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Development of A STEM-Based Mathematics E-Module to Improve 4C Skills of Vocational Students

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Abstract: This research aims to develop a STEM (Science, Technology, Engineering, and Mathematics) based mathematics e-module that is valid, practical and effective in improving vocational students' 4C *(Critical Thinking, Communication, Collaboration, Creativity*) skills. The research uses the Plomp development model with stages: 1) preliminary research, 2) prototyping phase, and 3) assessment phase. Research data collection uses questionnaire sheets, interviews, checklists, validation sheets, and test sheets. Product validation includes media, material, and language expert validation. The data collected was then analyzed quantitatively and qualitatively. The research results show that STEM-based mathematics e-modules are valid, practical and effective. Valid in terms of appropriateness of content, didactics/presentation, graphics, and language. Practical in terms of readability and clarity of material, ease of use, attractiveness and suitability of time allocation. Furthermore, it is said to be effective because the use of this e-module in the learning process can improve students' 4C skills with an N-gain of 0.58 on medium criteria and an average 4C skills assessment result of 79.00 with a good predicate.

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Introduction

Mathematics is a universal science that underlies various other exact sciences. The development of technology and human thinking power today cannot be separated from the role of mathematics in it, so that mathematics has become one of the mandatory subjects studied at all levels or levels of education. Vocational High School (SMK) is a form of advanced vocational education unit from junior high school or equivalent which aims to prepare students to be ready to work in a certain field. The curriculum structure at Vocational Schools consists of productive programs which are basic vocational subjects, normative programs which are general basic subjects and adaptive programs which are basic subjects which support productive programs. One of the adaptive programs in vocational schools is mathematics subjects (K. S. Handayani et al., 2018).

Vocational school-level mathematics learning in the dynamic technological era must provide a strong foundation of knowledge and skills in developing students' skill competencies to adapt to the world of work quickly and skillfully (Ayuningsih et al., 2022). Every mathematics material taught at vocational school will support the skills program taken by students. One example of mathematical material related to productive subjects in vocational schools is geometry, the volume of rotating objects, linear programming and many others. In the topic of the volume of rotating objects, we can find out the area of a flat plane, which is of course very useful for measuring the area of a plane in engineering. Meanwhile,

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geometry material is very useful in determining angle sizes and measuring the height of an object by using elevation angles (M Rizky, 2020).

Article 37 National Education System Law no. 20 of 2003 states that one of the compulsory subjects in the primary and secondary curriculum is mathematics. Students can gain many benefits by learning and developing math skills. It is said that the aim of learning mathematics is to develop students' logic and thinking. Another benefit of learning mathematics is that it can improve problem-solving abilities, develop creativity, train thinking and reasoning methods to draw conclusions, and foster perseverance and tenacity. This is in line with 21st-century learning where learning must be required to make changes to technology-based innovation. Learning in the 21st century must be able to prepare the Indonesian generation to welcome advances in information and communication technology in social life (Syahputra, 2018). To face changes in technological innovation, it is necessary to design learning that is student-centred and able to apply the 4C competencies *(Critical Thinking, Communication, Collaboration, Creativity).*

A preliminary study conducted at SMKN 1 Guguak, West Sumatra province, concluded that the majority of teachers still use simple teaching materials in the form of textbooks and student worksheets from publishers, so the learning process is still conventional with a teacher centered learning model. The methods and modules used are still conventional in the form of printed modules, the learning process is theoretical, and there is a lack of interaction between students so the learning process is less effective. This is shown by the students' average mathematics scores which are still low and students have not shown any change in attitude as per the educational goals that have been set, namely to make students have the 4C skills, namely creativity, critical thinking, collaboration and communication.

Furthermore, based on the results of interviews with students, it is known that they have never or are not used to learning concepts/material using modules that integrate science, technology, engineering and mathematics in one book. Apart from that, students still find mathematics material very difficult. This is in line with research conducted by Hamidah & Suherman (2016) that in general students experience difficulties in learning mathematics with different levels of difficulty. Even though mathematics should be a challenging subject so that it attracts students' interest in learning and great curiosity (Suherman, 2015). The main cause is the unavailability of teaching materials that suit students' conditions, so that learning using existing modules is less valid, practical and effective. The modules that are usually used are very simple, containing the module identity, learning activities which contain a summary of the material as reading material and close with several practice questions which are used as assessments. This module has not been integrated with existing learning models and is still in the form of a printed module and cannot be accessed electronically.

