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Development of Problem-Based Learning (PBL) Chemistry Modules to Provide Students' Numeracy-Literacy Skills in Materials of Colligative Property Solutions

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ABSTRAK

Pendidikan merupakan salah satu aspek yang perlu ditingkatkan dalam membangun Sumber Daya Manusia (SDM) yang berkualitas. Kehidupan di abad 21 memerlukan keterampilan penting yang harus dikuasai oleh semua orang, terutama siswa agar dapat menghadapi tantangan yang ada. Literasi numerasi merupakan bagian dari literasi dasar dalam kecakapan abad 21 yang perlu dimiliki. Penelitian ini bertujuan untuk mengembangkan modul pembelajaran kimia berbasis PBL untuk membekali keterampilan literasi numerasi siswa pada materi sifat koligatif larutan. Perbedaannya terletak pada isi modul yang dikembangkan, materi, dan kemampuan yang diteliti, dimana belum ada penelitian sejenis sebelumnya yang meneliti tentang pengembangan modul pembelajaran kimia berbasis PBL untuk membekali keterampilan literasi numerasi siswa pada materi sifat koligatif larutan. Pada modul ini sintak PBL digunakan sebagai panduan dalam pelaksanaan pembelajaran (uraian materi, studi kasus, hingga tes formatif literasi numerasi), dan literasi numerasi menjadi acuan muatan yang ingin dimuat dalam modul. Metode yang digunakan dalam penelitian ini adalah metode penelitian dan pengembangan atau Research and Development (R&D). Penelitian pengembangan yang dilakukan mengacu pada model 4D menurut Thiagarajan, yang terdiri dari Define, Design, Development, and Dissemination. Uji coba skala kecil melibatkan 8 orang siswa dari kelas XII MIPA dengan kriteria sudah pernah mempelajari materi sifat koligatif larutan. Uji coba skala besar melibatkan 36 orang siswa kelas XII-E sebagai kelas eksperimen dan 36 orang siswa kelas XII-D sebagai kelas kontrol, yang dipilih menggunakan teknik purposive sampling dengan pertimbangan dari guru. Hasilnya yaitu: 1) modul dinyatakan layak dengan hasil validitas media dan materi 100% (sangat valid) dan hasil keterbacaan dan keterlaksanaan mendapatkan presentase 92% (sangat baik); 2) modul dinyatakan cukup efektif dengan ketuntasan belajar klasikal di kelas XII-E sebesar 50%; dan 3) modul mendapatkan respon yang positif dari guru dan siswa dengan nilai respon guru sebesar 93% dan nilai respon siswa sebesar 78%. Berdasarkan hasil tersebut dapat disimpulkan bahwa modul pembelajaran kimia berbasis PBL layak dan cukup efektif digunakan dalam pembelajaran kimia, khususnya materi sifat koligatif larutan.

ABSTRACT

Education is one aspect that needs to be improved in building quality Human Resources (HR). Life in the 21st century requires important skills that must be mastered by everyone, especially students, in order to face existing challenges. Numeracy literacy is part of the basic literacy in 21st-century skills that must be possessed. This study aims to develop a PBL-based chemistry learning module to equip students with numeracy literacy skills on the topic of colligative properties of solutions. The difference lies in the content of the developed module, the material, and the abilities studied, where no previous similar research has examined the development of a PBL-based chemistry learning module to equip students with numeracy literacy skills on the topic of colligative properties of solutions. In this module, PBL syntax is used as a guide in the implementation of learning (material descriptions, case studies, and formative tests of numeracy literacy), and numeracy literacy becomes a reference for the content to be included in the module. The method used in this study is the Research and Development (R&D) method. The development research conducted refers to the 4D model according to Thiagarajan, which consists of Define, Design, Development, and Dissemination. A small-scale trial involved 8 students from class XII MIPA with the criteria of having studied the colligative properties of solutions. A large-scale trial involved 36 students of class XII-E as the experimental class and 36 students of class XII-D as the control class, selected using a purposive sampling

technique with consideration from the teacher. The results are: 1) the module is declared feasible with the results of media and material validity of 100% (very valid) and the results of readability and implementation getting a percentage of 92% (very good); 2) the module is declared quite effective with classical learning completion in class XII-E of 50%; and 3) the module received a positive response from teachers and students with a teacher response value of 93% and a student response value of 78%. Based on these results, it can be concluded that the PBL-based chemistry learning module is feasible and quite effective for use in chemistry learning, especially the colligative properties of solutions.

