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Inquiry Based Learning STEM Teaching Materials to Improve Students' Thinking Skills in Stoichiometry

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Abstract

In stoichiometry learning process, mostly educators focus on calculations. Students are not invited to think more critically about stoichiometry application in life. This constraint makes teachers have to develop new learning models, including Inquiry Based Learning (IBL) model, and Science, Technology, Engineering, Mathematics (STEM) based on chemical literacy. This study aims to develop general chemistry teaching materials on stoichiometry using IBL and STEM models based on chemical literacy that are feasible (valid) and capable of improving students' LOTS and HOTS abilities. The development model used is the ADDIE model, with research subjects of 34 students. The result shows that stoichiometry teaching materials using the IBL STEM model based on chemical literacy are valid (feasible) to be applied in learning with an average score of 4.42 for the material aspect and 4.55 for the design aspect. The developed teaching materials have been proven to significantly improve students' LOTS and HOTS abilities.

Keywords: inquiry-based learning, STEM, stoichiometry, thinking skills

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1. Introduction

The development of science and technology, especially in the field of communication and information in the 21st century has led to intense competition for life in the current era of globalization, so it requires students, especially students, to be able to hone skills and improve their learning to be able to overcome global challenges, such as critical thinking skills, the ability to communicate effectively, innovate and solve problems through negotiation and collaboration (Panggabean et al., 2021). From birth, humans use their thinking abilities to answer various challenges around them, both natural, cultural, and social (Kristiyono, 2018). There are two levels of thinking skills in education, Low Order Thinking Skills (LOTS) and High Order Thinking Skills (HOTS) (Sutrisno et al., 2018). LOTS is usually associated with the process of recalling information or applying concepts to familiar contexts and situations. While HOTS is used to solve new, unusual problems, it requires evidence and explanation and relates one concept to another to solve it (Firdausi, 2014). Armala et al. (2022), explained that to move to HOTS abilities students must have LOTS abilities.

Chemistry is included in the science family and is a branch of natural science that includes concepts, rules, laws, principles, and theories (Panggabean et al., 2022). This is a tool to achieve goals and train students to have both LOTS and HOTS thinking skills, especially critical thinking skills. Chemistry material and critical thinking skills are two things that cannot be separated, because chemical material is understood through critical thinking and vice versa critical thinking can be trained through learning chemistry.

The abilities and thinking skills possessed by each individual are certainly different, depending on the exercises that are often carried out to develop them. An educator including lecturers is also required to be able to design learning that is oriented towards active student involvement and is expected to stimulate students to be able to think and solve the problems they face (Purba et al., 2021).

Strategies to improve critical thinking skills are very urgent for students, this includes scientific activities such as asking questions, making statements, choosing the right choices, and making decisions in chemical experiments (Sutiani et al., 2021). One alternative learning strategy or model that can be applied to improve students' thinking skills, including in chemistry learning, is the inquiry-based learning (IBL) model. The IBL model is a series of learning activities that emphasize the active involvement of students to have learning experiences in discovering material concepts based on the problems posed (Suhada, 2017). The IBL model can also be interpreted as a series of learning activities that emphasize the process of thinking critically and analytically to seek and find answers to a problem in question (Rodiyana, 2015). Then involve students in problem formulation, making hypotheses, collecting and analyzing data, and making conclusions from existing problems (Puspita et al., 2022). Several studies also show that the IBL model has an effect and can improve critical thinking skills (Julianda et al., 2018), improve creative thinking skills (Rodiyana, 2015), improve science process skills (Suhada, 2017), increase HOTS abilities (Puspita et al., 2022; Izzatin & Nurmala, 2018; Fadillah et al., 2022), improve student learning outcomes (Firdausi, 2014; Cahyani et al., 2018), improve students' understanding of mathematics (Anastasha, 2020), and can develop students' 21st-century skills (Aji, 2019).

