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PAPER

Improving Chemical Literacy Skills: Integrated Socio-Scientific Issues Content in Augmented Reality Mobile

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ABSTRACT

This research aims to develop socio-scientific issues (SSI) content on chemical bonding material and is used to measure students' chemical literacy abilities. Currently, the chemistry literacy level of high school students is still relatively low, so a process of reconstructing the structure of chemistry learning content that is linked to real-life contexts is needed. One way to develop this material is to include SSI content in learning. SSI content includes articles containing reading and images as augmented reality (AR) markers, which will later be linked to AR technology on smartphones so that students' chemical literacy can increase. This study uses the R&D method with the ADDIE design. Research instruments used include material validation, media validation, student response tests, and chemical literacy pre- and post-test instruments. The results of SSI content validation have been declared feasible for use in learning (91.58% material validation; 91.33% media validation; 91.57% student responses). The implementation results show that SSI content has a significantly positive effect on students' level of chemical literacy skills. Student responses also show that the SSI content developed is easy to understand and motivates students to learn.

KEYWORDS

augmented reality (AR), chemical literacy, mobile learning, socio-scientific issues

1 INTRODUCTION

The 21st century is marked as a century of openness or a century of globalization, where human life is experiencing fundamental changes that are different from the order of life in the previous century. In the world of education, the learning paradigm in the 21st century suggests that teachers must be able to use digital technology [1]. Good education is education where teachers are able to manage classes and understand learning conditions so that they can run optimally [2]. In addition, the quality of learning can be measured through three learning strategies: organizing learning,

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delivering learning, and managing learning [3]. Arranging the teaching materials that will be given is one of the strategies for organizing learning. Efforts that can be made by teachers to improve student learning success include developing teaching materials.

Chemistry is one of the branches of natural science that is very important, has a direct connection, and contributes to the development of other sciences. However, until now chemistry is still not attractive, especially for high school students, because they consider the subject difficult because the material uses a lot of formulas and contains abstract concepts, so it is less interesting and difficult for students. Several concepts in chemistry studies create difficulties and errors for students because most of them are abstract [4], [5]. One of the areas of study in chemistry is chemical bonds. This subject is very important because it is the basis for understanding other material. Chemical bonding material explains how atoms form bonds, both with the same atom and with different atoms. Chemical bonds occur because a group of atoms shows a more stable unity because they have a lower energy level than the energy levels of the constituent atoms in a separate state [6]. Students have not fully understood the chemical bonding material [7]. An understanding of chemical bonding material is needed to minimize the percentage of students' misconceptions.

Factors that cause conceptual errors are divided into five categories, including those originating from students, teachers, learning media, context, and teaching methods carried out by teachers. The media used by teachers in teaching is limited to modules or worksheets [8]. Therefore, the integration of educational tools in the teaching and learning process serves to instill fresh passions and interests among students, foster learning motivation, and even bring psychology to students [9]. In addition, it is necessary to renew learning activities. The use of interactive multimedia is a good alternative. Interactive multimedia can make it easier to display abstract concepts that are difficult to visualize and explain sub-microscopic concepts that are difficult to explain further in students' textbooks [10].

Indonesian students rank 71 out of 79 countries in scientific literacy skills [11]. Therefore, one of the prerequisites for students to understand chemistry learning optimally is to apply scientific literacy-oriented learning. The chemical literacy level of high school students is relatively low; the process of reconstructing content requires a structure for learning chemistry that is related to real-life contexts. One way to develop this material is to include socio-scientific issue (SSI) content in learning [12]. The use of augmented reality (AR) technology in process learning can be a solution to increase scientific literacy, especially chemical literacy skills. Augmented reality in the learning process can provide a new learning experience and train skills and knowledge in the 21st century [13]. AR technology can display certain information in the virtual world and display it in the real world with the help of equipment such as smartphones, webcams, computers, or special glasses [14]. Some other studies also argue that AR technology contributes positively when it is utilized in the learning of molecular forms [15] and hydrocarbons [16].

Some studies have described the SSI concept as only limited to the use of manual teaching materials and have not associated it with technology [17], [18]. Based on the problems that occur and efforts to maximize technology to improve the quality of education, the way that can be done to improve chemical literacy skills is to apply the SSI concept in teaching materials integrated with AR technology. Representation using AR technology makes 2D objects 3D and real-time, so the utilization of AR technology will exert a notable impact on the educational process [19]. Based on the description of the problems and studies described earlier, this research has several research questions (RQ):

1. How to design SSI contents integrated into AR?
2. How is the feasibility of SSI contents integrated into AR?
3. How the effect of SSI contents is integrated into AR on chemical literacy skills?

