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DEVELOPMENT OF CASE METHOD-BASED STEM E-MODULES ON CARBON AND SILICON MATERIALS

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ABSTRACT
This study aims to: (1) Determine the validity of case method-based STEM e-modules on carbon and silicon materials; (2) Describe students' responses to case method-based STEM e-modules on carbon and silicon materials; (3) Describe chemistry teachers' responses to case method-based STEM e-modules on carbon and silicon materials. The population in this study were all chemistry teachers at State Senior High School 1 Kisaran (*SMA Negeri 1 Kisaran*), all chemistry lecturers at Medan State University, all computer science lecturers at Medan State University, all PTIK lecturers at Medan State University and all students in class XII IPA High School. The samples selected in this study were three Unimed chemistry lecturers, one computer science lecturer, one information and communication technology lecturer, and two chemistry teachers at State Senior High School 1 Kisaran as well as responses by 36 students in class XII IPA 5. The development model used was the ADDIE model. The instruments used were interview sheets, needs analysis questionnaires, teaching material analysis sheets, e-module validation sheets based on BSNP, student response questionnaires, and chemistry teacher response questionnaires. The results showed that (1) The case method-based STEM e-module on carbon and silicon material was declared "very valid" with an average percentage of material experts of 93.17% and media experts of 94.39%; (2) The response of students in class XII IPA 5 SMA Negeri 1 Kisaran to the developed e-module was categorized as "very practical" with an average percentage of 87.54%; (3) The chemistry teacher's response to the developed e-module was categorized as "very practical" with an average percentage of 97.39%..

Keywords *E-Module, STEM, Case Method, Carbon, Silicon.*

1. INTRODUCTION
The 21st century national education system faces complex challenges to prepare qualified, skilled human resources who are able to answer the challenges of world education (Meilia & Murdiana, 2019). Science, Technology, Engineering, and Mathematics (STEM) is an alternative learning solution for the 21st century. Technological advances have made the learning process move from paper to online, from physical space to online space, and from the classroom to anywhere, anytime, so the use of educational media plays an important role in learning. Educational media has also changed, with the use of soft copy media in the form of electronic modules (Jamun, 2018).

The use of electronic modules (e-modules) can help teachers in the learning process. This causes the teacher in learning only as a facilitator (Syahrial, et al., 2019). E-modules can be interactive media, because other media can be added such as images, animations, audio and video (Herawati & Ali, 2018).

According to research by Karnia *et al.* (2022) STEM e-modules on acid-base materials can stimulate student interest, motivation, and training of students' scientific attitudes, so that they are active in teaching and learning activities. Research by Tripripa et al. (2020) states that there are shortcomings in the development of STEM-based e-modules, namely the development of e-modules only emphasizes student independence in learning to find concepts, so interactive tasks must be added to improve student understanding.

The case method entails problem-based learning and can help students improve their analytical skills (Sobri et al., 2021). Carbon and silicon are suitable topics for case method-based STEM e-modules. Based on the results of interviews at State Senior High School 1 Kisaran that researchers have conducted on November 5, 2022 with one chemistry teacher in class XII IPA 5, several problems arise during the learning process, one of which is that students often feel bored.

Based on the results of distributing questionnaires at State Senior High School 1 Kisaran on November 10, 2022, researchers distributed them to XII IPA 5 class students totalling 36 people. The results showed that 86.11% of respondents stated that carbon and silicon were materials that were difficult to understand. 97.22% of respondents needed new teaching materials to increase students' knowledge of carbon and silicon lessons. Furthermore, 80.55% of respondents suggested using discussion-based e-modules as teaching materials to overcome a case/problem because in learning teachers rarely use group discussions in learning. Based on this description, the researcher is interested in conducting research on the "Development of Case Method-Based STEM E-Modules on Carbon and Silicon Materials". The objectives of this study are (1) to determine the validity of case method-based STEM e-modules on carbon and silicon materials; (2) to describe students' responses to the application of case method-based STEM e-modules on carbon and silicon materials, and (3) to describe chemistry teachers' responses to the developed e-modules.

2. LITERATURE REVIEW
1.1 Teaching Materials
According to Nuryasana & Noviana (2020) teaching materials are subject matter that is utilized in the learning process and arranged systematically. This definition explains that teaching materials must be designed and written in accordance with teaching principles because teachers use them to support the learning process. Learning materials are basically in the form of a field of study with topics/subtopics and details.