According to Rachmawati et al. (2017), the fields of Science, Technology, Engineering, and Mathematics (STEM) can prepare students to be able to think critically and competently in dealing with today's rapid developments in science and technology. In line with that, Irmita (2018) said that STEM can develop if it is associated with the environment so that learning is realized and presents the real world that students experience in everyday life. Several studies also show that the STEM approach can improve students' critical thinking skills (Lestari et al., 2018; Ariyatun & Octavianelis, 2020; Santoso & Arif, 2021; Atlanta & Puspita, 2021; Fadlina et al., 2021), improve skills think creatively (Fitriyah & Ramadani, 2021), and be able to improve student learning outcomes (Melina, 2022; Rahayu & Sutarno, 2021).

The term literacy cannot be separated from critical thinking skills, besides that, activity is very important in learning because it can help improve student achievement (Chasanah et al., 2020). According to Afandi et al. (2016), literacy skills are emphasized on literacy skills that are connected in the digital era as it is today. In line with that, Wahyuni and Yusmaita (2020) said that chemical literacy relates to how students can appreciate nature by utilizing the science/chemistry and technology they master. So that chemical literacy can be used as a forum for students to practice higher-level thinking where students associate it with everyday phenomena (Riyadi et al., 2018). The results of research by Alviah et al. (2020) also show that chemical literacy skills can improve students' HOTS abilities.

2. Research Method

The LOTS indicators in this development research include cognitive aspects at levels C1 (remembering), C2 (understanding) and C3 (applying). Meanwhile, the HOTS indicator includes cognitive aspects at levels C4 (analyzing), C5 (evaluating) and C6 (creating).

This research is a type of research and development (R&D) with 34 students as research subjects. The development model used refers to the ADDIE development model, shown in Figure 1 below.

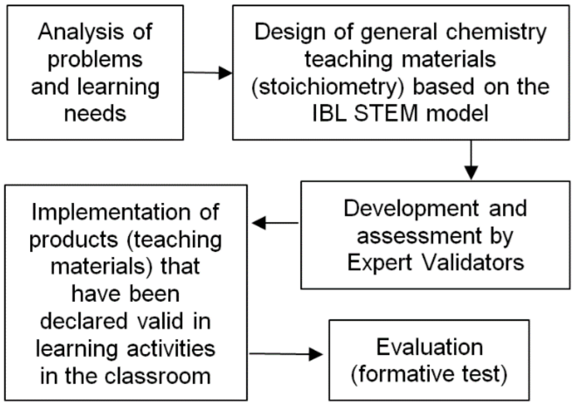

Figure 1. Research Flow Diagram

Research data were collected through interviews, expert validation sheets, and the LOTS and HOTS test instruments in the form of multiple choices, each with 20 questions that met the valid and reliable criteria. Interviews are used to obtain input and suggestions from expert validators regarding the teaching materials being developed. Expert validation sheets are used to obtain data on the validity of the teaching materials being developed. The test instrument is used to obtain data on student learning outcomes in stoichiometry material. The data obtained is in the form of qualitative and quantitative data. Feasibility (validity) of general chemistry teaching materials (stoichiometry) using the IBL STEM model based on chemical literacy was analyzed based on the results of expert validation (validator) taking into account input, comments, and suggestions from expert validators. The effectiveness and improvement of students' LOTS and HOTS abilities were obtained based on the results of tests completed by students and analyzed using a paired sample t-test approach with the help of the SPSS program.

3. Result and Discussion

The product developed in this research and development is in the form of General Chemistry teaching materials using the IBL STEM model based on Chemical Literacy. General Chemistry teaching materials using the IBL STEM model based on Chemical Literacy are compiled and developed on stoichiometry material to facilitate lecturers and students in the General Chemistry learning process.

