STEM – book on drinking water using 4S TMD models to develop students technology literacy

B Mardiyya¹, S Anwar², and D T Chandra³

¹Program Studi Pendidikan IPA, Sekolah Pascasarjana Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
²Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr.Setiabudi No. 229, Bandung 40154, Indonesia
³Departemen Pendidikan Fisika, Universitas Pendidikan Indonesia, Jl. Dr.Setiabudi No. 229, Bandung 40154, Indonesia

*Corresponding author’s e-mail: bunga.mardiyya@upi.edu

Abstract. This study aims to describe how to develop STEM – book on drinking water using 4S TMD models to develop student’s technology literacy. 4S TMD models consists of four stages i.e selection, structuring, characterization and didactic reduction. Developmental Research was used as method of the study consist of design, develop, and evaluation. In this article, we explain result of developed STEM – book on drinking water in selection and structuring stages. Selection stage consist of analysis science curriculum in junior high school related to the theme of drinking water, selection of concept label, selection of values that will appear in teaching material. in this book, we attempted interrelationships between students technology literacy and subject matter of science in junior high school. Structuring stage consist of make a concept maps, macro structure and multiple representation. In this paper, we only explained until the structuring stage. Characterization and didactic reduction stages are still in the research stage.

1. Introduction

Industrial Revolution 4.0 is a transformation effort to improve efficiency in each value chain by integrating digital capabilities and production lines in industries that refer to increased automation, communication machine-to-machine and human-to-machine, artificial intelligence, and the development of sustainable technology in the industry. The role of technology as a source of information requires young people to develop their literacy skills [1,2]. Technology literacy is defined as the ability of individuals to use, manage, evaluate, and understand technology [3-5]. Technology that continues to evolve makes it multifunctional as an object that must develop. Technology as a product that is re-created as a means to create new technology so as to reproduce new developments and become even better [6].

Education is the main facility for citizens, especially the younger generation, to develop their ability to respond to and develop technology. One of the subjects that trains the novelty process is science subjects. Science is developed as a subject in the form of integrated sciences with content originating from the disciplines of physics, chemistry and biology. Science learning aims to provide a more meaningful learning experience that enhances conceptual understanding and application of knowledge [7]. Images and facts about everyday life with integrated knowledge from various disciplines are linked to the development of technology and information. This shows that science teachers must teach their students for technology literacy. In developing students' technological...
literacy skills, many studies show that STEM learning can improve students' technological literacy [8-10].

The problem faced is how to define STEM and interpret it in a teaching and learning activity [11]. The limitations of the teacher in implementing STEM learning in class are still constrained by the teacher's ability to integrate STEM. The 2013 curriculum that did not explain clearly and implicitly about integrated STEM learning for junior high school students became one of the factors that made STEM learning has not been implemented widely and considered difficult. One of the times required for STEM learning is not enough to achieve the learning targets set in the school curriculum. The involvement of the use of integrated STEM teaching materials in the learning and teaching process in the classroom is one of the references as a source of guidance for STEM learning for teachers. In order for teachers to be aware of STEM integrated teaching materials the importance of STEM integrated learning goals in order to modify effective learning in the classroom [12].

The integrated model used in this study is a webbed. Webbed is an integrated learning model that uses a thematic approach in integrating subjects. Webbed cohesiveness models usually use a theme to combine subjects, such as drinking water subject. This subject is a suitable theme for science learning because water is the basis of human needs which covers all aspects of science. So that it can be described the integration of the subject matter with the theme of Drinking Water in the development of teaching materials such as Figure 1.

Figure 1. Webbed integrated learning model for drinking water

STEM integrated teaching materials namely teaching materials used in implementing the STEM approach have aspects of science, engineering activities, crosscutting concepts, and themes that accommodate these aspects. In learning these aspects are presented coherently. Standards for integrated STEM teaching materials must have a conceptual framework, describe engineering activities, and the relationship between them. In order for teaching materials to accommodate technological developments, teaching materials that explain the important role of student reflection on the application of knowledge are one of them when solving problems in integrated engineering design [13-17].

