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The Effectiveness of Stem-Modeling-based E-Modules of Voltaic Cell-Material on Creativity and Concept Mastery through Online Learning

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This study aims to produce an e-module based on STEM-Modeling in the Voltaic Cell material and to examine its effect on creativity and concept mastery in students. The method used in this research was education research and development. The research design used 4D (define, design, develop, and disseminate) and was limited to the third stage because of the situation at home due to the COVID-19 pandemic. The development stage was product trials using one group pre-test post-test design. Product trials in this study are through online learning in tenth-grade students with a target number of 60 students. Data were collected using an assessment sheet on e-modules, tests of thinking creativity and concept mastery, and the effectiveness of online learning. The data obtained were analyzed using quantitative descriptive. The results showed that STEM-Modeling-based e-module development was appropriate to use with a CVI score of the material aspect of 0.86, a presentation of 0.84, and a linguistic of 0.80. This research concludes that the e-module is quite effective in improving creativity and is effective in the mastery of concepts, which is characterized by an increase in the score of pre-test to post-test, with N-gain of creativity of 0.68 and N-gain of concept mastery of 0.77. The e-module implementation in online learning is quite effective with an effectiveness score reaching 72.06%.

Keywords: *Covid-19 Pandemic, Creativity, e-module, Modeling Instruction, STEM.*

Introduction

In the era of the industrial revolution 4.0, it is expected that 21st-century learning can be implemented. To teach students to have 21st-century skills, learning by teachers must also be oriented to 21st-century learning, which one of its principles is a learning approach centered on students and the way students gain knowledge constructively (Ah-nam & Osman, 2017; Redhana, 2019). One learning approach that can accommodate these learning characteristics is the Science, Technology, Engineering, and Mathematics approach or abbreviated as STEM (Meyrick, 2011; Wilcox et al., 2017; Ridwan & Rahmawati, 2017) and modeling-based learning (Jackson et al., 2007; Cullen, 2015).

Learning with the STEM approach and modeling needs to be supported by representative teaching materials. Representative teaching materials must pay attention to the following matters: Accuracy of content, Accuracy of coverage, Updated material, Comprehensiveness of texts, Use of Language, Use of illustrations. Especially in Vocational High Schools, the important point in teaching materials is the accuracy of the coverage and the updating of the material (Depdiknas, 2008; Ardiman, et al., 2019; Widodo et al., 2019). Electronic module (e-module) is a type of teaching material that is arranged systematically, so students can learn independently, actively, and creatively. E-modules should accommodate the characteristics of 21st-century learning to be able to create students who have strong concept mastery and high creativity (Shobrina et al., 2020; Kurniawati et al., 2020; Cahyani et al., 2020; Mulyadi, et al., 2019).

Based on a preliminary study by the author of 16 chemistry teachers in 16 different schools in the city and district of Sukabumi, it was found that teaching materials used in general were already good in several ways such as the use of language, digestibility of texts and use of illustrations. However, for the content component, some inadequate indicators are not yet accommodating the needs of contextual vocational students per their expertise competencies. No teaching material accommodates an approach that can make students as subjects of creative learners. From the analysis of the contents of existing teaching materials, it is found facts that show no contextual, causing problems for learning for students. The initial study found that the creative thinking ability of students only reached 27.03% of 95 students, while the mastery of concepts was also relatively low; the average score of learning outcomes was 22.4 from a maximum score of 100. The low creativity was due to teaching materials not yet oriented to lead students to create a work or product. The low mastery of students' concepts is thought to occur because the teaching material is packaged in the presentation of knowledge content directly, not accompanied by contextual activities that can encourage students to find concepts. Thus, it can be said that the teaching materials used by teachers in learning are not appropriate in terms of content, are not contextual, and do not facilitate students to build their scientific abilities in terms of presentation, resulting in low creativity and mastery of concepts.

The problem of teaching materials becomes increasingly complex in learning when research is conducted because of the COVID-19 pandemic situation (Firman & Rahayu, 2020). Students and research target schools which are in the red zone status, meaning students and teachers learn from home, which is done online. The situation of learning at home must still proceed according to government policy in Indonesia. The need for teaching materials to overcome the various findings in preliminary studies and the need to package the presentation of teaching materials online is very important to do research (Adawiyah et al., 2020). Teaching materials are developed so that students can increase their mastery of concepts and creativity in online learning situations, so the teaching materials are in the form of e-modules. If this is not done immediately, it is feared that the educational objectives, one aspect of which is to make students creative, cannot be achieved. (Triana et al., 2020)