Apart from that, based on the results of interviews with mathematics subject educators at Guguak State Vocational School 1, it is known that students still have difficulty understanding various subject matter because learning resource books are not able to facilitate students to learn independently so that if educators do not provide clear explanations then Students will not understand the material and ultimately students think that mathematics is a lesson that is difficult to understand because there are many formulas and abstracts. Apart from that, information was obtained that the average 4C skills of students were still low. A study revealed the importance of using the 4C skills in education, namely critical thinking and problem solving, creativity and innovation, and collaboration, especially to train students to have social skills and a global perspective (Nganga, 2019). The challenges faced by educators in the 21st century are not easy because they have the responsibility to produce quality students who are able to compete globally. Teachers equip students with 4C skills so

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that the learning process is not only oriented towards mastering the material but also equips students to have life skills (Nurhayati et al., 2024). For this reason, teaching materials are needed that are able to facilitate students to expand their thinking abilities, both critical and creative thinking abilities and metacognitive skills.

According to Gustiani et al., (2017), learning approaches are appropriate to current learning, one of which is the STEM (Science, Technology, Engineering, and Mathematics) approach. The STEM approach to learning is an approach that combines two or more fields of science contained in STEM. The recent emphasis on STEM learning can be seen as an opportunity to make innovation and change in mathematics. In STEM learning, students are given the opportunity to expand their thinking abilities such as metacognitive skills, critical and creative thinking. Students are not only taught theoretically, but also practically so that students experience the actual learning process. Thus, the STEM approach can be an innovative mathematics learning approach. Sanders; Fitzallen; Anwari et al; Septiani (Yekti & Perdana, 2019).

According to Hanover, E-Modules are a new breakthrough in the world of education in the 21st century, where in education in the 21st century, innovative schools are schools that use technology and pedagogical approaches which will become increasingly common in the future.(Fitriani, 2020). Teaching materials in the form of E-Modules have the main aim of readers being able to absorb material or teaching materials independently (Wibowo & Pratiwi, 2018). The use of e-modules in the learning process can control the digital-based learning process, learning is not limited to the classroom, and can organize the content of teaching materials according to the level of ability of students in accordance with the competencies expected by the curriculum (Rahmadani, 2023)Not only that, education in the 21st century must also be accompanied by a learning approach that can include various aspects, both technology and mathematical rules. One learning approach that is very suitable to be applied in the world of education today is STEM *(Science, Technology, Engineering, and Mathematics).*

STEM is an interdisciplinary approach that integrates four subjects *(Science, Technology, Engineering, and Mathematics)* in solving real-life problems (Tanjung et al., 2022). Collaboration in the learning process, STEM will help students to collect, analyze and solve problems that occur and be able to understand the relationship between one problem and other problems (F. Handayani, 2014). Honey, Pearson, & Schweingrube stated that education is based STEM forms human resources (HR) who are able to reason and think critically, logically and systematically, so that they will be able to face global challenges and be able to improve the country's economy. STEM refers to an individual's ability to apply an understanding of how intense competition works in the real-world which requires four interrelated domains (E. Febriyanti, 2018).

The advantages of the STEM approach have been proven in several studies. STEM can motivate students to design designs, develop and utilize technology, educate cognitive and affective, as well as apply knowledge, so that students experience increased achievement both academically and non-academicly (Marsitin & Sesanti, 2022). Other benefits of STEM-based learning are increasing students' sensitivity to real-world problems, involving students in team-work, enabling students to provide various answers or solutions with justification, involving students in applying design process skills, and giving students the opportunity to improve their answers or products (Utami, 2018). Furthermore, based on research conducted by Musnidar (2018) It was found that the implementation of STEM-based learning proves changes in the mindset and way of acting of Indonesian students to meet the criteria for superior human resources. The design of STEM-based learning activities aims to solve

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problems in everyday life involving 4 scientific literacy disciplines. Considering the importance of learning mathematics and the availability of e-modules as teaching materials that can support the learning process, it is necessary to develop STEM-based mathematics e-modules which are expected to improve the 4C skills of students in vocational schools.

Research Method

The research carried out is Research and Development (R&D) using quantitative and qualitative methods. The development model used is a development model adapted from Plomp. There are three stages in the Plomp development model, namely: (1) *preliminary research* (2) *prototyping phase* and (3) *assessment phase* (Plomp & Nieven, 2013). The data collection techniques used for qualitative data are observation and interviews. Meanwhile, for quantitative data, a questionnaire was distributed containing test instruments in the form of validation instruments, practicality instruments and effectiveness instruments.