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INTRODUCTION

Education is one aspect that needs to be improved in developing quality Human Resources (HR). The 21st-century education is a process of developing and empowering students' potential to shape a better character. In this century, teachers are no longer the sole source of learning; students are also encouraged to explore other learning resources, both through the internet and other media (Rahayu *et al.,* 2022). Life in the 21st century requires essential skills that everyone, especially students, must master to face the challenges ahead (Redhana, 2019). Literacy skills are a key component of 21st-century learning and are not simply defined as the ability to read and write, but rather as the act of understanding, seeking, and mastering information (Widodo *et al.,* 2019).

World Economic Forum (2016) in Laksono *et al.* (2018) stated that there are 16 skills needed by students to survive in the 21st century. These sixteen skills are further grouped into three categories: six basic literacies, four competencies, and six character traits. Numeracy literacy is one of the six basic literacies required for 21st-century skills. Numeracy literacy is the ability to develop knowledge and skills using mathematics in all aspects of life. Numeracy literacy encompasses behavior, positive attitudes, knowledge, and skills. A person cannot be said to possess numeracy skills based on mathematical knowledge alone (Ekawati *et al.,* 2022). However, in reality, students still have not applied numeracy concepts in their daily lives. The results of field studies show that students are not yet ready and are unable to apply numeracy literacy concepts in their daily lives (Rakhmawati & Mustadi, 2022).

Learning in the 21st century focuses not only on knowledge but also emphasizes mastery of character, literacy, skills, and technology (Maulidia *et al.,* 2023). This aligns with the current curriculum, the "Merdeka" curriculum, which emphasizes character as a crucial component of the learning process. The Merdeka Curriculum emphasizes character development in students through the six dimensions of the Pancasila student profile. Numeracy, literacy skills, and character are integrated, mutually supporting and reinforcing. This is because a lack of character can also impact mastery of numeracy literacy skills (Ain *et al.,* 2023).

The learning process needs to be supported or facilitated by supporting teaching materials, one of which is modules. Modules were chosen to support learning activities because they are independent learning packages studied by students individually and contain a collection of structured materials in the form of books whose contents are agreed upon by subject teachers to support learning (Gunawan *et al.,* 2023). Engaging learning media can motivate students to learn chemistry, while maintaining balanced teacher-student involvement. The development of a chemistry learning module based on a model that can equip students to apply numeracy literacy skills to solve everyday problems is deemed necessary. The chosen learning model is problem-based learning (PBL) because it is an approach that can stimulate curiosity, a desire to observe, motivate, and engage students in solving real-world problems (Amir, 2009). Problem-based learning is the most effective model in facilitating mathematical connection skills compared to other learning models (Abidin, 2020). The PBL learning model is also effective in improving students' numeracy literacy skills (Masliah & Nirmala, 2023).

Sari *et al.* (2022) studied the development of a PBL-based module on colloids, resulting in a valid and practical module for use in learning. Masliah & Nirmala (2023) examined the effectiveness of the PBL model on elementary school students' numeracy literacy skills and found that the PBL model is effective in improving students' numeracy literacy skills. Based on the explanation above, although there has been research on the development of PBL-based modules in chemistry, it differs from the current study. The differences lie in the content of the developed module, the materials, and the skills studied. No previous similar research has examined the development of a PBL-based chemistry learning module to equip students with numeracy literacy skills in the colligative properties of solutions. Furthermore, research on numeracy literacy is still low in Indonesia (Rakhmawati & Mustadi, 2022).

Based on the description above, the development of problem-based learning (PBL) chemistry modules to provide students' numeracy-literacy skills in materials of colligative property solutions is necessary to provide innovative learning resources that can help students learn, both in class and independently at home. In this module, PBL syntax is used as a guide in implementing learning (material descriptions, case studies, and formative tests of numeracy literacy), and numeracy literacy becomes a reference for the content to be included in the module. This development research was conducted to determine the level of feasibility, effectiveness, and how teachers and students respond to the use of the module in chemistry learning.

METHODS

The method used in this study was Research and Development (R&D). The development research conducted refers to Thiagarajan's 4D model, which consists of Define, Design, Development, and Dissemination (Sugiyono, 2019). The focus of this research was to develop a chemistry learning module whose feasibility, effectiveness, and teacher and student responses to the learning module were

known.

