Development of IBL STEM Model Based on Chemical Literacy to Improve Students‘ LOTS and HOTS Abilities

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Abstract. In part to the speed at which science and technology are developing, lectures must be able to equip students to think both higher level (HOTS) and fundamentally (LOTS). The science category includes chemistry, which can be utilized to help pupils develop their LOTS and HOTS skills. The goal of this study is to provide practical (valid) general chemistry teaching resources (books) on stoichiometry that enhance students' LOTS and HOTS skills. These materials will be produced by utilizing the Inquiry-Based Learning and Science, Technology, Engineering, and Mathematics (IBL STEM) approach. ADDIE is the development model used in this study. Using a viable (valid) chemical literacy-based IBL STEM model, this research and development generated instructional materials on stoichiometry that were considerably shown to improve students' LOTS and HOTS abilities with a probability value of 0.000 ($p=0.000<0.05$).

Keywords: IBL, STEM, Chemical Literacy, LOTS, HOTS.

1 Introduction

In the current era of globalization, competition is fierce due to the advancements in science and technology, particularly in the fields of communication and information. As a result, students, above all, must be able to sharpen their skills and enhance their learning in order to meet the challenges of the global community. These challenges include the need for critical thinking abilities, effective communication skills, innovation, and the capacity to solve problems through cooperation and negotiation [1]. Since the inception of time, people have used their ability to reason to find solutions to a variety of environmental, cultural, and societal problems [2]. Low Order Thinking Skills (LOTS) and High Order Thinking Skills (HOTS) are the two categories of thinking abilities in the field of education [3]. LOTS is typically linked to the ability to recollect knowledge or apply ideas to circumstances and contexts that one is familiar with. In the meantime, HOTS is used to answer novel, peculiar

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problems that call for justifications, supporting data, and conceptual connections in order to be resolved [4]. In order to transition to HOTS capabilities, pupils need to possess certain competencies, as explained by Armala et al [5]. Chemistry is a field of natural science that comprises ideas, regulations, laws, principles, and hypotheses. It is a member of the scientific family [6]. This tool helps students develop both LOTS and HOTS thinking skills, particularly critical thinking skills. Critical thinking abilities and chemical knowledge are inextricably linked as both require the other to be comprehended. Chemistry can be used to develop critical thinking skills.

Individuals possess varying abilities and thinking skills, which are influenced by the training they receive to enhance them [7]. The ability to create learning that is focused on active student participation and is meant to inspire students to think critically and solve problems is another skill that educators, including lecturers, must possess [7].

It is imperative that educators find ways to help students develop their critical thinking abilities. One such method is to involve them in scientific tasks like questioning, stating, selecting, and making decisions during chemistry experiments [8]. Inquiry-based learning (IBL) is a technique or alternative learning paradigm that can be used to enhance students' critical thinking abilities, notably in the study of chemistry. The integrated business learning (IBL) model comprises a set of instructional activities that prioritize student participation in order to facilitate learning experiences and the discovery of material concepts through problem-based learning [9]. An alternative interpretation of the IBL model is a set of educational exercises that highlight the use of critical and analytical thinking to look for solutions to given problems [10]. After that, get students involved in problem-solving techniques, hypothesis-building, data collection and analysis, and problem-drawing from previous work [11]. The IBL model has an impact and can enhance critical thinking abilities, according to numerous research [12], increase creative thinking abilities [10], improve science process skills [9], increase HOTS abilities [11]; [13]; [14], improving student learning outcomes [4]; [15], improve students' understanding of mathematics [16], and can cultivate students' 21st-century abilities [17].

Science, Technology, Engineering, and Mathematics (STEM) disciplines can equip students to think critically and properly in the face of the current rapid advancements in science and technology, claim Rachmawati et al [18]. Similarly, Irmita stated that STEM can advance if it is connected to the environment in order to make learning tangible and reflect the real world that children encounter on a daily basis [19]. The STEM method has also been shown in several studies to enhance pupils' critical thinking abilities [20] [21] [22] [23] [24], enhance one's capacity for innovative thought [25], also having the capacity to enhance the learning outcomes of students [25] [26].

