Vol 9 No 1 2023 DOI : 10.24036/jppf.v9i1.120546 Page : 104 - 112
JURNAL PENELITIAN PEMBELAJARAN FISIKA (JPPF)
Journal of Physics Learning Research
ISSN 2252-3014 (Print) | ISSN 2746-8445 (Electronic)

The Effects of Science Teaching Materials on Students' 21st-Century Skills: A Meta-Analysis

Dwi Anggraini Harita Putri[1*], Asrizal[2], Festiyed[2]

[1]Magister Program of Physics Education, Universitas Negeri Padang, Indonesia
[2]Physics Education Study Program, Universitas Negeri Padang, Indonesia

ARTICLE INFORMATION

Received : 18 November 2022
Revised : 21 January 2023
Accepted : 24 March 2023

Correspondence
Email : dwianggrainihp@gmail.com
Phone :

KEYWORDS :

Meta-analysis, Teaching materials, 21st century skills

ABSTRACT

This study aims to determine the effect of science and physics teaching materials on students' 21st-century skills. The type of research used is a meta-analysis that analyzes 20 international and national journals that have existed for the last five years. The data analysis technique in this study is to find the effect size value for each journal. From the research results, it is known that physics teaching materials affect students' 21st-century skills. So it is known that the use of science and physics teaching materials will produce higher effectiveness if applied to the high school education level. Based on the type of teaching materials, it will be effective if teaching materials are in the form of Science and Physics e-modules. Science and Physics teaching materials effectively impact three aspects of 21st-century skills: critical thinking, problem-solving, and creative thinking.

INTRODUCTION

Science and technology in the 21st century in various countries have developed rapidly. These changes aim to improve the quality of life in modern society (Pratiwi et al., 2019). In the world of education, the 21st century requires students to have skills, namely skills in creative thinking, skills to think critically and solve problems, skills to communicate, and abilities to collaborate, which can also be called 4C skills (Septikasari & Frasandy, 2018). 21st-century learning also requires students to be more active in learning than teachers and to have learning abilities and various skills (Pratama et al., 2022; Tanti et al., 2020). Therefore, 21st-century education must develop superior knowledge, skills, attitudes, and values (Asrizal et al., 2018).

Critical thinking is a characteristic that humans have in intelligence (Ramdani et al., 2019). One of the characteristics of critical thinking skills is to carry out activities to find their thoughts (Santoso & Mosik, 2019). Critical thinking skills in learning are very important for students because students will later use their minds to the maximum in solving problems encountered in everyday life (Sujanem & Swindra, 2020). In developing critical thinking skills and problem-solving, several factors influence, such as high or low interest in reading, physical condition, anxiety, motivation, intellectual development, independent learning,

interaction, cognitive ability, family atmosphere, how to educate parents, attention parents, associates, social media, applied curriculum and facilities to support the teaching and learning process in schools (Azrai et al., 2020; Batubara et al., 2022; Dores et al., 2020; Hanifa et al., 2018; Hijriani & Hatibe, 2021).

Creative thinking is a skill related to creativity. It is a way of thinking about improving or describing a problem, looking at it from the other side, and accepting various ideas and ideas (Meika & Sujana, 2017). Creative thinking is a person's ability to think at a higher level and includes various process skill activities (Marnita & Ernawati, 2017). Creative thinking emphasizes divergent, productive, and creative thinking (Ramdani et al., 2019). Student creativity is important in solving a problem encountered (Ernawati et al., 2019). Students' creative thinking skills can be influenced by the following factors, namely motivation, ability, intelligence, teacher readiness, student readiness, and the learning methods used (Anditiasari et al., 2021; Nada & Sari, 2022).

Communication is exchanging information between two sources (Aulia et al., 2018). In teaching and learning activities, communication is a process that plays a role in building interactions between teachers and students who exchange ideas, knowledge, and understanding (Chung et al., 2014). Communication skills, which include writing, listening, speaking, and interpersonal, must exist in teachers to facilitate students' understanding of teaching materials and have skills in being responsible effectively (Ihmeideh et al., 2010). Communication skills are important compared to technical skills, and this is because when students have completed their education, they have to face many situations that must show good communication skills, for example, namely working with work partners, communicating formally with teachers, making oral presentations and exams in writing and so on (Kovac & Sirkovic, 2017).