Thus, this study not only contributes to the development of current learning media technology but also provides special insights into SSI in chemistry material.

2 METHODS

The research methodology employed in the development of instructional materials in this study is the R&D method, utilizing the ADDIE approach formulated by Robert Maribe Branch [20], involving stages such as analysis, design, development, implementation, and evaluation. The R&D method is used to obtain the products and to verify their effectiveness [21]. In addition, the researchers also use experimental design in the implementation stage. The results of this research on developing SSI contents for chemical bonding integrate AR technology. They are verified for feasibility and undergo product trials to assess their feasibility and readability. The product feasibility test was carried out with validity. In addition, product trials will also be carried out with students to determine the effectiveness of the product on their chemical literacy skills.

The needs analysis stage is carried out to find out the problems faced by teachers related to the teaching materials used so far in the learning process at schools. Then, the researchers found a solution by developing SSI contents that integrated AR. Subsequently, the process involved identifying (1) the intended audience, particularly senior high school students, (2) educational goals, and (3) the corresponding instructional materials. The chosen subject matter in this instance is the concept of chemical bonding, and (3) the essential technology and components required for the development of this educational tool were AR technology.

The design stage is carried out to devise the teaching materials that have been developed in terms of design and material. In addition, the material and media validation sheets also designed student response questionnaires with pre-test and post-test questions tested on students. The development stage is carried out by researchers in developing teaching materials by storyboard. The storyboard is crafted by aligning the visual and content aspects of the media with the pre-established objectives. Subsequently, the physical educational media, in the form of SSI contents along with the necessary components, is generated. Corel Draw X7 is employed in designing the initial material for the development of this SSI content. Following the creation phase, the learning medium undergoes validation and experimentation in a designated class to assess its feasibility. The validation process involves assessments from both media experts and content specialists, while the implementation is carried out by 32 students in senior high school. The data obtained is analyzed using the percentage analysis technique with the following formula [22].

$$P = \frac{\sum X}{\sum Xi} \times 100$$

Descriptions:
P = Percentage
ΣX = Total score in questions item
ΣXi = Maximum score in questions item

Then, the results of the validation scores were averaged and converted to an assessment statement to determine the quality and usability level of the product. The conversion of scores into these assessment requirements can be seen in Table 1.

Table 1. Qualification criteria validation results [23]

No	Percentage	Validity Level
1	81%–100%	Very valid, can be used
2	61%–80%	Valid, can be used and need to be re-examined
3	41%–60%	Quite valid, but need to be revised
4	21%–40%	Less valid, it is recommended not to use because it requires revision
5	0%–20%	Invalid, not allowed to use, need a lot of revision

The implementation is intended to find out the attractiveness of learning media and the level of chemical literacy of students. After we know the validity of the teaching materials, the results of the students' pre- and post-tests are analyzed to measure the significance of the students' understanding and the level of chemical literacy before and after using the media. The overall results of the data that have been obtained are through the instruments presented in Table 2.

Table 2. Research instruments

No	Data	Instrument Types
1	Material validity	Material expert validation sheet
2	Design media validity	Design media expert validation sheet
3	Students' chemical literacy skill	The pre-test and post-test questions of chemical literacy aspects that students have obtained after using the product
4	Student learning interest	Student response questionnaire

The values obtained from the pre- and post-tests were analyzed through the ANCOVA test. The ANCOVA test is carried out with the SPSS Statistics 26 application. The results of the significance value obtained are used to identify whether there are differences in students' chemical literacy abilities between the experiment and the control class. The concluding phase involves assessing the product development at every step, analyzing data derived from product validation and implementation outcomes, and subsequently revising the product in accordance with the feedback and suggestions provided by the evaluators.

3 RESULTS AND DISCUSSION

The ultimate outcome of the media development is the integration of AR technology into SSI contents, specifically focusing on the topic of chemical bonding, designed for grade 10 senior high school or equivalent students. This SSI content in the product consists of three topics of discussion, namely ionic bonds, covalent bonds, and metallic bonds. Experts have validated the material contained in the SSI contents of chemical bonds. The following is a description of the physical learning media product of SSI content integrated with augmented reality.

a) The Design of Socio-Scientific Issue Contents Integrated Augmented Reality

In this study, the development of SSI contents integrated AR mobile for chemical bonding material has been carried out. The illustration in the first cycle of the product begins with the material on ionic bonds, which is the initial sub-topic in the subject of chemical bonds (see Figure 1). We continued with the second chapter, on covalent bonds and their kinds. In the second chapter it is entitled Polarity. Students are given a title with a word that has not been known before, so that they feel interested and motivated to read articles in learning media. Before the media was developed, an analysis of real-life phenomena and events in everyday life related to chemical bonding materials was carried out.

