

## Meta-Analysis: The Effect of Using Digital Physics Teaching Materials on Improving 21st Century Skills

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### ABSTRACT

The 21st century skills that students must possess include critical thinking, creativity, communication, and collaboration. One way to improve students' 21st century skills is with teaching materials that utilize the advantages of ICT (digital teaching materials) that can support students' 21st century skills in the learning process. This type of research is a meta-analysis that measures the effect of digital physics teaching materials on improving 21st century skills. The purpose of this research is to find out how much influence digital physics teaching materials have on improving students' 21st century skills, especially in learning physics. The data was obtained from analyzing 20 national and international articles in the last 4 years (2018-2022). The analysis technique used is to calculate the effect size for each article. The results showed that the meta-analysis study had an effect on digital physics teaching materials to improve 21st -century skills based on high school grade levels, physics learning materials, types of teaching materials used and 21st century skills achieved. The research findings show that digital physics teaching materials have an effect on improving 21st century skills, especially on critical thinking skills. Digital physics teaching materials have an effect on improving 21st century skills.

**Keywords :** 21st century skills; Digital teaching materials; Meta-analysis; Physics learning.



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## I. INTRODUCTION

Education is a requirement that cannot be isolated from human life. The existence of this education can form a moral and thinking human being [1]. Education in schools/madrasas is expected to build and improve various 21st century skills according to the demands of the industrial revolution 4.0. The 21st century skills are called "The 4Cs", namely, critical thinking, creativity, communication, and collaboration that students must master [2]. Improving 21st century skills must be accompanied by improving the quality of education, which is the reference in revamping the curriculum [3]. One of the efforts that have been made is the development of the education curriculum until the current 2013 Curriculum is implemented [4].

Implementation of Curriculum 2013 in the learning processes requires students to be creative, active, and inventive in order to have appropriate skills with "The 4Cs" skills that are in accordance with the 21st century. These skills are believed to be used to face the challenges of life intelligently, independently, critically, creatively, and rationally. The implementation of the 2013 Curriculum should be a learning that is basically not only learning about concepts, theories, and facts, but also the application of skills in life [5].

Referring to Permendikbud Number 69 of 2013, the 2013 Curriculum aims to prepare Indonesian human beings to be able to live as persons and as citizens who have the capacity to live a faithful, productive, creative, innovative, and affective life and are able to contribute to the life of society, nation, state, and world civilization [6]. The goals of the 2013 Curriculum can be viewed through how the current curriculum supports efforts to develop learning tools, such as the development of syllabi, textbooks, learning resources, learning models, and learning tools, which are outlined in the form of draft learning implementation plans (RPP), which are then

applied in learning practice in educational units. One of the learning tools that need to be considered is teaching materials.

Teaching materials are one of the resources needed by teachers in organizing the learning process [7]. Without teaching materials, teachers are likely to encounter obstacles in realizing their goals. Indeed, teachers must always prepare teaching materials in organizing the learning process. There are various types of teaching materials, some are in printed (handouts, books, modules, or student worksheets) and non-printed form (cassettes, radio, vinyl records, and audio compact disc) [8].

Teaching materials are very important for teachers and students in the learning process. Every teacher needs to know how to use teaching materials. Without teaching materials it will be more difficult for teachers to carry out the learning process. Likewise with students, students will find it difficult to follow the learning that has been organized in the lesson, especially if the teacher teaches the lesson quickly and less clearly. They cannot remember and repeat what has been taught by the teacher. Therefore, teachers and learners can utilise teaching materials as an instrument to improve the quality of learning [9].

Science and technology continue to develop so rapidly [10] and increasingly sophisticated. The increasing sophistication of technology makes teaching materials that are usually thick and difficult to carry anywhere, now making books can be carried easily, can be accessed anywhere and anytime with electronic devices such as smartphones. Technological sophistication makes many things in human life completely digital. The digital era can turn printed books into digital teaching materials that have a different appearance from teaching materials in other physical forms. In addition, it can be read using the help of electronic devices.

Curriculum 2013 states that teachers are facilitators who provide a variety of learning resources both designed by themselves and provided by the government. The learning process can be more effective because the teacher does not only act as a teacher, but as a facilitator who can guide students in understanding an educational material by using teaching materials. Teaching materials used by teachers are expected to be able to improve the skills demanded in the 21st century. One of the subjects that requires good 21st century skills from students is physics learning.

