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Development and Implementation of Chemistry STEM-Based Module on Buffer Solution Material in Senior High School

Litani Siregar*, Saronom Silaban
State Univesity of Medan
Email Coresponding*: litaniregar@gmail.com

Abstract: One of the issues class XI SMA Negeri 1 Purba students encounter is that the teaching materials still used aren't very diverse; they mostly consist of textbooks, which makes it difficult for students to comprehend the material in the textbook. The goal of this study is to create a STEM-based chemistry module that will enhance student learning outcomes and activities. Research and development (R&D) using the ADDIE development model is the research methodology applied. This STEM-based chemistry module scored on average 89.47% for content feasibility, 90.17% for presentation feasibility, 95.31% for STEM assessment, 82.69% for language feasibility, and 95.16% for graphics, placing it in the category of being "very feasible to use in learning." With average student pretest and posttest scores of 43.57 and 86.43 in small groups and 39.67 and 84.67 with an N-Gain score of 0.75 for student learning outcomes in large groups, the STEM-based chemistry module developed was deemed effective for improving student learning outcomes and student learning activities. The average value of all student learning activities was 77.4% with high criteria.

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Introduction

Students must possess 21st century skills in order to meet the difficulties of the twenty-first century, which call for competent human resources (HR) in order to compete in the global market. Digital skills for the twenty-first century have been identified as being technical, informational, communicative, collaborative, creative, critical-thinking, and problem-solving skills (Van Laar *et al.*, 2017). In actuality, Indonesia has a low human resource base due to a number of causes, one of which is the education system's poor quality. The low academic performance or learning outcomes of pupils in Indonesia provide evidence of the country's poor educational system. The PISA results provide as proof of this. In 2018, out of 79 participating nations, Indonesia came in at position 74. The PISA assessment results from prior years showed little variation, with Indonesia consistently placing in the bottom 10 (Hewi & Shaleh, 2020). According to Berahim's research from 2021, student learning outcomes in chemistry classes are still poor. For example, the average score for material on acid and base solutions is 56.74, with a classical completeness score of 37.21%, and the average score for material on stoichiometry is 61.16, with a classical completeness score of 25.58%. Low student learning activity is one of the variables contributing to poor student learning outcomes. Learning activities can motivate students to actively participate in their education, which will increase learning outcomes by encouraging students' critical thinking and problem-solving abilities.

The government changed the Education Unit Level Curriculum with the 2013 curriculum in an effort to address the subpar student learning activities and learning outcomes in the context of the global competition of the twenty-first century. In order for pupils to understand the material and make it more relevant, the 2013 curriculum encourages them to actively study rather than relying just on the teacher's explanations. According to Rahmawati et al. (2023), the core of the 2013 curriculum is a learning process whose implementation can encourage enthusiastic student engagement.

The 2013 curriculum has not been fully implemented by the majority of instructors in the learning process, according to researches' observations at SMA Negeri 1 Purba. This is demonstrated by the fact that the teacher uses the lecture approach, which makes learning less engaging, inspirational, and enjoyable. This leads to teacher-centered learning, which has low learning outcomes and student learning activities since only a small number of students participate in learning. The low student learning outcomes are evidenced by data from the list of students' daily test scores in chemistry subjects that have not been able to reach the Minimum Completion Criteria (KKM) standard of 75. The presentation of learning outcomes of 27 students reached the KKM standard by 25% with an average score of 77.4 while the remaining 75% of students got a score < 75. Applying an integrated approach to the learning process by connecting four disciplines can help to improve student learning outcomes and learning activities, which can help to address the issue of low learning outcomes and student learning activities. STEM is an integrated method that can be considered to be still developing in the fast expanding field of education that combines four scientific disciplines (English, 2016). STEM stands for science, technology, engineering, and mathematics.

According to Syukri et al. (2013), STEM (Science, Technology, Engineering, and Mathematics) refers to the four scientific disciplines of science, technology, engineering, and mathematics. In order to increase the workforce in STEM fields, develop STEM-literate citizens, and increase the global competitiveness of the United States (US) in science and technology innovation, the National Science Foundation of the United States first introduced STEM as the theme of the education reform movement in these four disciplines in the 1990s (Nugroho et al., 2021).Students may readily make connections between ideas from different academic fields and are pushed to think more creatively about their ideas and opinions through STEM education (Kelley and Knowles, 2016). By developing questions that are answered through inquiry to inform students before they engage in the engineering design process to solve problems, STEM education can also link scientific inquiry (Kennedy and Odell, 2014). STEM exposes kids to science, technology, engineering, and math (Vennix et al., 2018). Students should learn how to apply their newfound information in order to solve difficulties in their daily lives that are connected to the subjects they are learning in class.