2.1 E-Module
E-Modules are electronic forms of pre-printed modules that can be translated by computers or other devices and processed using

companion software. E-modules are a means or learning tool that contains material, methods, constraints, and evaluation methods that are systematically and interestingly designed to achieve the expected competencies based on the level of complexity. Elvarita *et al.* (2020) defined an electronic module or e-module as a book-like display of information that was presented electronically and can be read on a computer or other device.

1.2 STEM Approach

STEM stands for Science Technology Engineering Matemathics. Davidi *et al.* (2021) stated that STEM is an educational approach that integrates Science, Technology, Engineering, and Mathematics into the educational process, with an emphasis on solving problems in real life and the world of work. STEM education teaches students how to use the concepts, principles, and techniques of science, technology, engineering and mathematics (STEM) in an integrated manner to create products, processes, and systems that benefit people's lives.

1.3 Case Method

Case Method is a discussion-based participatory learning method to solve cases or problems. The application of this method will help students refine and improve critical thinking skills in problem solving, and the ability to communicate, collaborate and create. Content is presented in a narrative format, with questions and activities to encourage group discussion and complex problem solving (Sobri *et al.,* 2021).

2.2 Carbon and Silicon

Carbon and silicon are elements that do not react at ordinary temperatures. This element can form simple cations such as C4 + and Si4 + (Syamsidar, 2013). The difference between silicon and carbon is that carbon is non-metal while silicon is semimetal.

3. METHODS

The research model used by researchers is to use the ADDIE development model. According to Tegeh (2013) the steps in this model are as follows: analysis (analyze), design (design), development (development), implementation (implementation), and evaluation (evaluation).

3.1 Analysis Stage

The analysis stage is when researchers examine the need for the development of teaching materials as well as the feasibility and conditions of their development. The researcher's analysis stage includes two things, namely analyzing the needs and analyzing the teaching materials used. The needs analysis was carried out by distributing questionnaires to students of class XII IPA 5 and interviews with chemistry teachers at State Senior High School 1 Kisaran. While the analysis of teaching materials uses 3 chemistry books XII IPA High School.

3.2 Design Stage

At this stage, researchers designed a new version of the e-module. E-modules are designed with STEM-based integrated case methods to meet students' needs for teaching materials. In designing e-modules, it is seen in terms of material and media.

3.3 Development Stage

At this stage researchers make e-modules that are developed, such as producing material or content, selecting applications for developing e-modules, validating e-modules, and formulating evaluation plans.

3.4 Implementation Stage

The trial stage of the e-module aims to collect data on the responses of students and chemistry teachers by using case method-based STEM e-modules in the chemistry learning process. The data is obtained from the results of the student and teacher response questionnaire that has been made in the previous stage.

3.5 Evaluation Stage

The evaluation stage is an improvement after the implementation stage. The final revision of the e-module is carried out at the evaluation stage based on the student and teacher response questionnaires given at the implementation stage.

The research instruments used are interview sheets, needs analysis questionnaires, teaching material analysis sheets, e-module validation sheets (the points contained in the e-module validation sheet are sourced from BSNP teaching material evaluation), student response questionnaires and chemistry teachers. Data analysis of e-module validation is qualitative in the form of suggestions or comments, while the data used in validation is quantitative with reference to five assessment criteria. Validation by a team of validators uses a percentage score derived from a Likert scale. The assessment criteria are presented in Table 1:

Table 1. Likert Scale

Scale Value	Rating
5	Strongly Agree
4	Agree
3	Moderately Agree
2	Disagree
1	Strongly Disagree

(Source: Sugiyono, 2012)

Then the data that has been obtained is converted into qualitative values according to the criteria above. The formula for the percentage of validation scores:

$$P = \frac{n}{N} \times 100\% \quad \text{.....(Equation 1)}$$

Description:
P = Percentage score in percent (%)
n = Number of scores obtained
N = Maximum number of scores
So that the validity criteria are obtained (Karnia et al., 2022) which are presented in Table 2:

Table 2. Validity Criteria

Percentage Score (%)	Criteria for Validity
81-100	Very Valid
61-80	Valid
41-60	Fairly Valid
21-40	Less Valid
0-20	Invalid

(Source: Karnia et al., 2022)

The response questionnaire for students contains 10 statement items while the teacher response questionnaire consists of 18 statement items that show the response to the case method-based STEM e-module. The questionnaire is made with a Likert scale, the assessment criteria can be seen in Table 3:

Table 3. Likert Scale

Scale Value	Rating

4	Strongly Agree
3	Agree
2	Disagree
1	Strongly Disagree

(Source: Yuliarmi & Marhaeni, 2019)

To analyze data on responses, this study used percentages. The percentage of student and teacher response scores uses the formula in Equation 1. After the percentage is obtained, then match it to the criteria for practicality assessment guidelines (Akbar, 2013) presented in Table 4:

Table 4. Practicality Criteria

Percentage Score (%)	Practicality Criteria
81-100	Very Practical
61-80	Practical
41-60	Moderately Practical
21-40	Not Practical
0-20	Very Not Practical

(Source: Akbar, 2013)

4. RESULTS & DISCUSSION

The research was conducted in November 2022-February 2023, at State Senior High School 1 Kisaran. The development of case method-based STEM e-modules on carbon and silicon materials was preceded by an initial data collection stage through distributing questionnaires to students of class XII IPA 5 and interviews with class XII chemistry teachers to analyze needs and obtain information on variations in teaching materials used. The data obtained at the initial stage was used as a guideline in drafting the e-module developed. The following is a discussion of the research that has been conducted by researchers:

4.1 Analysis Stage

At this stage the researchers conducted a needs analysis in the form of distributing questionnaires to students and teacher interviews, as well as analyzing teaching materials. Questionnaires were distributed to 36 students of class XII IPA 5 at SMA Negeri 1 Kisaran to find out their needs for teaching materials. In addition, the needs analysis was also carried out by interviewing the chemistry teacher at State Senior High School 1 Kisaran. From the results of the analysis that has been carried out, the students' needs for teaching materials and some of the problems that occur during the chemistry learning process are illustrated. So, from these problems, researchers can conclude that students and teachers at State Senior High School 1 Kisaran need a solution that can overcome the problems that exist in the school. So that researchers want to present a solution by developing alternative teaching materials in the form of Case Method-Based STEM E-Modules on Carbon and Silicon Materials. The hope is that this e-module can improve students' ability to solve a problem because it is equipped with many cases related to carbon and silicon.

Then after conducting a needs analysis by distributing questionnaires and interviews, the next step is to analyze teaching materials in high school chemistry books. Researchers used 3 books. The book used in class XII IPA 5 State Senior High School 1 Kisaran is B-1 while B-2 and B-3 researchers get it from the internet. Analysis of teaching materials is carried out to determine the completeness of teaching materials used in learning. The three books analyzed have not discussed STEM and case methods. The analysis was carried out by identifying the shortcomings and advantages of teaching materials, then making aspects that will be developed in the e-module.

4.2 Design Stage

After analyzing the needs and analyzing teaching materials, the next stage is the preparation of the initial draft of the e-module. The e-module draft is the initial design or concept used to develop the e-module. Things that need to be considered in the preparation of e-modules are media selection and selection of the format to be used. The e-module cover was designed using the Canva application. Then it was combined into Microsoft Word. The e-module developed was designed using Microsoft Word. After the module preparation stage is carried out, the module is converted into PDF and then converted into an e-module using the Flip PDF Professional application.

4.3 Development Stage

At this stage, the making of the e-module begins. After the module preparation stage is complete, the module will be converted into PDF form and then converted into a flipbook using the Flip PDF Professional application and distributed in the form of a website link. Flip PDF Professional is an application that is able to convert pdf into a digital flipping page publication so that it can create interactive learning content with several supporting features. This application is easy to operate on laptops and mobile devices (Febrianti, 2021). The following is an overview of the e-module display that has been developed:

Figure 1. E-Module Cover and Instructions for Use

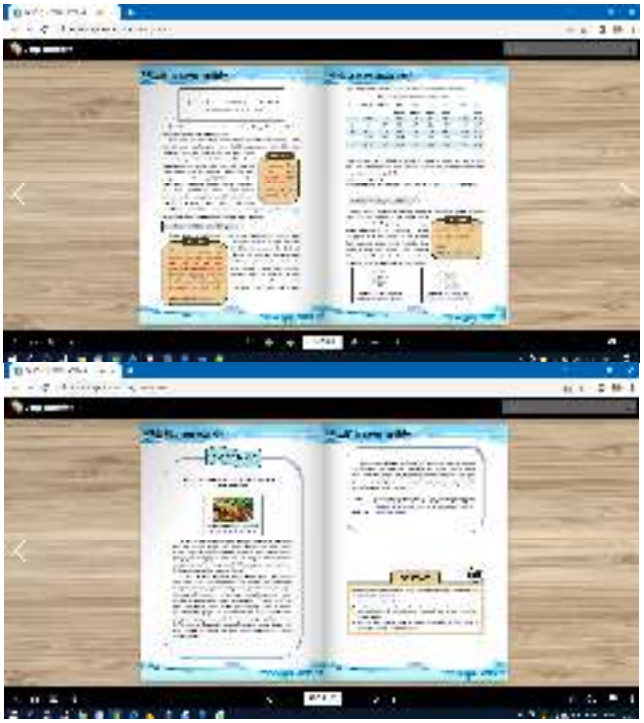

Figure 2. Contents and STEM page

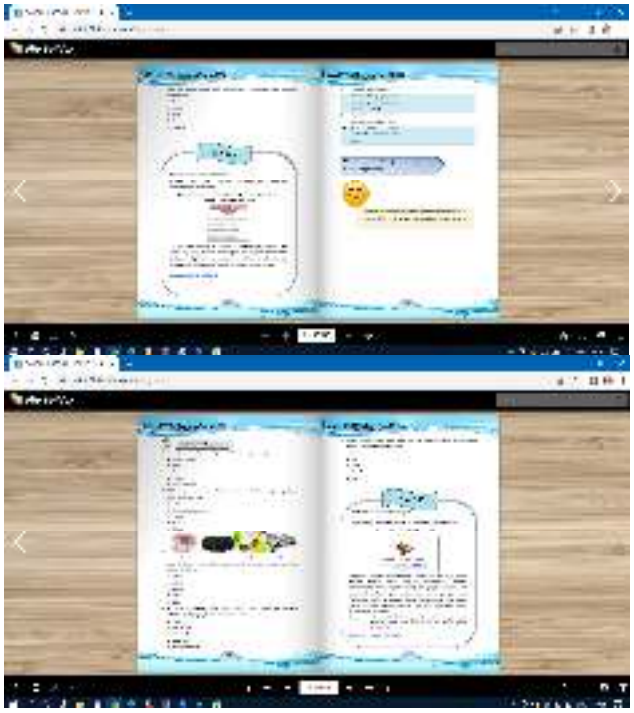

Figure 3. Case and Competency Test

After the e-module was developed, it was followed by the validation process of the e-module by validators. The material expert validity test was given to three chemistry lecturers from Unimed and two chemistry teachers from State Senior High School 1 Kisaran. The calculation of the material expert validation results is listed in Table 5.

Table 5. Material Expert Validation Results

Assessment Aspects	Average Percentage (%)					Average (%)	Criteria for Validity
	V1	V2	V3	V4	V5		
Content Feasibility	91.42	94.28	92.38	92.38	90.47	92.18	Very Valid
Language Feasibility	92.85	94.28	91.42	90.0	90.0	91.71	Very Valid
Presentation Feasibility	92.0	96.0	98.0	94.0	96.0	95.2	Very Valid
Contextual	95.0	87.5	95.5	95.0	950	93.6	Very Valid
Average (%)	**92.81**	**93.01**	**94.32**	**92.84**	**92.86**	**93.17**	**Very High**
Percentage Interpretation							
Criteria for Validity						**Very Valid**	

The results of the material expert validity test obtained an average percentage of 93.17% and included the "Very Valid" category. While the media expert validity test was given to three Unimed chemistry lecturers, one computer science lecturer, one PTIK lecturer, and two SMA Negeri 1 Kisaran chemistry teachers. The calculation of media expert validation is listed in Table 6.

Table 6. Media Expert Validation Results

Assessment Aspects	Persentase Rata-Rata (%)							Average (%)	Criteria for Validity
	V1	V2	V3	V4	V5	V6	V7		
Feasibility of Graphics	91.53	95.38	94.61	96.92	93.07	96.92	94.61	94.72	Very Valid
Word and Language Feasibility	93.33	93.33	95.0	96.66	93.33	96.66	95.0	94.75	Very Valid
E-Module Operation	86.0	96.0	96.0	96.0	96.0	94.0	92.0	93.71	Very Valid
Average (%)	**90.28**	**94.90**	**95.20**	**96.52**	**94.13**	**95.86**	**93.87**	**94.39**	**Very High**
Percentage Interpretation									
Criteria for Validity								**Very Valid**	

The results of the media expert validity test obtained an average percentage of 94.39% and included the "Very Valid" category. During the validation process, researchers obtained assessments and suggestions from validators which were used at the e-module revision stage. The revision aims to obtain a better e-module. The suggestions and input from the validators were typo words in the e-module, improvement of inappropriate cases, pictures on the cover must reflect the contents of the e-module, the logo on the cover must be clear, improvement of inappropriate STEM layout, completeness of the answer key, improvement of image sources, and so on.