Physics is a subject that is related to learners' daily lives [11]. The physics learning competence contained in Regulation of The Minister Of Education and Culture of The Republic Of Indonesia number 64 of 2013 is to develop critical and creative thinking skills through physics learning [12]. Physics studies natural phenomena that require students to have the ability to think logically and act in a comprehensive, integrated, and systematic manner [13]. One of the objectives of Physics is for students to have the opportunity to improve their reasoning skills in analytical thinking inductively and deductively by applying physics principles and concepts to describe natural phenomena and solve problems both qualitatively and quantitatively [14]. Not all learners have good 21st century skills.

The reality that occurs in the field shows that physics learning uses printed teaching materials that only focus on learning materials available in the library. Teachers tend to give examples in printed teaching materials only so that students cannot imagine and apply them. This causes the perception that physics subjects are difficult so that students find it difficult to solve problems other than those in the example. Actually, physics is easy and interesting if you are able to link physics concepts with everyday life using teaching materials that make students able to apply these concepts.

In addition, students usually only tend to listen to the teacher's explanation during the teaching and learning process, thus creating less cooperative and interactive learning [15]. Learners who are less enthusiastic in the learning process can be seen rarely students who ask questions and look still confused to answer questions given by the teacher. Students' ability to solve physics problems is also low because students tend to directly use existing equations and guess the results without analyzing the problem [15]. This causes the teacher to have to re-explain so that learning in schools is focused on the teacher as a conveyor of information which results in the learning process being teacher-centred again.

Based on the described problems, a solution to improving students' 21st century skills is the availability of teaching materials that can support students' 21st century skills in the learning process. The use of technologies in the learning process, particularly the use of the digital teaching materials, surely has a great impact on the learning process [15]. Teaching materials that can be used as a solution in facilitating students in accessing learning are teaching materials developed by utilising the advantages of ICT called digital teaching materials, including e-books, e-modules, worksheet and so on. This research is a meta-analysis study that aims to determine the effect of digital teaching materials on physics learning at high school grade levels, the type of teaching materials used, subject matter, and 21st century skills.

## II. METHOD

This is a research of meta-analysis type. The information is derived from journals published in the past five years, both domestically and outside. Through the use of the Sinta, Garuda, Google Scholar, and ScienceDirect databases, data collecting approaches are carried out by examining or tracking sources from national and international publications published in the last five years (2018–2023). This meta-analytical research uses journals related to all types of digital teaching materials in physics learning, where the number of articles analyzed consists of 20 articles. Each article obtained will be analyzed using an effect size formulation.

**Table 1.** Effect Size Calculation

Statistical Data	Formula
Average in one group	$ES = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$
Average in each group	$ES = \frac{\bar{x}_{eksperimen} - \bar{x}_{kontrol}}{SD_{kontrol}}$
Average of each group	$ES = \frac{(\bar{x}_{post} - \bar{x}_{pre})_{eksperimen} - (\bar{x}_{post} - \bar{x}_{pre})_{kontrol}}{\left(\frac{SD_{pre kontrol} + SD_{pre eksperimen} + SD_{post kontrol}}{3}\right)}$
Chi-square	$ES = \frac{2r}{\sqrt{1 - 2r}}; r = \sqrt{\frac{\chi^2}{n}}$
T-count	$ES = t \sqrt{\frac{1}{n_{eksperimen}} + \frac{1}{n_{kontrol}}}$
P value	CMA (Comprehensive Meta Analisis Software)

(Source: Ref [16])

The effect size categories are in Table 2.

**Table 2.** Effect Size Classification

Effect Size	Standard Category
$0 \leq ES \leq 0,2$	Low
$0,2 \leq ES \leq 0,8$	Medium
$ES \geq 0,8$	High

(Source: Ref [17])

Based on table 2 it can be concluded that the effect size results have been obtained from calculations through the formula in table 2.

## III. RESULTS AND DISCUSSION

### A. Effect of Digital Teaching Materials Based on Grade Level

Based on the high school grade level, the analysis of the effect of digital physics teaching materials on physics learning is shown in Table 3.

