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Development of Polymer E-Modules in Solution, Solids, and Amorphous Based on Problem-Based Learning

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ABSTRACT

This research was conducted with the aim to produce E-Modules of polymers in solution, solids, and amorphous based on problem-based learning that are valid, practical and effective. This research used the 4S-TMD (Four Steps Teaching Material Development) research model which consists of four stages, namely selection, structuring, characterization, and didactic reduction. After the material validity test was conducted by two expert lecturers. The target of the research is students of the Chemistry Education Study Program who have taken the Polymer Chemistry course with a total of 28 students. Data collection methods are test and non-test methods. Research instruments, namely interviews, questionnaires and tests Interviews. The material validation score was 0.96; pedagogical validation 1; and design validation 1. The practicality of this E-Module is proven by getting an average score of 95.7%, which is classified as very practical. In addition, the effectiveness test using the N-Gain value reached 0.91 (high category). Based on this value, it shows that the E- Module of polymers in solutions, solids, and amorphous based on problem-based learning has achieved valid practical and effective criteria.

INTRODUCTION

The impact of the pandemic that occurred in 2019 resulted in the implementation of a number of policies to stop the chain of the spread of Corona Virus Disease (Covid-19) in Indonesia. One of the measures applied to the general public is Work From Home (WFH) to be able to accommodate any work that can be done from home. Education in Indonesia is also one of the areas affected by the Covid-19 pandemic (Prawanti & Sumarni, 2020). Due to the lack of interaction due to the pandemic, the Indonesian Ministry of Education has implemented a policy of canceling schools and implementing teaching and learning activities replaced by a networked learning system or online learning (Siahaan, 2020).

Online learning is a learning method in which interaction between educators and students does not occur directly but through the use of technology that supports the teaching and learning process from a distance. The purpose of this network learning is to provide quality, safe, and open learning services to increase students' interest in learning should be more intensive and deeper (Fatmawati, 2020; Kurniati, 2022). With bold learning, students have the freedom of learning time, can learn anytime and anywhere. Students can interact with teachers using several online applications (Dewi, 2020).

Post-pandemic, online learning has a positive impact that can be a reference for the post-pandemic learning system (Ginting et al., 2022). In this case, technology plays an important role during learning and learning activities. In addition, using an online learning system makes students have more flexible time. The majority of students know that they want to maintain the learning system during the pandemic, such as online learning media which may be expected to make it easier for students to access material in more detail and efficiently, because many of today's students are more comfortable with flexible activities (Siregar et al., 2022).

One way of learning that is more flexible is by utilizing technology, one of which is the use of e-modules. E-modules are digital learning materials that are effective and efficient, and increase student motivation in completing learning activities (Lastri, 2023; Sofa et al., 2022). E-modules are one of the innovative teaching materials. As an innovative learning material, e-modules should be made by the educators themselves so that they are in accordance with the characteristics of the students and the learning methods used (Widiana & Rosy, 2021).

Polymer Chemistry is one of the elective courses available in the Chemistry Education study program of Sriwijaya University. This course covers basic aspects of polymer chemistry, including topics such as thermodynamics, kinetics, and polymer structure. This information is based on the results of a needs analysis collected through a questionnaire distributed to 7th semester students in the chemical education study program.The total number of respondents as many as 28 students obtained the results of the questionnaire that polymer material in solution, polymers in solids, and amorphous polymers are quite difficult to understand.

Polymer learning poses its own challenge for students because polymer materials are complex, abstract theories and limitations in the visualization of molecular processes. This can certainly hinder understanding if not addressed immediately. In this context, Problem Based Learning (PBL) can be a solution. PBL is a learning model that processes what students imagine into real problems. The existence of this problem can trigger students to research, describe and solve the problem (Ardianti et al., 2022) PBL will be a learning approach that seeks to apply problems that occur in the real world, as a context for students to practice how to think critically and gain skills for solving problems (Wardani, 2023). Problem Based Learning (PBL) which is packaged in the form of e-modules certainly allows students to face real situations and solve problems comprehensively. E-modules support this process in visualizing abstract concepts to be easier to understand.