Apart from the fact that activities are crucial to learning since they can raise student accomplishment, critical thinking abilities and literacy are synonymous [27]. Literacy skills that are connected in the current digital world are prioritized, according to Afandi et al [28]. Likewise, chemical literacy, according to Wahyuni & Yusmaita, is tied to how children may value nature by using the science, chemistry, and technology they have taught them [29]. Thus, chemical literacy can serve as a platform for pupils to engage in higher-order thinking by connecting it to real-world occurrences [30]. Chemical literacy abilities can help students become more proficient in HOTS, according to studies by Alviah et al [31].

2 Method

The goal of this project is to provide stoichiometry teaching materials for general chemistry classes utilizing an IBL STEM paradigm based on chemical literacy that can be implemented in the classroom to enhance students' HOTS and LOTS skills. 34 pupils served as the research subjects for this sort of research and development (R&D). The ADDIE development model is the development model that is being utilized.

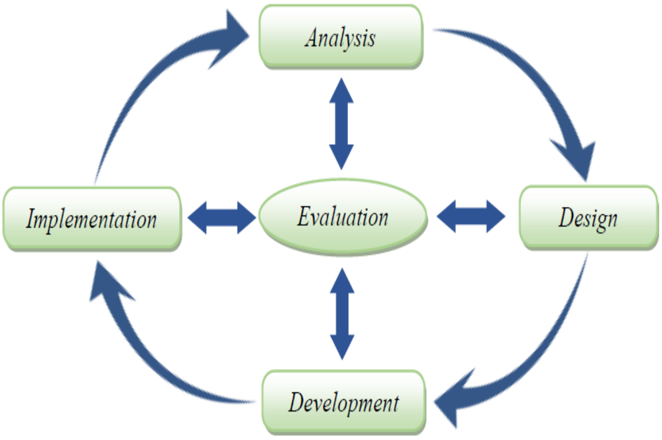

Fig. 1. ADDIE Development Model

In order to gather research data, multiple choice tests that satisfied valid and reliable criteria were used, expert validation sheets, interviews, and LOTS and HOTS test devices. Both quantitative and qualitative data are present in the acquired information. Based on expert validation (validator) results and taking into account feedback, comments, and recommendations from expert validators, the viability (validity) of general chemistry teaching materials (stoichiometry) utilizing the IBL STEM paradigm based on chemical literacy was examined. Students' tests were used to determine the efficacy and growth of their LOTS and HOTS skills, which were then evaluated using the paired sample t-test method and the SPSS software.

3 Results

In order to facilitate the general chemistry learning process for both lecturers and students, the research and development project produced general chemistry teaching materials based on stoichiometric material and prepared using the IBL STEM model based on Chemical Literacy. Expert validators in respective professions assess the validity or applicability of instructional materials (material experts and media experts). After being approved as valid (feasible) by professional validators, the general chemistry teaching materials developed utilizing the Chemical Literacy-based IBL STEM approach were put into use for students to evaluate their efficacy.

3.1 Feasibility of the IBL STEM Model Based on Chemical Literacy

The applicability of the information and the appropriateness of the media (design) were the criteria used by expert validators in developing, assessing, and validating the general chemistry teaching materials in stoichiometry learning utilizing the IBL STEM paradigm based on chemical literacy.

Table 1. Results of Expert Validation for Material Aspects

Assessment Aspect	Validator (Mean score)			Total Mean	Criteria
	I	II	III		
Content material	4.38	4.25	4.50	4.38	Valid
Presentation of material	4.50	4.13	4.00	4.21	Valid
Language	4.17	4.50	4.50	4.39	Valid
Using of learning models	4.80	5.00	4.60	4.80	Valid
Evaluation and assesment	4.17	4.50	4.33	4.33	Valid
Total average				4.42	Valid

Tabel 1, provides the findings of expert validation on material aspects (content suitability, material presentation, language, use of learning models, evaluation, and assessment), and it was determined that it met the valid requirements by obtaining an average score of 4.42 on the overall material aspects assessment. The General Chemistry teaching materials in stoichiometry learning using the IBL STEM model based on chemical literacy have met the valid criteria from the material aspect and are suitable for application in the learning process, according to the findings of the evaluation and assessment of the material expert validator.