For data analysis techniques, validity analysis, practicality analysis and effectiveness analysis are carried out. Validity analysis uses the Aiken's V statistical formula. Practicality analysis is carried out by calculating the practicality value. Analysis of the effectiveness of using E-Modules can be seen from various aspects based on the goals of 21st-century education, namely that students have the 4C competencies *(Critical Learning, Communication, Collaboration, Creativity*) in learning mathematics. Improvements in critical thinking, creative thinking and communication skills can be seen by giving tests before and after using the product that has been developed. Improvement can be seen by analyzing and measuring the *Gain value* using the equation proposed by Hake (1999). E-Module is declared effective if the minimum Gain value is within the medium criteria, namely greater than 0.3, and minimum average score of students' 4C skills assessment is in the good criteria.

Results and Discussion

Preliminary Research

The initial investigation phase or preliminary research is the initial stage carried out before developing or designing a product. At this stage, identification or analysis of the needs required for the development of STEM-based mathematics e-modules is carried out. Activities in this preliminary analysis start from needs analysis, curriculum analysis, student analysis, concept analysis and literature analysis. Overall, the results of the needs analysis at the preliminary stage can be seen in Table 2 below.

Table 1 Results of Needs Analysis at the Preliminary Stage

No.	Aspects Observed	Already	Not Yet
Teaching Materials			
1	The designed ATP is in accordance with the curriculum currently used.	√	
2	The teaching materials used facilitate the achievement of learning objectives.	√	
3	The teaching materials used have been able to facilitate students to construct their own understanding.		√
4	Teaching materials make students interested in learning them.		√
5	Teaching materials have encouraged students to improve 4C skills.		√
Student's			
6	Students follow the learning well	√	
7	Students respond to questions given by the teacher (There is good interaction)		√
8	Students grasp learning quickly		√

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9	Students ask questions and express opinions during the learning process	√
Learning Model		
10	The learning model used is able to direct students to be actively involved in the learning process.	√
11	The learning process is interactive	√

Prototyping Phase

a) *Prototype* Design

The e-module is designed according to the module components and integrates science, technology, engineering and mathematics so that it is hoped that it can guide students to gain their own knowledge and be able to improve 4C skills. The e-module developed consists of several parts, namely, front cover, table of contents, glossary, e-module description, competencies, instructions for using the e-module, material presentation, practice questions, and bibliography.

b) Validation of STEM-based E-Modules

1) Expert Review Results

This expert assessment stage is carried out after the e-module has been revised based on the results of the self-evaluation. Validation is used to assess the validity of the e-module that has been designed. At this stage, the e-module is validated by three experts, namely media experts, material experts and language experts. The following are the validation results of the STEM-based mathematics e-module.

Table 4. STEM-based E-Module Validation Results

No	Validated/Expert aspects	Validation Value	Category
1.	Media expert	0.966	Valid
2.	Material expert	0.807	Valid
3.	Linguist	1.0	Valid
Overall Validity Value		**0.924**	**Valid**

Overall, the e-module validation score from media experts was 0.966, from material experts 0.807, and from language experts was 1.0. This shows that according to experts, STEM-based e-modules are valid.

2) *One-to-one Evaluation* Results

One-to-one evaluation is carried out by asking for comments and suggestions from several students. The number of students used at this stage was 3 students with different cognitive abilities, namely high, medium and low. The selection of students is carried out by discussing with mathematics educators. After all learning activities have been carried out, each student is interviewed regarding the interesting appearance of the e-module, ease of understanding the e-module instructions, ease of understanding the material presented, ease of understanding the language, clarity of writing in the e-module and the time required for students to learn. using e-modules.

Overall, high, medium and low ability students at the one-to-one evaluation stage were able to use e-modules as teaching materials and were able to understand the material presented. Apart from that, the attractive colored display of the e-module and the presence of educational games make students interested in reading and understanding the material and problems in the e-module.

3) *Small Group Evaluation* Results

Small group evaluation was carried out on 6 students to test the practicality of the e-module being developed. The results of the small group practicality test questionnaire can be seen in Table 5 and Table 6.

