Students’ chemical literacy development through STEAM integrated with dilemmas stories on acid and base topics

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Abstract. The aim of this study was to develop students’ chemical literacy through the STEAM learning approach integrated with dilemmas stories on acid and base topics. The study was conducted in the 2018/2019 academic year and involved the thirty-six students of year 11. The research employed qualitative method to explore students’ chemical literacy through classroom observation, reflective journals, student interviews, researcher notes, and chemical literacy tests. This study used four chemical literacy components according to Shwartz et. al., namely scientific and chemical content knowledge, chemistry in context, high order learning skills, and affective aspect. The STEAM (science, technology, engineering art, and mathematics) integrated with dilemmas stories implemented through five stages, namely value reflection, problem solving, project development, monitoring and evaluation, and transformation. The overall results of the study showed that students were 8.33% at very good levels, 86.11% at good levels, 5.56% at fair levels, and there were no more students who were at poor level and very poor level. The challenges faced in this study are time management, engaging student, and public issues related to chemistry that in accordance with the topic of learning. STEAM integrated with dilemmas stories provides opportunities for students to develop chemical literacy through value reflection, problem solving, and STEAM project.

1. Introduction
Chemistry is one of the branches of sciences which is important to be understood by students, because chemistry is closely related to students’ lives [1, 2, 3]. According to scientific literacy survey that contain 20% of chemistry domain by the Trends in Mathematics and Science Studies (TIMSS) indicating that Indonesia was ranked 45th out of 48 countries [4]. This result is relevant to Indonesian researchers which shows that chemical literacy of teaching candidate is still low [5] and the chemical literacy of high school students is in fair level [6].

The low level of chemical literacy in Indonesia is caused by various factors, such as the low quality of educator resources and the low quality of the teaching and learning process. STEAM (Science, Technology, Engineering, Art, and Mathematics) is a learning approach designed by integrating five scientific disciplines that encourage curiosity in students to explore their own knowledge [7]. Various studies on the application of STEAM in Indonesia have an impact on motivation and the development of students’ soft skills. STEAM studies in Indonesia are related to various focuses, such as multiple intelligence [8], students' attitudes [9], 21st century skills [10], and chemistry learning [11, 12].

In this study, STEAM project was integrated to dilemmas stories in order to create challenging learning experiences and contextualizing STEAM project as problem solution. Dilemmas stories is a learning approach that have long been applied in learning since it was first introduced by Lawrence
Kohlberg in 1984 [13]. The further studies need to be developed in order to relate in local and global context. Study on dilemmas stories has been conducted in Indonesia and has various impacts, such as reflection on values, curiosity, responsibility, and argumentation [14] and critical reflection on their values, collaboration with others, on their roles in participating in environmental education, social issues, and deep chemistry learning [15]. Innovation of integration STEAM project with dilemmas stories in this study is focused on students’ chemistry literacy development. In this study, students’ chemical literacy was analyzed through five aspects of chemical literacy by Shwartz et. al., namely general scientific ideas, characteristics of chemistry, chemistry in context, high order learning skills and affective aspects [16].

2. Methods
The study employed qualitative research methodology with multiple data collection of classroom observations, reflective journal, chemical literacy tests, and interviews. These data were collected to provide the information on how the integration of STEAM and dilemmas stories developed chemical literacy in acid and base topic. This study was held six times across a three period and involved 36 students of 11 grade. The learning stages of the integration of STEAM and dilemmas stories in chemistry learning consist of five stages as shown in the picture below.

![Figure 1. Integration of STEAM and Dilemmas Stories in Chemistry Learning [17]](image)

Figure 1 shows the stages learning of the integration of STEAM and dilemmas stories. The dilemmas stories used in the value reflection and problem-solving stage with the issue raised in the story was detergent waste. Students are encouraged to be able to solve these problems by making STEAM project of detergent wastewater treatment. The collected data were analysed through three stages namely data reduction, data display, and conclusions [18]. Data were reduced by grouping, selecting, focusing, and removing unnecessary items based on the chemical literacy component and categorized each component into five levels [16]. Data were presented in the form of tables, graphs, and narrative texts and the conclusions that was drawn then verified by checking its consistency and compatibility with other data collected.

