Development of IBL STEM Model-Based Teaching Materials Using Wordwall to Improve Students' Critical Thinking Skills

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Abstract: *This study aims to develop teaching materials based on the IBL STEM model using the Wordwall application to improve students' critical thinking skills. The development model used refers to the ADDIE model with 30 students of the Chemistry Education Study Program, UNIMED as research subjects. The research instrument used an expert validation sheet and a test of students' critical thinking skills on stoichiometry material as many as 25 questions in the form of multiple choices. The results of the study indicate that teaching materials based on the IBL STEM model using the Wordwall application are feasible and effective in improving students' critical thinking skills in Stoichiometry learning. The feasibility is met qualitatively based on the assessment of material expert validators with an average total score of 4.36 (valid) and the assessment of media expert validators with an average total score of 4.32 (valid). Effectiveness is met based on the results of product implementation and evaluation results and is proven by statistical hypothesis testing ($p < 0.05$) with an average achievement of increasing students' critical thinking skills of 40.067 ± 9.318.*

Keywords: *teaching materials; IBL; stem; wordwall; critical thinking skills*

INTRODUCTION

General Chemistry Course is a tool to achieve goals and train students to have thinking skills. One of the things that needs to be developed in chemistry learning is critical thinking skills, in accordance with the goals of chemistry education. Chemistry material and critical thinking skills are two things that cannot be separated, because chemistry material is understood through critical thinking and vice versa critical thinking can be trained through learning chemistry. Critical thinking skills are very important for students because by having critical thinking skills students are able to act rationally and choose the best alternative choices for themselves. The ability and critical thinking skills possessed by each individual are certainly different, depending on the exercises that are often done to develop them (Purba et al., 2019).

Critical thinking skills are one of the high-level thinking skills that every student must have after completing their studies at university. However, the main problem in learning in higher education is how the planning and readiness of lecturers to manage learning in order to achieve the desired competencies in students (Panggabean et al., 2022).

Improving students' critical thinking skills certainly requires training and preparation by educators/lecturers, one of which is by preparing learning tools including teaching materials. Without appropriate teaching tools or materials, the learning that is applied will experience obstacles. Therefore, a lecturer is required to be able to design and develop innovative and creative teaching materials that can train and improve students' critical thinking skills. The rapid development of digital technology today can also be utilized by lecturers in developing innovative and interactive teaching materials based on digital technology, one of which is by utilizing the Wordwall application.

Wordwall is a software that works online and is used as a game-based learning medium for Kahoot, quizzes, and so on (Nadia et al., 2022); easy to use because its appearance immediately provides free access to its features, and allows for choosing the right options in creating digital learning media (Silalahi et al., 2023), (Nuraeni et al., 2023); presenting colorful images and videos can help students focus on quizzes and encourage students to learn independently outside of class (Maryanti et al., 2022); can be a solution to improve student learning outcomes with various interactive game concepts on the website (Fidya et al., 2021). Wordwall application is free for basic options with a choice of 5 templates. The games that have been created can also be directly shared via a link sent via the Whatsapp application, Google Classroom or Email. The games that have been designed can also be printed in PDF format, making it easier for students who are constrained by the network (Sari & Yarza, 2021).

In addition to the availability of teaching materials, strategies to improve critical thinking skills are very urgent for students (Sutiani et al., 2021). One of the alternative learning strategies or models that can be applied is the inquiry-based learning model (IBL). The IBL model is a series of learning activities that emphasize active student involvement to have a learning experience in finding material concepts based on the problems presented (Suhada, 2017); emphasizes the critical and analytical thinking process to find/discover the answers to the problems being questioned and involves students in formulating problems, making hypotheses, collecting and analyzing data and drawing conclusions from existing problems. (Puspita et al., 2022).

Several studies also show that the IBL model can improve critical thinking skills. (Julianda et al., 2018), improve creative thinking skills (Rodiyana, 2015), improve science process skills (Suhada, 2017), improve high order thinking skills (HOTS) (Puspita et al., 2022); (Izzatin & Nurmala, 2018); (Fadillah et al., 2022), (Cahyani et al., 2018), improve students' understanding of mathematics (Anastasha, 2020), and can develop students' 21st century skills (Aji, 2019).

