

## DEVELOPMENT OF TEACHING MATERIALS BASED ON STEM EDUCATION TO IMPROVE STUDENT'S KNOWLEDGE, DATA LITERATURE, AND TECHNOLOGY

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### ABSTRACT

*In the 4.0 industrial revolution, it demands to have literacy skills in the 4.0 era which includes data literacy and technological literacy. There is STEM (Science, Technology, Engineering, Mathematics) education, students can improve skills in the fields of science, technology, engineering and mathematics in accordance with the demands of the industrial revolution 4.0. The purpose of this study was to determine the validity of STEM-based ICT-based teaching materials to improve students' data and technology literacy. This type of research is research and development. The instrument used in this study was a validity sheet. The results showed that the five assessment indicators had a validation value of 0.84 which were in the valid criteria. Therefore, STEM education ICT-based teaching materials to improve data literacy and technology are feasible to be used and tested for students.*

**Keywords :** Teaching materials; STEM; data literacy; technology literacy



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## I. INTRODUCTION

Industrial revolution 4.0 makes changes to the world because technology has become the basis of human life. Industrial revolution 4.0 demands changes in the field of education. Education based on the industrial revolution 4.0 requires alternative solutions that produce active and innovative learning methods to improve the learning process [1]. Education and the industrial revolution 4.0 can support thinking patterns and learning patterns in developing various creative innovations from students. In other words, there are demands for generations who can compete globally and have the literacy skills of the 4.0 era.

In industrial revolution 4.0, there is data, technological, and human literacy. Information literacy is the ability to read, analyze and use or utilize information in the advanced world [3]. Technological literacy is a continuation of advanced literacy which emphasizes the importance of social media and the use of technology in life, especially in the field of education[2]. Where is the age of advanced literacy, namely the ability to determine and access a variety of information in computerized technology[4].

Now the world of education is facing the challenges of the Covid-19 pandemic since early March 2020, especially in Indonesia. Various activities of human life that were originally normal changed drastically following government regulations. All community activities are carried out from home, such as work, school, worship, and many other activities. Likewise in the field of education, Covid-19 has been in the implementation of learning being carried out online from all levels of education[5]. Conventional or face-to-face learning is abolished, learning is carried out at home with a distance learning system and using online media[6]. The implementation of online learning is an alternative that can be done so that the learning expected in the world of education can be fulfilled.

To answer the challenges of the artificial revolution 4.0 requires an invention to learn to follow it. One of them can apply a new system, STEM education. STEM is veritably applicable to be enforced at this time. scholars are asked and needed to be suitable to master chops in the fields of wisdom, technology, engineering, and

mathematics. So that scholars can suppose logically, totally, and critically. This clearly has a good impact on literacy, especially learning about physics [7].

This STEM education includes the integration of technology and techniques into science and mathematics, incorporates strategies such as project-based learning, and also incorporates appropriate technologies to enhance learning [8]. Learning with STEM education is very important because it provides training to students so that they can integrate every aspect. So that the learning process that includes these four aspects will form a more comprehensive knowledge of the subject being studied [2]. This means the implementation of a comprehensive integrated learning plan that includes the details of the learning procedures.

In learning physics, it's necessary to inculcate introductory generalities into the development of core concepts. One of the supporting sources in the perpetration of physics literacy is tutoring accouterments. tutoring accouterments are accouterments or coffers that are totally arranged to help scholars and preceptors in carrying out the literacy process. In addition, training accouterments can give clear guidance on the capabilities to be achieved by scholars [9]. In addition, scholars don't have to depend on the schoolteacher because scholars can learn singly [10]. training accouterments have an important part in literacy, therefore training accouterments can follow technological developments that live moment. One of the training accouterments that are by technological developments in the 4.0 artificial revolution is ICT- grounded training accouterments.