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Table 5. Results of the STEM-based E-Module Practicality Questionnaire (*Small Group Evaluation*– Student Response)

No.	Rated aspect	Practical Value (%)	Category
1.	Readability and clarity of material	88.54	Very Practical
2.	Applicability and ease of use	92.5	Very practical
3.	Attractiveness	93.75	Very practical
4.	Suitability of time allocation	79.16	Practical
Average		**88.48**	**Very practical**

Table 6. Results of Educator Practicality Questionnaire Analysis

No.	Rated aspect	Practical value (%)	Category
1.	Readability and clarity of material	100	Very Practical
2.	Applicability and ease of use	90	Very practical
3.	Attractiveness	93.75	Very practical
4.	Suitability of time allocation	75	Practical
Average		**89.68**	**Very Practical**

In Table 4.6 it can be seen that the practicality value of the e-module as a whole is 88.48% in the very practical category, while in table 4.7 the practicality value of the e-module by educators is 89.68% in the very practical category. Overall, respondents considered that the STEM-based mathematics e-module for trigonometry comparison material could be used.

1) *Assessment Phase*

In the field test activity, the effectiveness of STEM-based mathematics e-modules was tested as seen from the results of the students' 4C skills assessment. Assessment of students' 4C skills takes the form of tests and non-tests. Non-test assessment is carried out by filling out a formative assessment questionnaire on students' 4C skills, and for the test questions are given before and after learning using STEM-based e-modules in the form of essays totaling 3 questions. The percentage results obtained for each 4C skill indicator in the pre-test can be seen in Table 7.

Table 7. Percentage Results for Each Student's 4C Skill Indicator in the Pre-test

4C Skills Indicator	Percentage (%)
Communication	53,85
Critical Thingking and Probelm Solving	35,58
Creativity	29,81
Collaboration	-
Average Percentage (%)	**39,74**

The percentage results for each indicator of students' 4C skills in the post-test can be seen in Table 8.

Table 8. Percentage Results for Each Student's 4C Skill Indicator in the Post-test

4C Skills Indicator	Percentage (%)
Communication	76,92
Critical Thingking and Probelm Solving	78,85
Creativity	70,19
Collaboration	-
Average Percentage (%)	**75,32**

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Based on Table. 7 and Table. 8. It can be seen that the percentage value of each indicator of students' 4C skills has increased after participating in learning using STEM-based mathematics e-modules. Furthermore, to see the effectiveness of STEM-based e-modules, it can be seen by analyzing and measuring the Gain value. The results of the Gain value measurement can be seen in Table 9.

Table 9. Result N-Gain

4C Skills Indicator	Scor (<g>)	Criteria
Communication	0,50	Curenly
Critical Thingking and Probelm Solving	0,67	Curenly
Creativity	0,58	Curenly
Average N-Gain	**0,58**	**Curenly**

Based on Table 9, the Gain value for communication skills has a score of 0.50 with medium criteria, critical thinking and problem solving has a score of 0.67 with medium criteria, and creativity has a score of 0.58 in the medium category. Based on the analysis and measurement of the Gain value, the STEM-based mathematics e-module was declared effective because it was in the medium criteria with an average Gain value of 0.58. Furthermore, the effectiveness of STEM-based e-modules can also be seen from the results of the analysis of assessment questionnaire sheets on students' 4C skills. The results of the student's 4C skills assessment can be seen in Table 10.

Table 10. Results of Student 4C Skills Assessment

4C Skills Indicator	Average of Each Indicator	Predicate
Communication	84,38	Good
Critical Thingking and Probelm Solving	79,40	Good
Creativity	75,79	Good
Collaboration	78,18	Good
Rata-Rata	**79,00**	**Good**

Based on Table 9, the STEM-based mathematics e-module is declared effective because the average student score for each 4C skill indicator is in the good category with an average score of 79.00.

Discussion

1) *Characteristics of Valid STEM-based Mathematics E-Modules*

Validity is needed to test research accurately, correctly, authentically, and validly. The STEM-based e-module was declared valid by the validator through several aspects observed, namely content feasibility aspects, didactic or presentation aspects, graphic or display aspects and language aspects. Graphic validation is carried out to see the suitability of the appearance, use of letters, physical criteria, and ease of use of the e-module (Dafit & Mustika, 2021), material validation to see the suitability of the material used (Nila & Mustika, 2022). Meanwhile, language validation aims to test the completeness of the language in terms of the language used (Ismawati & Mustika, 2022). The STEM-based mathematics e-module on trigonometry comparison material that was developed has met the product validity requirements with a validation value of 0.924 in the valid category.