2. Method
The research method used in this study is Developmental Research by Richey, Klein, and Nelson. The development model is the DDE model (Design, Development, and Evaluation). This research is used to develop and validate educational products [18]. The products that will be produced in this study are student learning materials in the form of books developed through 4S TMD. This stage of the research model development model Richey, Klein, & Nelson starts from:
a) Design is an activity to make a product plan that will be made. This activity begins with a needs analysis carried out through field studies and literature studies. At this stage the researcher determines the theme namely Drinking Water which is associated with technological literacy.

b) Development is the activity of making products based on the designs that have been made. At this stage the researcher will develop teaching materials using the 4S TMD method (Four Step Teaching Material Development) which consists of 4 stages, namely the stages of selection, structuring, characterization, and didactic reduction.

c) Evaluation is an activity to test and assess how high the teaching material is made whether it meets the specified specifications. At this evaluation phase the researcher will test the teaching material developed and then make a revision of the results of the trial. Tests of teaching materials will be conducted on junior high school / MTs students. Students will be given teaching materials for their study, and students will be given back teaching materials that have been evaluated in order to measure the level of understanding of the teaching material. In addition to students, science teachers will also be asked to assess the feasibility of the teaching materials to be developed.

3. Result and Discussion

3.1. Characteristics of STEM Book on Drinking Water

STEM – book on drinking water using 4S TMD models to develop students technology literacy were developed using the 4S TMD method which consisted of selection, structuring, characterization and didactic reduction stages. The results of the development using the 4S TMD method are as follows

3.1.1 Selection

The selection stage is the process of selecting materials that are in accordance with the demands of the applicable curriculum, including also identifying the values and skills that can be developed [19]. This stage begins with curriculum analysis to determine Basic Competencies (KD) which then select concepts that are relevant to the theme. In addition, at this stage identification of values and skills can also be developed that can be developed in certain concepts. The selection phase also developed learning objectives for achieving technology literacy competencies that were in accordance with relevant concepts. In addition, the components of technology literacy were also developed in the compilation of the material compiled. The results of the selection stage are compilation of material which is then reviewed by expert lecturers.

Based on the results of the science curriculum selection for junior high school related to the theme of drinking water, the Basic Competencies related to the chosen theme can be seen in Table 1. In Table 1 the selected example Basic Competencies we have lowered into learning goals and labeled conceptual concepts for each Basic Competency.

| No | Basic Competence | Learning Objectives | Concept Labels |
|----|------------------|---------------------|----------------|
| 1. | 3.3 Presents results of investigations or works about the nature of solutions, changes in physics and chemical changes, or separation of mixtures | 4.3.1. Students can design technology from the application of a method of separation of mixture by distillation to treat seawater into fresh water as a technological innovation in the coastal area. | • Method of separating the mixture by distillation |
|    |                  | 4.3.2. Students can make simple tools to get decent water for use in a small scope against polluted water. | • Criteria for drinking water |

3.1.2 Structuring

The material that has been compiled at the selection stage is then structured in a didactic manner, in accordance with the characteristics of the instructional materials structure [19]. The structure of
teaching materials is arranged in macro forms, concept maps, and multiple representations. Gilbert and David (2009) explain that multiple representations are divided into 3 levels, namely:

a) Macroscopic: presents phenomena related to observable concepts.

b) Microscopic: explanation of the phenomenon presented

c) Symbolic: the presentation of concepts using symbols, such as images, signs, or others.