Conditions in the field are not the expected conditions. The first real condition of the questionnaire analysis on the use of teaching materials and the use of ICT in teaching materials. The second real condition, from research journals, stated that 46% of students were less interested in sound wave lessons because students still had difficulty working on sound problems, teachers did not provide motivation and teachers did not use teaching aids in learning. Then light waves are one of the difficult materials because learning only focuses on formulas without understanding physical phenomena [11]. Also, when studying physics students cannot only rely on activities that are minds on activity but also need hands-on activities that can be done with simple experimental activities [11]. The third real condition based on the analysis of STEM integration in the physics book for class XI SMA is still relatively moderate from the average obtained of 53.30. The fourth real condition based on the analysis of student learning outcomes data obtained from the average UTS value of semester 1 students, which is 62.16, is in the medium category. The fifth real condition of the performance assessment instrument, namely students' data literacy and technology skills is still relatively low with an average score of 49.34 and 39.31.

The results of the initial study obtained have a gap between real conditions and ideal conditions or expected conditions. The solution provided by the researcher is to develop STEM-integrated ICT-based physics teaching materials to improve students' data and technology literacy. These teaching materials are practically developed and interestingly which makes the learning process more effective and efficient to the demands of the industrial revolution 4.0 that teachers and students must be technologically proficient and relate it to the field of education.

Training accouterments are one of the literacy coffers that must be arranged in such a way by the schoolteacher and developed according to being vittles so that scholars can use them as study attendants and be suitable to learn singly. training accouterments contain learning accouterments designed to achieve literacy objects [12]. The development of information and communication technology should be an occasion to encourage imagination literacy for scholars. In the face of 21st-century literacy and the 4.0 artificial revolution, it's necessary to develop training accouterments, videlicet ICT- grounded training accouterments These ICT- grounded tutoring accouterments are in principle the same as training accouterments in general, but ICT- grounded training accouterments are more important because they're formatted in electronic form. This ICT- grounded tutoring material has advantages including; having a more seductive appearance, ICT- grounded tutoring accouterments containing multimedia content similar to sound, videotape, and images [13], adding pupil learning provocation, bringing less, and being easy to store. tutoring accouterments are interactive for both preceptors and scholars and can be designed according to requirements.

ICT-based teaching materials have advantages over other teaching materials. First, ICT-based teaching materials provide convenience and assist teachers in explaining abstract material. Second, ICT-based teaching materials contain audio, video, quizzes, or other interactive multimedia [14]. Third, students become more active in learning. Fourth, it can be used or accessed anywhere and anytime. With the existence of ICT-based teaching materials, learning will become more interesting and the competencies mastered by students can increase, learning becomes more effective, innovative, and efficient.

STEM education is a way of literacy that surfaced during the period of the Industrial Revolution 4.0. STEM education includes Science, Engineering, Technology, and Mathematics. The purpose of learning through STEM education is for scholars to have a strong understanding of scientific and technological knowledge, and be suitable to apply this knowledge to break STEM-related diurnal life problems [15]. STEM-integrated education can give

benefits to scholars, similar to developing problem-working chops, being innovative, and being familiar with technology [16].

In addition, in the face of 21st-century literacy and the 4.0 artificial revolution, there are new chops, new knowledge chops. This new knowledge is a refinement of the old knowledge to face the 21st century. The new knowledge is also an instrument to answer the challenges of the artificial revolution 4.0. knowledge is the capability to write, read, see, and hear effectively that can be accepted by the mortal mind[17]. Old knowledge consists of reading, jotting, and counting. Meanwhile, new knowledge consists of data knowledge, technological knowledge, and mortality knowledge.

Data literacy is a way of critical thinking that's applied to the process of assessing data sources and how to interpret and-communicate the data attained. This data literacy only focuses on reading data, writing data, and archiving data that are easy to understand extensively, not only quantitatively but also qualitatively. The pointers contained in data literacy are reading data, assaying data, communicating the results of data analysis, and making conclusions grounded on data [3].

Technological literacy is an understanding of technology at a position that allows its effective use in an ultramodern technological society conforming to three main factors, knowledge, chops and critical thinking, and decision timber. pointers of technological literacy are being suitable to understand the work of mortal technology, being suitable to connect wisdom with technology, and the capability to use computers and virtual laboratories[18]. The significance of technological literacy is as a reference in the use of technology systems to help the literacy process for scholars and preceptors.