The rapid development of science and technology in the 21st century also requires educators to prepare students who are able to think at a high level and are competent in various fields. The required competent fields are Science, Technology, Engineering, Mathematics (STEM). STEM includes critical thinking processes, analysis and collaboration where students integrate processes and concepts in the real-world context of science skills and competencies for college, career and life (Rachmawati et al., 2017)

STEM can develop if it is linked to the environment, so that learning is realized that presents the real world that students experience in everyday life (Irmita, 2018). Several studies also show that the STEM approach is able to improve students' critical thinking skills (Lestari et al., 2018); (Ariyatun & Octavianelis, 2020); (Santoso & Arif, 2021); (Allanta & Puspita, 2021); improve creative thinking skills (Fitriyah & Ramadani, 2021), and able to improve student learning outcomes (Melina, 2022); (Rahayu & Sutarno, 2021).

The application of technology in learning according to the demands of 21st

century education and the importance of training and improving students' critical thinking skills so that students are able to compete and face various challenges of the 21st century after completing their studies at the University, it is necessary to develop teaching materials based on the IBL STEM model using the Wordwall application in the General Chemistry course on Stoichiometry material, which is expected to support the implementation of an innovative and interactive learning process and be able to improve students' critical thinking skills.

LITERATURE REVIEW

Critical Thinking Skills

Chemistry is the branch of science that studies the properties of matter, the structure of matter, changes in matter, and the energy involved in reacts (Az-Zahra & Darmana, 2023). 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 (Panggabean et al., 2023) .

Critical Thinking is a skill to perform various analyses, assessments, evaluations, reconstructions, decision-making that lead to rational and logical actions. Thinking activities regarding subjects, content, and problems are carried out through analysis, assessment, and reconstruction activities (Redhana, 2019). Critical thinking is a directed and clear process used in mental activities such as solving problems, making decisions, persuading, analyzing and conducting scientific research. Critical thinking is the ability to explain an organized way. Critical thinking is the ability to systematically broadcast the weight of personal opinions and the opinions of others. (Septikasari & Frasandy, 2018).

Critical thinking skills usually begin with a person's ability to criticize various phenomena that occur around him, then assess

from the perspective he uses. Then position himself, from an inappropriate situation to a situation that is on his side (Sugiyarti et al., 2018). Critical thinking ability is an intellectual thinking process in which the thinker deliberately assesses the quality of his/her thinking, using reflective, independent, clear, and rational thinking. When students get used to thinking critically, students can be rational in determining and choosing the best alternative choices for themselves (Djawa et al., 2022). The aim of critical thinking in the learning process is to direct students to have a structured and intelligent way of thinking in organizing and arranging concepts to solve problems (Wartini, 2021).

Critical thinking skills are cognitive skills used to identify, interpret, conclude, explain, analyze, and evaluate material. Students' critical thinking skills can be improved through continuous practice (Purnami et al., 2021). Critical thinking skills have the same meaning as high-level thinking skills, especially in the evaluation aspect.

Wordwall Application

Wordwall is one of the many digital learning media that have emerged in the current technological era. WordWall is a website that allows teachers to create various digital learning media (Nuraeni et al., 2023). Wordwall is an application that can be used as a learning media, learning resource or online assessment tool that is interesting for students. The advantage of this application is that it has many templates that can be created by teachers (Sari & Yarza, 2021). Wordwall is a game platform that provides a variety of useful and interesting game formats for the audience. With careful selection of materials, namely by combining education and entertainment harmoniously and consistently, it can increase interest and increase student learning motivation (Maryanti et al., 2022). Meanwhile, the Wordwall game provides various educational games which aim to be fun assessment aids and evaluation tools for students (Irham et al., 2024).

Wordwall is a software that works online and is used as a game-based learning medium for Kahoot, quizzes, and so on (Nadia et al., 2022); easy to use because its appearance immediately provides free access to its features, and allows for choosing the right options in creating digital learning media (Silalahi et al., 2023), (Nuraeni et al., 2023); presenting colorful images and videos can help students focus on quizzes and encourage students to learn independently outside of class (Maryanti et al., 2022); can be a solution to improve student learning outcomes with various interactive game concepts on the website (Fidya et al., 2021).