**Table 3.** Meta-analysis by journal and year of publication

Code	Researcher	Journal	Year Published
A1	Santoso & Mosik	National	2019
A2	Putri & Yohandri	National	2021
A3	Shavira, et al	National	2018
A4	Christi, et al	National	2020
A5	Mubarok, et al	National	2022
A6	Kholishah, et al	National	2020

Code	Researcher	Journal	Year Published
A7	Cahyati & Yohandri	National	2021
A8	Nurhayati, et al	National	2019
A9	Anggreni, et al	National	2022
A10	Suyatna, et al	National	2020
A11	Zulaikha, et al	National	2022
A12	Artiwi, et al	National	2020
A13	Aprilia, et al	National	2022
A14	Wijaya & Jumadi	International	2021
A15	Sujanem, et al	International	2020
A16	Desnita, et al	National	2022
A17	Rahayu, et al	National	2019
A18	Marnah, et al	International	2022
A19	Al Fath & Dewi	National	2022
A20	Purwanto & Suwasono	National	2019

**Table 4.** Meta-analyses by study type

Jenis Penelitian	Frekuensi
Kuantitatif	13
R&D	7

Table 3 indicates that from the meta-analysis results, there were 17 national journals and 3 international journals published in 2018-2022. In addition, Table 4 explains that there are 13 types of quantitative research and 7 types of R&D research. The meta-analysis with the effects of digital physics teaching materials was also reviewed from the grade level in high school. The effect size calculation of each of the articles results in an average effect size by grade level. The average effect size per grade level using 17 articles from national and 3 articles from international journals can be found in Table 5.

**Table 5.** Meta-analysis by high school grade level

Grade Level	Effect Size
X	2,11
XI	2,20

Based on Table 5, the effect of digital physics teaching materials on improving 21st century skills at the Xth and XIth grade high school level obtained an effect size price of 2.11 and 2.20 with a high category. There are two effect sizes that are in the medium category, namely one article at grade X level of 0.56 and one article at grade XI level of 0.78. From the effect size price obtained, it can be seen that the effect size price at the XI grade level is higher than the X grade level. Therefore, it can be concluded that there is an effect of digital physics teaching materials on improving 21st century skills based on grade level in high school.

One of the focuses of the 2013 curriculum implementation is to realize learning that is in line with 21st century skills. The sophistication of technology makes many things in human life all digital in this century. The digital 21st century requires educators and learners to be able to use technology such as smartphones and computers in the process of learning [3]. The utilization of technology in learning is one of them by using digital teaching materials that can be accessed with a digital reader.

## B. Effect of Digital Teaching Materials Based on Physics Learning Materials

The physics learning materials taught using digital teaching materials in the research journal articles analysed in detail can be seen in Figure 1.

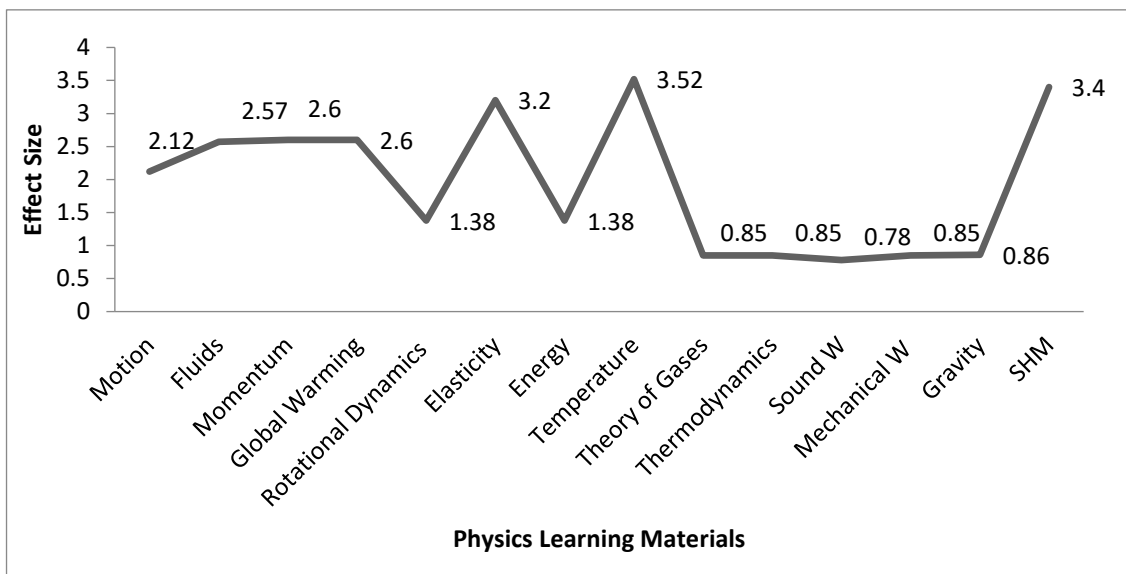


Fig. 1.

