Promoting Scientific Literacy in Chemistry Learning on the Subject Colloid through Instructional Material Development

Hatta\(^{(ab)}\), Miterianifa\(^{(bc)}\), Zona Octarya\(^{(ac)}\)

\(^1\)Islamic Elementary School Education Department, UIN Suska Riau, Indonesia
\(^2,3\)Chemistry Education Department, UIN Suska Riau, Indonesia

Corresponding author: \(^b\)miterianifa@uin-suska.ac.id

Abstract. Students' scientific literacy skills are still low because they are still minimal or not the availability of chemistry teaching materials that contain balanced scientific literacy skills. The research objective was to develop scientific literacy-based chemistry teaching materials that contain balanced scientific literacy, validity, readability, and effectiveness. This research conducted research and development methods with the ADDIE approach which consists of five steps; analyze, design, develop, implement, and evaluation. Based on the research results, the teaching materials were based on science literacy colloid material which developed has the characteristics of a balanced scientific literacy content, namely 41.17% of science as the body of knowledge, 17.64% of science as a way of investigating, 17.64% science as a way of thinking, and 23.52% interaction of science, technology, and society. 7 validators of scientific literacy-oriented teaching materials were declared feasible and have criteria easy to understand with average readability of 74.11%. An increase in scientific literacy skills students who use science literacy-based teaching materials is higher than students who using teaching materials used in school.

1. Introduction

Scientific literacy is very important for students to have as a provision to face the challenges of 21st-century development [1][2]. Science literacy is directly related to building a new generation, in this case, students who have strong scientific thoughts and attitudes can effectively communicate knowledge and research results to the community [3]. A student who has scientific literacy is a student who uses scientific concepts, has science process skills to assess in making daily decisions when dealing with other people, society, and their environment, including social and economic development.

In addition to scientific literacy skills, chemistry learning also provides students with character development so that they become accustomed themselves to daily life. The roles in this learning method can help build the character that students have to develop and culture. Scientific literacy requires specific scientific literacy skills, including scientific cognitive understanding inquiry, design, and communication [4].

The Program for International Student Assessment (PISA) is a study that aims to determine the results of the education system related to the literacy abilities of students aged 15 years [5]. PISA studies were conducted in several developed and developing countries starting in 2000 with intervals of every three years. The fields of study that are researched and assessed include reading literacy, mathematical literacy, and scientific literacy. The results of the PISA study from 2000 to 2012 show Indonesia's ranking continues to decline. In 2012, Indonesian students' scientific literacy was at the 64th level of the...
65 participating countries with a score of 382, and Indonesia was ranked 69th out of 75 participating countries in 2015 [6]–[8]. These results indicate that the scientific literacy of Indonesian students is still low so that the results of each test held by PISA still place Indonesia at the bottom of the rankings and in general are still below the standard average score of the Organization for Economy, Cooperation, and Development [7]. This score is still far below the international average score set by PISA, which is 500 [8]. Indonesia's average score, which is still relatively low, reflects that students in Indonesia are largely unable to analyze and apply concepts to solve a problem [9]. The students are very good at memorizing, but still less skilled in using the knowledge they have.

The low scientific literacy skills of students in Indonesia are influenced by the selection of teaching materials used in schools. Teaching materials play an important role in the learning process, namely as a medium for delivering information. Thus, good teaching materials are needed so that learning objectives are maximally achieved. Good teaching materials are teaching materials that contain a balanced component of scientific literacy. Namely that one of the factors that cause students to have low scientific literacy and is directly and closely related to students is learning sources, both from textbooks and from other sources [10]–[13]. Wilkinson (1999) suggests a scientific literacy category that is close to a balanced proportion, namely 42% for the science knowledge category, 19% for the investigation of the nature of science, 19% for the science category as a way of thinking, and 20% for the interaction of science, technology, and society [14]. Based on Utami's research (2014), the teaching materials used in Semarang City have an unbalanced content of scientific literacy. Categories 4 that contain scientific literacy are less balanced, namely science as a body of knowledge, science as a way of investigating, science as a way of thinking, and the interaction of science, technology, and society (Interaction of science, technology, and society) has not been presented in a balanced manner. Utami (2014) with the results of his research shows that the percentage of each aspect of the content of scientific literacy is less balanced. The aspects that appear most in each book are aspects of science as a body of knowledge, namely 65.19%, aspects of science as a way to investigate 12.15%, aspects of science as a way of thinking 11.61% and aspects of the interaction between science, technology, and society. 11.05% [15]. Textbooks that have been analyzed emphasize the aspects of science as a body of knowledge so that they present more facts, concepts, principles, laws, hypotheses, theories, models, and questions that ask students to remember information or memorize the answers [16].