Ideal teaching materials, according to the demands of 21st-century learning, must be able to encourage students to be creative and be able to develop their scientific concepts. Teaching material that can encourage creative students has a characteristic in its presentation that makes students the center of learners (Czajka & Mcconnell, 2019; Rayens & Ellis, 2018). Teaching materials that can encourage mastery of students' concepts are contextual teaching materials that are appropriate to life (Prins et al., 2018) and that is per expertise competencies (Supriadi & Suparno., 2020). Student creativity can also be developed through teaching materials by integrating various scientific fields. In this case, STEM can increase creativity (Henriksen, 2014). As for the mastery of student concepts, based on research by Edwards et al. (2016), Cullen (2015), and Jackson et al., (2007) can be improved by modeling learning. Many researchers combine STEM with learning models or other approaches (Allan et al., 2019; Ardianti et al., 2020; Seage & Türegün, 2020). Likewise STEM-based teaching materials implemented with learning modeling will be a unique and interesting combination. There is a considerable gap between the conditions of teaching materials in various schools with the ideal conditions of teaching materials that are per the criteria of learning in the 21st-century. If this condition is not immediately overcome by developing contextual teaching materials, integrating various fields of science, and is presented in a constructivist manner, it will have a major impact on the low creativity and mastery of concepts in students. So, it is very important to immediately make teaching materials per these criteria.

The purpose of this study is to produce teaching materials in the form of e-modules based on STEM-Modeling, assessment of teaching materials, and know their effectiveness on creativity and mastery of student concepts. The assessment of teaching materials focused on aspects of content and presentation. The teaching material is limited to the topic of voltaic cells in increasing the creativity and mastery of the concept of vocational students. Analysis of student creativity is limited to thinking creatively, and mastery of concepts is limited to voltaic cell concepts that are per students' competency expertise. Also, this study measures the effectiveness of online learning by using e-module teaching materials that have been produced as a result of the learning process due to COVID-19 pandemic.

Methods

This research was conducted with education research and development methods which include the 4D stages (Figure 1), namely define, design, develop and disseminate and are limited to the third stage (Thiagarajan, 1974). The defined stage is gathering initial information about the importance of developing STEM integrated teaching materials, analyzing curriculum, and integrating STEM elements. The design stage is designing STEM-integrated teaching materials. The stage of development is done with expert validation, limited evaluation, and implementation. Detailed research stages are presented in Figure 1.