Wordwall application is free for basic options with a choice of 5 templates. The games that have been created can also be shared directly via a link sent via the Whatsapp application, Google Classroom or Email. The games that have been designed can be printed in PDF format, making it easier for students who are constrained by the network (Sari & Yarza, 2021).

Inquiry Based Learning (IBL)

Inquiry Based Learning (IBL) is one of the learning models that can be applied to improve 21st century skills, such as critical, creative, communicative and collaborative thinking skills. The goal of implementing the inquiry learning model is optimal student involvement in learning activities. In the inquiry learning model, the knowledge and skills obtained by students should not be the result of memorizing a set of facts, but based on the results of finding it themselves (Charolina et al., 2021). Inquiry learning students will be faced with a problem that must be observed, studied, and examined so that teaching materials are needed as a support (Sutiani & Fayaddah, 2021).

The IBL model is a series of learning activities that involve all students' abilities to search and investigate systematically, critically, logically, creatively and analytically so that students can formulate their own findings with confidence. The inquiry learning model is the process of forming questions, investigating, and creating knowledge and new things that require full student involvement in learning (Ulandari et al., 2019).

The IBL model is defined as a strategy or learning model that is able to increase student activity and systematic logical and critical thinking or develop intellectual abilities as part of the mental process, so that the IBL model can be implemented in class to improve critical thinking skills (Gunardi, 2020). Investigation of critical thinking skills with the IBL model tends to improve independent learning in students. Investigation can foster critical thinking skills and information processing skills, and tends to improve independent learning skills in students (Rihyanti & Budiyati, 2024).

Science, Technology, Engineering, Mathematic (STEM)

STEM was initiated by the United States and first used in 1990 by the NFS, with the four disciplines integrated in a problem-based learning method. STEM includes critical thinking, analysis and collaboration processes where students integrate processes and concepts in the real-world context of science, skills and competencies for college, career and life. (Rachmawati et al., 2017).

STEM can develop if it is linked to the environment, so that learning is realized that presents the real world that students experience in everyday life (Irmita, 2018). The STEM approach is an approach that unites knowledge consisting of science, technology, engineering/engineering, and mathematics which is used to solve problems that often occur in everyday life (Siregar & Amdayani, 2023). A distinctive feature of the STEM approach is activities that connect context to the classroom learning environment by demonstrating applications in practice and activities (Santoso & Arif, 2021).

The four components of STEM (Science, Technology, Engineering, Mathematics) are able to create an active and cohesive learning system, can train and stimulate students' critical thinking skills so

that they are able to analyze, make decisions, evaluate, investigate and solve problems well (Allanta & Puspita, 2021).

STEM in learning is very popular because it is needed in science learning to hone cognitive, manipulative, design, utilize technology, and apply knowledge (Rahayu & Sutarno, 2021). STEM-based learning can train students to apply their knowledge to create designs as a form of solving environmental problems by utilizing technology (Ariyatun & Octavianelis, 2020).

METHODS

This research is a type of development research (research and development / R&D), which is a type of research that produces products that are used to develop and validate educational products and test the effectiveness of these products. The development model refers to the ADDIE development model. The ADDIE development model uses 5 stages as the name suggests, namely: Analysis, Design, Development, Implementation, and Evaluation (Purba et al., 2022).
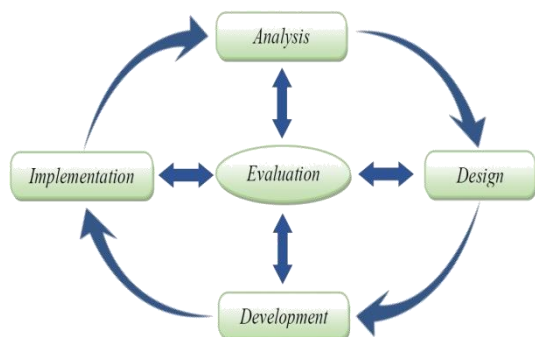

Figure 1. ADDIE development model

The research procedure is carried out through the following stages: (a) Analysis, namely conducting an analysis to collect information related to student needs and reviewing literature related to the product being developed; (b) Design, is a stage carried out to identify objectives and create a design for teaching materials based on the IBL STEM model using the Wordwall application in Stoichiometry learning that will be developed; (c) Development is a stage to realize the design into a product that is ready to be implemented; (d) Implementation, namely implementing the product being developed,

namely teaching materials based on the IBL STEM model using the Wordwall application in Stoichiometry learning; and (e) Evaluation, namely conducting an evaluation by analyzing the effectiveness of implementing teaching materials based on the IBL STEM model using the Wordwall application in Stoichiometry learning on students' critical thinking skills.

