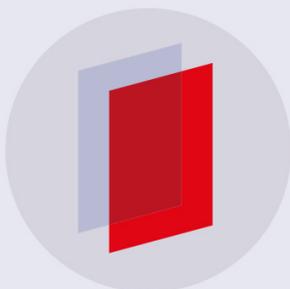


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Developing critical and creative thinking skills through STEAM integration in chemistry learning

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Abstract. This paper describes a second year of two-year of longitudinal study of the integration of Science, Technology, Engineering, Art, and Mathematics (STEAM) in chemistry learning in secondary schools in which the importance of critical and creative thinking skills were explored. The study involved 76 students of Year 11 from two secondary schools in Indonesia. The STEAM integration was implemented in the teaching of acid and base through a project-based learning model. The research employed a qualitative approach to explore the integration of STEAM in chemistry, students' critical and creative thinking skills development. Data were collected through observations, interviews, reflective journals, critical and creative thinking skills assessment. The students develop their STEAM projects by integrating chemistry concepts with STEAM principles. The study results were analyzed based on the pattern themes found in different data sources. It showed that students developed creativity and critical thinking skills. The study faced challenges of STEAM integration with chemistry concepts, empowering teachers, engaging students, and managing time and resources. The integration of STEAM provided the opportunities for students in chemistry learning engagement and several areas of thinking skills development in relation to the current curricula objectives.

1. Introduction

The science and technology development in various aspects of life has an impact on the demands of graduate competencies. Therefore, the learning reform needs to be conducting in implementing education in 21st century era. Various efforts for preparing the 21st century generation have been conducted. The aims of education in secondary school should ensure the students to have competences in facing the challenge in college and in the workplace [1]. However, the stakeholders of the companies claim that the secondary schools graduates don't have the necessary basic skills that they need. In Indonesia, the secondary schools consist of the senior high schools and vocational schools which have different aims of preparing graduates for continue the study and work. However as stated by [2] there is still debate in postsecondary institutions in defining "readiness".



The 21st-century learning has been discussed for facing the challenges in revolution industry 4.0. The term 21st-century skills is generally refer to core competencies of collaboration, digital literacy, critical thinking, and problem-solving in facing globalisation world [3]. In addition to the Partnership for 21st Century Skills also believes that graduates should have learning skills in information, the communication, critical thinking and problem solving [4]. Therefore, it is important to teach the higher order thinking skills, especially problems solving in real-world problems [5]. Rich stated that 21st-century learning refers to students should have competences in producing, synthesizing, and evaluating information within different cultures [6]. As the results, they demonstrate digital literacy and civic responsibility. Virtual tools and open-source software create borderless of students' learning [7]. The design of classroom learning experiences should relate to students' competencies development within this 21st-century learning. Besides, these learning experiences should empower students as individual and citizen [8].

Chemistry is the study of matter and the changes, interactions, and rules that underlie its change [9]. Chemistry education focuses on students' learning to understand the chemistry concepts, however, chemistry with its abstract concepts is considered difficult for students to connect it with the real situations [10]. According to [11], chemistry education research should focus to improve chemistry learning engagement. In this paper, not only focused on the fundamental concepts, but also 21st-century skills development [12].

[13] states that the STEAM approach is an evolving approach of integrating art into the STEM. It plays the important role to enhance understanding of the structure of science, technology, art, and mathematics. In this study, the STEAM has been integrated with project-based learning which focusing on student-centered within dynamic classroom approach. The integration of art in STEM learning can make learners more creative and innovative as students involved in exploration of real-world challenges and problems [14-16] suggest that STEAM as an integrated approach to encourage creativity. In STEAM, learners are taught to think comprehensively. STEAM is integrated into the curriculum as a whole as a supporter of project-based learning methods. Learners will learn, solve and analyze problems using technology tools and collaborative learning strategies across the STEAM curriculum [17]. Each learner will be given the material cross-science by putting forward work collaboration and high social capabilities. This educational system is believed to trigger learners into individuals full of responsibility, leader, and entrepreneur [18].

This STEAM approach leads learners to develop problem solving, critical thinking, and collaboration skills [19]. The previous study by [2] stated that the STEAM approach has engaged students in developing 21st century skills. The main aim of education is not only to teach basic knowledge, but to use thinking skills such as creative thinking skills [20], problem-solving skills [21], scientific and technological abilities [22-23] as these are skills needed for sustainability and lifelong education. Starke made a discussion about the importance of creativity in the classroom, so creative students can learn more in the classroom [24]. In addition, the National Center for Education and the Economy [25] states that for the curriculum reform in education, creativity and innovation are essential. In addition to [26] also predicts that in the future, the world will be increasingly complex with problems that require new solutions, therefore creative and critical thinking are important. In addition to critical thinking allows learners to evaluate the evidence, assumptions, logic, and language that underlies others' statements [27]. According [28], critical thinking is a well-organized mental process in decision-making to solve problems by analyzing and interpreting data in scientific inquiry activities. It employs evidence, logic, and understanding to solve the problems.