Stoichiometry material developed includes sub-material on Basic Laws of Chemistry, Relative Atomic Mass (Ar) and Relative Molecular Mass (Mr), Mole Concept, Compound Nomenclature, Empirical Formulas and Molecular Formulas, Chemical Formulas for Hydrate Compounds, Writing Reaction Equations, Limiting Reagents, Reaction Efficiency, as well as the Mixed Reaction Equations sub-material. The teaching materials designed include cover (title and identity), foreword, table of contents, competencies and material descriptions using the IBL STEM model based on chemical literacy, practice questions, evaluation, bibliography, and glossary.

The validation or feasibility of teaching materials is evaluated by an expert validator in their field. The resulting teaching material products have been declared valid (proper) by expert validators and then applied to students to analyze the effectiveness of the resulting teaching materials.

3.1. Feasibility of Teaching Materials

Feasibility (validity) of General Chemistry teaching materials stoichiometric material using the IBL STEM model based on chemical literacy developed was evaluated and assessed by expert validators based on the eligibility of the material and the eligibility of the media.

Table 1. Validation Results of Teaching Materials on the Material Aspect

Assessment Aspects	Average Score	Criteria
Content material	4.38	Valid
Presentation of material	4.21	Valid
Language	4.39	Valid
Use of learning models	4.80	Valid
Evaluation and assessment	4.33	Valid
Total average	**4.42**	**Valid**

Table 1 shows the results of the material expert validation obtained an average total score of 4.42 or was declared to have met the valid criteria. Based on the results of the material expert validator's assessment, it was concluded that General Chemistry teaching materials on stoichiometric material using the IBL STEM model based on chemical literacy are classified as valid from the material aspect and are feasible to be applied in the learning process.

Table 2. Validation Results of Teaching Materials on the Media Aspect (Design)

Assessment Aspects	Average Score	Criteria
Graphics	4.54	Valid
Language	4.56	Valid
Total average	**4.55**	**Valid**

Table 2 shows the results of the validation of media experts (design) obtained an average total score of 4.55 or declared to meet valid criteria. Based on the results of the media expert validator's assessment it was concluded that General Chemistry teaching materials on stoichiometric material using the IBL STEM model based on chemical literacy are classified as valid from the media aspect (design) and are feasible to be applied in the learning process.

3.2. Achievement of Students' LOTS and HOTS Abilities

The achievement of students' LOTS and HOTS abilities was obtained through tests given before (pretest) and after utilizing General Chemistry teaching materials using the IBL STEM model based on chemical literacy. The application of the resulting teaching materials was carried out to 34 students and carried out in three stages: (1) the initial stage, the initial test (pre-test) before students were given action; (2) the second stage, the learning process in which students used Chemistry teaching materials. In general, stoichiometric material uses the IBL STEM model based on chemical literacy that has been produced, and; (3) the third stage, which is the final test (post-test).

Table 3 shows the results of the student pretest before being given the action obtained an avera ge LOTS value of 51.32 ± 8.286 and the data has a normal distribution (p = 0.078), and the average student HOTS pretest achievement was 58.09 ± 9.130 and the data had a normal distribution (p = 0.081). After being given the action by utilizing General Chemistry teaching materials on stoichiometry using the IBL STEM model based on chemical literacy, the results of the LOTS posttest obtained an average LOTS score of 84.26 ± 8.084 and the data had a normal distribution (p = 0.074); for the achievement of the HOTS posttest results, the average HOTS score for students was 81.32 ± 8.101 and the data had a normal distribution (p = 0.085).

Table 3. Achievement of Students' LOTS and HOTS Abilities

	LOTS		HOTS	
	Pretest	**Posttest**	**Pretest**	**Posttest**
N	34	34	34	34
Min	35	65	40	65
Max	70	100	75	95
Mean	51.32	84.26	58.09	81.32
St.Dev	8.286	8,084	9.130	8.101
KS test	0.142	0.143	0.142	0.141
Sig.	0.078	0.074	0.081	0.085

3.3. The Effectiveness of Teaching Materials

The effectiveness of General Chemistry teaching materials on stoichiometry using the IBL STEM model based on chemical literacy is analyzed from the increase in students' LOTS and HOTS results in completing tests using the pretest-posttest design. The effectiveness of increasing student LOTS and HOTS was analyzed using a paired sample t-test approach using the SPSS program.