The subjects of this development research consisted of 3 (three) material expert validators (Lecturers) and 3 (three) media expert validators (Lecturers); and 30 students of the Chemistry Education Study Program, UNIMED. The instruments and data collection techniques used in this research were expert validation sheets (checklists) and critical thinking ability test instruments in the form of multiple choice questions totaling 25 questions that had met the valid and reliable criteria.

The data obtained are qualitative and quantitative data. Qualitative data are obtained from the assessment, suggestions and input of media experts and material experts based on the expert validation sheet instrument. Quantitative data are obtained from the achievement of students' critical thinking ability test results through the Wordwall application on the Stoichiometry material. The effectiveness and improvement of students' critical thinking abilities are analyzed using the paired sample t-test approach with the help of the SPSS program.

RESULT AND DISCUSSION

The product developed in this study is a teaching material based on the IBL STEM model using the Wordwall application in General Chemistry learning on Stoichiometry material with the aim of making it easier for lecturers and students in the stoichiometry learning process and is expected to help lecturers in conducting diagnostic tests and in making academic policies for students. Products that have been developed and declared feasible by expert validators are then

applied to students to analyze the effectiveness of the products developed.

Product Eligibility

The feasibility (validity) of teaching materials based on the IBL STEM model using the Wordwall application in the General Chemistry course on the Stoichiometry material developed was evaluated and assessed by expert validators based on the feasibility of the material and the feasibility of the media.

Table 1. Validation results on material aspects

Assessment Aspects	Mean Score	Criteria
Content	4.43	Valid
Presentation	4.34	Valid
Language	4.29	Valid
Graphics	4.39	Valid
Total Mean	4.36	Valid

Table 1 shows the results of the validation of material experts on the content aspect of the material obtained an average score of 4.43 (valid); on the presentation aspect obtained an average score of 4.34 (valid); on the discussion aspect obtained an average score of 4.29 (valid); on the graphic aspect obtained an average score of 4.39 (valid); with an average total score for all aspects obtained of 4.36 or declared valid. Thus, based on the results of the assessment of the material expert validator, it is concluded that the teaching material based on the IBL STEM model using the wordwall application is valid so that it is feasible to be applied in the learning process based on the aspects of the feasibility of content, presentation, language and graphic aspects according to BSNP which is modified for the university level.

Table 2. Validation results on media aspects

Assessment Aspects	Mean Score	Criteria
Software engineering	4.20	Valid
Interface displa	4.47	Valid
Verbal communication	4.28	Valid
Total Mean	4.32	Valid

Table 2 shows the results of media expert validation on the software engineering aspect obtained an average score of 4.20 (valid); on the interface aspect obtained an average score of 4.47 (valid); on the verbal communication aspect obtained an average score of 4.28 (valid); with an average total score for all aspects of 4.32 or declared valid. Thus, based on the results of the media expert validator assessment, it is concluded that the teaching materials based on the IBL STEM model using the wordwall application are valid so that they are feasible to be applied in the learning process based on the software engineering aspect, interface appearance and verbal communication aspects according to BSNP which has been modified for the university level.

Achievement of Students' Critical Thinking Skills

The achievement of students' critical thinking skills was obtained through a critical thinking skills test given before and after the implementation of IBL STEM model-based teaching materials using the wordwall application. This stage was carried out on 30 students and was carried out in 3 (three) stages including: (1) the initial stage, namely the initial test (pretest) through the Wordwall application before students were given action, (2) the second stage, namely the implementation stage where students learned by utilizing IBL STEM model-based teaching materials using the Wordwall application, and (3) the third stage, namely the final test (posttest) through the wordwall application.