Macro structure results, concept maps, and multiple representations are then reviewed by expert lecturers. Then the initial draft of the teaching material is prepared based on the results of selection and structuring. The concepts that have been obtained at the selection stage, was then made a concept map to clarify the interrelationships between concepts, making it easier for teachers to teach using this teaching material. The process of developing teaching materials requires a set of materials for teaching materials for teaching materials. Therefore, each subject matter of teaching materials needs to be analyzed and mapped into a model of text representation, called macro structure. Macro structure is a mapping of how teaching material concepts and materials are arranged in a discourse. Macro structure that shows a picture of propositions that describe the relationship between concepts / subject matter. Macro structure is a two-dimensional model, namely the dimensions of progressions that reflect the order of material (into material) and mapped down, and dimensions of elaboration that describe the position of explanatory paragraphs (breadth of material) and mapped sideways [20]. Examples of macro structures in this teaching material can be seen in Figure 2.

![Macro Structure of Drinking Water Teaching Material](image1)

**Figure 2. Example of Macro Structures**

To find out the composition of blood that is so tiny, scientists use technology as a tool. Technology that utilizes centrifugal force due to the centripetal force on a rotating object. This technology is the application of a mixture separation technique by centrifugation. Representation is a description of a concept that aims to help someone learn concepts by connecting concepts with phenomena. Basically, a concept can be represented in various ways such as descriptive (verbal, graphic, table), experimental, mathematical, figurative, kinesthetic, visual, and optional-operational modes [21]. The use of representations with various forms and models of representation such as verbal, graphical, and numerical is called multiple representation [22]. Furthermore, multiple representations are made consisting of macroscopic, submicroscopic and symbolic as in Figure 3.
3.1.3 Characterization

At the characterization stage, the draft teaching material is tested to students to identify the difficulty level of the material in the teaching material. Then, measured the level of students' understanding of the material provided. As for measuring students' understanding of the presentation of the material carried out by the main idea writing test. Based on the results of the main idea writing test that can be known the difficulty level of the teaching material presented. Furthermore, these results are used to carry out didactic reduction grids.

3.1.4 Didactic Reduction

Based on the didactic reduction grid produced at the characterization stage, concepts that are in the category of difficulty are reduced in difficulty. Didactic reduction can be done in various ways, including returning to the qualitative stage, ignoring, using explanations in the form of images, symbols, sketches, and experiments, using analogies, using levels of historical development, generalization, particularization, or ignoring differences in concept statements. In the research that has been done there are no pictures or pictures that are considered unclear by the teacher.

3.2 STEM-book on drinking water to develop students technology literacy

In this study, the development of integrated STEM teaching materials is to make engineering activities an activator in solving problems [1]. The ability of technological literacy can be viewed from three complex dimensions namely knowledge, capacity, and critical thinking and decision making, which are interrelated and coordinated and create additional synergies [3]. For junior high schools the ability of technology literacy in learning encompasses design and technology. In the application of design and technology to high school students, design and technology are seen as subjects and processes. The design and technology described in scientific technology literacy are catalysts to explain and understand how all man-made objects work and relate to society. Teaching materials used in implementing the STEM approach have aspects of science, engineering activities, crosscutting concepts, and themes that accommodate these aspects. In learning these aspects are presented coherently. The standards for integrated STEM teaching materials must have a conceptual framework, describe engineering activities, and their relationship. The characteristic of integrated STEM teaching materials is having hands on activities with activities such as engineers in the form of instructions. This teaching material in improving technological literacy skills can be integrated into the basic competencies contained in the curriculum. The selection of themes in the structuring stage forms a major theme in describing science learning involving technology, engineering and mathematics. In this study included supporting facilities that embody interaction between teachers and students as that is in the form of knowledge formation involving questions [1]. Then the placement of integrated problem instructions becomes an important part in making book design. The use of STEM integrated teaching materials is the use of mathematics and science as student learning content. Science and mathematics
in STEM learning have an integrated relationship where both support engineering activities. The use of technology is an aspect found in STEM education.