Collaboration is a partnership between two or more students who share responsibility, accountability, and roles to achieve a common understanding of the problem and its solution (Davis et al., 2018; Fonte & Barton-Arwood, 2017). Collaboration is an ability to work together effectively and show respect for team members, forging skills in making decisions to achieve common goals (Greenstein, 2012). Collaboration skills are important when learning activities because they can increase students' knowledge in achieving learning goals (Ulhusna et al., 2020). Collaboration in learning has a role as a mediation between interactivity abilities and learning achievement because active collaborative learning is a media link between interactivity and learning achievement (Chan, 2019).

To realize students who have various skills, the teacher, as a facilitator who has various roles in the class, must be good at training students in basic knowledge and equipping their students with various skills (Rahmawati & Suryadi, 2019). Teachers must also be proficient in guiding students and making optimal use of the available facilities, one of which is teaching materials. A teacher must be good at preparing the teaching materials needed in the learning process.

Teaching materials are created and arranged systematically, whether written or not, so that learning conditions allow students to learn (Wahyuni, 2015). Teaching materials can be classified into four types, namely (1) printed teaching materials such as books, handouts, modules, wallcharts, student worksheets, brochures, leaflets, photos/pictures, models/models; (2) audio teaching materials, for example, LPs, radio, cassettes, and audio CDs; (3) audio-visual teaching materials, such as video CDs, films; and (4) interactive teaching materials such as interactive CDs (Majid, 2006). The use of teaching materials is so important in a quality learning system. Teaching material must provide opportunities for students to learn effectively and for teachers to teach efficiently to achieve the desired skills based on the curriculum (Hustarna & Melati, 2019). Teaching materials are created as a tool to help make learning more effective for educators and students (Asrizal et al., 2018).

Many science teaching materials have been implemented in schools' science and physics learning processes with various teaching materials. However, an analysis was carried out on research articles published in various trusted scientific journals to find out the effect of science teaching materials. Therefore, researchers feel it is important to do an effect-size analysis of the influence of science teaching materials on students' 21st-century skills. The problem of this research is how to use science teaching materials on students' 21st-century skills, which are reviewed based on the level of education, types of teaching materials, and aspects of 21st-century skills. The research has the objectives of first, knowing how big the impact is caused by applying science teaching materials when viewed based on educational level. Second, knowing how much impact is generated from applying science teaching materials in terms of type. Third, to find out how much impact the application of science teaching materials has on 21st-century skills.

METHODS

The research method used in this study is meta-analysis. *Meta-analysis* is a statistical technique that combines two or more similar research results to obtain a combination of quantitative data. *Meta-analysis* is a study summarizing, reviewing, and analyzing data from several studies conducted. This meta-analytic research method seeks to describe the effect size of the impact of using science teaching materials on students' 21st-century skills.

The subjects needed in this study were 20 journals consisting of national journals and international journals. The selected journal has criteria, namely (1) a journal that discusses the use or implementation of science teaching materials on various aspects of students' 21st-century skills, (2) the journal has an ISSN, both national and international journals, (3) the selected journal is published within five last year. The variables in this study are science teaching materials as the independent variable and 21st-century skills as the dependent variable.

The steps in analyzing the data consist of three parts. The analysis step includes: (1) analyzing the type of research and research variables found, then entering them into the appropriate variable column, (2) identifying the mean and standard deviation of the experimental and control group data for each subject/sub research that has been tested, (3) determines the magnitude of the effect size can be searched by the equation as shown in Table 1.

After obtaining the effect size value, then the results obtained are interpreted based on the criteria according to Cohen (1988), namely the low category if the ES value is (ES ≤ 0.2), the medium category if the ES value is (0.2 < ES < 0.8), and included in the high category if (ES ≥ 0.8).

Table 1. Find the size of the effect size

No.	Statistics	Formula
1	One group average	$ES = \frac{\bar{X}_{post} - \bar{X}_{pre}}{SD_{pre}}$
2	The average of the two groups (*two groups posttest only design*)	$ES = \frac{\bar{X}_E - \bar{X}_C}{SD_C}$
3	Mean in the two groups (*two groups pre-posttest design*)	$ES = \frac{(\bar{X}_{post} - \bar{X}_{pre})_E - (\bar{X}_{post} - \bar{X}_{pre})_C}{\frac{SD_{preC} + SD_{preE} + SD_{postC}}{3}}$
4	Chi-Square	$ES = \frac{2r}{\sqrt{1 - r^2}}$; $\sqrt{\frac{X^2}{n}}$

5	t count	$ES = t\sqrt{\frac{1}{n_E}+\frac{1}{n_C}}; \sqrt{\frac{2t}{n}}$

RESULTS AND DISCUSSION

Results

This study aims to see the impact of science teaching materials on students' 21st-century skills by reviewing and analyzing several moderator variables. Data were obtained from various journals that are significant to this research and support the calculation of the effect size of each journal. Researchers collect data from various sources such as Google Scholar, Journal of Physics, and Semantic Scholar.

