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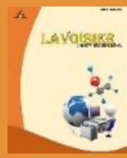

Problem-Based Teaching Material Innovation: Improving Vocational School Students' Learning Outcomes in Element Symbols and Reaction Equations

Silvia Elastari Matondang[1], Putri Junita Sari Nst[2]

[1] Chemistry Education Study Program, Faculty of Teacher and Training, UIN Syekh Ali Hasan Ahmad Addary Padangsidimpuan, Jl. H. T. Rizal Nurdin KM 4.5, Sihitang, Southeast Padangsidimpuan, Padangasidimpuan City, North Sumatera.
[2] STIKes Namira Madina

*Corresponding author: silvia@uinsyahada.ac.id

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Abstract
This study aims to determine the improvement in student learning outcomes by applying innovative teaching materials based on Problem-Based Learning, and to analyse the relationship between student characteristics and chemistry learning outcomes using teaching materials based on Problem-Based Learning. The study was conducted on 72 Grade X vocational high school students using an experimental method with a control class and an experimental class. The results showed a significant improvement in learning outcomes in the experimental class (73%) compared to the control class (69%). There was a significant relationship between characteristics such as curiosity, independence, discipline, hard work, and honesty with improved chemistry learning outcomes on the topics of element symbols and chemical equations.

1. Introduction

The learning process is considered effective and efficient if the teaching materials used are appropriate to the needs of the students, support the competencies to be achieved by the students, have a systematic description, standardised tests, and appropriate learning strategies for the students. (Situmorang et al., 2015). Innovations in instructional materials can serve as a unique attraction for students through the inclusion of illustrations, examples, and problems that utilise computer technology. Learning innovations incorporated into instructional materials can lead to better learning outcomes and character development, as well as improved efficiency and effectiveness in learning toward innovation (Kusuma, 2018).

Many factors cause low student learning outcomes, one of which is thought to be the lack of development and optimal use of teaching materials. Teachers only provide teaching materials in the form of ready-made textbooks that can be used directly, without the need to go through the trouble of creating them. This results in an inefficient learning process in terms of time and an ineffective learning process (Junita et al., 2024). Even in an optimal learning process, the characteristics and potential of each student, such as their talents and interests, must be developed through the teaching process. The differences in student characteristics must be considered and taken into account in teaching and learning activities. Therefore, the learning process at school must be tailored to the characteristics, learning styles, and intelligence of each student (Hanifah et al., 2020).

Vocational High Schools (SMK) are educational institutions that equip their students not only with knowledge but also with life skills. This aims to prepare graduates as workers who can compete in the job market (Yustiandi & Saepuzaman, 2016). State Vocational High Schools (SMK Negeri) are one type of SMK that offers various fields of expertise. Character development of students is one of the pillars of the Ministry of Education and Culture's program. Concerning this, character is a complete personality that reflects harmony and balance. Therefore, in addition to introducing, training, and familiarizing students with TSM (Motorcycle Technology), it is equally important that the developed learning media incorporate elements of character education and social skills, including actively asking questions, being independent in completing tasks, actively sharing ideas or opinions, being a good listener, having a high curiosity about lessons, and collaborating to solve problems (Hanifah et al., 2020).

The development of teaching materials through learning innovation is expected to facilitate teachers in their responsibility to produce students who are competent in science. The product to be obtained in this study is the development of chemistry teaching materials for vocational high school students in Grade 10, Semester 1, that can effectively improve learning outcomes and nurture students' character. The character values to be developed in this research include: 1. Curiosity, 2. Independence, 3. Discipline, 4. Hard work, and 5. The objective of developing chemistry teaching materials for Grade 10 Semester 1 vocational high school students to improve their academic performance in chemistry can be achieved. The objectives of this study are: 4. To determine whether there is a relationship between learning outcomes that include character and students' chemistry learning outcomes taught using the developed chemistry teaching materials.

Problem-Based Learning

Problem-based learning is an approach to learning that begins with solving a problem, but to solve it, students need new knowledge to be able to solve it. The use of learning models fundamentally aids the success of the teaching and learning process. The success of a lesson in the classroom is evident from the progress of the ongoing learning process. Learning will be successful if the teacher can control the classroom, master the teaching material, utilise learning methods, learning models, learning media, and other learning resources that support the success of problem-based learning or what is known as the Problem-Based Learning model.

Problem-based learning is a learning model that emphasises how actively students think critically and skillfully when faced with solving a problem. The process of how students learn depends on the complexity of the problems they face. Problem-based learning was first introduced in 1969 at a medical school called McMaster University in Hamilton, Canada. Since then, many schools and universities around the world have adopted this teaching method, which continues to be used and developed to this day.