The learning process which only expresses the concept alone certainly does not provide experience for students and makes students' scientific literacy skills low. The presence of teaching materials to support learning so that students' scientific literacy skills increase certainly plays a role. So that competent teachers must have teaching materials that are used as relevant references and practical instructions as one of the effective media in scientific literacy in schools [17]. Therefore, the development of chemistry teaching materials is carried out as an effort to organize better learning and maximum student learning outcomes [18], [19].

Based on this background, teaching materials are needed that can build independence and character to manage thought patterns in a directed way in the learning process. Teaching materials that contain components of scientific literacy and character values can play an important role in fostering noble behaviors and directing students' mindsets in finding a learning concept. Thus, the researcher intends to develop teaching materials that have a balanced composition of scientific literacy and character values, easy to understand, feasible, and effective for high school students.

2. Materials and Methods
This research uses the research and development of the Research and Development (R&D) method which produces the final product in the form of scientific literacy oriented teaching materials on colloid material. The R&D design in this study is the ADDIE model. In this study, researchers used the ADDIE model because the ADDIE Model is the most widely used framework for learning [20]. ADDIE stages are Analysis, Design, Development, Implement, and Evaluation [21], [22]. The research design according to ADDIE models was carried out through 5 steps as shown in Figure 1:
Product validation is carried out in two stages, namely design validation and product validation. Design validation is carried out by the validator as an expert. This validation is of the nature of the experts' judgment. Furthermore, product validation was carried out by one chemistry lecturer and two MA / SMA chemistry teachers. Testing the validity of the product using a feasibility questionnaire for teaching materials to assess the suitability of the material content, material presentation, language, graphics, scientific literacy content, and character content.

The research was conducted at MA Darel Hikmah Pekanbaru and SMA Negeri 2 Pekanbaru. The first step is to test the similarity of two variances to determine the homogeneity of the population. Because the population is homogeneous, the sample was selected using a simple random sampling technique. Class XI MIA 1 as the control class and class XI MIA 2 as the experimental class. The initial product test was a readability test using a gap test with 22 students. The final product testing was carried out with a Pretest-Posttest Control Group Design.

After selecting the research sample, a pretest was carried out on 22 students of the control class and 20 students of the experimental class. The pretest questions consist of 10 description questions. The pretest results are used to determine students' initial abilities. In the next stage, the experimental class conducted learning using character-based science literacy oriented teaching materials and the control class used the teaching materials used in schools.

This division of scientific literacy aspects to be balanced in teaching materials has a ratio of 2: 1: 1: 1. The science aspect as the body of knowledge has the largest percentage, which is 40% and the other three aspects have a percentage of 20%. The percentage of aspects of scientific literacy is calculated based on the indicators to be achieved [23].

The increase in students' scientific literacy skills was tested using the gain test based on the pretest and posttest scores of the control class and the experimental class. The results of the gain normality test indicate that the data is normally distributed so that the hypothesis analysis uses parametric statistical techniques. Hypothesis testing was carried out using the two-mean similarity test (right side t-test) to determine the difference in the increase in students' scientific literacy skills between the experimental class and the control class.