One of the subjects in school is chemistry. According to Silaban (2017), chemistry is a branch of nature's natural sciences which studies the structure and properties of matter in relation to changes that occur within it or energy. In other scientific disciplines such as biology, physics, geography, health care, geology & even law, chemical research is required. The chemistry has a number of microscopic concepts such as structure, chemical reaction and complex chemical processes. Chemistry lessons include many tiny concepts like structure, chemical reactions, and intricate chemical processes. Many students believe that chemistry is challenging to learn because of its intricate ideas. Buffer solution is one of the academic resources that students find challenging. One of the chemical materials that contains numerous intricate ideas is buffer solution material. A little acid, little base, or diluted solution does not significantly modify the pH of a buffer solution, according to chemical science, which explains why. Students must comprehend the underlying materials, such as acid-base material and chemical equilibrium, in order to comprehend buffer solution material (Djangi et al., 2021). It is a given that pupils will struggle to learn the content for buffer solutions if they struggle to understand these two materials. The usage of teaching materials is one of several elements that have a big impact on how well students learn chemistry and whether they meet their learning goals. A module is one of the learning processes that may be carried out by teachers and students more easily and effectively with the use of instructional materials (Utami et al., 2018).

In order to attain the intended potential in accordance with the level of complexity, modules are learning tools or means that comprise content, techniques, limits, and ways to evaluate (Utami et al., 2018). The completion of larger tasks or long-term goals can also be included to a module, which will tremendously help teachers and students in their learning activities (Yoda et al., 2011). A module is a comprehensive unit of curriculum material. According to Setyowati et al. (2013), using modules allows students to learn autonomously without or with teacher support. Competency requirements within each module that must be met by students can also be used to govern student learning outcomes, making students more accountable for all of their actions. A student who learns material quickly can outperform slower learners with the help of module learning (Wati et al., 2021). Because they will completely understand the causes for the incorrect answers, corrective feedback modules have the ability to successfully support students who struggle with learning (Tazkiyah et al., 2020). In order for students to engage in independent and more focused learning, a module that may capture their interest and pique their curiosity is required.

The educational materials used by teachers in teaching have a lower number of variables, given that they are solely packaged books supplied by the school, according to observations from Senior High School 1 Purba situated at Simalungun Regency. Indeed, according to Silaban (2021) teachers should be using a variety of teaching materials so that they can help students acquire the identified competences. The results of interviews with chemistry teachers at Senior High School 1 Purba reinforce the need for the module. It is known that while using modules as additional teaching materials, teachers have not been able to enhance and foster learning outcomes and thinking skills in their students. Additionally, because the teacher created the module on his own to serve as a supplement to the package book exclusively, it has not been validated for its viability and lacks activities that can engage students in active learning. Additionally, there is no integrated science education in engineering, technology, or math. Based on the module's issues, the researcher hopes to introduce an innovation by creating a STEM-based module for the teaching and learning process that will enhance students' learning outcomes and creative thinking abilities regarding buffer solution material and its application in real-world situations in a logical, engaging, structured, and simple manner. This is corroborated by research by Susanti et al. (2018) that demonstrates how the N-gain test results for students using STEM-based modules on redox reaction materials reveal an improvement in learning outcomes or cognitive capacities. The same thing was also claimed by Pane et al in 2022, who used hypothesis testing data with a significance level of 0.05 (5%) that showed 10.63> 1.714 (t count> t table) to demonstrate how STEM-based learning modules applied to General Chemistry lectures might enhance learning outcomes. The high number of students in the experimental class who have high N-Gain scores, which is 67.8%, as compared to the

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percentage of students who receive high N-Gain scores in the control class, which is 20%, indicates an improvement in learning outcomes. 76% of respondents to the study on learning motivation fell into the very high category, while 9% fell into the high category.

Based on the background that has been described, the author wishes to conduct a study with the title development and implementation of stem-based chemistry modules on buffer solution material at senior high school.