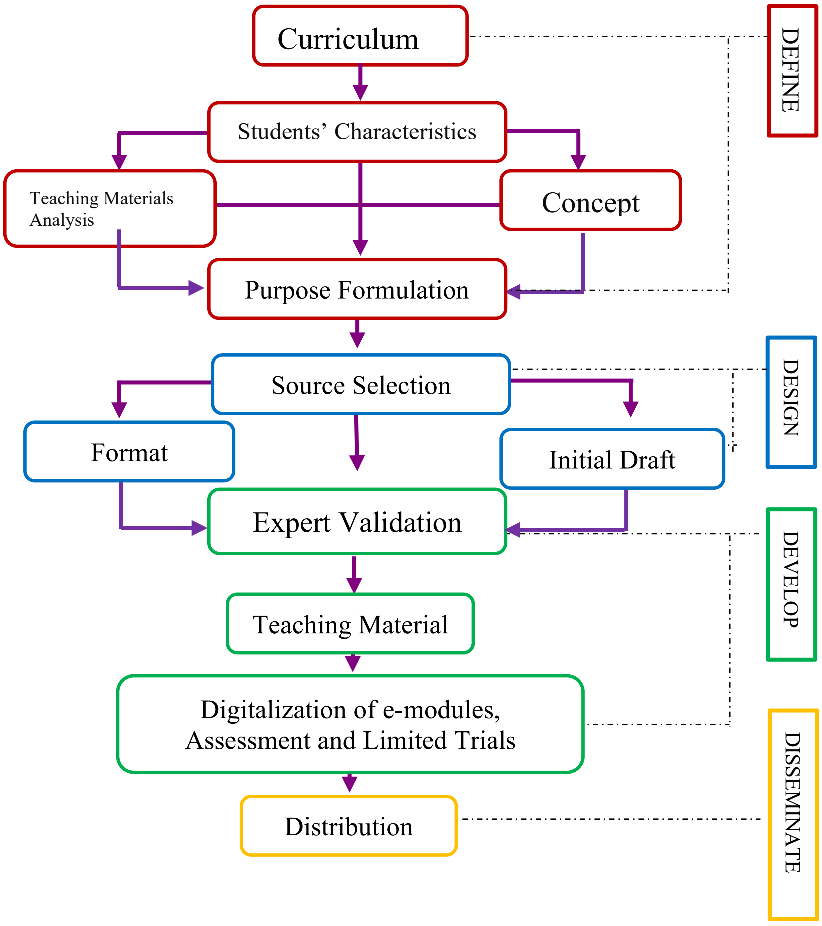

Figure 1: Flowchart of Research with 4D Teaching Material Development Model

The target of the teaching materials trial is 60 students in class X with the expertise in Automotive Light Vehicle Engineering competence. The study design used a one-group pretest-posttest design in which the study only contained an experimental group without a control or comparison group, as shown in Figure 2 (Fraenkel et al., 2005; Creswell, 2017). The research procedure includes the planning stage, the implementation stage, and the final stage. The planning stage is curriculum analysis and preliminary studies. The implementation stage includes the development of teaching materials based on STEM-M. Teaching material effectiveness test is through online learning by using the Zoom Meeting application as a learning strategy due to the impact of COVID-19. While the final stage is by conducting data analysis, discussion, and drawing research conclusions.

Pre-test	Treatment	Post-test
O	X	O

Figure 2: Design of STEM-M integrated Teaching Material Implementation

Information:
O = test given to the experimental group
X = treatment of Chemistry learning using STEM-M integrated teaching material on Voltaic Cell material.

Data collection techniques in this study used tests, assessment sheets, and questionnaires, all of which were carried out online using Google Form. The written test is used to test the mastery of concepts and creative thinking on voltaic cell topics. The written test of mastery of concepts is in the form of multiple-choice questions, while the creative thinking test uses the question description. The aspects of creativity that are used based on the category of Munandar (1992), there are four aspects of creativity that are measured namely the aspects of flexibility, originality, elaboration, and fluency. The voltaic cell concept tested consisted of the concept of an oxidation-reduction reaction, analyzing the anodes, analyzing the direction of electron flow and electric current, determining the sell notation, calculating the theoretical E^0 Sell, and the voltaic cell argumentation. Creativity and concept data mastery in the form of scores are then analyzed by determining the N-Gain based on Hake criteria (1999) (Table 1). The data obtained were then analyzed using quantitative descriptive.

Table 1: N-Gain Interpretation

N-Gain (%)	Interpretation
(g) ≥ 70	*High*
70 > (g) ≥ 30	*Medium*
(g) < 30	Low

The assessment sheet is used to assess the appropriateness of teaching materials. The level of appropriateness of teaching materials was assessed by teachers in the City or District of Sukabumi with a total of 20 chemistry teachers from different schools using a teaching material appraisal sheet. The selection of teachers as assessors of the appropriateness of teaching materials is carried out by purposive sampling, taking into account the teaching experience of at least 5 years. So, armed with mature experience can provide an objective appropriateness assessment based on facts. The data is processed by calculating the score of the CVR (Content Validity Ratio) and CVI (Content Validity Index) of teaching materials. While the pre-test and post-test data are processed by calculating N-Gain, while the questionnaire is calculated by finding the percentage of scores obtained compared with the maximum score. While the questionnaire was used to find out students 'opinions after using STEM-Modeling-based teaching materials and students' perceptions after attending online learning. The results of the questionnaire were scaled which was calculated using a percentage calculation of the acquisition score compared to the maximum score. The percentages obtained are then analyzed and categorized (Toch, et al., 2019). All data in this study were collected online.

Results and Discussion

The product developed in this study is teaching material in the form of an e-module that contains concepts and steps that guide students to integrate these concepts with the concepts of technology, engineering, and mathematics (STEM). Also, students are encouraged to do modeling, so students find their concepts, develop creativity and solutions to problems in the competencies of their expertise (Lim et al., 2020; Purwaningsih et al., 2020; Wilson et al., 2020). Therefore, this teaching material is called an e-module based on STEM-Modeling. The module specifications are presented in table 2 and the front cover of the e-module is presented in figure 2. The e-modules can be accessed through https://www.canva.com/design/DAD654QCrw/qJp1zia1L7WtFIyrqfIWPA/view?utm_content=DAD6-54QCrw&utm_campaign=designshare&utm_medium=link&utm_source=sharebutton.