Problem-based learning guides students in acquiring new knowledge, using analysis from various sources of knowledge and learning experiences. Students then connect what they have learned with the learning problems given by teachers. Essentially, problem-based learning is developed to provide learning experiences for students. The learning process emphasises students' ability to analyse learning materials independently. By using real-world problems to tackle, students can learn to think critically (Kusuma, 2018). This process also helps them develop problem-solving skills and acquire knowledge independently.

Problem-based learning is carried out by providing stimuli in the form of problems, which are then solved by students, with the aim of improving their skills in achieving and mastering learning materials (Khakim et al., 2022). The Problem-Based Learning model focuses more on learning that is oriented toward problems in the surrounding environment, so that students are trained to solve the problems they face.

According to Khakim et al. (2022), in Wina Sanjaya (2010: 214-215), there are three main characteristics of Problem-Based Learning, namely: a) The Problem-Based Learning (PBL) model is a series of learning activities, meaning that in the implementation of the problem-based learning model, there are some activities that must be carried out by the students. The problem-based learning model does not expect students to merely listen, take notes, and memorise lesson material; rather, through the PBL method, students are expected to think, communicate, search for and manage data, and ultimately draw conclusions. Learning activities are directed toward solving problems. PBL places problems at the centre of the learning process. This means that without problems, there can be no learning process; c) Problem-solving is carried out using a scientific thinking approach. Thinking using the scientific model is a process of deductive and inductive thinking. This thinking process is carried out systematically and empirically. Systematic means that scientific thinking is carried out through certain stages (Pratiwi et al., 2014), while empirical means that the problem-solving process is based on data and facts.

The characteristics of the Problem-Based Learning model are generally oriented towards problems given by teachers to students, who then discover the nature of the problems themselves. Once the problems are identified, students are trained to solve the problems they face by thinking about possible solutions. Problem-Based Learning (PBL) begins with a problem that can be posed by either the students or the teacher. The students then deepen their understanding of what they already know to solve the problem.

Students can also choose problems that they find interesting to solve, so that they are encouraged to take an active role in the learning process. The role of the teacher in applying this model is to guide students to be able to solve each problem that has been identified (Wijoyo & Haudi, 2021).

Student Character

According to the Big Indonesian Dictionary, character is the psychological traits, morals, and manners that distinguish one person from another. Character is the unique values embedded within oneself and manifested in behaviour. Character coherently emanates from the results of one's or a group's patterns of thought, emotions, feelings, and intentions, as well as physical exercise. (Ansori, 2020) Character in English: “character” in Indonesian “karakter”. Derived from the Greek words character and charassain, which mean to sharpen or to make sharp, in Poerwardarminta's dictionary, character is defined as disposition, temperament, psychological traits, morals, or manners that distinguish one person from another. The name for the totality of personal traits, including things like behaviour, habits, likes, dislikes, abilities, potential, values, and patterns of thought (Nurhasanah et al., 2022).

The Ministry of National Education has formulated 18 character values to be instilled in students as part of efforts to build national character. These 18 character values have been aligned with general educational principles, making them more practical for implementation in educational practice, both in schools and madrasahs. However, the research will assess five specific character traits, namely: a. curiosity, b. independence, c. discipline, d. hard work, e. honesty.

2. Methods

This study was conducted in Mandailing Natal Regency, North Sumatra, during the odd semester and was an experimental study using developed chemistry teaching materials. The samples were divided into experimental and control classes. Before using the developed chemistry teaching materials, a pretest was conducted to determine the initial abilities of students in both the experimental and control classes (Wahab & Rosnawati, 2021). Teaching was then conducted using innovative chemistry teaching materials for the experimental class and school textbooks for the control class. Student learning outcomes were obtained from an evaluation test conducted at the end of the teaching period. Before the test was conducted, the validity, reliability, discriminative power, and difficulty level of the instrument were tested. Student character development was studied during the learning process by an observer and using a questionnaire (Hanifah et al., 2020). Character traits were shared with students at the end of the learning process using measurements conducted through observation based on a character assessment rubric developed based on indicators such as curiosity, independence, and hard work.

3. Results and Discussions

Before conducting the research, 40 multiple-choice questions with five options (a, b, c, d, and e) were prepared. To be used as a research instrument, the questions were analysed for validity, reliability, difficulty level, and discriminating power. The test was administered to 30 students in the 11th grade of a vocational high school. The results of the test are as follows:

Test Instrument Validation

Validity testing is an effort to determine the extent to which the test measures what it is intended to measure. The validity of the test instrument was calculated using the product-moment correlation formula (Appendix 11) with the condition that if rhitung > rtabel at $\alpha = 0.05$ with n = 40, the question is considered valid, and conversely, if rhitung < rtabel, the question is considered invalid. Based on the validity table, out of the 40 questions tested, 23 were valid, while 17 were invalid.