This research was conducted at SMA Negeri 6 Purworejo through two trial stages: a small-scale trial involving 8 graduating grade XII MIPA students (who had previously learned the colligative properties of solutions) and a large-scale trial involving 36 students from grade XII-E as the experimental class, and 36 students from grade XII-D as the control class, selected using purposive sampling techniques with teacher considerations. Data collection was obtained through: 1) Observation/Interviews; 2) Numeracy literacy skills test instruments (trial questions and implementation phase); 3) Distribution of questionnaire sheets; and 4) Documentation. Data analysis techniques are carried out by knowing: 1) validity (with a likert scale then calculated the percentage) and reliability (using the Rasch method with PCM (Partial Credit Model) model analysis through ministep software) of the numeracy literacy test instrument; 2) module validity is then analyzed using descriptive percentage techniques; 3) student learning completeness in a classical manner through posttest scores to determine the effectiveness of the module; and 4) how teachers and students respond through questionnaires which are then analyzed descriptively by percentage.

RESULT AND DISCUSSION

Result

The results obtained in this study consist of the validity and reliability of the numeracy literacy test instrument, the module's feasibility, as assessed by the validity of the media and materials, the module's readability and implementation, the module's effectiveness, based on student learning outcomes, and teacher and student responses to the module. These results are presented in Tables 1 through 9.

The validity of the test instrument by the expert validator is presented in Table 1.

Table 1. Test Instrument Validation Results

No.	Aspects Assessed	Average Score	Max Score	Results (%)	Criteria
1	Content	2,6	4	65	Valid
2	Constructions	4	4	100	Valid
3	Language and Spelling	4	4	100	Valid
Overall Aspect Average		**3,5**	**4**	**88**	**Valid**

Source: Expert Validation Data

The validation results above indicate that the test instrument created is valid for use with revisions. The reliability values of the trial test items are shown in Table 2.

Table 2 Summary Statistics Results

No.	*Output*	Score	Category
1	*Cronbach Alpha*	0,77	Good
2	*Person Reliability*	0,67	Adequate
3	*Item Reliability*	0,71	Adequate

Source: Data from Testing Analysis

The test results showed a person reliability value of 0.67, indicating that the consistency of students' thinking during the test fell into the sufficient category. The item reliability value of 0.71 was considered sufficient. The summary statistics data values were based on the grouping by (Sumintono & Widiharso (2015). This means that the quality of the test instrument items was good enough to be used.
The module validity from the media expert validator is presented in Table 3.

Table 3 Module Validation Results by Media Experts

No.	Aspects Assessed	Average Score	Max Score	Results (%)	Criteria
1	Presentation	1	1	100	Very Valid
2	Graphics	1	1	100	Very Valid
Overall Aspect Average		**1**	**1**	**100**	**Very Valid**

Source: Qualitative Data Analysis

Table 3 shows that the module's validity in terms of presentation and graphics achieved an average of 100%, categorizing it as highly valid. Therefore, the PBL-based chemistry learning module is suitable for use in terms of media.

The material contained in the PBL-based chemistry learning module was validated by a subject matter expert, a chemistry teacher at SMA Negeri 6 Purworejo. The module's validity from the subject matter expert validator is presented in Table 4.

Table 4 Module Validation Results by Material Experts

No.	Aspects Assessed	Average Score	Max Score	Results (%)	Criteria
1	Content Feasibility	1	1	100	Very Valid
2	Language Feasibility	1	1	100	Very Valid
Overall Aspect Average		**1**	**1**	**100**	**Very Valid**

Source: Qualitative Data Analysis

Table 4 shows that the module's validity in terms of content feasibility and language feasibility has an average percentage value of 100% and is included in the very valid category. Therefore, the PBL-based chemistry learning module is also suitable for use in terms of material. Based on these results, it is shown that in terms of media and material, the module is valid and suitable for use. This result is supported by the findings of Aufa *et al.* (2020) regarding the development of modules using the PBL model, which found that the module was declared valid, practical, and effective for use as a student learning resource.

Student response data regarding readability and implementation were obtained through a questionnaire that had previously been validated by one expert instrument validator, a chemistry lecturer at Semarang State University. The results of the module's readability and implementation tests are presented in Table 5.

Table 5 Module Readability and Implementation Test Results

No.	Aspects Assessed	Average Score	Max Score	Results (%)	Criteria
1	Presentation	3,7	4	93	Very Good
2	Graphics	3,7	4	92	Very Good
3	*Problem Based Learning*	3,7	4	91	Very Good
4	Implementation	3,6	4	89	Very Good
Overall Aspect Average		**3,7**	**4**	**92**	**Very Good**

Source: Quantitative Data Analysis

Table 5 shows that the module's readability and implementation test achieved a score of 92%, meeting the very good criteria. This aligns with the module's readability objective, which is to assess the extent to which the text within the module can be read (Himala, 2017 in Rahima *et al.* (2022). The results of the evaluation value analysis of 36 class XII-E students are presented in Table 6.