Research Method

The ADDIE development model, which consists of five development stages, including Analysis, Design, Development, Implementation, and Evaluation, is the basis for this research, which is a development research (R&D). The goal of this research is to create STEM-based chemistry modules that can enhance student learning outcomes and activities with buffer solution materials. Tests, questionnaires, interviews, and observation were all employed as data collection methods. Three distinguished lecturers and one chemistry teacher verified the created STEM-based chemistry module. Thirty students from class XI IPA 1 were chosen as a big group and seven students from class XI IPA 2 were chosen as a small group using purposive sampling. The N-Gain value was calculated using the pre- and post-test results to assess the effectiveness of the proposed module.

Result and Discussion

1) Analysis

The two tasks that make up the analysis stage are the needs analysis and the instructional materials analysis. Interviews with teachers and students at SMA Negeri 1 Purba served as the basis for the needs analysis, which was later used to examine the problems with the school's learning process using descriptive methodologies. According to the interview data gathered, teachers still frequently use one-way teaching techniques and are more teacher-centered, which causes students to pay less attention to the material they are being taught, feel sleepy because they are bored, be less engaged in asking questions and having discussions during the learning process, and use less varied teaching materials where the teaching mat.

It is clear from the presentation of data from the list of students' daily test scores in chemistry subjects that many students who receive chemistry scores do not meet the KKM standard of 75. Out of 27 students, 25% met the KKM standard with an average score of 77.4, while the remaining 75% received a score below 75. Therefore, it can be said that student learning outcomes in chemistry are poor. In order to address this problem, researchers are creating a (*Science, Technology, Engineering, and Mathematics*).

Additionally, researchers looked at three publishers' high school textbooks that are widely utilized by students. The book is identified by the codes B1, B2, and B3. Based on assessment sheets and BSNP eligibility guidelines, researchers examined chemistry textbooks. Figure 1 displays the findings of the researchers' analysis of chemistry textbooks.

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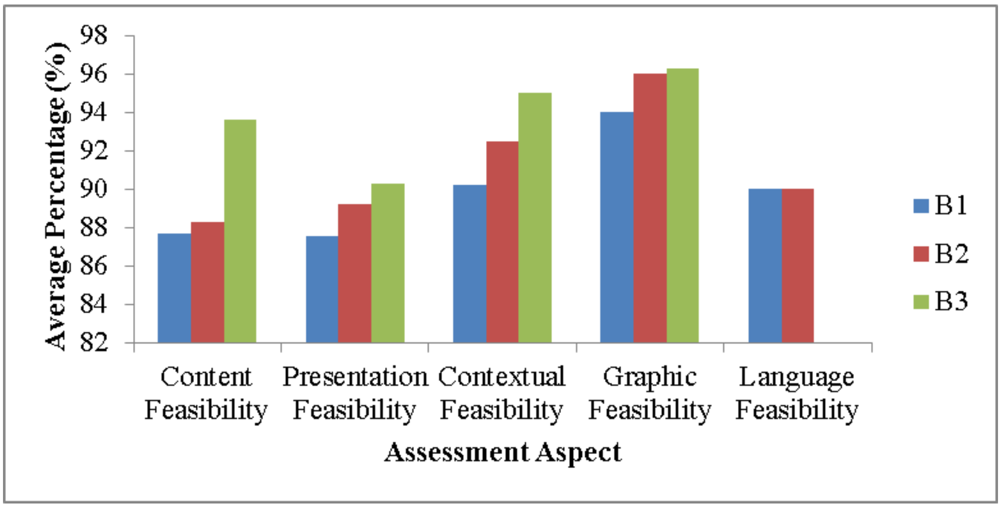

Figure 1. Diagram of High School Chemistry Book Analysis by Researchers

Figure 1. shows that the high school chemistry textbook (on the topic of buffer solutions) that the researchers examined is plausible in terms of its content, presentation, context, images, and language in accordance with the requirements for BSNP eligibility. The book used in class XI IPA Senior High School 1 Purba is therefore placed in the decent category from all angles. These three novels don't yet focus on STEM, though. Therefore, the researchers created and constructed a teaching resource for class XI IPA Senior High School that takes the shape of a STEM-based Module on buffer solution material.