The important role of teaching materials in improving learning efficiency, especially in higher education, is undeniable. According to the Guidelines for Writing Textbooks issued by the Ministry of Education, learning materials include all information provided directly by educators to students, which they are expected to understand and master to achieve targeted learning objectives. Therefore, the development of learning materials is very important to improve the quality of education. In more depth, the content of the material is the result of the competency criteria in the curriculum, which must be easy to understand, interesting, and easily accessible (Arsanti, 2018) Creating a supportive learning environment can increase student participation and motivation in studying chemistry (Priyambodo et al., 2021).

Several previous research results show that PBL learning can improve learning outcomes (Farenta et al., 2016; Suswati, 2021). The problem-based learning-based e-modules developed can train students to solve problems(Fitri & Iryani, 2023; Zhafirah et al., 2020). Other research results show that the Problem Based Learning learning model can improve creative, critical, and environmentally conscious thinking skills (Anesa & Ahda, 2021; Aufa et al., 2021; Handayani & Koeswanti, 2021; Tsurayya et al., 2021). Based on some of the results of these studies, the research gap is that the development of e-modules based on Problem Based Learning is still at the primary and secondary education levels. Therefore, it is necessary to develop problem-based learning-based e-modules at the higher education level so that students can have problem-solving skills in real contexts.

METHODS

Research Design

The type of research used is development research (Development Research) with research procedures using the 4S-TMD (Four Step Teaching Materials Development) development model which consists of 4 stages, namely the selection stage, the structuralization stage, the characterization stage, and the reduction stage which can be used to create teaching materials that will be used as teaching materials(Hendri & Setiawan, 2016).

The development research procedure used is the 4S TMD (Four Step Teaching Materials Development) development model. The reason for choosing the 4S TMD development model is because the development of the 4S TMD model processing method is motivated by several things, namely that there are still many textbooks in schools, especially science (chemistry) subjects, which are still not fully in accordance with the demands of the applicable curriculum, especially in the breadth and depth of the material. In addition, there are still many textbooks that are not scientifically correct or misconceptions. This is due to the absence of control from certain parties that ensure the correctness of the concepts described in the textbook. Therefore, the development of the 4S TMD model has several criteria that can be used as a reference in the development process including referring to the applicable curriculum, scientifically correct, developing values and/or skills, structured and systematic, usefulness for students, considering the time available, essential, and easy to understand. By following the procedures from the E-Book published by Sjaeful Anwar entitled Teaching Material Development, the following research steps will be carried out by researchers:

1. Selection Stage

This selection stage is the first stage that must be done from the 4 stages of the 4S TMD method. Based on the book published by Anwar (2015) entitled Teaching Material Development that at this selection stage, the developer must carry out several work steps as follows:

- Material Selection
  Teaching materials to be developed must refer to the content standards in the curriculum (competency standards / basic competencies). This content standard contains concept labels.
- Source Selection
  To be able to develop material from concept labels that have been inventoried, it is necessary to collect from various sources of teaching materials, which can be textbooks, textbooks, journals, magazines, and other sources.
- Context Selection
  The next step is the selection of contexts related to the material to be developed. There are two kinds of contexts that are selected and developed according to the characteristics of teaching materials and the student environment. The two concepts are substance context and pedagogical context.

2. Structuring Stage

The next stage is structuralization. At this stage the draft collection at the selection stage will be structured dictatically according to the characteristics of the teaching material structure. At this stage there are three main things that are part of it, namely making concept maps, macro structures and multiple representations.