3. Result
The product produced in this study is character-based science literacy-oriented teaching materials on colloid material used in senior high school students of class XI. The research data included the characteristics of scientific literacy-based teaching materials, the results of the feasibility test of teaching materials, the results of the reading of teaching materials, and the results of the analysis of students' scientific literacy abilities. The scientific literacy-based teaching materials developed taking colloid
material include sub-topics of understanding colloids, the nature, and types of colloids, manufacture, and colloid samples. The composition of each aspect of scientific literacy can be seen in Table 1.

| Aspects of Science Literacy | Definition of Colloids | Colloid properties | Colloid Type | Colloid preparation and samples | Average |
|-----------------------------|------------------------|--------------------|--------------|--------------------------------|---------|
| Science as a stem body of knowledge | 35.71\%               | 38.89\%            | 41.67\%      | 35.29\%                        | 37.89\% |
| Science as a way Investigate | 21.43\%               | 22.22\%            | 25.00\%      | 11.76\%                        | 20.10\% |
| Science as a way Think      | 28.57\%               | 22.22\%            | 16.67\%      | 23.53\%                        | 22.75\% |
| The interaction of science, technology and Public | 14.29\%               | 16.67\%            | 16.67\%      | 29.41\%                        | 19.26\% |

On the subject of colloids, the first aspect, namely science as a body of knowledge, is contained in the Let's Learn feature. The Ayo Belajar feature contains facts and concepts on the difference between suspension, colloid, and solution. The science aspect as a way of investigating invites students to conduct experiments to distinguish suspensions, colloids, and solutions. The aspect of science as a way of thinking is represented by the Let's Thinking feature. This feature addresses colloid pegging.

The aspects of the interaction of science, technology, and society are represented by the features of science in life that describe solidity in everyday life [24]. The discourse explains how the colloid system is a way to mix substances that do not dissolve homogeneously such as oil and water which can be formed by soap, mayonnaise, or butter so that they can be homogeneous and tend to be stable. The linkage between the elements of science, technology, society, and the environment allows students to use science in technology to meet their needs without damaging the environment [25].

Based on the results of the analysis, the comparison of the content of scientific literacy in the developed teaching materials includes science as the body of knowledge, science as a way of investigating, science as a way of thinking and the interaction between science, technology, and society is 37.89\%: 20.10\%: 22, 75\%: 19.26\%. The study gave the results that the content of scientific literacy in books was different, but which was close to balanced, namely 42\% for science as a body of knowledge, 19\% science as a way of investigating, 19\% science as a way of thinking and 20\% of the interaction between science, technology, and society or in general has a ratio of 2: 1: 1: 1 [14].

The feasibility level of teaching materials was tested using a feasibility questionnaire for teaching materials. The book feasibility assessment indicator refers to the criteria of the National Education Standards Agency, namely aspects of content eligibility, presentation techniques, language assessment, and graphics (BSNP, 2007) as well as one aspect of scientific literacy according to Chiapetta, et.al (1991). Questionnaires were given to 7 expert experts, namely 3 lecturers and 4 high school teachers. The results of the feasibility test for teaching materials can be seen in Table 2 and Table 3.
Table 2. Results of Feasibility Test for Teaching Materials by Validators

| No. | Validation | Percentage | Criteria          |
|-----|------------|------------|-------------------|
| 1.  | Media Design | 88%        | Very Worth it     |
| 2.  | Learning materials | 87%  | Very Worth it     |
| 3   | Character Integration of Learning Materials | 80%  | Well worth it     |
|     | Percentage Average | 85%  | Very Worth it     |