The teaching materials developed in this study were designed using Flip PDF Corporate Edition software which can produce interesting and practical teaching materials. In addition, the material in this teaching material is by the 2013 curriculum. This teaching material is also equipped with a worksheet to conduct virtual lab experiments using PhET Simulation which can improve students' knowledge, data literacy, and technology skills.

In detail, the solution for this research is to design ICT-based teaching materials to improve students' data and technology literacy. The research conducted has one goal. This study at to determine the validity of teaching materials for sound waves, light waves, and optical devices based on STEM education ICT to improve students' knowledge, data literacy, and technology.

## II. METHOD

The research used is research and development (R&D). Development research is a research method that is needed to produce or make certain products and test the effectiveness of these products[19]. The development model used is the Sugiyono development model.

Sugiyono's (2012) development model consists of ten steps. The first step is the potential and the problem. The second step is gathering information. The third step is to design research products. The fourth step is the validation of the research product design. The fifth step is to revise the research product. The sixth step is testing the research product that has been designed. The seventh step is to revise the research product. The eighth step is testing the use of the product. The ninth step is the revision of the research product. The tenth step is the mass production of research products.

There are six procedures in this study, implicit and problems, data collection, product design, product confirmation, product modification, and product testing[15]. This exploration is limited to product confirmation. ICT- grounded tutoring accouterments are developed at the exploration product design stage. The coming step is that the product is validated after the design stage is carried out. confirmation of exploration products is carried out by a platoon of validators who are experts in their fields. After the exploration product is validated, the coming step is to revise the exploration product grounded on the suggestions given by the validator.

The instrument used in this study was a confirmation distance. The confirmation distance consists of several pointers to measure the validity of the developed exploration product. The pointers from this confirmation distance correspond to five pointers conforming to material substance, visual communication display, learning design, software operation, and STEM assessment of ICT- grounded tutoring accouterments. The products produced and tested for validity are tutoring accouterments for sound swells, light swells, and STEM- integrated ICT- grounded optical tools to ameliorate scholars' data and technology literacy.

Product assessment is carried out based on a questionnaire that has been filled out by experts and then analyzed the results of the data to find out how the level of validity of the teaching materials developed. Validity scores are processed using V Aikens formula. The equation is as follows:

$$V = \frac{\sum s}{[n(c-1)]}$$

Scale the assessment from V Aiken formula is that for the value obtained is large or equal to 0.6, then the STEM-integrated ICT-based teaching materials are said to be valid and suitable for use in the learning process. And for a small value of 0.6, STEM-integrated ICT-based teaching materials are said to be invalid and not yet feasible to be implemented in the learning process.

Score	Criteria
$\geq 0,6$	Valid
$<0.6$	Invalid

Source: Sarifuddin (2015)

### III. RESULTS AND DISCUSSION

Based on the problems from the preliminary study stage, the next stage of development or manufacture. At this stage, STEM-integrated ICT-based teaching materials are designed to improve students' data and technology literacy. Teaching materials are used as learning resources and make it easier for teachers to deliver learning materials and students become easier to understand the material being studied. ICT-based teaching materials were developed using Flip PDF Corporate Edition software. The cover design of the developed ICT-based teaching materials can be seen in Figure 1.



Figure 1. Cover Design of Sound Wave Teaching Materials

The cover is an initial display of the ICT-based teaching materials developed. The cover display contains an image of a submarine, five images of the application of STEM from sound waves, and is filled with the words "STEM Integrated Physics Teaching Materials, Sound Wave Materials". The cover display is equipped with the author's name along with the author's intuition. In addition, the cover also contains the words "Class XI Semester 2".

The next stage is an assessment initiated by the researcher himself. The researcher reads as a whole, and checks and corrects any parts that are felt to be lacking or there are errors. Then test the validity of STEM-based ICT-based teaching materials by validators who are experts in their fields.