3. Characterization Stage

Anwar (2015) explained that this stage was carried out with the consideration that each teaching material has a variety of characters. Based on the level of difficulty, there are teaching materials that have easy or difficult characteristics. Characterization of teaching materials is needed so that teaching materials that are in the difficult category can be processed (packaged) specifically according to the concept of each characteristic. So that in the end the teaching materials produced can be in accordance with the characteristics of students.

4. Didactic Reduction Stage

The last stage is that the teaching material is reduced didactically, which means reducing or simplifying the level of complexity of the material so that the resulting teaching materials can be more easily understood by students.

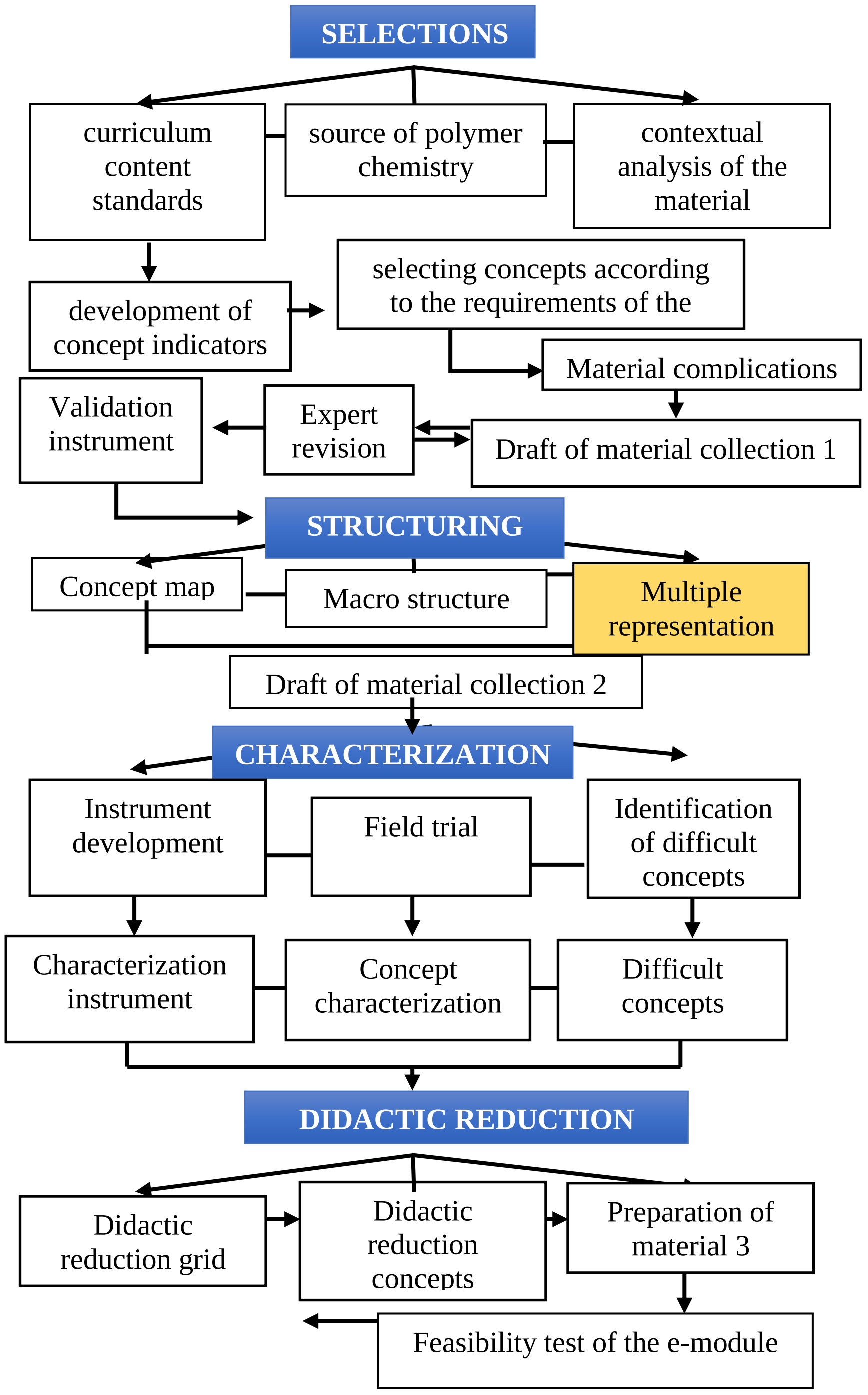

Figure 1. 4S-TMD Research Flow

Research Target

The target of the research is students of the Chemistry Education Study Program who have taken the Polymer Chemistry course with a total of 28 students. The validator consists of two experts. The object of the research is E-Modules for Solution, Solid, and Amorphous Polymers Based on Problem-Based Learning (PBL).

Research Data

The data collection technique carried out by the researcher to develop a Polymer Chemistry E-Module on polymer materials in solution, polymers in solids, and amorphous polymers that are valid, practical, and effective. Data collection methods are test and non-test methods. The non-test method is used to determine student needs, validity and practicality. The test method is used to determine the ability of students.

Research Instruments

Research instruments, namely interviews, questionnaires and tests Interviews were conducted for initial needs analysis to find out the state of the learning process and the need for the development of Polymer Chemistry E-Modules on polymer materials in solution, polymers in solids, and amorphous polymers for Chemistry Education Study Program Students. Interviews were conducted to find out the needs of students for teaching materials and learning methods. In conducting interviews with Polymer Chemistry lecturers, researchers prepared several short questions related to the initial needs analysis to develop the E-Module.

Data collection by filling out a questionnaire sheet conducted at the one-to-one stage. The questionnaire sheet used contains comments and suggestions on the products produced and also an assessment of the practicality of the products that will be given to students. The questionnaire sheet given to students aims to find out the responses of students in order to obtain information on the practicality of using the E-module. The data collection carried out is used as a reference for revision of the product.