3. Result and Discussion
The results show that the integration of STEAM and dilemmas stories has developed students’ chemical literacy. The implementation of STEAM in chemistry learning has been shown in Table 1.
Table 1. STEAM Integration in Detergent Wastewater Treatment Project

| Science                | Technology                                      | Engineering                                      | Art                              | Mathematics                     |
|------------------------|-------------------------------------------------|--------------------------------------------------|----------------------------------|---------------------------------|
| The concept of acid and base | Making a device to reduce negative impact of detergent wastewater | Designing a device | Decorate the device according to the creativity of the students | Calculation in device production |
| Testing the pH solution using universal indicators | Detergent wastewater treatment technology | Assembling the tools | Display powerpoint as presentation material | Calculate time for project making |
|                        | Using laptop, handphone, projector, and powerpoint as media presentation | Arranging the filtering substances in the device | Making a creative media | Measure the solution pH |

Table 1 shows that STEAM provided the opportunities for students to develop the competences of hard skills such as deep chemical knowledge on acid and base topics, mathematics skills, and skilled in operating computer and other electronics devices. Besides, STEAM encouraged students to develop soft skills such as communication, creativity, and collaboration [10].

In my opinion the integration of STEAM and dilemmas stories is a new thing for me, in the process students are expected to be able to think creatively, critically, and be able to take existing risks according to experience in problems that have been determined in the story

(Reflective Journal, Answer of Student 2, 23 January 2019)

Figure 2. Detergent Wastewater Treatment Making and pH Test by Students

The project making encouraged students to be critical to the high pH of detergent waste, so students need to use the concept of acid-base to carry out the process of neutralization to reduce the adverse effect on environmental balance. The reflective journal and figure 2 are relevant to the finding STEAM integration in chemistry learning developed students’ creativity and critical thinking [19].

The development of students’ chemical literacy through the integration of STEAM and dilemmas stories has been shown in the figure below.

Figure 3. Histogram of Students’ Chemical Literacy Achieving Levels

The figure 3 shows that most of the students reach good levels in chemical literacy tests. This result indicated that students have been able to conduct scientific inquiry, generalize findings, explain...
microscopic phenomena, use chemical knowledge to explain phenomena in life and have an interest in various chemical issues [16]. There were no more students at poor and very poor level indicate that students’ chemical literacy has developed. The following is a discussion of each aspect of chemical literacy during the learning process.

3.1. General Scientific Ideas
The integration of STEAM and dilemmas stories can improve student’s ability to carry out scientific investigations, generalize findings, and use knowledge to explain phenomena in other fields, such as earth science and biological sciences [16]. The results of this study indicated most of students reach good levels. This finding proven by the classroom observation below.

Student 35 : From the examples given, is it true if strong acid and strong base have direct arrow in the ionization while weak acid and weak base have reversible arrow?
Teacher : Yes, that is true. Do you remember in which chapter we learnt about reversible reaction?
Student 15 : In chemical equilibrium chapter
Teacher : Good. Do you remember in the equilibrium reaction there is an equilibrium constant value symbolized by k? So what is you can conclude?
Student 26 : Weak acid has acid equilibrium constant symbolized by $K_a$ and weak base has base equilibrium constant symbolized by $K_b$.
(Classroom observation, 9 January 2019)

Based on the observations above, students have been able to investigate the difference between strong and weak acid and bases based on the direction of the arrows through the examples given and they able to draw conclusions related to one of the characteristics of weak acid which has acid equilibrium constant ($K_a$) and weak base which has base equilibrium constant ($K_b$) [20].

3.2. Characteristics of Chemistry
Characteristics of chemistry is one of the important aspects in measuring chemical literacy, because studying chemistry aims to understand and explain life that is associated with structures and processes in the system of life [16]. The results of this study showed that students reach good levels at this aspect. This result indicated that students were able to discuss macroscopic phenomena in the form of material structures, process dynamics and reaction equations as student interview below.