Average Effect Size Based on Learning Materials

Based on Figure 1, the effect of digital physics teaching materials on improving 21st century skills is very influential on physics learning materials. Almost all effect sizes are in the high category. The average value of the greatest effect is 3.52 on temperature and heat material. The cause of the effect size being high is because the study used one group in the study. Research in one class has a high value because of the pretest and posttest class tests. The posttest value will have an impact and the value is definitely high compared to the pretest value. While the learning material that is found in many research articles is straight motion material. Straight motion is one of the physics materials in the field of mechanics and in its application can be found in everyday life [25]. Studying straight motion material using digital-based teaching materials will make it easier for students to better understand the material.

According to Permendikbud No. 54 of 2013, the characteristics of Physics learning are as follows the material is arranged in a balanced and systematic manner by covering core competencies, the approach used is based on the scientific process, physics material is enriched to help students think critically and analyse, physics material contains knowledge including factual, conceptual, and procedural, as well as metacognitive, and physics learning helps direct the ability to think and act effectively [37]. Physics learning objectives will be achieved when applying learning resources, namely teaching materials.

**C. Effect of Digital Teaching Materials Based on the Teaching Materials used**

The analysis of the effect of various digital physics teaching materials in improving students' 21st century skills is shown in Figure 2.

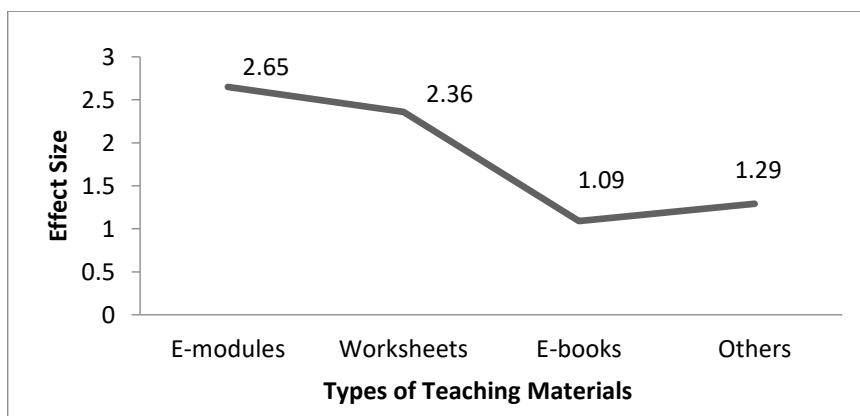


Fig. 2. Average Effect Size by Teaching Material Type

Based on Figure 2, it can be seen that the results of the meta-analysis of the effect of digital-based teaching materials based on the type of teaching materials used in physics learning from the analyzed research articles, there are 4 types of digital teaching materials used, namely e-module, student worksheet, e-book, and teaching materials in other forms with an average effect size that is included in the high category. Teaching materials in the form of e-modules have the largest effect size with an effect size value of 2.65. The average effect size results conclude that various types of digital teaching materials have an effect on the acquisition of effect size results obtained with e-modules having a high category compared to other teaching materials.

The use of e-modules can improve 21st century skills, namely critical thinking, creativity, collaboration, and communication skills. E-modules are digital modules that are packaged in a more interactive way [38]. A module is a set of teaching materials that are systematically packaged in such a way that the user can learn with or without the help of the facilitator or teacher [39]. Modules have characteristics, namely *Self Instruction*, which is an important characteristic in modules that present students learning independently and do not depend on other parties by providing practice questions and the like that can measure students' mastery [40]. Students who learn independently must be able to provide basic ideas for solving problems contained in the module and find various ideas to solve the problems given. Then, learners must be able to collaborate and communicate the information contained in the module to solve the problems in the module.

Other characteristics of the module are *Self Contained* and *User Friendly*, meaning that all the learning materials needed are contained in the module so that it provides an opportunity for students to learn the material completely. The module is presented with the use of simple and easy to understand language. [40]. Learners will certainly be able to collaborate and communicate various information related to a material contained in the module to solve various problems given independently [41].

#### D. Influence of Digital Teaching Materials Based on 21st Century Skills

Finally, the analysis of the effect of digital physics teaching materials based on the improvement of 21st century skills consisting of critical thinking, creativity, collaboration, and communication is presented in Figure 3.