Expert validation is carried out at the expert review stage of the data collected by several validation sheet questionnaires containing assessments from validators on design, material, and pedagogical aspects. Giving this questionnaire is done in a Walk Through. The E-Module product design that has been made is given to the expert. Furthermore, the experts commented on the design, material, and pedagogics and then the researchers recorded all the suggestions and comments submitted. This stage aims to determine whether the E-Module product developed is valid or not.

The learning outcomes test was conducted to determine the success rate of students after learning using the Polymer Chemistry E-Module on polymer material in solution, polymers in solids, and amorphous polymers to see the effectiveness of the E-Module that had been developed. This test is based on pretest and posttest scores.

Data Analysis

The results of interviews conducted by researchers at the needs analysis stage at the beginning of the research aim to formulate the background of why it is necessary to develop E-Modules for polymers in solution, polymers in solids, and amorphous polymers based on Problem Based Learning) for Chemistry Education Study Program Students to be implemented at Sriwijaya University Chemistry Education Study Program.

To be able to determine the validity category of the E-Module produced, namely using the Likert Scale measurement scale. Measurement data obtained from the Likert scale measurement results in the form of numbers. The assessment score of each answer choice in the questionnaire with the criteria that can be seen in Table 1.

Table 1. Likert Scale

No.	Categories	Skor
1.	Strongly Agree	4
2.	Agree	3
3.	Disagree	2
4.	Strongly Disagree	1

Source: (Widoyoko, 2018)

The scores obtained from the questionnaire assessment of each validator, namely pedagogical expert validators, material expert validators, and design expert validators will then be converted to determine the percentage of validity of the E-module with the formula used is as follows:

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

Description:
S = r-Io
Io = lowest validity assessment number
c = highest validity assessment number
r = the number given by the assessment

Then the results of the calculation of the percentage of feasibility obtained, then identified into categories according to Table 2 below.

