table 6** can reveal the difference in the average value and the results of the statistical testing of students' human literacy skills in the two sample groups. The descriptive statistical analysis results show differences in students' human literacy skills in the experimental and control groups. Data from both experimental groups were tested for normality. Based on the data in **Table 6**, the difference in the value of students' human literacy skills in the two sample groups can be described. The descriptive statistical analysis results show differences in students' human literacy skills in the experimental and control groups. Data from both experimental groups were tested for normality. From the results of the data analysis, the value of L_0>L_t means that both the data on the value of the human literacy skills of the two sample groups come from populations that are not a normal distribution. The value of students' human literacy skills must also be tested for homogeneity. From the data obtained, the value of F_c>F_t means that the two data values of students' human literacy skills have non-homogeneous variances. Because the data are not regular and not homogeneous, Mann Withney U test is used to test the hypothesis. Data analysis indicates that the value of the Z-test is outside the area of acceptance of the null hypothesis. The result of this hypothesis test stated that using STEM-integrated PDTM significantly affected students' human literacy skills. Thus, using STEM-integrated PDTM in physics learning improves students' human literacy.

DISCUSSION

The first discussion related to the effects of PDTM-integrated STEM on students' conceptual understanding. The results of the data analysis stated that the use of PDTM-integrated STEM had a positive effect on students' conceptual understanding. This means that STEM-integrated PDTM effectively developed the students' conceptual understanding. Because this STEM-integrated PDTM can relate the material to real-world problems, it can make it easier for students to acquire knowledge and concepts of physics (Prasetyo et al., 2021). In addition, these teaching materials also consist of interrelated fields of science, technology, engineering, and mathematical formulation, making it easier for students to build their knowledge (Asrizal et al., 2022). STEM-integrated PDTM developed is unique and exciting to read and study so that students enjoy studying physics, which will positively impact students' knowledge (Rochsun & Agustin, 2020; Triwahyuningtyas et al., 2020). This research aligns with the results of Asrizal et al. (2022), which showed that STEM-integrated PDTM, one of which was an e-module, could improve student learning outcomes, especially aspects of conceptual understanding. Therefore, STEM-integrated PDTM effectively improves the students' conceptual understanding.

The second discussion related to the effects of PDTM-integrated STEM on students' data literacy skills. Four indicators of data literacy skills have been improved, namely, reading data, collecting data, analyzing data, and concluding the result of data analysis. First, the ability to read data includes the ability to read values and units in experimental activities (Smolnikova, 2020). Based on the results, it was found that the ability to read data in the experimental group was higher than the ability to read data in the control group. It is because the experimental group uses virtual experiments so that the readings of values and units are correct and precise.

In contrast, the control group uses actual experiments, so there is the possibility of relative errors affecting the reading of values and units during the experiment. Second, the skills to collect data include activities in the provided tables, ensuring the accuracy of data sources, and selecting dependent and control variables (Kartika et al., 2021; Smolnikova, 2020). Being able to collect data in the experimental and control group has an average value that is not much different. It means that students' skills in collecting data in the two sample groups are good. Third, the skills to analyze data include the skills to analyze data according to the concept of physics and the skills to analyze data according to the formulation of physics (Kartika et al., 2021; Rahmawati et al., 2021; Smolnikova, 2020). The results show that the skill to analyze data in the experimental group is higher than in the control group but has an average value that is not much different. It is because the experimental group is supported by electronic learning resources that make it easier for students to master the concepts and formulations of physics independently. Fourth, the skills to conclude the results of data analysis includes concluding in graphical form, the form of interpretation, and mathematical form (Kartika et al., 2021). From the data, it can be seen that the value of the skills to conclude the results of data analysis in the experimental group is higher than in the control group. It is because experiments using virtual labs in DTM have clear and complete data so that experimental conclusions can be drawn properly.

Based on the results, it was found that STEM-integrated PDTM developed could improve students' data literacy skills. It is because STEM activities in teaching materials contain experimental activities that can encourage students to improve their data literacy skills well (Šlekienė & Lamanauskas, 2020). By conducting experiment activities, students can read and collect the data obtained (Kartika et al., 2021; Rahmawati et al., 2021). In addition, students can also analyze the data and conclude the results of data analysis that has been obtained in the form of graphs, pictures, formulations, and others (Liao et al., 2018; Smolnikova, 2020). So, STEM-integrated PDTM effectively improves students' data literacy skills.

The third discussion concerned the effect of STEM-integrated PDTM on technological literacy skills. Four indicators of technology literacy skills have been improved: the skills to use virtual laboratories or experimental sets, the skills to use modern tools, the skills to use the Internet, and the skills to use electronic learning resources. First, the skills to use a virtual lab includes the ability to open and close a virtual lab, the skills to set up experiments correctly, and the skills to determine the independent and dependent variables (Arista & Kuswanto, 2018). The data shows that the skills to use a virtual laboratory or experimental set in the experimental and control group have a similar average value. In the experimental group, students use a virtual lab in software and PhET simulation, while in the experimental group use direct experiments. Second, the skills to use modern tools include cell phones, laptops, or computers and experimental tools such as lasers (Abed, 2019; Baker et al., 2012). From the result of the data, it can be referred that the student's skills in using modern tools in the experimental and control groups have an average value that is not much different. The modern tools used by the experimental group of students are cell phones and laptops, while the control group uses cell phones and lasers. The two sample groups use the same two types of modern tools.