Fig. 1. SSI contents on ionic bond subtopic

Socio-scientific issue contents prove to be a valuable educational instrument across different educational levels. Their application has been observed in various educational research domains, demonstrating their efficacy in the realm of education [24]. The narrative of SSI is more captivating than traditional modules, making it efficacious in averting student monotony [18]. In addition, students are more interested in reading SSI articles about learning media. Students can see the implementation of the material in daily life contained in the SSI contents, so that the enthusiasm of the students gets bigger. Through the integration of material with scientific phenomena in life, students will easily understand the material of chemical bonds. Students' conceptual knowledge will influence how they describe and interpret a scientific phenomenon of daily life [25]. In addition, SSI contents are integrated with AR technology to facilitate the representation of submicroscopic objects on chemical bonding materials. AR is a potential tool that enables users to represent and manipulate 3D chemical structures [26]. SSI contents on this learning medium will contain AR markers that can be scanned with an application so that they can display 3D AR objects (see Figure 2). The following is an illustration display of a 3D AR object in the SSI content.

Fig. 2. 3D AR illustration on covalent bond subtopic

The utilization of the SSI framework in chemical literacy-focused education can facilitate students in linking the subject matter to everyday social issues [27], [28]. When environmental issues are incorporated into the SSI context, it enables students to cultivate awareness about the environment [29]. Furthermore, the integration of the SSI context into instructional materials aids students in recognizing the significance of science in addressing societal problems, leading to an enhancement in students' chemical literacy skills. As defined by Shwartz et al. [30], the instructional materials encompass all components of chemical literacy, including content, context, higher-level learning skills, and attitudes.

An SSI has an additional component that requires a level of moral reasoning or ethical concern in the process of finding solutions to problems [31]. Through the context of SSI, students will naturally discuss and build arguments to solve problems [32], [33]. In addition, the need for contextual problems to be included in chemistry learning is intended to develop students' skills and affective dimensions. The SSI framework consists of three aspects, namely the teacher experience, the learner experience, and the learning design that is integrated into the classroom [34]. The chemistry topics presented in SSI are able to encourage students to actively participate in group discussion and debate activities so as to improve their science literacy skills [35]. Cahyana et al. [36] revealed that AR technology is effective in improving science literacy among high school students in chemistry and biology to a satisfactory level.