Test Instrument Reliability

Reliability is the stability/dependability/consistency of a measuring instrument, so that when the instrument is used, it always produces consistent results. This reliability test is determined using the Kuder & Richardson (KR-20) formula. Based on the reliability calculation of the test (Appendix 12), the overall reliability of the test (rhitung) was 0.862. When compared with rtabel = 0.361, rhitung > rtabel at $\alpha = 0.05$ with n = 40, the questions in the test instrument of this study are reliable.

Test Instrument Discrimination Power

The ability of a question to distinguish between students with high ability and those with low ability can be measured by the discrimination power of the test instrument. Based on the discrimination power calculation, 15 questions were categorised as having poor discrimination power, 18 questions were categorised as having adequate discrimination power, 7 questions were categorised as having good discrimination power, and no questions were categorised as having very good discrimination power.

Test Instrument Difficulty Level

A good question is neither too difficult nor too easy. Based on the difficulty level calculation (Appendix 14), there were 3 questions categorised as difficult, 31 questions categorised as moderate, and 6 questions categorised as easy.

Before the two samples were given different treatments, an initial test was administered to determine the initial abilities of each student in both classes. Subsequently, different learning methods were implemented: the experimental class was taught using the Problem-Based Learning model with chemistry teaching materials developed by the researcher, while the control class was taught using the Problem-Based Learning model without the developed chemistry teaching materials. At the end of the learning process, a final test was administered to assess the students' learning outcomes. The results of the study, analysed using SPSS 21 for Windows, are presented in Table 1.

Table 1. The results of hypothesis testing using SPSS 21 for Windows were obtained using an independent sample test.

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	**Sig. (1-tailed)**	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pretest	Varians yang sama diasumsikan	2.96	.090	2.38	70	**.020**	4.58	1.922	.750	8.417
	Varians yang sama tidak diasumsikan			2.38	66.5	**.020**	4.58	1.922	.746	8.420
Postest	Varians yang sama diasumsikan	.005	.941	2.98	70	**.004**	4.86	1.628	1.613	8.109
	Varians yang sama tidak diasumsikan			2.98	69.9	**.004**	4.86	1.628	1.613	8.109
Gain	Varians yang sama diasumsikan	.066	.797	2.73	70	**.008**	.053	.019	.014	.092
	Varians yang sama tidak diasumsikan			2.73	69.5	**.008**	.053	.019	.014	.092

From the data in the table above, the test results obtained Sig. (1-tailed) < α (0.008 < 0.05) with a one-tailed T-test, it can be concluded that the first hypothesis is accepted. This means that the learning outcomes of students taught using chemistry teaching materials on element symbols and reaction equations developed in the Problem-Based Learning model are better than the learning outcomes of students taught using the Problem-Based Learning model without the developed chemistry teaching materials.

Measurements of student character were conducted through observation by an observer during the learning process and using a character questionnaire distributed to students at the end of the learning process conducted in the experimental class, as shown in Table 2.

Table 2. Correlation test results using SPSS 21 for Windows

Correlations							
		Rasa ingin tahu	Mandiri	Disiplin	Kerja keras	Jujur	Postest
curiosity	Pearson Correlation	1	.598**	.126	.531**	.476**	.404**
	Sig. (1-tailed)		.000	.232	.000	.002	**.007**
	N	36	36	36	36	36	36
independence	Pearson Correlation	.598**	1	.536**	.569**	.626**	.377*
	Sig. (1-tailed)	.000		.000	.000	.000	**.012**
	N	36	36	36	36	36	36
discipline	Pearson Correlation	.126	.536**	1	.146	.208	.339*
	Sig. (1-tailed)	.232	.000		.198	.111	**.021**
	N	36	36	36	36	36	36

hard work	Pearson Correlation	.531**	.569**	.146	1	.812**	.289*
	Sig. (1-tailed)	.000	.000	.198		.000	**.044**
	N	36	36	36	36	36	36
honesty	Pearson Correlation	.476**	.626**	.208	.812**	1	.348*
	Sig. (1-tailed)	.002	.000	.111	.000		**.019**
	N	36	36	36	36	36	36
Postes Eks_1	Pearson Correlation	.404**	.377*	.339*	.289*	.348*	1
	Sig. (1-tailed)	**.007**	**.012**	**.021**	**.044**	**.019**	
	N	36	36	36	36	36	36

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

The table above shows that the criteria used in testing with SPSS 21 for Windows are that if Sig. (1-tailed) < α, then Ha is accepted, but if Sig. (1-tailed) > α, then Ha is rejected. From the test results, Sig. (1-tailed) < α (0.007 < 0.05) was obtained for the Curiosity character, Sig. (1-tailed) < α (0.012 < 0.05) for the Independent character, Sig. (1-tailed) < α (0.021 < 0.05) for the Discipline trait, Sig. (1-tailed) < α (0.044 < 0.05) for the Hardworking trait, and Sig. (1-tailed) < α (0.019 < 0.05) for the Honesty trait. Therefore, it can be concluded that the hypothesis is accepted. This means that there is a relationship between learning outcomes that include character traits and the chemistry learning outcomes of students taught using the developed chemistry teaching materials.