Judging from the content feasibility aspect, STEM-based e-modules have valid criteria. This shows that the e-module developed is in accordance with the learning outcomes (CP) and learning objectives contained in the independent curriculum, and the e-module developed can be seen as a form of learning creativity and innovation. In line with (Hendri et al., 2021) who state that a valid e-module must have KD, main material

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and development of clear learning objectives so that students understand it more easily. Clear learning mapping can help students organize the information needed in the learning process, so that students do not experience misconceptions in receiving learning material (Darnella et al., 2020). Furthermore, Sari (2020 in Fauziah et al., 2023) said that the appropriateness of the content of a teaching material can be seen from the preparation of the material which is carried out systematically and in detail regarding the concepts presented. According to Mulyadi (2015 in (Astuti et al., 2022), the suitability of the material functions to increase motivation, interest in learning, and the user's desire to study the material presented in the teaching materials that have been developed.

From the validation results of the e-module presentation aspect, it can be concluded that the e-module contains instructions for use, actively involves students in understanding mathematical concepts, motivates students to ask questions, and learns mathematics lessons on their own with guided activities and is equipped with examples and exercise. In line with (Asri & Dwiningsih, 2022) which states that the presentation of other complementary elements in e-modules such as example questions and practice questions functions to make it easier for students to learn.

The display aspects formulated are classified as valid. The e-module already has all the graphic components, namely having an attractive and proportional layout, text, illustrations and images, choosing appropriate colors and appearance, choosing a background, appropriate type of writing and font size, overall the e-module being developed has a good appearance. It's quite clear and interesting. Using the appropriate font size is important so that the meaning can be conveyed and minimizes misunderstandings (Syahrul, 2019). The combination of colors and background used must also be designed to be comfortable and easy to read to produce an attractive appearance that can influence interest in reading (Mumpuni & Nurbaeti, 2019). In line with this, (Riefani et al., 2020) stated that the use of real, colorful and familiar images in teaching materials will provide real experience in improving students' critical thinking abilities. Permana emphasized that layer design must be considered when developing an e-module (Febriyanti & Ain, 2021).

The language aspect is also clear, the sentences used in the e-module are in accordance with Indonesian language rules, the information conveyed is clear, the sentences are communicative, using the shape and size of letters according to the characteristics of the students. This is in accordance with the validity value obtained with the valid category. Communicative language is language that matches the communication functions of language so that it is easy for readers to understand (Yastini et al., 2018). Apart from that, when writing, using vocabulary and applying punctuation correctly is necessary so that the meaning of the writing can be conveyed (Sukirman, 2020).

2) *Practicality of STEM-based Mathematics E-Modules*

Practicality is used to see the ease of use of the product being developed, namely STEM-based e-modules. The practicality of the e-module can be known after carrying out activities at the small group evaluation stage. Practicality can be seen from the results of the student response questionnaire and the results of interviews with students and teachers.

a) Student and teacher response questionnaire

Student responses were obtained from giving questionnaires to students who took part in the small group evaluation. The results of the student response questionnaire at the small group evaluation stage showed that the overall average practicality of the e-module was 88.48% with very practical criteria. Teacher responses were obtained

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from giving questionnaires to teachers. The results of the teacher response questionnaire showed that the overall average practicality of the e-module was 89.68% with very practical criteria.

b) Results of interviews with students
Based on the results of interviews with students, it was concluded that the STEM-based e-module used was interesting, easy to use and understand, and students admitted that the presence of links for educational videos and games in the e-module made them feel happy and enthusiastic about learning.

c) Results of interviews with teachers
Based on the results of interviews with teachers, it was concluded that the description of the material presented in the e-module was capable and easy to understand by teachers and students, the questions contained in the e-module were also able to support students' understanding and complement the explanation of the material, delivery The material is interesting and relates to real problems.
Based on the results of student responses and the results of interviews with students and teachers, it shows that the e-module developed is included in the practical category, because it is in accordance with Nieveen's opinion in Plomp (2013) which states that a learning device is said to be practical if the device can be used effectively. easily by teachers and students in the learning process.

3) *Effectiveness of STEM-based Mathematics E-Modules*

Effectiveness can be seen from the extent to which STEM-based e-modules have an influence on students after using them in the learning process. Effectiveness was also carried out to see whether using STEM-based mathematics e-modules could improve students' 4C skills. STEM learning is a learning concept that gives students the opportunity to expand their thinking abilities such as metacognitive skills, critical and creative thinking. The STEM approach to learning is also able to train students cognitively, skills and affectively, by integrating four fields of knowledge, namely Science, Technology, Engineering and Mathematics.

To determine the effectiveness of the e-module, researchers gave tests to students. The test questions given are 3 questions and are adjusted to the 4C skill indicators. Apart from the tests, affective and psychomotor assessments were also carried out for each 4C skill indicator using an assessment questionnaire sheet. Based on the results of the 4C skills test at the field test stage, it is known that the Gain value obtained for communication skills is 0.50 with medium criteria, critical thinking and problem solving skills have a value of 0.67 with medium criteria, and creativity has a score of 0.58 in the category currently. Based on the analysis and measurement of the Gain value, the STEM-based mathematics e-module was declared effective because it was in the medium criteria with an average Gain value of 0.58.