Table 3. The results of the Teaching Material Feasibility test by the teacher

| Type of Questionnaire | Indicator | Part Number | Score | Percentage (%) | Criteria          |
|-----------------------|-----------|-------------|-------|----------------|-------------------|
| Questionnaire for teacher practicality test | Module Organization | 2, 3 | 10 | 90% | Very Practical |
|                       | Truth of Concept |          | 32    | 80% | Very Practical |
|                       | Suitability of Material |       | 4, 5  | 34 | 85% | Very Practical |
|                       | Content of the 2013 Curriculum |     | 6, 7, 8 | 52 | 87% | Very Practical |
|                       | Level of Exercise Execution | | 9, 10 | 32 | 80% | Very Practical |
|                       | Learning Evaluation |           | 11, 12 | 34 | 85% | Very Practical |
|                       | Clarity of Sentence and Readability |          | 13, 14, 15, 16, 17 | 83 | 83% | Very Practical |
|                       | Physical Display of Chemistry Module |         | 18, 19, 20, 21, 22 | 80 | 80% | Very Practical |
|                       | Total       |           | 365   | 83% | Very Practical |

The analysis of the level of readability of science literacy-based teaching materials was carried out using the gaps test involving 22 students from the experimental class as respondents. The legibility test results show that the teaching materials used have easy-to-understand criteria with average readability of 74.11%.

Even though the readability of the teaching materials had easy to understand criteria, 5 students only met the legibility requirements. The different results of each student are influenced by several factors. The difference in results obtained by students is likely due to differences in the ability to understand and manage different student learning activities. This fact is in line with the opinion of Reigeluth (1983) in which explains that learning outcomes are a function of personal input and input comes from the environment (environmental input). Personal input consists of (1) motivation or values, (2) expectancy, (3) intelligence and initial mastery, and (4) cognitive evaluation while environmental input includes: (1) management motivational, (3) intelligence and initial mastery, and (4) cognitive evaluation while environmental input includes: (1) management motivational, (3) management of reinforcement [27].

To increase the level of readability, it is necessary to improve teaching materials by reviewing words or sentences in teaching materials. Sakri argues that readability depends on the vocabulary and sentence structure chosen by the author for his writing [28]. Using unfamiliar vocabulary will be more difficult to understand than using familiar vocabulary. Also, long and complex sentence structures will make it difficult for readers to understand the text. Therefore, words or sentences that were answered incorrectly by the majority of students were then corrected or replaced with more familiar words and more effective sentences. This improvement aims to make the teaching materials developed easier for users to understand.


Table 4. Results of Students’ Science Literacy Ability

| Result     | Experiment Group | Control Group |
|------------|------------------|---------------|
| Gain test  | 0.63             | 0.38          |
| T-test     | 7.5739           |               |

Based on the two average similarity test analysis, thus it can be interpreted that the increase in scientific literacy skills of students who use the teaching materials developed is higher than students who use the teaching materials used in school.

The results of the scientific literacy abilities of the control class and experimental class students are shown in Figure 2.

![Figure 2](image)

Figure 2. The Ability of Each Aspect of Science Literacy in the Control and Experimental Classroom

The highest aspect of scientific literacy in the experimental class is the interaction of science, technology, and society, second place in science as a body of knowledge, third is science as a way of investigating and the lowest is science as a way of thinking. The interaction aspect of science, technology, and society which occupies the first position with a percentage of 82.89% indicates that students have the skills to use science at various events in life. This result is by Agustini's research (2013) which shows that the use of science, technology, and learning models society can improve science problem-solving skills in everyday life. The American National Science Teachers Association (NSTA) even considers that the interaction between science, technology, and society is the basis of science education because it emphasizes the importance of teaching interactive relationships between science, technology, and society in decision-making on everyday problems [29].

The ability of students in the experimental class in the aspect of science as a way of thinking is high because the practice questions contained in the textbook used in the experiment class ask students to use concepts and analyze questions. It is in line with the research conducted by Rusilowati (2011) that to develop students' ability to construct concepts cannot be done spontaneously [13]. To develop a concept, students need to be given practice or habits first. Students who are often faced with analytical questions and conceptual concepts have better skills [30].