In Indonesia, the current curriculum of Curriculum 2013 embraces the pattern of students' character development and the 21st-century learning principles. Chemistry in context should be taught, so that students can learn to solve real lives problems by using their chemistry knowledge. In this study, the innovation of integration of STEAM in chemistry learning within Indonesia context has been explored. According to [15], STEAM approach can develop students' understanding and creativity which has been implemented in Korea and 17 other countries. In addition to enrichment of chemistry learning within

perspectives of different disciplines. Therefore, the research focusing on the implementation of STEAM and exploring the implications on students' learning.

2. Method

This qualitative research was employed the with data collection of interview, observations, reflective journal, and critical and creative thinking assessment. The quantitative results of test were not explored in this paper. The activities carried out through the phase of relating, planning, developing, cooperating, and transferring [30]. The focus on developing the STEAM project with employed acid base chemistry concepts as the principles through the hydroponics plants project. The steps of teaching methods in STEAM approach shown below.

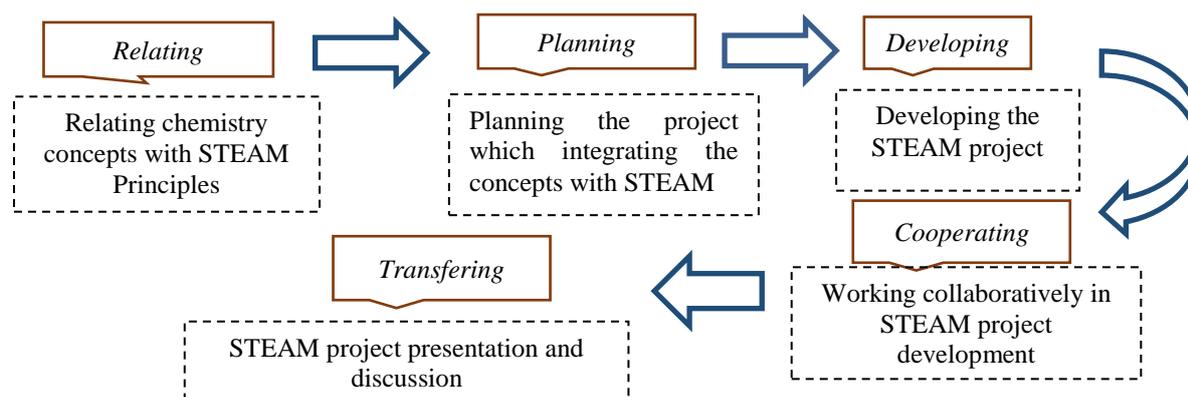


Figure 1. Project Based Learning in STEAM Project [30]

In the project, students had to find out the pH that the plan can grow well. They have tried different acid and base solution to get the best condition for the plants. In addition to they have to learn in constructing the hydroponic plants the challenges were integrating the STEAM in chemistry learning as chemistry is studied as a discipline, not as an interdisciplinary subject. Therefore, relating step becomes the main challenge in the project development. In each process, teachers play important roles as facilitators, then students' working collaboratively in completing the project.

3. Results and Discussion

In this initial study of the implication of STEAM project in students' learning has been explored which focusing on critical and creative thinking skills. As stated before there are challenges in integrating chemistry subject with different disciplines. The integration of STEAM has encouraged students to exploring daily lives problems by using their chemistry knowledge. STEAM project was conducted with the group working. The STEAM approach which was integrated through project-based learning of hydroponics plants has helped students to develop knowledge and skills by working for certain period of time. In the project, students have integrated the concept of STEAM (figure 1). In science, they have to find out the pH of suitable for Kangkung to grow up which is related to acid and bases concept. In technology, engineering, and mathematics, the students developed and designed the hydroponics pot structure to optimize the plants' growth, including using the aerator. Then in art, the students engaged in creating an aesthetic structure of hydroponics plants.



Figure 2. Hydroponics STEAM Project

In the process of a STEAM project, the students are stimulated to develop their critical and creative thinking skills as stated below.

The student asked if the aerator is not used, do the plants die? Should it have certain pH?
(Observer of Students 1, January 18, 2017)

after continuous observation, we found that the kangkung died at pH 12 because the solution's pH is too high, and not suitable with suitable pH from literature which states 6.5- 8.4
(Student Interview, Student 29, January 18, 2017)

Our group hydroponics plants have a pH of 8 when was checked using universal indicators and pH meters. It is because our hydroponics nutrition solution consists of 100 mL of HCl solution and 300 mL of KOH solution so it tends to be alkaline
(Student Observation Sheets, Student 11, January 30, 2017)

The students also found out and solve the problems by found out different learning resources, including internet and books. The students explored different resources and asking critical questions in completing the project.