Apart from that, the results of the 4C skills assessment from an affective and psychomotor perspective show that the average for each indicator is 84.38 for Communication skills with a good rating, 79.40 for Critical Thinking and Problem Solving with a good rating, the average for Creativity is 75.79 with a good predicate, and Collaboration skills have a good predicate with an average of 78.18. It can be concluded that the e-module developed is effective in improving students' 4C skills.

Conclusion

Based on the findings and data obtained in this research, it can be concluded that; The STEM-based mathematics e-module for trigonometry comparison material is valid from the

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aspect of appropriate content, didactic/presentation aspect, graphic aspect and language aspect; The STEM-based mathematics e-module for trigonometry comparison material is practical from the aspects of readability and clarity of the material, usability and ease of use, attractiveness, and appropriateness of time allocation; STEM-based mathematics e-modules for trigonometry comparison material have been effective in improving students' 4C *(Critical Thinking, Communication, Collaboration, Creativity)* skills.

Recommendation

This E-Module can be used by mathematics teachers as teaching material in the learning process. In the e-module, interactive training features are added that students can do directly. Apart from that, for the smooth implementation of STEM-based mathematics e-modules in the school environment, schools are expected to improve supporting facilities such as the availability of computers, projector screens and adequate internet service access so that all students can access e-modules easily.

References

Asri, A. S. T., & Dwiningsih, K. (2022). Validitas E-Modul Interaktif sebagai Media Pembelajaran untuk Melatih Kecerdasan Visual Spasial pada Materi Ikatan Kovalen. *PENDIPA Journal of Science Education*, *6*(2), 465–473. https://doi.org/10.33369/pendipa.6.2.465-473

Astuti, N., Kaspul, K., & Riefani, M. K. (2022). Validitas Modul Elektronik "Pembelahan Sel" Berbasis Keterampilan Berpikir Kritis. *Jurnal Eksakta Pendidikan (Jep)*, *6*(1), 94–102. https://doi.org/10.24036/jep/vol6-iss1/667

Ayuningsih, F., Sutama, & Suyatmini. (2022). PENGEMBANGAN MODUL AJAR MATEMATIKA MATERI KUANTOR Universitas Muhammadiyah Surakarta , Sukoharjo , Indonesia E-mail : Abstrak PENDAHULUAN Pendidikan di abad 21 harus fokus pada matematika dan sains serta ilmu sosial , seni , teknologi dan humaniora . Pend. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(4), 3285–3299. https://doi.org/10.24127/ajpm.v11i4.6021

Dafit, F., & Mustika, D. (2021). Pengembangan Bahan Ajar Membaca Berbasis Higher Order Thinking Skills pada Siswa Sekolah Dasar. *Edukatif : Jurnal Ilmu Pendidikan*, *3*(6), 4889–4903. https://doi.org/10.31004/edukatif.v3i6.1565

Darnella, R., Syarifah, S., & Afriansyah, D. (2020). Penerapan Metode Concept Mapping (Peta Kon sep) dan Pengaruhnya Terhadap Kemampuan Berpikir Kritis Siswa pada Materi Sistem Gerak di MAN 1 Palembang. *Jurnal Intelektualita: Keislaman, Sosial Dan Sains*, *9*(1), 73–86. https://doi.org/10.19109/intelektualita.v9i1.5579

Fauziah, Z., Susanti, D., & Sari, L. Y. (2023). Validitas E-Modul Pembelajaran Berbasis Proyek pada Materi Perubahan Lingkungan Untuk SMA / MA. *Jurnal Pendidikan Tambusai*, *7*(3), 21197–21201.