This validity assessment is attained from a confirmation instrument which has several five corridors of the assessment, each of which consists of several pointers and has factors that are the results of the elaboration of these pointers. Each index element in the instrument has the loftiest score of 4 and the smallest score of 1. The score attained from the instrument in the form of a scoring rubric will be anatomized using Aiken's V validity analysis. The results of the analysis can be distributed as valid if they meet Aiken's V measure limit.

The first result is an assessment of the substance of the material. The material substance has four indicators with four sub-component divisions. The four indicators are truth, material coverage, current, and legibility. The overall results of the assessment of the substance of the material are obtained from the validity analysis of Aiken's V. The results of the analysis of each indicator can be seen in Table 2.

Table 2. Validity Value of STEM-Based ICT-Based Teaching Materials on Material Substance Indicators

No	Sub-Indicators	Aiken's V. Value	Criteria
1	Truth	0.83	Valid
2	Coverage material	0.89	valid
3	Present	0.78	Valid
4	Legibility	0.83	Valid
Average		0.83	Valid

Based on Table 2, the value of the material substance indicator ranges from 0.78 to 0.89 which consists of four indicators. The highest value was obtained from the material coverage section, namely 0.89, and the lowest value was obtained from the present section, namely 0.78. Of the four sub-indicators of the substance of the material already classified as valid criteria. This value is analyzed based on the analysis of the validity of Aiken's V. The average value obtained on the material substance indicator is 0.83, which is included in the valid category. So, the overall material substance indicator value is valid.

The second result is an assessment of the appearance of visual communication. The visual communication display consists of six indicators, namely navigation which contains instructions and instructions in the use of teaching materials, letters, media, colors, animations and the last is the layout. The results of the validity of the visual communication display can be seen in Table 3.

Table 3. Validity Value of STEM-Based ICT-Based Teaching Materials on Visual Communication Display Indicators

No	Sub-Indicators	Aiken's V. Value	Criteria
1	Navigation	0.78	Valid
2	Letter	0.72	Valid
3	Media	1	Valid
4	Color	0.89	Valid
5	Animation	0.72	Valid
6	Layout	0.72	Valid
Average		0.81	Valid

In Table 3 it can be explained that the value of the visual communication display indicator which consists of six indicators ranges from 0.72 to 1. The highest value is obtained from the media section, namely 1, and the lowest value is obtained from the letters, animation, and layout sections, which is 0.72. Six of the visual communication display sub-indicators are valid. The average value obtained on the visual communication display indicator is 0.81, which is included in the valid category. Thus, the overall visual communication display indicator value is valid.

The third result is an assessment of learning design. Learning design includes things that must be in an integrated STEM ICT-based teaching material. Therefore, the learning design consists of eight indicators, namely titles, core competencies and basic competencies, learning objectives, materials, sample questions, exercises, work steps, compilers and the last is a reference. Each indicator consists of two sub-components. The following are the results of the learning design analysis in Table 4.

Table 4. Validity Value of STEM-Based ICT-Based Teaching Materials on Learning Design Indicators

No	Sub-Indicators	Aiken's V. Value	Criteria
1	Title	0.83	Valid
2	KI and KD	0.78	Valid
3	Learning objectives	0.89	Valid
4	theory	0.78	Valid
5	Problems example	0.78	Valid
6	Exercise	0.83	Valid
7	Work steps	0.83	Valid
8	Compiler	0.89	Valid
9	Reference	0.83	Valid

Average	0.83	Valid
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Based on Table 4, it can be explained that the value of the learning design indicator which consists of nine indicators ranges from 0.78 to 0.89. The highest score was obtained from the learning objectives and preparation section, namely 0.89, and the lowest score was obtained from the core competencies and basic competencies sections, material, and sample questions. Nine of the learning design sub-indicators are valid. The average value obtained on the learning design indicators is 0.83, which is included in the valid category. Therefore, the overall value of the learning design indicators is valid.

The fourth result is an assessment of software usage. The indicator of the use of the software is the software used or also supporting applications in the manufacture of these teaching materials. Because the validated teaching materials are ICT-based teaching materials. Indicators of software usage consist of three parts, namely interactivity (feedback from system usage), supporting software, and originality. Each indicator consists of 2 sub-components. The results of the analysis of software usage indicators can be seen in Table 5.