A total of 20 journals were selected based on specific benchmarks. First, the journal studies print and non-print science teaching materials, and the second is implemented in science and physics learning. Third, the journals used are sourced from international and national journals. The results of calculating the effect size of 20 journals are classified into three parts. First, it is based on educational level. Second, based on the type of teaching materials. Third, it is based on aspects of 21st-century skills acquired by students. The journal codification is shown in table 2.

Table 2. Effect Size Calculation Result Data

Journal Code	*Effect Size*	Category
J1	3,87	High
J2	0,53	Medium
J3	2,20	High
J4	0,41	Medium
J5	0,68	Medium
J6	1,75	High
J7	0,71	Medium
J8	0,66	Medium
J9	0,31	Medium
J10	0,09	Low
11	0,83	High
J12	2,58	High
J13	1,63	High
J14	1,93	High
J15	1,19	High
J16	0,67	Medium
J17	1,54	High
J18	0,30	Medium
J19	0,54	Medium
J20	0,26	Medium

Based on the Education Level

Based on the level of education, the calculation results obtained for the impact of science teaching materials on 21st-century skills based on education level in this study are shown in Figure 1.

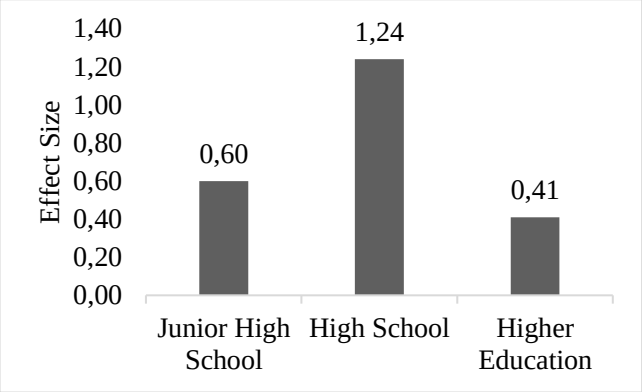

Fig. 1. Learner's Competency Skills

From the results of calculating the effect size of the impact of science teaching materials based on educational level, it is obtained that an average effect size with a value of 0.60 indicates a medium category for the junior high school level, an effect size of 1.24 with a high category for high school level, an effect size of 0.41 in the moderate category for the Higher Education level.

According to the Type of Teaching Materials

The calculation results obtained from the impact of science teaching materials on 21st-century skills according to the type of teaching materials are shown in Figure 2.

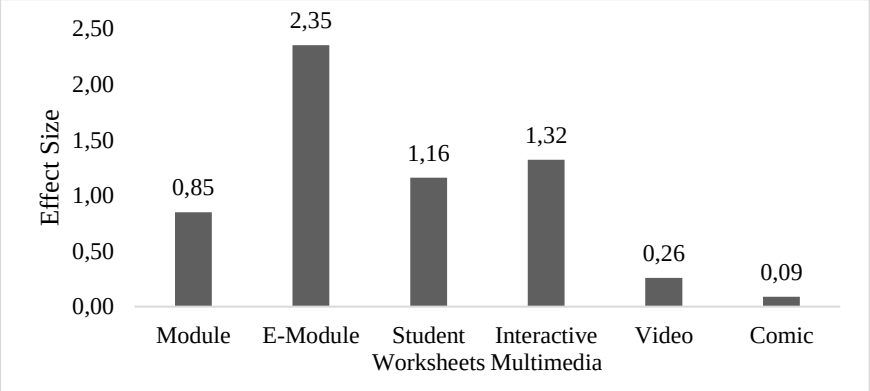

Fig. 2. Effect Size Based on the Type of Teaching Materials

Based on the results of the calculation of the effect size of the impact of science and physics teaching materials seen by the type of teaching materials, an effect size score of 0.85 is obtained in the high category for the type of module teaching materials; effect size of 2.35 in the high category for the type of e-module teaching materials; effect size with a score of 1.16 in the high category for student worksheets teaching materials; effect size with a value of 1.32 in the high category for interactive multimedia teaching materials; video type teaching materials have an effect size with a result of 0.26 in the medium category, and comic type teaching materials have an effect size of 0.09 in the low category.