Table 2. Percentage Categories of Validity

Score V	Categories
0,00 – 0,33	Low
0,034 – 0,67	Medium
0,68 – 1,00	High

Source: (Aiken, 1985)

The questionnaire data analysis was conducted simultaneously at the one-to-one stage. The questionnaire sheet assessment of the product is given at the trial stage where the results of the assessment will be used to determine the characterization of difficult concepts and the level of practicality of the E-Module developed. The characterization of difficult concepts and the practicality of the developed product will be seen from the value produced by the assessment questionnaire sheet that has been analyzed by the researcher. The results of the questionnaire sheet that has been filled in, then the percentage is calculated using the following formula:
Difficult Concept Characterization

$$Score = \frac{many\ students\ who\ answered\ (easy\ or\ difficult)}{total\ students\ who\ answered} x\ 100\%$$

Then, the percentage value obtained from the characterization of difficult concepts is converted based on the understandability category in table 3 below:

Table 3. Criteria for Understanding

Total number of students	Category
≤50 %	Difficult
≥50 %	Easy

Source: (Azwar, 2015)

Practical data analysis as follows: $Score = \frac{score\ obtained}{maximum\ score} x\ 100\%$

Afterward, the score obtained is converted based on the practicality category in table 4 below:

Table 4. Practicality Categories

Achievement Level (%)	Category
81-100	Very Practical
61-80	Practical
41-60	Practical Enough
21-40	Less Practical
0-20	Not Practical

Source: (Widoyoko, 2018)

The test was conducted to see the effectiveness of the E-Module that had been developed. The pretest was given at the beginning of the meeting and the posttest was given at the end of the meeting after carrying out learning activities:

$$< g > = \frac{< \%Sf > - < \%Si)}{(100 - < \%Si >)}$$

Description:
g = average of the normalized gain score
Sf = final score (post-test)
Si = initial score (pre-test)
100 = maximum score

Afterward, the N-gain is converted into the gain index category. Table 5 gain score acquisition criteria obtained by students can be observed in the following table.

Table 5. Gain Score Acquisition Criteria

Criteria	Category
$g \geq 0,7$	High
$0,3 \leq g < 0,7$	Medium
$g < 0,3$	Low

Source: (Hake, 1999)

RESULTS AND DISCUSSION

This research was conducted with the aim of developing a product in the form of a valid, practical, and effective problem-based E-Module Polymers in Solutions, Solids, and Amorphous. This research has gone through stages using the 4S-TMD development model which consists of the selection stage, the structuring stage, the characterization stage, and the reduction stage. This development model is the result of the development by Syaiful Anwar. The 4S-TMD development model is used because of the advantages of its systematic and structured approach, providing a thorough framework from the Define to Disseminate stage. This model emphasizes a learner-based approach, focuses on the characteristics and needs of learners, and allows developers to make iterative improvements through a development cycle that can be evaluated and revised at each stage (Hendri & Setiawan, 2016) The following is an explanation of the discussion of the research results:

1. Selection Stage

The selection stage is the first stage of the 4S-TMD development model. At the selection stage, researchers began by analyzing the material to be developed, focusing on the material selection process. The main source of reference in the material selection stage is a book entitled "Polymer Chemistry" written by Sebastian Koltzenburg, Michael Maskos, & Oskar Nuyken, and published by Springer Nature. Furthermore, in the source selection stage, researchers collected and selected the selected materials. The material selection process began by selecting two or more reliable sources, including, journals, websites, books and other sources. This whole process supports the validity and accuracy of the material that will be used in making products in the form of E-Modules Polymers in Solutions, Solids, and Amorphous based on problem-based learning.