Table 6 Learning Completion Results of Class XII-E Students

No.	Learning Outcomes	Total Number
1	Highest Score	93
2	Lowest Score	45
3	Average Class Score	69
4	Number of Students Who Completed the Course	18
5	Number of Students Who Did Not Complete the Course	18
6	Total Number of Students	36
Classical Completion (%)		**50**

Source: Quantitative Data Analysis

The results of the evaluation value analysis of 36 class XII-D students are presented in Table 7.

Table 7 Learning Completion Results of Class XII-D Students

No.	Learning Outcomes	Total Number
1	Highest Score	93
2	Lowest Score	36
3	Average Class Score	57
4	Number of Students Who Completed the Course	7
5	Number of Students Who Did Not Complete the Course	29
6	Total Number of Students	36
Classical Completion (%)		**19**

Source: Quantitative Data Analysis

The analysis results in Tables 6 and 7 show that class XII-E, the experimental class, achieved a classical completion percentage of 50%, which falls within the sufficient criteria. Meanwhile, class XII-D, the control class, achieved a classical completion percentage of 19%, which falls within the very poor criteria. This indicates that classes using the PBL module have higher classical completion rates. This is in line with Fadiana *et al.* (2022), who studied the effect of PBL on students' numeracy literacy skills and found that the problem-based learning model can be applied to improve students'

numeracy literacy skills.

The results of the analysis of teacher responses to the PBL-based chemistry learning module are presented in Table 8.

Table 8 Results of Teacher Response Assessment to the Module

No.	Aspects Assessed	Average Score	Max Score	Results (%)	Criteria
1	Presentation	3,8	4	94	Very Good
2	Graphics	3,4	4	85	Very Good
3	*Problem Based Learning*	3,5	4	88	Very Good
4	Module Benefits	4	4	100	Very Good
Overall Aspect Average		**3,7**	**4**	**93**	**Very Good**

Source: Quantitative Data Analysis

Table 8 shows that the developed module received a 93% rating from a chemistry teacher at SMA Negeri 6 Purworejo, categorizing it as very good.

The student response assessment was completed by 36 grade XII-E students who had learned using the PBL-based chemistry learning module. The results of the student assessments of the module are presented in Table 9.

Table 9 Results of Student Response Assessment to the Module

No.	Aspects Assessed	Average Score	Max Score	Results (%)	Criteria
1	Presentation	3,17	4	79	Very Good
2	Graphics	2,89	4	72	Good
3	*Problem Based Learning*	3,03	4	76	Very Good
4	Module Benefits	3,35	4	84	Very Good
Overall Aspect Average		**3,11**	**4**	**78**	**Very Good**

Source: Quantitative Data Analysis

The table shows that the developed module received a score from 36 students with a percentage of 78% and falls into the very good criteria.

Discussion

Feasibility Results of PBL-Based Chemistry Learning Modules

The feasibility data of the module validity was obtained from the questionnaire instrument score using the Guttman scale, while the feasibility data of the module's readability and implementation test were obtained from the questionnaire instrument score using the Likert scale. Both instruments have been assessed by validators. The feasibility of the PBL-based chemistry learning module was determined through the validity results of the chemistry learning module assessed by two experts and the results of the module's readability and implementation tests obtained from students in a small-scale trial. Media

validation consisted of two aspects, namely the presentation aspect and the graphic aspect. Media validation obtained a percentage result of 100% and entered the very valid criteria. Material validation was also assessed from two aspects, namely the content aspect and the linguistic aspect. Material validation obtained a percentage result of 100% and entered the very valid criteria. The validity results in terms of media and materials indicate that the PBL-based chemistry learning module to equip students with numeracy literacy skills obtained very valid validity results so that it is suitable for use in learning activities.

In line with Fitri (2019) conducted research on the development of a PBL module on the colligative properties of solutions for grade XII high school students and concluded that the module produced using the 4-D development model has a high validity and practicality category. Tafonao *et al.* (2022) also examined the feasibility of the PBL e-module on the colligative properties of solutions and found that the electronic module based on Problem Based Learning (PBL) was generally very suitable for use as a learning medium. Furthermore, before the module was used in a large-scale test, the module was tested on a small scale first. The purpose of implementing the small-scale test was to assess the readability and implementation of the module developed in learning. The module's readability and implementation test obtained a percentage result of 92% and fell into the very good criteria. In accordance with the purpose of module readability, namely the extent to which the text in the module can be read (Himala, 2017 in Rahima *et al.* (2022)).