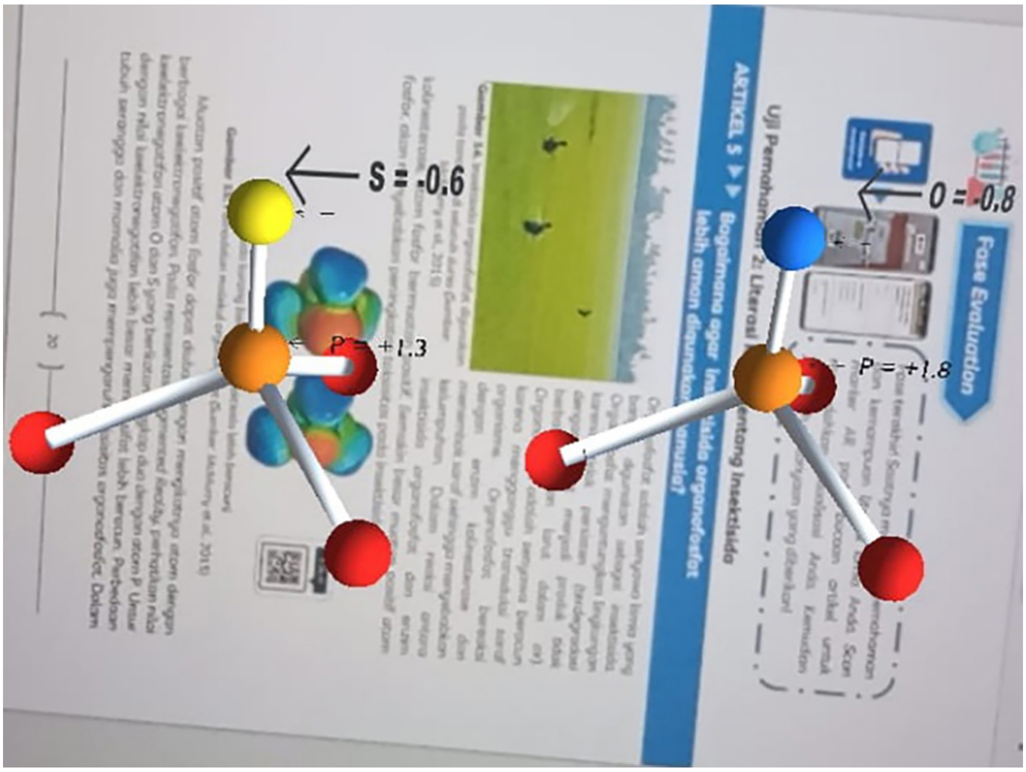

Fig. 3. SSI content on safe insecticides for humans

Figure 3 is an example of the SSI content in the article discussion about insecticides that are safe for living things, especially humans. In addition to explaining the structure of the insecticide through SSI content, this medium also represents the structure of the insecticide in the form of 3D AR animation. That way, students understand more details about insecticide knowledge.

b) Product feasibility in terms of material and media

During the development phase, the validator evaluates the viability of the instructional media utilized in the classroom by evaluating the SSI content. This learning tool undergoes validation with respect to both content and media aspects. The material validation is overseen by a lecturer specializing in inorganic chemistry at the Department of Chemistry at Universitas Negeri Malang. The outcomes of this validation process are detailed in Table 3.

Table 3. Results of material validation of products

No	Indicator	Percentage (%)	Criteria
1	The suitability of the material on the SSI contents integrated AR	92	Highly feasible
2	The conformity of the material on the SSI contents integrated AR	91	Highly feasible
3	Completeness of chemical literacy aspect in SSI contents integrated AR	90.33	Highly feasible
4	The effectiveness of media in growing students' learning motivation	93	Highly feasible
Average Percentage		**91.58**	**Highly feasible**

Derived from Table 3, the average outcomes of material validation stand at 91.58%, indicating the high validity and suitability of this educational medium for grade 10 senior high school students studying chemical bonding. Recommendations include incorporating additional real-life materials into the SSI contents. Furthermore, the validation process extends to the media design, particularly the AR objects. Evaluation of the product's viability as a learning tool relies on questionnaire responses from experts in media design. The comprehensive results of the validation for product development concerning the learning medium are detailed in Table 4.

Table 4. Results of material validation of products

No	Indicator	Percentage (%)	Criteria
1	Overall view of physical media design on AR objects	91	Highly feasible
2	Information display on AR objects	90	Highly feasible
3	Illustration on AR objects	93	Highly feasible
Average Percentage		**91.33**	**Highly feasible**

Using the provided data, the average percentage of validation results for the product as a learning tool is 91.33%. In comparison with the eligibility criteria outlined in Table 1, the development of the product as a learning medium falls within the category of being highly valid and very suitable for use.

c) Results of Learning Media's Implementation

The implementation stage was conducted using a revised development product based on comments and suggestions from the validators. The test subjects in the experimental class were 32 students in grade 10 and got the results that can be seen in Table 5.

Table 5. Results of questionnaire response of products

No	Indicator	Percentage (%)	Criteria
1	Visual media presentation	91.84	Highly feasible
2	Motivation in learning	88.80	Highly feasible
3	Media effectiveness	91.12	Highly feasible
4	Student literacy in learning	94.53	Highly feasible
Average Percentage		**91.57**	**Highly feasible**

The test evaluating students' responses yielded an average percentage of 91.57%. Consequently, it can be inferred that, based on students' perspectives as potential users, this learning medium is highly valid and very suitable. Among the four evaluated criteria, the highest percentage was recorded for students' literacy in utilizing the product, reaching 94.53%, which means that most students feel easy to learn while using this medium because the real phenomena of chemical bonding material presented in SSI contents integrated with AR technology can increase students' insight and literacy. SSI contents and AR technology are believed to be effective learning media to foster student interest in learning [37]. This is because stories about SSI contents can make students feel comfortable in imagining the material and its implementation in life. In addition, the researchers also tested students and found an increase in their scientific literacy skills. This data was obtained by researchers through the quasi-experimental design method. Based on the test data conducted by the researchers, the post-test scores exceeded the pre-test scores administered to the students. Additionally, the data can be subjected to a different examination through the use of ANCOVA to find out the difference between the control class and the experiment class that use a medium.