We concluded that the aerator used should not be exposed to water because if the battery is exposed to water it will die
(Student Observation Sheets, Student 33, January 11, 2017)

I recorded the color change after solution added natural indicators and matching observations with reference to books and on the Internet
(Student Interview, Student 11, January 18, 2017)

Ruby planted crops with hydroponics media cannot grow properly because Rubi plants kangkung at pH 3 and 8, where the pH is not a suitable pH. pH suitable for kangkung that is 6,5-7. "
(Test Results, answer of Student 2, January 25, 2017)

The students learned to develop different ways of learning by asking critical questions and explored different resources in the project. According to [29], the students had opportunities to express their arguments which was different from their learning experiences. According to [19-30], the integration between STEAM learning and project-based learning not only keeps students learning basic theories in project completion techniques but learners will also learn problem-solving skills, critical thinking, and collaboration skills. Project-based learning enables learners to go through a lengthy process of inquiry,

responding to questions of complex problems, or challenges, practicing the skills demanded in the 21st century, one of which critical thinking is [3]. Students' creativity and critical thinking have been stimulated in this STEAM project as students have to find and solve the problems in hydroponic plant within their understanding of acid-base concepts.

In this study, students can continuously develop their critical thinking by asking questions, defining a problem, examining evidence, analyzing assumptions, and considering other interpretations [31]. The result shows the opportunities to further development of higher order thinking skills in STEAM integration in chemistry learning. However, teachers play important roles to stimulate the process. In globalization world, information, media, and technology skills are important, thus in a STEAM project, students learn to find out the information for the project development and the problems solving of determining the best pH conditions.

Students are able to use various creative ways to get ideas, such as found out different answers and ideas to solve the problems. Students were able to create new ideas by using their experiences. Therefore, when the learning process takes place, it is important to stimulate the students to provide different ways or suggestions to do various things.

*I felt my creative ideas were developed because I found different new things in the project
(Student Reflective Journal, Student 11, January 23, 2017)*

*My creative idea is flourished, I knew new things, such as the pH solution for hydroponics' plants
(Student Reflective Journal, Student 11, January 13, 2017)*

Their answers are the indicators of the ability to think fluently which when students can generate ideas, questions, and answers in varied ways. Students can see a problem from different perspectives. As a result, when they face different problems, the students can change the way of thinking to provide various alternative solutions to solve the problems.

*Student's (number 24) way of thinking was developed as they were able to create questions from different perspectives. Other students focused on the plant's stem, while student 24 asked about the roots of plants
(Observation of, Student 24, January 23, 2017)*

Learners 24 have a good flexibility in thinking skills, this can be seen through the observation results when the students 24 answered the question when the discussion. In addition, the students also keep asking questions

*Our plants were wilted because it is not exposed to sunlight as we put the plants on the table
(Student Observation Sheets, Student 9, January 11, 2017) "*

*"What is this technology called? What does it do for? Later if the batteries run out how the effect on our plants?
(Observation of Student 34, January 18, 2017) "*

Students have generated the ideas into designing a product and carrying out activities. Therefore, learners become accustomed and continue to develop their creative thinking skills.

*The cause of one wilted plant is because the nutrient solution is alkaline, while the cause of the three wilted plant is due to the acidic nutritional solution. Plant 2 does not wilt because it is neutral, then the need for plant minerals is sufficient.
(Test Results, answer of Student 9, January 9, 2017)*

Based on the answers given by learners 9, overall it is close enough to the indicators and test instructions. However, learners 9 have not been able to explain in detail the reasons. Students have faced the challenges in looking different information to solve the problems in the project. They understood that the information widely provided on the internet, however sometimes it is not considered as valid information. Therefore, they not only learned to explore the information but also to evaluate it.

Jackson and Shaw discuss strategies for developing students' creativity and designing learning systems to help students to develop their creativity [32]. For example, providing opportunities for learners to experience and practice their own creativity through stimulating, relevant, and authentic learning experiences in the field of their subject matter. In addition, it also gives students with the problems in the project which allow them to practice for developing creativity and active inquiring. In addition, individuals who are creative have a positive attitude toward creative thinking [32]. Therefore, creative thinking as a logical and divergent thinking to produce something new. This is especially important in the Curriculum 2013 that requires the development of the holistic students. Chemistry learning is also expected to educate graduates who are able to interact socially with the environment, school environment, community, and environment.

Finally, the STEAM approach has helped students to relate the chemistry concepts and different disciplines of STEAM through an application of knowledge into everyday life. The STEAM approach provides the opportunity for helping students to understand working in real-life projects through collaborative working and use their knowledge and skills from different subjects, beside the challenges of relating the chemistry concepts, time and resources management.

4. Conclusion

The study explored that STEAM approach can be integrated into chemistry learning within real-lives problems in Indonesia context. The important elements of critical and creative thinking skills have been stimulated in the study by active self-reflection and questioning followed by defining the problem, examining evidence, analyzing assumptions, and considering other interpretations. Students learnt to implement their chemistry knowledge in solving the problems within different ways of knowing. They learnt to think fluently by exploring problem solution from different perspectives. In Indonesia context, the STEAM integration has provided the opportunity to develop students' competencies in relation to the curriculum 2013. The challenges of integrating STEAM within the chemistry curricula, empowering students, and managing the teaching and time resources need to be explored. However, the further research will be conducting in exploring the challenges of implementing the STEAM in chemistry learning.

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