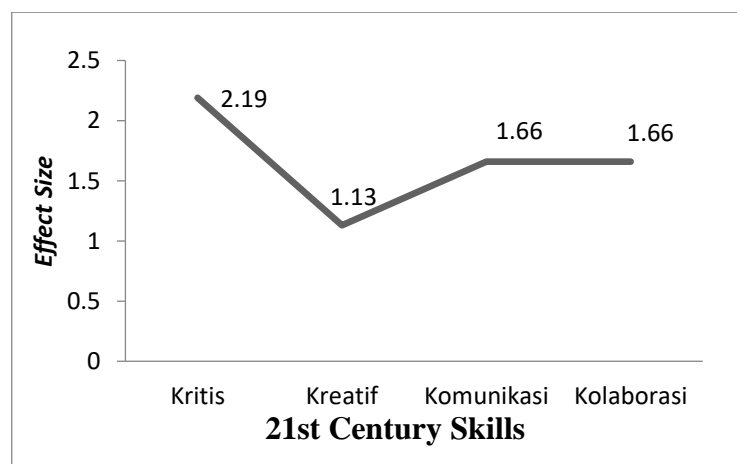


Fig. 3. Average Effect Size Based on 21st Century Skills

Based on Figure 3, there is an effect of digital teaching materials on improving the 21st century skills as indicated by the average price of effect size based on the skills needed in the 21st century, namely thinking critically, thinking creatively, communication and collaboration with a high category. Among the 21st century skills that have the largest effect size value of other skills is critical thinking skills with an effect size value of 2.19. This indicates that the use of this digital teaching material for students can improve their critical thinking skills. This is also in line with some research which argues that digital physics teaching materials can increase students' thinking skills including digital teaching materials in the form of student worksheets that contain problems to hone students' critical thinking skills which can facilitate the learning process [33].

In additional, the study conducted by Artiwi in 2020 digital teaching materials in the form of e-books are used as a learning tool because it is a technology that uses computers [28]. The benefits of this E-Book tool are

hoped to be able to encourage students to learn more creatively, critically, effectively, and efficiently. Likewise with e-modules as digital teaching materials that make the students more autonomous in learning and learning and more student-focused. The learning process with e-modules has made students no longer dependent on the teacher as the only source of information [30].

The realization of digital technology can increase the active involvement and interactivity of students in learning so that there is an integrated process in shaping their understanding through exploration, communication, and elaboration activities. Likewise, the usage of digital technology in teaching materials that can display the material clearly through images, videos and animations, are interestingly designed, and can interact with learners. Interactive digital teaching materials will combine two, three or even more media (audio, text, graphics, images, and video) that can be user-manipulated to control the natural commands of a presentation.

The utilisation of digital teaching materials will train learners to think critically through various problems presented. Students are able to understand and reveal various procedures, rules, terms, data, and information that are presented in audio, text, graphics, images, and videos in the teaching materials. Then learners must also be able to analyse the relationship between existing information and the actual material concepts presented in the teaching materials. After analysing, learners will determine the right strategy to solve the problem presented and draw conclusions for the final stage of completion. All activities that students will do are in accordance with the indicators of critical thinking according to Facione including interpretation, analysis, evaluation, and inference [42].

The utilization of digital teaching materials by teachers is very useful for carrying out the learning process which has a good impact on students. The success of learning objectives can be greatly influenced by the use of digital teaching materials by teachers as a guide in the teaching process. According to this study, digital teaching materials, especially in physics learning, have an impact on the development of high school students' 21st century skills such as critical thinking, creativity, communication, and collaboration. This research is expected to be taken into consideration in the selection of digital physics teaching materials based on the study findings. It is suggested for future researchers that more meta-analysis studies be conducted by collecting larger research findings related to the effect of using digital physics teaching materials.

#### IV. CONCLUSION

Based on the meta-analysis conducted, it could be summarized that: 1) The use of digital learning materials in physics learning to improve 21st century skills has a significant effect on classes X and XI; 2) The usage of digital learning materials in physics learning in any subject has a significant effect in facilitating 21st century skills; 3) The use of types of learning materials has a significant effect in facilitating 21st century skills; 4) The usage of digital learning materials in physics learning has a significant effect in facilitating the improvement of 21st century skills, especially in critical thinking skills.

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