The analysis stage is a crucial first step in the creation of educational materials that is used to ascertain the fundamentals for carrying out development. This is consistent with the research of Rosilia et al. (2020), which found that needs analysis is a crucial step in the creation of teaching materials. Analysis is carried out to identify actual learning phenomena so that the outcomes are in line with the conditions and qualities required by students. In order to predict what material will be examined, how the readiness and relevance of the teaching materials will be used, and the status of students' learning, Hadi and Agustina (2016) stated that it is essential for the production of teaching materials to analyze needs and identify difficulties.

2) Design

The outcomes of the analysis performed at the analysis stage serve as the foundation for the design stage of the STEM-based chemistry module. This stage starts with choosing the structure of the draft module preparation, STEM-based learning procedures, and selecting examples of real-world issues or phenomena to be included in the module. The first step in creating the draft module is deciding what will be covered in it by looking at the three high school chemistry textbooks that have been examined, as well as a number of online and printed sources. The draft module is created in docx format using the Microsoft Word program.

According to Syahirah et al. (2020), developing modules with bright, eye-catching displays and illustrative presentations can improve student interest and knowledge in utilizing modules for learning. According to Fauziah's research (2015), in order for educational materials to have the ability to alter students' behavior, they must be specifically adapted to the needs and characteristics of their target audience.

3) Development

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At the design stage, the module's original design was created in accordance with the standards for creating instructional materials at that time. The module's output was afterwards validated by knowledgeable lecturers and chemistry topic instructors to assess the module's quality from a feasibility perspective. The STEM-based chemistry learning module is stated to be legitimate if it has been evaluated by qualified validators and has undergone revisions in response to their comments and recommendations to generate a module that falls into the "good" category. The following are the findings of the validation of the STEM-based chemistry learning module.

Table 1. STEM-based Chemistry Module Validation Results

No	Assessment Aspect	Validator Answer Score			Average	Persentase (%)	Criteria Percentage	Criteria Validation
		1	2	3				
1	**Content Feasibility**	64	72	-	68	89,47	Very High	Valid
2	**Presentation Feasibility**	50	51	-	50,5	90,17	Very High	Valid
3	**Language Feasibility**	42	44	-	43	82,69	Very High	Valid
4	**STEM Assessment Feasibility**	30	31	-	30,5	95,31	Very High	Valid
5	**Graphics Feasibility**	116	121	117	118	95,16	Very High	Valid
Total		302	319	117	310		Very High	Valid
Average Persentase (%)		88,82	93,82	94,35	90,56			

According to the information in Table 1, the percentage results from validators 1 through 3 are 88.82%, 93.82%, and 94.35%, respectively. The percentage of results from the validation assessment for each aspect is also 89.47% for the content feasibility, 90.17% for the presentation feasibility, 82.69% for the language feasibility, 95.31% for the STEM assessment, and 95.16% for the graphics feasibility. It can be concluded that this STEM-based chemistry module is valid or feasible to use and that the percentage criteria are in a very high category based on the feasibility test of STEM-based chemistry modules on buffer solution material based on BSNP standards, which yielded an average percentage of 90.56%. Additionally, researchers made changes to the module that had been evaluated by a team of experts; these changes were made in response to the team's advice and input on specific indicators that needed to be fixed. Riyanti (2019) asserts that if the generated product has not been deemed flawless, it is crucial to make modifications to it.

4) Implementation

The modules are implemented in small-group tests and large-group testing after they have completed the development stage and undergone changes based on advice and input from expert validators. In this stage, it is determined whether the developed STEM-based module is useful and whether there are any challenges to using it. 30 students from class XI IPA I were chosen for the large group and 7 students from class XI IPA II were chosen at random for the small group. Preliminary testing was done by the researcher to gauge the students' initial readiness before the learning process was started in accordance with the Learning Implementation Plan (RPP) that had been created. Three meetings were held to complete the learning process. The researcher conducted a posttest to see whether or not student learning outcomes had improved as a result of being taught using the produced STEM-based module after the researcher had done studying.

Researchers instructed and aided students in using the created STEM-based chemistry module in meeting I. The STEM component used in this learning process is science; researchers instruct students to observe, inquire about, and express ideas on the offered canning food illustrations in the STEM 1 learning activity part. Researchers attempted to utilize the STEM component of technology in meeting II. The researcher invited the students to divide into multiple study groups before showing a straightforward practical video about the buffer solution and asking the students to watch it. Following the completion of the film, the researcher assisted students in using their cellphones to discover information pertaining to a number of questions regarding the color changes that took place in the video. Then, in front of the class, talk about the search's findings and present the discussion's findings. Researchers attempted to incorporate STEM concepts, specifically engineering and mathematics, in meeting III. On the first sheet, students were asked to estimate the amount of the solution that may form a buffer system. On the second sheet, there were various images that explained the idea of buffer solutions and their function. Additionally, based on each student's grasp of buffer solutions, the researcher requested students to create posters about them. Table 2 provides a summary of the small-group test's pretest and posttest results.