Thus, it can be seen that the use of chemistry teaching materials that have been developed is effective in improving student learning outcomes. This aligns with the findings of a study (Pratiwi et al., 2014) on the development of innovative chemistry textbooks for 11th-grade students in the second semester of senior high school/madrasah aliyah, which revealed that teaching using innovative chemistry textbooks can improve learning outcomes by an average of 74.24%, while teaching with student workbooks improves learning outcomes by an average of 73%. This is in line with the results obtained (Salim Efendi: Development of Innovative Chemistry Teaching Materials on Solutions Based on the 2013 Curriculum Integrated with Character Education. Thesis. Medan: Chemistry Education Program, Postgraduate Program, University of North Sumatra, 2015. This study aims to determine, 2015) the development of innovative chemistry teaching materials based on the 2013 curriculum integrated with character education resulted in an increase in student learning outcomes in Experiment Class I with the implementation of innovative chemistry teaching materials, which was 64%, while in Experiment Class II without the implementation of innovative chemistry teaching materials, it was 57.6%. Furthermore, Leny Novita (2015) developed innovative chemistry textbooks using the Project-Based Learning (PJBL) model based on the 2013 curriculum, which resulted in an increase in the chemistry learning outcomes of students at Hang Tuah Belawan High School in the experimental class using innovative chemistry textbooks by 52% and an increase in the learning outcomes of the control class without using innovative chemistry textbooks by 36%.

This is in line with the opinion (Wibawa, 2014) that learning is any relative change in behavior that occurs as a result of practice and experience. So learning is not a goal but a process to achieve a goal. Therefore, students will gain experience by going through the steps or procedures of the learning process. The results of the above study indicate that the implementation of chemistry teaching materials using element symbols and reaction equations, which have been developed as an alternative approach to chemistry education, is quite interesting, aspirational, innovative, and effective. This is evident from the research findings, which show that the implementation of the developed chemistry teaching materials significantly enhances chemistry learning outcomes. The average normalized gain in chemistry learning outcomes for students who learned using the developed chemistry teaching materials on element symbols and reaction equations was 0.73, while the normalized gain for students who learned without the developed chemistry teaching materials on element symbols and reaction equations was 0. 69 in the Problem-Based Learning model in the subject of element symbols and reaction equations in the first semester of grade X vocational high school.

In addition to cognitive learning outcomes, affective/character values have also been well developed from the book that has been developed. The characters tested were curiosity, independence, discipline, hard work, and honesty. Based on the results of hypothesis testing conducted using correlation analysis. The criteria applied in data testing using SPSS 21 for Windows are that if Sig < α, then Ha is accepted, but if Sig > α, then Ha is rejected. From the test results, Sig < α (0.007 < 0.05) was obtained for the trait of curiosity, Sig. < α (0.012 < 0.05) for the trait of independence, Sig. < α (0.021 < 0.05) for the trait of discipline, Sig. < α (0.044 < 0.05) for the Hardworking trait, and Sig. < α (0.019 < 0.05) for the Honest trait. Therefore, it is concluded that the second hypothesis is accepted. This means there is a relationship between learning outcomes that include character traits, particularly in the affective domain, and the chemistry learning outcomes of students taught using the developed chemistry teaching materials.

This is in line with what was stated by (Hanifah et al., 2020) that individuals with high individual character tend to learn better, can monitor, evaluate, and manage their learning effectively, save time in completing their tasks, manage their learning and time efficiently, and achieve high scores in science.

It turns out that having good character development is believed to be important in strengthening individual motivation to achieve and obtain maximum learning outcomes. The materials developed in this study are very effective in fostering such character. The results of the study show that the teaching materials developed can improve both cognitive and affective learning outcomes. Therefore, this study has identified a book that is highly effective in improving student learning outcomes, including cognitive and affective/character scores. The teaching materials developed in this study are able to meet the learning objectives based on the curriculum.

5. Conclusions

There is a significant difference in the learning outcomes of students who were taught using the teaching materials developed in this study, which include chemical symbols and reaction equations, compared to the learning outcomes of students who were not taught using these materials. There is a significant relationship between learning outcomes that include character and the chemistry learning outcomes of 10^{th}-grade vocational high school students in the first semester who were taught using the chemistry teaching materials developed in this study, which include element symbols and chemical equations, within the Problem-Based Learning model.

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