Table 6. Pre-test and post-test results of implementation

	Minimum	Maximum	Mean
Pre-test Experiment	25	54	37.16
Post-test Experiment	45	100	80.06
Pre-test Control	25	53	36.28
Post-test Control	44	89	71.34

Based on the pre-test and post-test data obtained in Table 6, it is evident that the maximum post-test value of the experiment class is greater than the control class. In addition, the following are the results of the ANCOVA test obtained from the post-test data. This is reinforced by increasing students' chemical literacy skills through several indicators that can be seen in Figure 4.

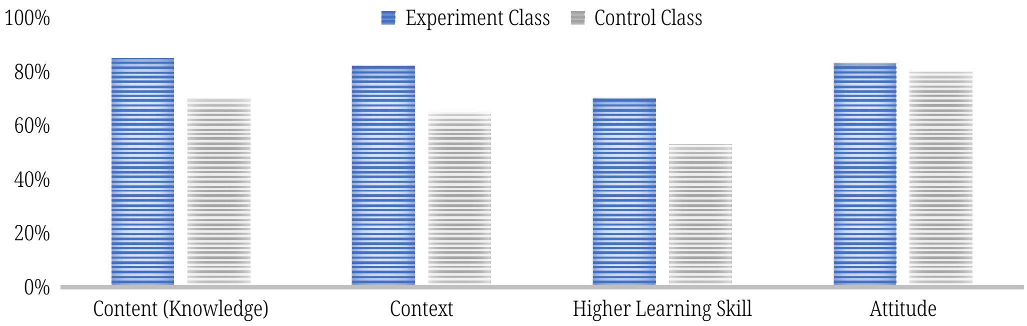

Fig. 4. Post-test results of chemical literacy skill

Table 7. Result of ANCOVA test

Tests of Between-Subjects Effects				
Dependent Variable: Post-Test				
Source	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1216.266	6.732	.012	.098
Intercept	366781.641	2030.200	.000	.970
Class	1216.266	6.732	.012	.098
Error	180.663			
a) R Squared = .098 (Adjusted R Squared = .083)				

Based on Table 7, the significance value in the class column is 0.012 (< 0.05). A significance value of less than 0.05 means that H0 is rejected or H1 is accepted, so there are differences in students' chemical literacy skills between the experimental class taught using teaching materials that have been developed and the control class (Morgan et al., 2004). This shows that the use of teaching materials has an influence on students' chemical literacy skills. In addition, from the results of the ANCOVA test, the partial eta squared value in the class column is 0.098, which indicates that the magnitude of the influence of the use of teaching material on students' critical thinking skills is 9.8%. The indicator of increasing chemical literacy is marked by the ability of students to make predictions, explore examples of real phenomena, explain the reasons why a phenomenon occurs, and draw appropriate conclusions from the data presented [38]. All of these aspects have been tested by researchers during implementation using pre-test and post-test questions. The assessment aspect used in measuring chemical literacy does not only focus on content aspects but can also focus on context and application aspects of chemistry in solving everyday life phenomena [39].

The results of the difference in the percentage of pre-test and post-test scores that answered correctly on all aspects of chemical literacy showed that students had increased chemical literacy skills. The highest result is obtained on the indicator of content (knowledge). This shows that when students are presented with data through depictions in SSI content, it is easy for them to interpret it. In addition, students also got high results on indicators of attitude, so they can implement their knowledge well in real life from the data presented. Through these several abilities, students had an increase in chemical literacy skills.

4 CONCLUSION

To improve chemical literacy skills, the content of SSIs that integrate AR technology is a way that can be implemented in chemical bonding materials and associated with real phenomena in everyday life. The average percentage of material and media validation results as learning media were 91.58% and 91.33%, respectively. While the implementation on 32 high school students got a result of 91.57%. Therefore, it can be inferred that the implementation of this learning medium is highly suitable. This implementation is anticipated to cultivate a more enjoyable learning environment, enhance students' engagement, and facilitate a better understanding of the chemical bonding material. In addition, pre- and post-tests were also conducted to test chemical literacy skills, which were tested on students using ANCOVA test analysis. A significance value of 0.012 was obtained, which means there was a significant difference between the control class and the experiment class using the media, and it means that their chemical literacy skills have increased.

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