Table 2. Results of Expert Validation for Media Aspects

Assessment Aspect	Validator (Mean Score)		Total Mean	Criteria
	I	II		
Graphics	4.42	4.67	4.54	Valid
Language	4.50	4.63	4.56	Valid
Total average			4.55	Valid

Tabel 2, displays the findings of expert validation for the media (design) component, which includes the linguistic and graphic aspects. The media (design) aspect's overall average score was 4.55, meaning it met the valid requirements. The general chemistry teaching materials for stoichiometry learning using the IBL STEM model based on chemical literacy were found to be valid from the media (design) aspect and appropriate for use in the learning process, according to the findings of the media (design) expert validator's assessment.

3.2 Student LOTS and HOTS Ability Achievements

Exams conducted both before (pretest) and after the implementation of General Chemistry teaching materials based on the IBL STEM paradigm based on chemical literacy allowed students to meet their LOTS and HOTS ability goals in the stoichiometry learning process. 34 students in a single class participated in the implementation, which was done in three phases: (1) a pretest before students were given any assignments, (2) a learning process where students used chemistry teaching materials, and (3) a final stage. (3) the third stage, which is the final test (posttest), generally utilizing the IBL STEM model based on chemical literacy that has been produced in stoichiometry learning

Table 3. Student LOTS and HOTS Ability Achievements

	LOTS		HOTS	
	Pretest	Post-test	Pretest	Post-test
N	34	34	34	34
Minimum	35	65	40	65
Maximum	70	100	75	95
Mean	51,32	84,26	58,09	81,32
Std. Deviation	8,286	8,084	9,130	8,101
K-S Test	0,142	0,143	0,142	0,141
Sig.	0,078	0,074	0,081	0,085

Tabel 3, provides the pretest results for the pupils, with an average LOTS score of 51.32 ± 8.286 before any action is taken. The data was distributed normally, with a Kolmogorov-Smirnov test value of 0.142 (p = 0.078) and an average achievement of 58.09 ± 9.130 for the students' HOTS pretest results.Following implementation with General Chemistry teaching materials based on chemical literacy in stoichiometry learning, the average student score on the LOTS post-test was 84.26 ± 8.084; the data showed a normal distribution with Kolmogorov-Smirnov test scores of 0.143 (p=0.074); the average student score on the HOTS post-test was 81.32±8.101; the data showed a normal distribution with Kolmogorov-Smirnov test scores of 0.141 (p=0.085).

3.3 Effectiveness of the IBL STEM Model Based on Chemical Literacy

Students' enhanced LOTS and HOTS scores on tests with a pretest-posttest design demonstrate how well the general chemistry teaching materials teach stoichiometry utilizing the IBL STEM model, which is based on chemical literacy. Using the SPSS software, a paired sample t-test method was used to assess the significance of the rise in student LOTS and HOTS.

Table 4. Product Effectiveness Test Results

		Paired Differences		*t*	*df*	*Sig. (2-tailed)*
		Mean	*Std. Deviation*			
LOTS	Posttest – pretest	32,941	11,018	17,434	33	0,000
HOTS	Posttest – pretest	23,235	9,445	14,344	33	0,000

Tabel 4, the t-count value for the students' LOTS ability data was 17.434 with a probability (sig.) of 0.000 < 0.05; on the other hand, the t-count value for the students' HOTS data was 14.344 with a probability (sig.) of 0.000 < 0.05. This led to the conclusion that students' LOTS and HOTS abilities were improved by the use of General Chemistry teaching materials in stoichiometry learning using the chemical literacy-based IBL STEM model. The average difference in LOTS scores (posttest-pretest) was 32,941±11,018; the average difference in HOTS values (posttest-pretest) was 23.235±9.445.

4 Conclusion

Using the IBL STEM approach based on chemical literacy, research and development efforts resulted in books on stoichiometry for use in General Chemistry classrooms. Teaching resources for general chemistry that are based on chemical literacy and use the IBL STEM model, which was developed through the ADDIE development paradigm, have been deemed viable (valid) for use in stoichiometry instruction. The qualitative assessment of material expert validators-which covers aspects of material content, presentation, language, use of learning models, evaluation, and assessment-as well as media or design expert validators-which cover graphic aspects and aspects of Spoken). Students' LOTS and HOTS have been shown to increase with the use of General Chemistry Teaching Materials based on the IBL STEM Model based on chemical literacy in the stoichiometry learning process. The average increase in LOTS ability (posttest-pretest difference) was 32.941 ± 11.018, and the average increase in HOTS ability (posttest-pretest difference) was 23.235 ± 9.445.

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