Effectiveness of PBL-based Chemistry Learning Modules

The effectiveness of the PBL-based chemistry learning module that has been applied in learning activities is known from the classical mastery of student learning from the posttest score. This analysis refers to the set KKTP value of 70. The results of the learning mastery analysis of 36 students in class XII-E obtained 18 students who successfully completed and 18 students who did not complete. The highest score was 93 and the lowest score was 45. The classical mastery result of 50% was obtained from the percentage of the number of students who completed compared to the total number of students in the class in learning colligative properties of solutions. The large percentage includes sufficient criteria in the completion of posttest results but has not reached the minimum limit of classical mastery, which is 80% which can be interpreted that the use of the PBL-based chemistry learning module in learning is still at a fairly effective stage because the percentage of classical mastery of students in class XII-E has not reached 80% as stated by Hobri (2010) in (Ramadhana & Hadi, 2018).

The results of the learning completeness analysis of 36 students in class XII-D showed that 7 students successfully completed the course and 29 students who had not completed it. The highest score was 93 and the lowest score was 36. The classical completeness result was 19% and entered the criteria for completeness of the posttest results very poorly. The large percentage has not reached the minimum

limit of classical completeness, which is 80%, which can be interpreted that in classes that do not use PBL-based chemistry learning modules in their learning, the student learning completeness is different and lower compared to classes that use PBL-based chemistry learning modules. This shows that PBL-based chemistry learning modules have an effect on student learning outcomes. In line with the research of Siregar & Lubis (2022) who examined the use of PBL e-modules on student learning outcomes in the colligative properties of solutions and produced a positive influence on the learning outcomes of high school students. Supported by research from Qomariyah (2019) which stated that the PBL model can improve student learning outcomes in experimental classes that apply the PBL model compared to control classes that apply the conventional model.

Teacher and Student Responses to PBL-Based Chemistry Learning Modules

Teacher and student responses to the PBL-based chemistry learning module were used to determine whether the developed module could be reused in subsequent learning of colligative properties of solutions. The teacher response questionnaire was given to chemistry teachers of SMA Negeri 6 Purworejo who teach in grades XII-E and XII-D. The student response questionnaire was only given to students in grade XII-E which is the experimental class. The teacher response questionnaire and the student response questionnaire each consisted of four aspects, namely presentation, graphics, problem-based learning, and benefits.

All aspects of the teacher response questionnaire received an average score of 3.7 with a 93% result percentage. This means that the teacher's response to the PBL-based chemistry learning module is included in the very good criteria. All aspects of the student response questionnaire received an average score of 3.11 with a 78% result percentage and falls into the very good criteria. This indicates that the PBL-based chemistry learning module received a very good response from students. In accordance with the findings of Alfiantara *et al.* (2016) who also studied the development of PBL-oriented modules, but in this case based on an android application, the resulting module was valid and received a good response from users so that it can be used as a learning resource.

CONCLUSION

The conclusions that can be drawn based on the research results and discussion above are that the PBL-based chemistry learning module to equip students with numeracy literacy skills on the colligative properties of solutions is declared feasible with media and material validity results of 100% (very valid) and readability and implementation results of 92% (very good). The module is declared quite effective with classical learning completion of 50%, and received a positive response from teachers and students with a teacher response score of 93% and a student response score of 78%. This study shows that the PBL-based chemistry learning module is feasible for use in learning, quite effectively influences students' classical learning completion, and receives a positive response from users (teachers & students). Theoretically, these findings contribute by strengthening evidence that the PBL model influences

students' numeracy literacy skills. This study also provides an alternative learning approach that can be used by teachers to improve the quality of numeracy literacy learning in the classroom.

Suggestions that can be conveyed based on this research, namely each topic of learning material should be equipped with direct practicum implementation as much as possible, the application of the problem-based learning model should be carried out with an important role from the teacher in solving student problems, further research is needed regarding the development of learning modules to equip students with numeracy literacy skills with various learning models in other chemical materials or other subjects, and before conducting research, it is important to ensure whether the research steps to be carried out are appropriate according to procedures or not in order to minimize the occurrence of errors and research limitations.

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