Table 2. Description of Small Group Test Study Results

Observed Data	The pretest results obtained	Posttest results obtained
Highest score	55	95
Lowest score	30	75
Average	**43,57**	**86,43**

The pretest and posttest data are shown in Table 4.4 above. It is clear that the seven students who get instruction utilizing the designed STEM-based module see an improvement in their learning outcomes. where the mean posttest score (86.43) is higher than the mean pretest score (43.57). Table 3 details the pretest and posttest results for the extensive group test.

Table 3. Description of Large Group Test Study Results

Observed Data	The pretest results obtained	Posttest results obtained
Highest score	60	95
Lowest score	25	70
Average	**39,67**	**84,67**

Table 3 above shows that there is an improvement in learning outcomes for the 30 students who are being taught using the newly constructed STEM-based module. where the mean posttest score (84.67) is higher than the mean pretest score (39.67). The researchers calculated the N-Gain score to assess how much the learning outcomes of 30 students improved after being taught utilizing the produced STEM-based program. Table 4 provides an overview of the outcomes of the N-Gain score calculation.

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Table 4. N-Gain Score Criteria

No	*N-Gain* Index	Criteria	Frequency	Persentase (%)	Average *N-Gain*
1	g > 0,70	High	17	57	0,75
2	0,30 < g ≤ 0,70	Medium	13	43	
3	g ≤ 0,30	Low	0	0	
Total			**30**	**100**	

According to Table 4, 17 students (57% of them) had an N-Gain score with high criterion, while 13 students (43% of them) received an N-Gain score with intermediate criteria. Overall, the student learning outcomes on the buffer solution material have an N-Gain score of 0.75, which may be construed as meeting good standards. As a result, it can be concluded that using STEM-based chemistry learning modules in the classroom helps students learn more. STEM-based electronic modules, according to Umbara (2022), are successful in enhancing learning outcomes, as shown by the fact that the average N-Gain value of the experimental class is higher than the control class's, at 59.30 and 14.20, respectively. Each learning process was witnessed by the observer while they tracked student behavior. This observation was made during the course of three meetings' worth of educational exercises. Table 5 displays the data on student activity.

Table 5. Development of Student Learning Activities

Meeting	Group	Activity Average (%)	Criteria
I	Small	59,0	Less
	Big	54,7	Less
II	Small	80,9	High
	Big	80,0	High
III	Small	96,2	Very High
	Big	93,5	Very High
Average		**77,4**	**High**

The development of student learning activities in small and large groups has grown while employing STEM-based chemistry learning modules, as seen in Table 5 above. This may be seen by looking at the average student learning activities from meetings I and II and III for small groups and large groups, respectively. For small groups, meeting I has an average value of 59.0, meeting II has an average value of 80.9%, and meeting III has an average value of 96.2%. Therefore, given "high" criteria, the overall average value of student learning activities is 77.4%. In light of this, it can be said that the STEM-based chemistry learning module is successful in boosting student learning activities. This is consistent with Kanza, et al.'s (2020) explanation that children become more engaged when studying with STEM since they are forced to connect and build knowledge, understanding, and analytical abilities of the surrounding nature.

Conclusion

It can be concluded that this STEM-based chemistry module is valid or feasible to use and that the percentage criteria are in the very high category because the expert validators gave the developed STEM-based chemistry module an average score of 90.56% feasibility. According to activity observations, pretest and posttest results, and the average value of the pretest and posttest of the small-scale group test, which is 43.57 and 86.43, and the average value of the pretest and posttest of the large-scale group test, which is 39.67 and 84.67 with

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the N-Gain score of student learning outcomes, the STEM-based chemistry module developed is effective.

Recommendation

Chemistry teachers are anticipated to apply the produced module items to support learning process activities and aid pupils in comprehending chemical materials, particularly buffer solutions and their advantages in daily life. Researchers can continue to create electronic-based modules with other uses, allowing for a far wider range of applications.

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