Table 3. Achievement of students' critical thinking ability test results

Data	Mean	Std. Deviation	K-S Test	Sig
Pretest	41.33	6.244	1.115	0.167
Posttest	84.40	8.621	0.812	0.526

Table 3 shows the achievement of the results of the initial critical thinking ability test (pretest) of students before being given the action obtained an average value of 41.33 ± 6.244 and the data has a normal distribution with a Kolmogorov-Smirnov test (KS-Test) = 1.115 and p = 0.167. After the action was carried out using teaching materials based on the IBL STEM model using the wordwall application, the results of the posttest obtained an average value of students' critical thinking

ability of 84.40 ± 8.621 and the data has a normal distribution with (KS-Test) = 0.812 and p = 0.526.

Product Effectiveness

The effectiveness of teaching materials based on the IBL STEM Model using the Wordwall application in Stoichiometry learning that was developed was analyzed from the increase in students' critical thinking ability achievements using a pretest-posttest design. The results of the critical thinking ability test were analyzed using a paired sample t-test approach with the help of the SPSS program.

Table 4. Product effectiveness test results

	Paired Differences		t	Sig
	Mean	Std. Dev		
Posttest - pretest	43.067	9.318	25.315	.000

Table 4, obtained a t-value of 25.315 with a probability (sig.) of 0.000 <0.05 so it is concluded that the implementation of teaching materials based on the IBL STEM model using the wordwall application in General Chemistry learning on the Stoichiometry material has proven effective in improving students' critical thinking skills with an average difference in value (posttest-pretest) of 43.067 ± 9.318.

Discussion

The learning product developed in this study is a teaching material based on the IBL STEM model using the Wordwall application in the general chemistry course on the Stoichiometry material that has met the criteria for being feasible and effective to be implemented in learning/lecture activities in the classroom. The feasibility of the product developed has been qualitatively met based on the assessment of the material expert validator and the media expert validator. Teaching materials based on the IBL STEM model using the Wordwall application are said to be feasible, meaning that the teaching materials developed are feasible to be used as learning resources in learning/lecture activities in the classroom.

Teaching materials are included in the criteria for being feasible (valid) if the material contained in the teaching materials is in accordance with state of the art knowledge and all components in the teaching materials are consistently connected. The level of feasibility of the teaching materials developed is known from the results of the validation or assessment of the material expert validator including the feasibility of content, presentation, language and graphic feasibility; and the results of the validation or assessment of the media expert validator including aspects of software engineering, interface display, and verbal communication according to the BSNP which has been modified for the university level.

The effectiveness of teaching materials based on the IBL STEM model using the developed wordwall application can be seen from the results of the evaluation of students' critical thinking ability test achievements and analyzed based on the improvement of students' critical thinking abilities with a t-test or Paired Sample T-Test approach. According to (Sundari et al., 2021), the IBL learning model trains students not only to learn by listening to the teacher lecture, but also learn the students while doing experiments. The implementation of teaching materials is said to be effective, meaning that teaching materials based on the IBL STEM model using the wordwall application on the developed Stoichiometry material have achieved the expected targets. Effectiveness is measured based on the achievement of learning objectives by implementing the developed teaching materials, and is obtained through the evaluation of students' critical thinking ability tests. The evaluation results show an increase in students' critical thinking abilities with an average increase of 40.067 ± 9.318. Student responses to teaching materials based on the IBL STEM Model Using the wordwall application on General Chemistry learning on the developed Stoichiometry material are also very positive.

CONCLUSION

This study produces learning products in the form of teaching materials based on the IBL STEM model using the Wordwall application in General Chemistry learning on Stoichiometry material developed using the ADDIE model, and has met the criteria for feasibility and has been proven effective in improving students' critical thinking skills. The feasibility of teaching materials based on the IBL STEM model using the Wordwall application has been met qualitatively based on the results of the expert material validator assessment (content feasibility, presentation, language and graphic feasibility) and the results of the media expert validator assessment (software engineering, interface display, and verbal communication) according to BSNP which was modified for the university level.

The effectiveness of teaching materials based on the IBL STEM model using the Wordwall application in Stoichiometry learning is met quantitatively based on the average increase in students' critical thinking skills of 40.067 ± 9.318 and the results of statistical testing with a sig. value of 0.000 <0.05. The findings of this research and development also provide implications that to improve students' critical thinking skills can be done by developing innovative and interactive learning, one of which is by developing teaching materials based on the IBL STEM model using the Wordwall application. Through teaching materials based on the IBL STEM model using the Wordwall application, it can help students improve their understanding and critical thinking skills.

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