Table 5. Validity Value of STEM-Based ICT-Based Teaching Materials on Software Usage Indicators

No	Sub-Indicators	Aiken's V. Value	Criteria
1	Interactivity (feedback from the system to the user)	0.78	Valid
2	Software support	0.83	Valid
3	Originality	0.89	Valid
Average		0.83	Valid

Based on Table 5, it can be explained that the value of the software usage indicator which consists of three indicators ranges from 0.78 to 0.89. The highest value is obtained from the originality section, which is 0.89 and the lowest value is obtained from the interactivity section, which is 0.78. Three of the sub-indicators of the software used are valid. The average value obtained on the software usage indicator is 0.83, which is included in the valid category. So, the overall value of the learning design indicator is valid.

The final result is the STEM assessment. STEM includes four indicators, namely science, technology, engineering, and mathematics. The four indicators have two sub-components. ICT-based teaching materials have integrated STEM which includes all STEM indicators. The results of the analysis of the STEM indicators can be seen based on Table 6.

Table 6. Validity Value of STEM-Based ICT-Based Teaching Materials on STEM Indicators

No	Sub-Indicators	Aiken's V. Value	Criteria
1	Science	0.94	Valid
2	Technology	0.83	Valid
3	Engineering	0.78	Valid
4	Mathematics	0.94	Valid
Average		0.88	Valid

In Table 6 it can be explained that the value of the STEM assessment indicator which consists of four indicators ranges from 0.78 to 0.94. The highest value was obtained from the Science indicator section, which was 0.94 and the lowest value was obtained from the engineering indicator section, namely 0.78. Four of the sub-indicators of the STEM assessment are valid. The average value obtained on the STEM assessment indicator is 0.88, which is included in the valid category. Thus, the overall value of the learning design indicators is valid.

ICT-based teaching materials have five validation indicators that have been analyzed. Five indicators that have been analyzed consist of material substance (SM), visual communication display (TKV), learning design (DP), software usage (PLP), and STEM assessment (PSTEM). The average analysis of these five indicators can be plotted in the form of a graph as shown in Figure 2.

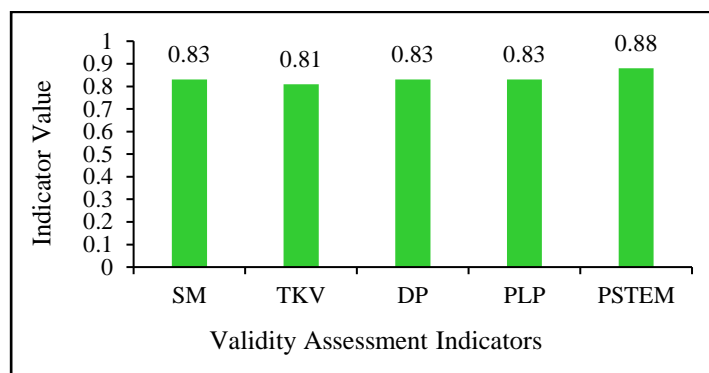


Figure 2. Validation Value of Validity Assessment Indicator

Based on the average value obtained, it can be stated that the validation value of ICT-based teaching materials is in the range of 0.81 to 0.88 with valid criteria. The average value of the validation of ICT-based teaching materials for the five indicators is 0.84. So, the validation of sound and light wave teaching materials as well as STEM-integrated ICT-based optical tools for class XI SMA students are in the valid category which means very good.

Teaching materials are arranged coherently to make it easier for students to learn. In this case, the teaching materials are systematic. This means that teaching materials are designed in such a way that certain competencies can be achieved [16]. With the indicators of material substance, it can be seen what sub-components already exist in the teaching materials, namely in terms of truth, material coverage (coverage of material arranged based on the competencies to be achieved), current, and most importantly readability. Readability here includes conformity with good and correct Indonesian rules in other words Standard and easy-to-understand language, clarity of information from designed teaching materials, consistent use of Physics symbols, and good writing rules [20].