2. Structuring Stage

In the structuralization stage, researchers designed microstructures and concept maps to facilitate student understanding of polymer material in solutions, solids, and amorphous. The macro structure of polymer chemistry is divided into three branches of sub-matter, namely polymers in solution, solids, and amorphous. Each of these branches has specific sub-materials. Polymers in solution includes Chain Model, Chain Strength, Entropy Elasticity, and Thermodynamics of Polymer Solutions. Polymers in solids consist of Phase Transitions in Polymer Solids and Methods for Determination of TG and Tm. While amorphous polymers consist of sub-materials Dependence of Mechanical Properties of Polymers on Temperature, Amorphous State, Glass Transition, Factors Affecting Glass Transition Temperature, Rheological Behavior of Polymer Melts, and Viscoelasticity. The purpose of this information collection is to make the learning materials developed more organized and structured, making it easier for students to be more involved in the learning process (Suprihatin, & Manik 2020). Furthermore, concept maps are made to help students group or organize the teaching materials studied and connect each topic with appropriate learning resources (Harahap, 2019).

3. Characterization Stage

At the characterization stage, researchers present the material using simpler language so that it is easy to understand. During this stage, researchers asked for suggestions and comments from material validators. The characterization results provided several suggestions that were taken for improvement, including: the problem orientation section is suggested to cover topics that are more relevant and close to everyday problems, the concept map should cover all the sub-materials discussed in the E-Module, the pictures should include their sources, the material review section is more focused on material reviews related to the problem-based learning topics discussed, there are some images that are still blurry, evaluation questions should be in line with the Sub-CPMK in the module, starting from general material evaluation questions and then heading towards more specific material, the image on the front page of the E-Module is considered less attractive, it is recommended to be replaced with a more attractive image but still related to the content of the material, by paying attention to the proportion of color, shape, and size. After receiving suggestions and comments, the researcher provided a material validation instrument to assess the validity level of the material that had been developed. The results of material validation using Aiken's V formula resulted in a value of 0.96 which is categorized as high based on (Aiken, 1985) indicating that the developed material has passed the validation stage well.

4. Didactic Reduction Stage

At the didactic reduction stage, researchers improved and also refined the concepts that were considered difficult by the material experts. By following the suggestions of the expert, the researcher made reductions so that the material developed could be more easily understood and accepted by students during the learning process. Some of the improvements that have been made include: the problem orientation section has been replaced with topics that are more relevant and closer to everyday problems, concept maps have been added with all the sub-materials in the E-Module, images are included by including the source. the material review section is arranged more concisely according to the topic of the problem-based learning discussed, blurry images are replaced with clearer image quality, evaluation questions are improved according to the Sub-CPMK in the module, the image on the front page of the E-Module is replaced with a more attractive image, adjusted to the proportion of color, shape, and size according to the content discussed in the E-Module. These improvements or refinements are implemented to improve the quality of the material and ensure that the E-Module can be effective in supporting student learning.

The next step in this research is to compile the E-Module using the planned structure. The title of this E-Module is E-Module Polymers in Solutions, Solids, and Amorphous Based on Problem Based Learning. At the beginning of the module, a description of the polymer chemistry course, CPMK, sub-CPMK, objectives, and instructions for using the e-module are presented. The content of the developed e-module adopts problem-based learning with stages ranging from problem orientation, description of polymer material in solution, solids, amorphous, to evaluation. After learning, at the end of the module also contains evaluation questions. At the end of the E-Module polymer in solution, solids, amorphous, based on problem-based learning there is a glossary, and a bibliography containing references used in the development of this E-Module. The next step in the research was the validation test of the developed E-Modules. Researchers asked for suggestions and also input from two validators after completing the 4S-TMD stage to assess whether or not the results were prepared. Expert validation was carried out by validators on the pedagogical and design aspects of the E-Module through the Walk Through method. By using the V'aiken formula to calculate the results of the instrument sheet filled out by two validators. The following are the validator results:

Table 6. Validation Results

Validators	V Aiken	Category
DKS	0,96	High
ARI	0,96	High

After receiving recommendations from DKS validators and ARI validators, researchers made improvements, such as improving the appearance, removing irrelevant information, and enlarging illustrations in the module. After the improvements were made, the researcher gave the validation instrument sheet to the two validators to assess whether the modified E-Module had met the criteria. Therefore, it can be concluded that the E-Module that has been produced can be considered valid because it has met the standards or criteria that have been set in the analysis.