Students must be taught to develop their design skills and technology through combining their designs and making skills with the knowledge and understanding to design and make. Science learning is built using a framework: science and engineering practice; crosscutting concept that connects science learning with technological and mathematical elements; and core ideas in subjects. The crosscutting concept has the potential to help students see science unity. In short a concept is called crosscutting concept when students communicate scientific ways to explain a subject, and this applies to various disciplines of science and engineering. The purpose of crosscutting is to help students deepen their understanding of core ideas in a subject matter and develop a scientific and coherent perspective on the world.

4. Conclusion
In general, this study aims to produce integrated STEM teaching materials on the theme of drinking water in developing technological literacy that is suitable for use by junior high school students. The development of teaching materials in this study used the 4S TMD development model which consisted of 4 stages namely didactic selection, structuring, characterization and reduction stages. In this article we discuss the results at the stage of development of selection and structuring. In the selection phase consists of determining basic competencies related to the theme of drinking water, determining learning objectives based on basic competencies and determining label concepts. The structuring stage consists of the preparation of concept maps, macro structures and multiple representations.

5. References
[1] English L D & King D T 2015 International Journal of STEM Education. 2 pp 14
[2] Varela B, Sesto V and García-rodéja I. 2018 Research in Science Education Mar:1-26.
[3] Avsec, S., & Jams, J. A path model of factors affecting secondary school students’ technological literacy. 2016.
[4] Avsec S and Szewczyk-Zakrzewska A 2017 International Journal of Technology and Design Education. 27 pp 233–250.
[5] Kwon H 2017 International Journal of Technology and Design Education 27 pp. 431-44.
[6] Lawrenz F, Gravemeijer K and Stephan M. 2017. International Journal of Science and Mathematics Education 15 pp 1–4.
[7] Wei, B. 2018 An Exploratory Study of Teacher Development. Research in Science Education. pp 1-18
[8] Lo J M 2017 International Journal of Technology and Design Education 27 pp 329–362.
[9] Kelley T R and Sung E 2016 International Journal of Technology and Design Education. 27 pp. 363-386
[10] Schmidt M and Fulton L 2016 Journal of Science Education and Technology 25 pp.302–315.
[11] Page C and Sugira, V 2017 Journal of General Internal Medicine 32 pp 497–499.
[12] Gallard Martínez A J, Pitts W, Ramos de Robles S L, Milton Brkich K L, Flores Bustos B, Claeyts L 2019 Discerning contextual complexities in STEM career pathways: insights from successful Latinas
[13] Bell D, Morrison-Love D, Woff D, and McLain M. International Journal of Technology and Design Education, 2018. 28 pp 721–737.
[14] Capobianco B M., DeLisi J, and Radloff J. 2017 Science Education 102 pp. 342–376.
[15] Guzey S S, Ring-Whalen E A, Harwell M and Peralta Y 2017 International Journal of Science and Mathematics Education. 17 pp. 23-42
[16] Moore T J, Stohlmann M S, Wang H, Tank K M, Glancy A W and Roehrig G H 2014 Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardella (Eds.), Engineering in pre-college settings: Research into practice. 35–60. West Lafayette, IN: Purdue University Press.
[17] Wendell K and Lee H 2010 Journal of Science Education and Technology 19 pp 580–601.
[18] Richey R C, Klein J D and Nelson W A 2004 Handbook of Research for Educational Communications and Technology 2 pp 1099-1130
[19] Anwar S 2014 Pengolahan Bahan Ajar. Bandung: Universitas Pendidikan Indonesia.
[20] Gilbert JK and Treagust DF 2009 Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education. In Multiple representations in chemical education (pp. 1-8). Springer, Dordrecht.
[21] Setiadi R 2014 Penerapan Analisis Wacana dalam Pengembangan Bahan Ajar Materi Pokok Pada Kegiatan Workshop Penulisan Bahan Ajar di Jurusan Pendidikan Kimia FPMIPA UPI.
[22] Waldrip B, Prain V and Carolan 2006 Electronic Journal of Science Education 25 pp 13531368.