Table 2: Teaching Material Specification Results

E-Module Aspects	Specification
Content	- Contextual
	- Specific, according to students' competency needs
Presentation	- STEM-Modeling integrated
	- Student-centered
	- Stimulates creativity through engineering activities

Figure 2: E-module front cover

The STEM-Modeling-based e-module that was developed consists of 25 pages and is divided into three chapters: introduction, content, and conclusion. The introduction consists of the title page, preface, and table of contents. The contents chapter consists of 3 subchapters, namely the understanding of voltaic cells, voltaic cell series, and evaluating Accu in cars. The conclusion consists of a material summary, bibliography, index, and glossary. STEM-Modeling-based e-modules are created with the Canva application, stored on Canva hosting, and shared with students via a share link via WhatsApp Group, so students don't have to bother downloading e-modules. The e-module is a digitalized version of the printed module which is less interactive, so online learning becomes more interesting. Besides that, the use of e-modules is certainly more practical because students can simply open it on their android screens.

There are five aspects of integration in this STEM-Modeling module. The science aspect as the most important aspect is integrated into the form of a discussion of voltaic cell material in each sub-chapter. The technological aspects are integrated with the form of applying the concept of voltaic cells in the automotive world. The engineering aspect is integrated with the form of student activities designing voltaic cells with the tools and materials around them. The integrated aspects of mathematics in student activities analyze voltaic cell data and their implementation in solving voltaic cell problems. The modeling aspect is a student activity where students design an experiment to find from beginning to end then pouring it in the whiteboard to discover the concept of the voltaic cell itself.

The appropriateness of teaching materials is reviewed from three components: content, presentation, and linguistics. Analysis of the CVR score in the teaching material sub-component varies from 0.6 to 0.9, indicating that each sub-component in the teaching material is valid. After an average of each component is made, the CVI scores for teaching materials are presented in Table 3.

Table 3: The results of the analysis of the appropriateness of teaching materials

No	Component	CVI Score *(Content Validity Index)*	Criteria
1	Content	0,86	Valid
2	Presentation	0,84	Valid
3	Linguistics	0,80	Valid
Average		0,83	Valid

The three components of teaching materials are categorized as valid and suitable for use because the CVI score is above the minimum limit of 0.42 for 20 validators (Lawshe, 1975; Salajegheh et al., 2020).

The result of N-Gain for concept mastery is 0.77 as shown in table 4.

Table 4: N-Gain Data Test for creative thinking

No	E-module Implementation Data	Pretest	Posttest
1	Number of Students	60	60
2	Lowest Score	10	50
3	Highest Score	50	90
4	Average score	23	82
N-Gain score		0,77	(High)

N-Gain results for students' creative thinking abilities on average of 0.68 (medium category) for each category are shown in table 5.

Table 5: N-Gain Data Test for creative thinking

No	Creativity Aspects	*N-Gain Score*	Criteria
1	Flexibility	0,73	Very good
2	Originality	0,61	Good
3	Elaboration	0,69	Good
4	Fluency	0,67	Good
Average		0,68	Good

Learning by using STEM-Modeling-based e-modules causes a significant increase in both the ability to think creatively and the mastery of student concepts, as well as the N-Gain analysis. The biggest aspect of creative thinking of students lies in the aspect of flexibility while the N-Gain of the other three aspects has Good criteria. The high N-gain aspect of flexibility shows that many students can be creative in learning by finding solutions to battery problems by using various possible solutions. This data indicates that the e-modules produced can develop students' thinking from various perspectives. So that the various perspective, the more alternative solutions have been produced. The other three aspects are likely to be improved, especially fluency. The relatively low aspect of fluency is supported by the condition of vocational students who are generally proficient in field practice rather than thinking work.

Online learning has provided new experiences for students to surf in cyberspace according to their needs, to develop creativity, and solve their problems (Song et al., 2020; Yu, 2020). Students are given the freedom to determine when to study and do the activities in the e-module. So, students practice responsibility for the acquisition of knowledge for themselves, while the teacher is only as a facilitator by monitoring via *WhatsApp* group and *zoom meeting* application (Lassen et al., 2020; Wendt et al., 2020). This is what makes students not burdened, learning independently so that their creativity in thinking can develop more optimally.

The increase in students' creative thinking skills is also caused during the learning activities of students doing various activities such as designing and designing something related to the topic of voltaic cells. As in STEM-based learning, there are student activities in the form of engineering. Engineering activities in learning can encourage students to design, develop and utilize technology, hone cognitive, manipulative, and effective, and apply knowledge (Kapila et al., 2014; Guzey et al., 2017). Although online-based learning engineering activities are not as much as face-to-face learning in general, students remain enthusiastic about carrying out these engineering activities. This shows that, although there are fewer engineering activities, e-modules can make students independent in learning. This finding is supported by research conducted by Anik et al., (2019) which states that e-modules can increase learning independence and are effective in supporting constructive learning.