Febriyanti, D. A., & Ain, S. Q. (2021). Pengembangan Modul Matematika Berbasis Etnomatematika Pada Materi Bangun Datar di Sekolah Dasar. *Jurnal Basicedu*, *5*(3), 1409–1417. https://jbasic.org/index.php/basicedu/article/view/933

Febriyanti, E. (2018). *Pengembangan Modul Berbasis Stem (Science, Technology, Engineering, and Mathematics) Untuk Materi Fluida Statis Pada Pembelajaran Fisika Smk – Teknik Kendaraan Ringan Otomotif*. http://repository.unej.ac.id/handle/123456789/87878

Fitriani, Z. (2020). *Pengembangan E-Modul berbasis STEM (Science, Technology, Engineering, And Mathematics) berbantuan android pada materi segiempat*

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(Doctoral dissertation, FKIP). https://repository.unja.ac.id/id/eprint/14788

Gustiani, I., Widodo, A., & Suwarma, I. R. (2017). Development and validation of science, technology, engineering and mathematics (STEM) based instructional material. *AIP Conference Proceedings*, *1848*. https://doi.org/10.1063/1.4983969

Hafsah, N. R., Rohendi, D., & Purnawan, P. (2016). Penerapan Media Pembelajaran Modul Elektronik Untuk Meningkatkan Hasil Belajar Siswa Pada Mata Pelajaran Teknologi Mekanik. *Journal of Mechanical Engineering Education*, *3*(1), 106. https://doi.org/10.17509/jmee.v3i1.3200

Hamidah, K., & Suherman, S. (2016). Proses Berpikir Matematis Siswa dalam Menyelesaikan Masalah Matematika di tinjau dari Tipe Kepribadian Keirsey. *Al-Jabar: Jurnal Pendidikan Matematika*, *7*(2), 231–248.

Handayani, F. (2014). Pengembangan Lembar Kerja Siswa (LKS) Berbasis Science, Tecnology, Engineering, and Mathematics (STEM) Pada Materi Hidrolisis Garam. *ETD Universitas Syiah Kuala*, 24.

Handayani, K. S., Mundilarno, M., & Mariah, S. (2018). Implementasi Manajemen Teaching Factory Di Prodi Kriya Kulit SMKN 1 Kalasan. *Media Manajemen Pendidikan*, *1*(1), 122. https://doi.org/10.30738/mmp.v1i1.2880

Hendri, S., Handika, R., Kenedi, A. K., & Ramadhani, D. (2021). Pengembangan Modul Digital Pembelajaran Matematika Berbasis Science, Technology, Enginiring, Mathematic untuk Calon Guru Sekolah Dasar. *Jurnal Basicedu*, *5*(4), 2395–2403. https://jbasic.org/index.php/basicedu/article/view/1172

Ismawati, S., & Mustika, D. (2022). Validitas Media Video Animasi Dalam Pembelajaran Tematik. *INNOVATIVE: Research & Learning in Primary Education*, *1*(2), 688–695.

Linda, R., Zulfarina, Z., Mas'ud, M., & Putra, T. P. (2021). Peningkatan Kemandirian dan Hasil Belajar Peserta Didik Melalui Implementasi E-Modul Interaktif IPA Terpadu Tipe Connected Pada Materi Energi SMP/MTs. *Jurnal Pendidikan Sains Indonesia*, *9*(2), 191–200. https://doi.org/10.24815/jpsi.v9i2.19012

M Rizky, A. (2020). ANALISIS PROSES PEMBELAJARAN MATEMATIKA DI SMK RSBI SURAKARTA. *Paper Knowledge . Toward a Media History of Documents*, 12–26.

Marsitin, R., & Sesanti, N. R. (2022). Pengembangan E-Modul Statistika Matematika Berbasis STEM. *JMPM: Jurnal Matematika Dan Pendidikan Matematika*, *6*(2), 129–140. https://doi.org/10.26594/jmpm.v6i2.2505

Mumpuni, A., & Nurbaeti, rizki U. (2019). Analisa Faktor yang Mempengaruhi Minat Baca Mahasiswa PGSD. *DWIJA CENDEKIA Jurnal Riset Pedagogik*, *3*(2), 123–132. https://doi.org/10.33373/dms.v11i2.4060

Musnidar, L. (2018). Pengaruh Penerapan Pembelajaran STEM (Science, Technology, Engineering, Mathematics) terhadap Keterampilan Creatif Problem Solving dan Komunikasi Siswa. *Prosiding SEMNAS MIPA IV 174179*.

Nganga, L. (2019). Preservice teachers' perceptions and preparedness to teach for global mindedness and social justice using collaboration, critical thinking, creativity and communication (4cs) Lydiah Nganga 1. *Journal of Social Studies Education Research*, *10*(4), 26–57.

Nila, W. T., & Mustika, D. (2022). Pengembangan E-modul Berbasis Model Problem Based Learning (PBL) materi Organ Gerak Hewan dan Manusia kelas V. *Jurnal Pendidikan Dan Konseling*, *4*(2), 411–422.