Based on the analysis of the post-test results of the experimental class and the control class, the use of scientific literacy-oriented textbooks can improve scientific literacy skills and student learning outcomes on colloid material. These results are in line with research conducted by Taslidere (2012) and Shwartz (2006) using science literacy textbooks which are more effective in improving chemistry learning outcomes compared to other learning strategies [31], [32]. The results of this study indicate that
the textbooks that have been developed are proportionally balanced between knowledge, thinking activities, and balanced interactions of science, technology, and society [14].

4. Conclusion
Based on the research results, the scientific literacy oriented teaching materials on the developed colloid material is very valid. The teaching materials developed contain material descriptions consisting of balanced content characteristics, namely scientific literacy, science as a body of knowledge, science as a way of investigating, science as a way of thinking, and the interaction of science, technology, and society. Teaching materials that contain scientific literacy components can play an important role in fostering and directing students' mindsets in finding a learning concept. The findings of this study indicate that to improve students' scientific literacy, teaching materials that have a balanced content of scientific literacy are needed. Sufficient coverage of the theme of scientific literacy in terms of knowledge and technology must have a chemistry curriculum to support students' learning experiences. Based on the results of the research, it is based on teachers, schools, and curriculum development to be able to develop chemistry teaching materials that are scientifically oriented. For further researchers, they can develop theories and models that can support and improve understanding of chemical science as well as analysis of the chemistry curriculum which provides the theme of scientific literacy in all curriculum units in the same research.