Table 4. The Results of the Effectiveness Test of Teaching Materials

	Paired Differences		t	sig
	Mean	***St. Dev***		
LOTS	32.941	11.018	17.434	0.000
HOTS	23.235	9.445	14.344	0.000

Table 4 shows that the students' LOTS data obtained a t_{count} of 17.434 with a probability (sig.) of 0.000 < 0.05; while for students' HOTS data, a t_{count} value of 14.344 is obtained with a probability (sig.) of 0.000 < 0.05. Thus it was concluded that the implementation of General Chemistry teaching materials on stoichiometric material using the IBL STEM model based on chemical literacy produced proved effective in increasing students' LOTS and HOTS abilities with a difference in the average LOTS score (posttest-pretest) of 32.941 ± 11.018; and the difference in the mean value (posttest-pretest) of HOTS is 23.235 ± 9.445.

The product developed in this research and development is in the form of General Chemistry teaching materials on stoichiometry material using the IBL STEM model based on chemical literacy and refers to material aspects and media (design) aspects. The results of the expert and practitioner validator's assessment of General Chemistry teaching materials using the IBL STEM model based on chemical literacy developed have been declared valid and feasible to implement in the learning process. The validity of General Chemistry teaching materials was fulfilled qualitatively based on the assessment of material expert validators and media expert validators (design) which as a whole were stated in the valid category.

The implementation of General Chemistry teaching materials on stoichiometric material using the IBL STEM model based on chemical literacy has also proven effective in increasing students' LOTS and HOTS abilities. The effectiveness was met statistically based on the increased ability of students' LOTS and HOTS in completing the tests carried out. Student responses to General Chemistry teaching materials using the IBL STEM model based on chemical literacy produced are also very positive.

The research findings are in line with previous research which states that the IBL model is influential and can improve critical thinking skills (Julianda et al., 2018), improve HOTS abilities (Puspita et al., 2022; Izzatin & Nurmala, 2018; Fadillah et al., 2022), and improve student learning outcomes (Firdausi, 2014). The STEM approach can improve students' critical thinking skills (Lestari et al., 2018; Ariyatun & Octavianelis, 2020; Santoso & Arif, 2021; Atlanta & Puspita, 2021; Fadlina et al., 2021), and is able to improve student learning outcomes (Melina, 2022; Rahayu & Sutarno, 2021).

The findings of this research and development have implications for lecturers that improve learning outcomes as well as students' LOTS and HOTS abilities, it can be done by developing innovative learning and one of them is by developing teaching materials using the IBL STEM model based on chemical literacy. General Chemistry teaching materials using the IBL STEM model based on chemical literacy can help students improve their understanding, mastery, and fundamental skills (LOTS) and higher-order thinking skills (HOTS).

4. Conclusion

This research and development produced General Chemistry teaching materials (books) on stoichiometry material using the IBL STEM model based on chemical literacy. General Chemistry teaching materials using the IBL STEM model based on chemical literacy were developed through the ADDIE development model and have been declared valid (feasible) and proven to be effective in increasing students' LOTS and HOTS abilities. Validity (feasibility) is met qualitatively based on the assessment (validation) of the validators of material experts and media experts who are overall declared in the valid category. Effectiveness is fulfilled based on the implementation of General Chemistry teaching materials using the IBL STEM model based on chemical literacy in the learning process and is proven from the results of statistical hypothesis testing with a probability value of < 0.05. The increase in students' LOTS and HOTS abilities is also evidenced by the increase in student learning outcomes before and after utilizing General Chemistry teaching materials on stoichiometry material using the resulting chemical literacy-based IBL STEM model. The average increase or difference in student LOTS pretest-posttest scores was 32.941 ± 11.018, and the average increase or difference in student HOTS pretest-posttest scores was 23.245 ± 9.445.

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