Teacher : ... what kind of natural source that you choose to neutralize the base from detergent waste?
Student 20 : Lemon because it has citric acid
Teacher : Why citric acid categorized as acid compound? Draw its ionization reaction
Student 20 : Because citric acid produces $H^+$ ions, $C_6H_8O_7^{-}$ ionized produce $C_6H_5O_7^{3-} + 3H^+
(Classroom observation, 9 January 2019)

The student interviews above shows that student give reasons related to the selection of natural materials to neutralize bases and write the reaction equation for acidic compounds. The ability to explain macroscopic phenomena at the microscopic level is important for students to be able to understand modern science and understanding of the other sciences [21].

3.3. Chemistry in Context
Chemistry in context is one aspect of chemical literacy that measures ability in looking at the relevance and usefulness of chemistry in life and the use of chemical knowledge in explaining everyday phenomena [16]. The results of this study showed that students reached good levels at this
aspect. This result indicated most of students have been able to use understanding chemistry in lives which influences on decision making as student interview below.

Teacher : ... what kind of natural source that you choose to neutralize the base from detergent waste?
Student 16 : Lemon because it easy to find and it contain acid
Teacher : What kind of acid contained in lemon?
Student 16 : Citric acid, ascorbic acid and malic acid  
(Student Interview, 28 January 2019)

The results above show students used their chemistry understanding which indicated by mention the acid content in determining natural sources that can be used to neutralize bases. Based on the research conducted by Khosravi, et.al. [22], it shown that lemons contain mostly ascorbic acid, citric acid, and malic acid. Chemistry in context is one of the important aspects of chemical literacy because understanding chemistry helps humans in making decisions related to public issues and helps people understand life and the environment [23].

3.4. High Order Learning Skills

High order learning skills is aspect of chemical literacy that measure ability to identify scientific issues, explain scientific phenomena, use scientific evidence, and evaluate the pros / cons of debate [16]. The results of this study showed that students reach fair levels at this aspect. This is evidenced by the following student’s reflective journal.

The disposal of detergent waste directly into the river can damage the river ecosystem, the pH of the water will rise and many fish will die because the fish just live in neutral water  
(Reflective Journal, Answer of Student 25, 16 January 2019)

The student answers above show that students begin to explain the phenomenon of detergent waste which can damage the river ecosystem because it increases the pH of water which affects the number of dead fish. The development of high-order learning skills needs to be developed because in addition to providing students with an understanding of chemistry, it also educates students to literate in the future so that students are able to use their chemical understanding in daily life [24].

3.5. Affective Aspect

Affective aspect is one of the chemical literacy aspects that measures the ability to understand the effects of chemistry and its applications and shows interest in chemical issues [16]. The results of this study show that students reach fair levels at this aspect. This result proven by the classroom observation below.

Teacher : Currently there are many detergent advertisements that promise many advantages, such as producing a lot of foam, quickly cleaning stains, and giving fragrant scents. How do you respond to this?
Student 19 : Actually detergent that produces a lot of foam can damage the river ecosystem, besides it also causes plants that live under the river to die. But detergents that produce lots of foam are cheap  
(Student Interview, 29 January 2019)

The results of the interview above show that student only briefly explained the effects of detergents that produce a lot of foam on the death of plants that live underwater. However, in the student’s answer did not relate the phenomenon of the abundance of foam to the death of plants and did not provide a solution. Affective aspects have six important aspects, namely the development of attitudes, interests, motivations, self-conceptions, morals, and values, so that affective aspects play an important role in learning chemistry [25]. This is in line with [16] which states that affective aspect encourages someone who has a realistic view of chemistry and its application.
4. Conclusion
The integration of STEAM and dilemmas stories can be applied to chemistry learning and can develop students’ chemical literacy in various aspects. Based on the result, it can be concluded that for overall aspects, most of students reached good levels but they still reached fair levels on high order learning skills aspect and affective aspect. Detergent wastewater treatment project is designed to solve the detergent waste problem from laundry business. The challenges faced in this study are time management, engaging student, and public issues related to chemistry that in accordance with the topic of learning. The other skills that has been found in this study are critical thinking skills and creativity. Thus, the integration of STEAM and dilemmas stories can provide meaningful learning for students, because students not only learn concepts, but can apply their understanding in daily life through project-making activities.

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