References
[1] J. Voogt and N. P. Roblin, “A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies,” J. Curric. Stud., vol. 44, no. 3, pp. 299–321, 2012.
[2] P. Turiman, J. Omar, A. M. Daud, and K. Osman, “Fostering the 21st Century Skills through Scientific Literacy and Science Process Skills,” Procedia - Soc. Behav. Sci., vol. 59, pp. 110–116, 2012.
[3] D. J. Treacy and M. S. Kosinski-Collins, “Using the Writing and Revising of Journal Articles to Increase Science Literacy and Understanding in a Large Introductory Biology Laboratory Course,” Atlas J. Sci. Educ., vol. 1, no. 2, pp. 29–37, 2011.
[4] L. D. Yore, D. Pimm, and H. L. Tuan, “The literacy component of mathematical and scientific literacy,” Int. J. Sci. Math. Educ., vol. 5, no. 4, pp. 559–589, 2007.
[5] K. Ananiadou and M. Claro, “21st century skills and competences for new millennium learners in OECD countries,” OECD Educ. Work. Pap., no. 41, p. 33, 2009.
[6] OECD, Pisa 2009 Results: Changes in Student Performance Since 2000, vol. V. 2010.
[7] OECD, Overview: Excellence and Equity in Education, vol. 1. Paris: OECD Publishing, 2016.
[8] OECD, PISA 2012 Results: What Students Know and Can Do StuDent PeRfoRmAnCe In mAthemAtICS, ReADIng AnD SClenCe, vol. 1. Paris: OECD Publishing, 2014.
[9] H. N. Dinni, “HOTS (High Order Thinking Skills) dan Kaitannya dengan Kemampuan Literasi Matematika,” Prisma, vol. 1, pp. 170–176, 2018.
[10] C. Yuenyong and P. Narjaikaew, “Scientific literacy and thailand science education,” Int. J. Environ. Sci. Educ., vol. 4, no. 3, pp. 335–349, 2009.
[11] J. M. Reveses, R. Cordova, and G. J. Kelly, “Science literacy and academic identity formulation,” J. Res. Sci. Teach., vol. 41, no. 10, pp. 1111–1144, 2004.
[12] M. I. S. Putra, W. Widodo, and B. Jatmiko, “The development of guided inquiry science learning materials to improve science literacy skill of prospective mi teachers,” J. Pendidik. IPA Indones., vol. 5, no. 1, pp. 83–93, 2016.
[13] A. Rusilowati, S. E. Nugroho, and S. M. Susilowati, “Development of Science Textbook Based on Scientific Literacy for Secondary School,” J. Pendidik. Fis. Indones., vol. 12, no. 2, pp. 98–105, 2016.
[14] J. Wilkinson, “A quantitative analysis of physics textbooks for scientific literacy themes,” Res. Sci. Educ., vol. 29, no. 3, pp. 385–399, 1999.
[15] B. Utami, S. Saputro, Ashadi, and M. Masykuri, “Scientific literacy in science lesson,” Pros. ICTTE FKIP UNS 2015, vol. 1, no. 1, pp. 125–133, 2016.
[16] I. Devetak and J. Vogrinc, “Critical Analysis of Science Textbooks,” Crit. Anal. Sci. Textb., no. December 2016, 2013.
[17] V. Dragoş and V. Mih, “Scientific Literacy in School,” Procedia - Soc. Behav. Sci., vol. 209, no. July, pp. 167–172, 2015.
[18] N. Asikin and I. Yulita, “Scientific Literacy-Based Chemical Teaching Materials Design of Chemical Solution Materials on Sea Pollution Context,” J. Penelit. Pendidik. IPA, vol. 5, no. 2, p. 204, 2019.
[19] R. Marks and I. Eilks, “Promoting scientific literacy using a sociocritical and problem-oriented approach to chemistry teaching: Concept, examples, experiences,” Int. J. Environ. Sci. Educ., vol. 4, no. 3, pp. 231–245, 2009.
[20] B. Military and H. Molenda, “5403107_7145778_Wk05_Molenda_ADDIEModel_PIJ2003,” no. June, pp. 34–36, 2003.
[21] R. M. Gagne, W. W. Wager, K. C. Golas, J. M. Keller, and J. D. Russell, “Design, 5th Edition,” no. February, pp. 44–46, 2005.
[22] C. Peterson, “Bringing ADDIE to life: instructional design at its best,” J. Educ. Multimedia. Hypermedia, vol. 12, no. 3, pp. 1–5, 2003.
[23] J. R. Bormuth, “Development of standards of readability: Toward a rational criterion of passage performance,” U. S. Dep. Heal. Educ. Welf., no. (ERIC Doc. No. ED O54 233).
[24] C. Bolte claus.bolte@fu-berlin.de, “A Conceptual Framework for the Enhancement of Popularity and Relevance of Science Education for Scientific Literacy, based on Stakeholders' Views by Means of a Curricular Delphi Study in Chemistry.,” Science Education International, vol. 19, no. 3, pp. 331–350, 2008.
[25] A. Rusilowati, “Pengembangan Bahan Ajar Berbasis Literasi Sains Materi Fluida Statis,” UPEJ Unnes Phys. Educ. J., vol. 5, no. 3, pp. 25–31, 2016.
[26] L. M. Morrow, “Literacy Development in Early Years: Helping children read and write,” Handb. Instr. Pract. Lit. Teach. Examples Reflections From Teach. Lives Lit. Sch., p. 400, 2001.
[27] C. M. Reigeluth, Instructional-design Theories and Models: An overview of their current status. Psychology Press, 1983.
[28] Permendikbud Nomor 24 Tahun, “Permendikbud,” in Permendikbud, 2016, pp. 1–5.
[29] N. Mansour, “Science-Technology-Society (STS),” Bull. Sci. Technol. Soc., vol. 29, no. 4, pp. 287–297, 2009.
[30] J. E. Upahi, R. Gbadamosi, and V. E. Boniface, “Scientific literacy themes coverage in the nigerian senior school chemistry curriculum,” J. Turkish Sci. Educ., vol. 14, no. 2, pp. 52–64, 2017.
[31] E. Taslidere and A. Eryilmaz, “The Relative Effectiveness of Integrated Reading Study Strategy and Conceptual Physics Approach,” Res. Sci. Educ., vol. 42, no. 2, pp. 181–199, 2012.
[32] Y. Schwartz, R. Ben-Zvi, and A. Hofstein, “The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students,” Chem. Educ. Res. Pract., vol. 7, no. 4, pp. 203–225, 2006.