Third, the Internet includes using the Internet to open a virtual lab, find other references, and open DTM (Asrizal et al., 2022; Baker et al., 2012; Yurnetti et al., 2020). The difference in average value of the experimental and control groups does not differ much. The experimental group of students used the Internet on all sub-indicators, while the control group only used the Internet to find other reference sources. Fourth, the skills to use electronic learning resources include DTM, crocodile physics software, and sound generator software (Abed, 2019; Arista & Kuswanto, 2018; Baker et al., 2012). Students' skills in the two sample groups significantly differ in this last indicator. The mean score indicates that students in the experimental group possess superior abilities compared to their counterparts in the control group. This is because the experimental group already uses electronic learning resources and is supported by virtual activities with the help of software, while the control group only uses direct experiments.

From the analysis that has been done, it is found that the product developed can improve students' technology literacy skills. The research data shows differences between the control and experimental groups on indicators of the use of electronic learning resources, even though the use of electronic learning resources is one manifestation of students' literacy skills (Asrizal, 2020). Technology literacy can be improved by using DTM as learning resources and using virtual laboratories to conduct experiments (Arista & Kuswanto, 2018; Brata et al., 2022). Students' technology literacy skills can also be improved by using cell phones or laptops as modern tools and using the Internet to find additional references in learning (Ali et al., 2022; Sung et al., 2016). Therefore, using STEM-integrated PDTM in learning can improve students' technology literacy skills.

The fourth discussion is about the results of data analysis on aspects of human literacy skills. The measured human literacy skills consist of the ability to communicate in writing, collaborate, think critically, and think creatively. First, the ability to communicate in writing includes using capital letters, punctuation marks, and hyphens and correctly relating information in language, physics symbols, physics formulations, and graphics (Azizah et al., 2020; Šlekienė & Lamanauskas, 2020). The data shows that the student's written communication skills in the experimental group are higher than in the control group. It is caused by students' lack of interest in making physics assignments so that teachers cannot assess students' writing and communication skills optimally. Second, the skills to collaborate include the ability to work together in groups, be responsible and flexible, and respect the opinions of others (Reaves, 2019; Zakiyah, 2022). From the data, it was found that the student's skills to collaborate in the experimental and control groups had not had much difference. In collaborating, the experimental and control groups students can work together and respect each other in virtual and in-person activities. However, students are more enthusiastic about conducting virtual experiments and collaborating well. Third, critical thinking includes asking questions, answering questions, finding alternative solutions, and finding reasons (Ennis, 2011; Khoiri et al., 2021). The results of the data analysis found that the experimental group students had higher critical thinking skills than the control group students. It is due to using PDTM, which is connected to the surrounding problems to encourage students' critical thinking skills. Fourth, creative thinking skills include providing many ideas, questions, answers, and ways (Ennis, 2011; Melisa et al., 2021). From the results of the data analysis, it can be seen that the creative thinking ability of students in the experimental group is higher than that in the control group. It is due to PDTM, which is faced with actual events and has animations, pictures, and videos that can trigger students' creative thinking skills.

Based on the results of data analysis, it can be stated that there are two indicators of students' human literacy skills with better value, namely, the skills to collaborate and the ability to communicate in writing. STEM activities in these teaching materials have experiments that can involve students directly and actively in learning to improve students' collaboration and communication skills (Kartika et al., 2021; Šlekienė & Lamanauskas, 2020; Wahono et al., 2020). The STEM-integrated DTM already contains problems that can encourage students to ask questions and arrange quick answers as a form of problem-solving (Zakiyah, 2022). It is a form of improving students' critical thinking skills. Students' critical thinking skills have not been able to increase significantly because students have not been able to find alternative solutions and reasons for the solutions proposed appropriately (Ennis, 2011; Khoiri et al., 2021). The developed STEM-integrated DTM contains real-life problems to encourage students' creativity (Han et al., 2016; Siregar et al., 2019; Zakiyah, 2022). However, the increase in students' creative thinking skills did not significantly increase. A person is considered critical and creative if he can solve problems in many unique and innovative ways and reasons (Melisa et al., 2021; Ola W. A. Gafour, 2020). Therefore, STEM-integrated DTM effectively improves students' human literacy skills.

CONCLUSIONS

From the data analysis, there are two conclusions from this research. First, using STEM-integrated physics digital teaching material (PTDM) significantly affects aspects of students' physics conceptual understanding, with a t-test value of 3.34. Second, using STEM-integrated PTDM significantly affects students' new literacy skills, including data, technology, and human literacy. The t-test values for data literacy and technology literacy indicators are 3.61 and 7.67, while the Z-test value for human literacy is -3.71. These results indicate that using STEM-integrated PDTM in physics learning effectively develops aspects of students' conceptual understanding and new literacy skills. As an implication of the results of this research, support for digital physics teaching materials, which contain student worksheets for conducting experiments and discussing problems with a physics topic to construct students' new literacy.

Implementation

STEM-integrated PDTM can be used as an alternative learning resource to achieve learning objectives. This STEM-integrated PDTM can make students more enthusiastic about learning and encourage and improve students' understanding and new literacy skills. This STEM-integrated PDTM can support teachers in implementing more structured, time-saving, and exciting learning. Holding STEM-integrated PDTM development training for teachers can assist teachers in developing PDTM on other perfect and exciting materials and applying them in learning. Therefore, teachers and students can use STEM-integrated PDTM in learning physics to achieve educational goals.

Limitations

The researcher admits that there are limitations in this research, including:

1. STEM integrated with this DTM is only in the activities and work steps section. For this reason, other researchers can integrate STEM from the beginning of the material section to the end of the teaching material to make a perfect STEM-integrated PDTM.
2. The aspects measured are limited, namely only increasing students' conceptual understanding and new literacy skills. It should be possible to use STEM-integrated PDTM to measure improvement in other aspects, such as student attitudes, student interests, scientific literacy skills, and other things.

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