The high number of N-Gain for mastery of concepts is caused by modeling activities carried out per a series of processes contained in teaching materials. This is consistent with the findings of researchers such as Sujarwanto and Hidayat (2014) in the study of Physics and Jackson et al., (2007), Kimberlin and Yezierski (2016), Azhar (2017) in learning Chemistry, modeling activities can significantly improve students' mastery of science concepts. Likewise, Jenkins and Elizabeth (2019) have implemented modeling instruction on the topic of matter and energy resulting in a significant increase in students' mastery of concepts by more than 60% compared to traditional learning. Modeling instruction activities are carried out through face-to-face and group learning while this time learning is done online and individually. Not all students can display the activity, due to time constraints; it is done by sampling alone. Of course. this is a challenge both for students and teachers.

To teach voltaic cells constructively, this modeling activity plays a very important role. This is because abstract things can be concreted with this modeling approach based on students' interpretations (Kimberlin & Yezierski, 2016; Edwards & Head, 2016). Interpretations of abstract concepts in voltaic cells include the concept of electron particles, electron flow, electric current flow, oxidation reaction processes, and reduction. Modeling activities are shown when students conduct voltaic cell experiments using tomatoes. In this case, a question that they must find the answer to in the e-module is why a series of tomatoes, zinc metal, and copper can turn on LED lights (Light Emitting Diode). In the process, students vary in pouring answers into mini whiteboards. From the sampling of five students, the students answered incorrectly, this was sourced from the liquid tomatoes. The other student answered correctly, which is from metals that experienced certain reactions. Subsequent modeling processes were able to produce a concept that they discovered themselves, through a series of activities such as literature studies and discussions, which LED lights to come on because of the reduction and oxidation reactions of the electrode metal, while tomatoes are only a medium.

STEM-based teaching materials also facilitate students to produce something meaningful or product. In this study, students can make products in the form of simple batteries made with materials and tools around students. The engineering activities of making a simple battery project integrated with science, technology, and mathematics also support deepening student knowledge. Activities that involve design and engineering facilitate students to be actively involved in creating creative products (Mayasari et al., 2016). The integration of engineering design and modeling in the learning process encourages students to conceptualize the design of the project they have made into a prototype that is actually like a professional technician in the field (Pangesti & Yulianti, 2017; Jackson et al., 2007). This can stimulate students' curiosity, imagination, challenges, and creativity of students (Lou, 2017; Yi, et al., 2015). This condition is further strengthened by online learning which gives students the freedom to think when completing projects in e-modules. Freedom of learning for students encourages the creation of more optimal creative products amid the COVID-19 pandemic.

The e-module implementation online is quite effective with 72.06% of effectiveness score, seen from the feedback of students while running online learning. From the data above, there are still 27.94% of students who are low in providing feedback in the form of structured assignments. This is due to the limitations of students in providing quotas and internet access and this is one of the obstacles in online learning for vocational students (Shah et al., 2019). The findings of this study confirm that the packaging of teaching materials in the form of e-modules that were developed made it easier for students to learn online at home. The e-module teaching materials are produced using operational and contextual languages so that even without the help of the teacher, students can learn independently. This finding is reinforced by the results of research Anik et al., (2019) and Pangellah et al., (2019) the use of e-modules is effective enough to make students learn independently.

Conclusions

Based on the results of the research conducted, it was concluded that teaching materials in the form of e-module based on STEM-Modeling which contains material about Voltaic Cells for vocational high school students have been developed, with unique specifications of teaching materials which are contextual and specific content according to expertise competencies and aspects of the presentation, integrating STEM-Modeling, student-centered, and stimulating student creativity. Teaching materials have also been through a process of appropriateness assessment, testing the effectiveness of creativity and mastery of student concepts. The results of the appropriateness test using the teaching material assessment sheet, processed with the CVI / CVR procedure showed the teaching materials were categorized as suitable for use with an average CVI of 0.83. The effectiveness test for creativity and concept mastery shows that teaching materials in the form of STEM-Modeling-based e-modules that are learned online can increase both creativity and concept mastery characterized by increasing pre-test to post-test. The increase was marked by a relatively high N-gain, namely 0.68 of N-gain creativity and 0.77 of N-Gain concept mastery. Implementing e-modules online is also quite effective with an effectiveness score reaching 72.06%.

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