After the E-Module has been declared valid by two validators, the researcher proceeds to the field test stage with students who are research subjects with the criteria of students who have taken the Polymer Chemistry course. Students were given a questionnaire sheet about the practicality of the E-Module after reading it. This limited test involved 28 students, results of the analysis of the practicality questionnaire sheet which shows a percentage value with an average of 95.7% which is considered very practical.

The next step is a learning outcomes test with 28 Chemistry Education students class of 2020. The pretest showed that 37.5% of students initially did not understand polymer material in solutions, solids, and amorphous. However, after conducting PBL-based learning activities with the developed E-Module, the post-test results showed that 95% of students had a strong understanding of the material.

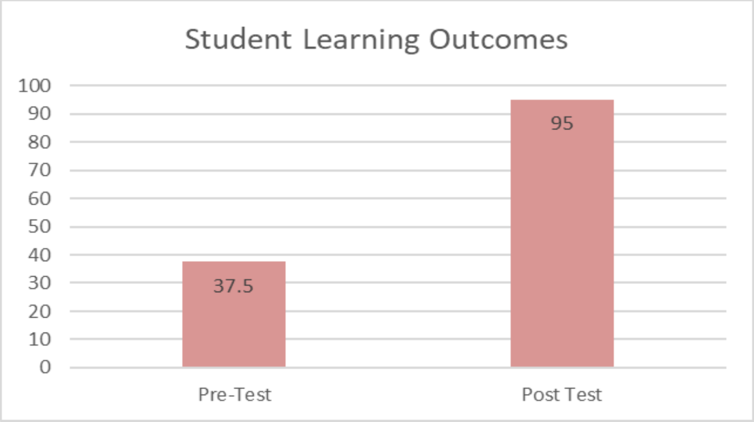

Figure 2. Graph of Pre-Test and Post Test

Based on the graph above, it shows that there is an increase in learning outcomes before and after using e-modules using PBL. The N-Gain result of 0.91 was classified as high, indicating that the E-Module developed by the researcher was effective in improving student learning outcomes, in accordance with the criteria. This indicates the success of the E-Module in delivering PBL-based polymer chemistry material regarding polymers in solution, solids, and amorphous. Learning with PBL-based E-modules can have a positive effect on student learning outcomes (Mahendra et al., 2023; Pramana et al., 2020). With the combination of teaching materials and learning models, this can be used to create innovative learning so that students are motivated to learn (Musaad & Suparman, 2023; Pramana et al., 2020). Through this PBL stage, students can ask questions, provide explanations, carry out investigative activities, create work and draw conclusions (Ismanida et al., 2023; Nia et al., 2022; Tosun & Taskesenligil, 2013)

CONCLUSION AND RECOMMENDATIONS

Based on the E-Module development research that has been carried out, it is concluded that the problem-based Polymers in Solutions, in Solids, and Amorphous E-Modules are valid, practical, and also effective. The validity of this E-Module has gone through material, pedagogic, and design validation tests which resulted in high scores from two validators, namely a material validation score of 0.96 pedagogic validation 1 and design validation 1. In the field trial, the practicality of this E-Module was also well tested as evidenced by getting an average practicality score of 95.7%, which is classified as very practical. In addition, the effectiveness test using the N-Gain value reached 0.91 (high category), proving that this E-Module succeeded in improving student learning outcomes. Thus, this E-Module can be considered as a valid, practical, and also effective learning resource in supporting the learning of polymer materials in solution, solids, and amorphous. Suggestions for further research are to develop teaching materials using PBL in other materials so that students' ability to solve problems that occur in real life increases.

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