Teaching materials that are well-designed and attractive will motivate students to learn. In other words, the visual communication display must be designed attractively, both from the content, illustrations, or animations that are designed to arouse students' interest in learning[20]. When the display of teaching materials is designed completely, it means that there are adequate media elements that will affect the atmosphere during the learning process, so that learning activities that occur in students will be more optimal. Coupled with instructions for using teaching materials as a guide to study it and make it easier for students to use these teaching materials.

Learning design means the design of learning system development and perpetration including installations and procedures to be suitable to ameliorate the quality of literacy [21]. This is supported by several factors, especially how to present the material in tutoring accouterments. The accouterments designed in the tutoring accouterments are by the core capabilities and introductory capabilities of certain accouterments, the accouterments in the tutoring accouterments formerly have accurate sources and clear references. As well as the experimental work way has been arranged as well as possible including data literacy and technology knowledge. so, learning design is the most important part of training accouterments. So that the literacy objects in it'll be achieved as anticipated.

The validated teaching materials are ICT-based teaching materials. The existence of software assistance is used in the design of this teaching material. The development of the current era requires students to have independence in learning. Learning independence is the most important part that must be improved, especially in learning physics [22]. The existence of technology-based teaching materials can encourage students to be more active in looking for learning resources so that they can build their knowledge independently, not always depending on the teacher[14].

ICT- predicated training accouterments use supporting software Flip PDF Commercial, Virtual Lab, and Crocodile Physics. Flip PDF Commercial is a software that can convert PDF lines that can be published in digital form like a book. Flip PDF Corporate has an advantage, the workmanship and operation of the product aren't delicate because it can be published offline so that it can be run on a laptop/ computer and published online which can be opened and run on a smartphone. This makes it easier to make training accouterments for those who don't know the HTML programming language [18]. In this software, images, audio, vitality, and quizzes can be added to training accouterments. The Virtual Lab or Crocodile Physics software contains practical conditioning that can be penetrated online or offline.

Science, technology, engineering, and mathematics (STEM) is an approach to learning with the stopgap of perfecting scholars' data knowledge and technology. Its operation is carried out using tutoring accouterments that have four STEM pointers. Learning associated with STEM pointers can give openings for scholars to understand physics generalities when combined with technology, engineering, and mathematics through discussion and internship conditioning [23]. The literacy process can eventually attract scholars' interest and have an impact on

perfecting learning issues. piecemeal from that, STEM can give scholars guests in literacy, learning becomes more active

Based on the validity results obtained, ICT-based teaching materials have been said to be valid. However, these ICT-based teaching materials need to be revised. This revision was made based on suggestions and input from the validator team so that the ICT-based teaching materials developed could meet the criteria for each validation component.

When conducting research, researchers have limitations in carrying out it. Therefore, a solution is needed to overcome these limitations. The first limitation is that there are only two ICT-based teaching materials developed, consisting of KD 3.8 on sound and light waves and KD 3.9 on optical instruments in class XI semester 2. Researchers recommend for further research, namely teaching materials developed based on all material in class XI semester 2 so that the teaching materials are complete.

The second limitation is that the ICT-based teaching materials developed can only be accessed online. This makes it difficult for users to access if they are in a place that is constrained by the network. The researcher's recommendation for further research is that ICT-based teaching materials can be used with other supporting software, where later ICT-based teaching materials can be accessed online or offline.

#### IV. CONCLUSION

Based on the results of the study, it was obtained the validity value of STEM-based ICT-based physics teaching materials. The value of each indicator is in the valid category. The material substance indicator section with an average value of 0.83, visual communication display indicators with an average value of 0.81, learning design indicators with an average value of 0.83, software usage indicators with an average value of 0.83, and the last STEM assessment indicator with an average value of 0.88 average. From the validation results, it can be concluded that the teaching materials of sound waves, light and optical devices based on STEM integrated ICT to improve data and technology literacy with a validation value of 0.84 have valid criteria.

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