Nurhayati, I., Satum, K., Pramono, E., & Farida, A. (2024). Keterampilan 4C (Critical Thinking, Creativity, Communication and Collaboration) dalam Pembelajaran IPS

Copyright © 2024, The Author(s)

untuk Menjawab Tantangan Abad 21. *Jurnal Basicedu*, *8*(1), 44–53.

Plomp, T., & Nieven, N. (2013). *Educational Design Research-Part A: An Introduc tion Enschede: Netherland Institute for Curriculum Development (SLO) PQ4R Strategy Accompanied by Refutation Text reading*.

Rahmadani, F. (2023). Effect Of Stem Integrated Physics E-Modules To Improve Creative Thinking Ability. *Pillar of Physics Education*, *16*(20), 155–161.

Ridwan. (2012). *Pengantar Statistika Sosial*. Alfabeta.

Riefani, M. K., Badruzsaufari, & Dharmono. (2020). The practicality of odonata handout in invertebrate zoology course. *Journal of Physics: Conference Series*, *1422*(1). https://doi.org/10.1088/1742-6596/1422/1/012028

Suhendri, H., & Ningsih, R. (2018). Peranan Ketahanmalangan Dan Kreativitas Dalam Pembelajaran Matematika. *Jurnal Penelitian Dan Pembelajaran Matematika*, *11*(1). https://doi.org/10.30870/jppm.v11i1.2982

Suherman, S. (2015). Kreativitas siswa dalam memecahkan masalah matematika materi pola bilangan dengan Pendekatan Matematika Realistik (PMR). *Al-Jabar: Jurnal Pendidikan Matematika*, *6*(1), 81–90.

Sukirman. (2020). Tes Kemampuan Keterampilan Menulis dalam Pembelajaran Bahasa Indonesia di Sekolah. *Jurnal Konsepsi*, *9*(2), 72–81. https://p3i.my.id/index.php/konsepsi72

Syahputra, E. (2018). PEMBELAJARAN ABAD 21 DAN PENERAPANNYA DI INDONESIA. *Prosiding Seminar Nasional SINASTEKMAPAN (E-Journal)*, *1*(November), 1276–1283.

Syahrul, Y. (2019). Penerapan Design Thinking Pada Media Komunikasi Visual Pengenalan Kehidupan Kampus Bagi Mahasiswa Baru Stmik Palcomtech Dan Politeknik Palcomtech. *Jurnal Bahasa Rupa*, *2*(2), 109–117. https://doi.org/10.31598/bahasarupa.v2i2.342

Tanjung, M. R., Asrizal, A., & Usmeldi, U. (2022). Pengaruh Pembelajaran IPA Berbasis STEM Terhadap Literasi Sains dan Hasil Belajar Peserta Didik: Suatu Meta Analisis. *Jurnal Penelitian Pembelajaran Fisika*, *8*(1), 62. https://doi.org/10.24036/jppf.v8i1.115860

Utami, T. N. (2018). *Pengembangan Modul Matematika Dengan Pendekatan STEM (Science, Technology, Engineering, And Mathematics) Pada Materi Segiempat Dan Segitiga Untuk Kelas Vii Smp*.

Wibowo, E., & Pratiwi, D. D. (2018). Pengembangan bahan ajar menggunakan aplikasi kvisoft flipbook maker materi himpunan. *Desimal: Jurnal Matematika*, *1*(2), 147–156.

Yastini, Y. N., Nurdian, A. R., & Wikanengsih. (2018). Kemampuan Penggunaan Bahasa Baku Mahasiswa Program Studi Bahasa Indonesia Ikip Siliwangi. *Parole: Jurnal Pendidikan Bahasa Dan Sastra Indonesia*, *1*(5), 659–664. https://journal.ikipsiliwangi.ac.id/index.php/parole/article/view/821/pdf

Yekti, S. M. P., & Perdana, R. D. P. (2019). Analisis Kebutuhan Pengembangan Modul Matematika Berbasis STEM (Science, Technology, Engineering, And Mathematics) sebagai Upaya Penguatan Karakter …. *Dharma Pendidikan*, *14*(April 2019), 56–67. http://journal.stkipnganjuk.ac.id/index.php/jdp/article/view/105%0Ahttp://journal.stkipnganjuk.ac.id/index.php/jdp/article/download/105/138

Zaharah, Z., & Susilowati, A. (2020). Meningkatkan Motivasi Belajar Peserta Didik Dengan Menggunakan Media Modul Elektronik Di Era Revolusi Industri 4.0. *Biodik*, *6*(2), 145–158. https://doi.org/10.22437/bio.v6i2.8950

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