E-Modules that have been declared valid are suitable for use in learning (Sakdiah *et al.,* 2020). Based on the average percentage obtained from media experts and material experts, it can be concluded that the e-modules that have been developed are very valid and very suitable for use in the learning process and can be used in the implementation stage at State Senior High School 1 Kisaran.

4.4 Implementation Stage

This stage is carried out through a limited trial using the e-module that has been developed for learning and distributing response questionnaires to 36 students of class XII IPA 5 State Senior High School 1 Kisaran and 1 chemistry teacher of State Senior High School 1 Kisaran. Before entering the class, the researcher gave the valid e-module to the chemistry teacher so that the chemistry teacher could provide a response. At the first meeting, the researcher together with the chemistry teacher entered the class to introduce the e-modules that had been developed. Then, the researcher divided the students into 3 groups and applied the STEM contained in the e-module by making a simple water purification device using charcoal as activated carbon and sand as silicon. The results obtained are water that was initially cloudy becomes clear and clear. After making the tool, students work on enrichment questions by means of group discussions. In addition, students also discuss one of the cases contained in the e-module.

At the next meeting, students presented the results of their group discussions in front of the class. Researchers directed students to use the e-module at home so that students could respond to the e-module. The response questionnaire aims to determine the level of practicality of the e-module. Based on research by Rahayu, *et al.* (2019), teaching materials are easy to use if the responses of teachers and students get practical results. After the researcher together with the chemistry teacher used the e-module in the classroom, students and chemistry teachers were asked to fill out a questionnaire according to their respective opinions based on experiences experienced during learning activities.

The results obtained related to the response of students to the e-module developed were obtained an average percentage of 87.54% and included the category "Very Practical". While the results obtained related to the chemistry teacher's response to the e-module obtained with an average percentage of 97.39% and included the "Very Practical" category. So, it can be concluded that based on the results of the response questionnaire, the e-module developed is classified as "Very Practical" when used in learning, this happens because of the advantages possessed by the e-module developed.

4.5 Evaluation Stage

In making this e-module, researchers experienced obstacles, including (a) the selection of designs and preparation of materials takes quite a long time due to considering several things so that the e-modules developed can be used properly; (b) lack of knowledge about using software to help make this e-module into a flipbook.

This e-Module is an interactive teaching material that can be used in the chemistry learning process. This is because the developed e-module has the following advantages (a) e-modules can be used on smartphones, laptops, and computers; (b) e-modules can be accessed anytime and anywhere; (c) spreading the e-module link is easy,and can be through WhatsApp, Telegram, and email; (d) there is a link that can be accessed directly by simply "clicking" on the link; (e) integrated with STEM (Science, Technology, Engineering, and Mathematics) which can add insight to students' knowledge of the relationship between carbon and silicon in real life; (f) contains cases that must be solved in groups so as to train learner cooperation through discussion; (g) has many other features that can increase students' knowledge. In the development of this e-module, there are shortcomings, namely to access the e-module must use an internet connection.

5. CONCLUSION

5.1 Conclusion

Based on the results of the research and discussion discussed earlier, it can be concluded that the validation of the case method-based STEM e-module on carbon and silicon material is declared "very valid" with an average percentage of material expert validation of 93.17% and media experts of 94.39%. Students' responses to the application of case method-based STEM e-

modules on carbon and silicon materials show that the developed e-modules are "Very Practical" so that they are easy to use in the learning process with an average response percentage of 87.54%. While the response of chemistry teachers to the development of e-modules shows that the e-modules developed are "Very Practical" with an average response percentage of 97.39%.

5.2 Suggestions

Based on the research that has been done, the authors provide suggestions in the hope that the e-modules that have been developed can be even better. The suggestions that researchers can provide for teachers and prospective teachers are advised to use this e-module as an alternative teaching material that can increase the knowledge of students in class XII IPA High School. Then the development of case method-based STEM e-modules can be made on other learning materials, so as to increase students' understanding of chemistry learning. In addition, future researchers can develop E-Modules with other applications so that the features that can be used are far more varied and diverse.

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