Based on Aspects of 21st-Century Skills

Based on 21st-century skills, the results obtained from the study of calculating the effect size of the impact of science and physics teaching materials on 21st-century skills are grouped into four aspects. The calculations obtained are shown in Figure 3.

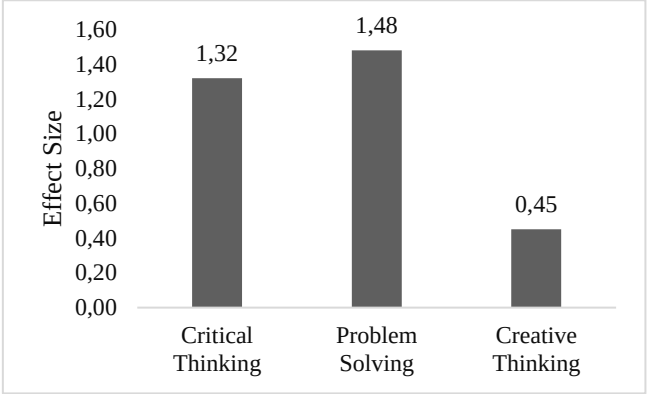

Fig. 3. Effect Size Based on Aspects of 21st-Century Skills

Based on the results of calculating the effect size of the impact of science and physics teaching materials on 21st-century skills, an effect size score of 1.32 is obtained with a high category on the aspect of critical thinking; an effect size score of 1.48 is in the high category for the problem-solving aspect, and an effect size score of 0.45 is in the medium category for the creative thinking aspect.

Discussion

The results obtained from this study were classified into three parts, namely, based on the level of education, types of teaching materials, and aspects of 21st-century skills. The analysis results based on the education level found that teaching materials were more effectively used in senior high schools compared to junior high schools and universities. The teaching materials applied in SMA also have a larger average effect size than the other two education levels. The influence of teaching materials used at the high school level has a high category, while junior high school and tertiary education levels have a moderate category. This proves that science and physics teaching materials are very effective at all levels of education, especially at the senior high school level. The use of teaching materials significantly influences attitude competence, knowledge, and skills students possess (Yuliana & Asrizal, 2019).

The analysis obtained from the impact of teaching materials based on the type of teaching materials found that the effect sizes were in the high category, namely on the types of teaching materials modules, e-modules, worksheets, and interactive multimedia. The effect size is in the moderate category, namely the types of teaching materials in videos and videos. Whereas for the low category, namely the type of comic teaching materials. The highest effect size value is based on the type of teaching material, namely the e-module. With textbooks, students can increase their activeness in learning activities, so by increasing this activity, students' learning outcomes will also increase (Muchsinin & Handhika, 2018). The learning process still uses many teaching materials in the form of student worksheets which have yet to develop knowledge and thinking skills, so students still need help solving the problems given to them (Shavira et al., 2018). E-module is an ICT-based module with advantages compared to printed modules, namely its interactive nature so that it presents

images, audio, video, and animation. With e-modules, students are not only facilitated in their use. However, they can also carry out the skills demanded by the industrial revolution 4.0, namely the utilization and use of technology. Based on the analysis of e-module teaching materials, it has the largest effect size for science and physics learning.

The 21st-century skills are divided into three parts, namely (1) foundation-al literacies, namely how students apply core skills to their daily tasks; (2) competencies, namely how students can approach complex challenges; and (3) character qualities, namely how students can approach a changing environment. However, it is widely used in research, namely the 4C skills, namely critical thinking and problem-solving, creativity or creative thinking, communication skills, and the ability to work together. The calculation results found that science and physics teaching materials were effectively used in three aspects of 21st-century skills, especially in the problem-solving section. Teaching materials can influence student learning outcomes and 21st-century science skills (Khoiri & Haryanto, 2018).

CONCLUSION

Based on the result data obtained, three results can be presented. First, based on the level of education, the use of science and physics teaching materials will have a high effect size if applied at the high school level. The second is based on the type of teaching materials, which will have a high effect size if the teaching materials are used in the form of Science or Physics e-modules. Finally, science and physics teaching materials effectively impact three aspects of 21st-century skills: critical thinking, problem-solving, and creative thinking.

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