STEAM INTEGRATION IN CHEMISTRY LEARNING FOR DEVELOPING 21ST CENTURY SKILLS

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This paper is based on the results of first year of two-year study in integrating Science, Technology, Engineering, Art, and Mathematics (STEAM) in chemistry learning. The research focused on developing 21st-century skills of chemistry students in secondary schools. The 21st-century skills are a set of abilities that students need to develop in facing the future challenge which involves learning, literacy, and life skills. The study was conducted in two secondary schools both public and private on the topics of hydrocarbon, petroleum, solubility, and acid base in year 10 and 11. A qualitative methodology was applied to explore the students' learning experiences and understanding the research context. Data was collected through observation, interview, reflective journal and 21st-century rubric. The STEAM approach was integrated through modification of project-based learning model. The students had opportunities to develop their own projects by integrating chemistry and STEAM principles to their project. The results showed that students have developed their higher order thinking skills namely critical and creative thinking, problem-solving, collaboration and argumentation. They also learnt to develop skills of information, literacy and the self-direction.

KEYWORDS: STEAM, Chemistry Learning, Project-Based Learning, 21st-Century Skills, Qualitative Research
INTRODUCTION

The aims of education in secondary school should ensure that students should have knowledge and skills to be successful in college and in the workplace (O’Sullivan & Dallas, 2010). 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 study and work. However, as stated by Olson (2006), there is no consensus among post-secondary institutions as to what constitutes “readiness”, and “readiness”. The concept of 21st-century learning has been becoming an issue in education which is relating to the students' competencies for facing the challenges in their real and future lives. The term 21st-century skills are generally used to refer to certain core competencies such as collaboration, digital literacy, critical thinking, and problem-solving that advocates that schools need to teach to help students thrive in a globalised world (Partnership 21, 2008). The Partnership for 21st Century Skills also believes that the secondary schools graduates and the high school graduates must obtain strong learning skills in information, communication, critical thinking and problem solving (Jobs for the Future, 2005). Therefore, the secondary school students need to be taught to develop higher order thinking skills, especially in solving the problems related to real world. However, the idea of what learning in the 21st century should look like, is open to interpretation and controversy. Rich (2010) explained that 21st-century learning means that students master content while producing, synthesizing, and evaluating information from a wide variety of subjects and sources with an understanding of and respect for diverse cultures. Students not only demonstrate the three Rs, but also demonstrate the three Cs: creativity, communication, and collaboration. They demonstrate digital literacy as well as civic responsibility. Virtual tools and open-source software create borderless learning territories for students of all ages, anytime and anywhere. The classroom learning experiences need to be designed to develop students' competencies in term of collaborative, problem solving, self-control, critical thinking, and ICT skills. These learning experiences should empower students as individual and citizen as an agent of changes who is responsible, creative, innovative and able to contribute to society, nation, and world civilization.

Chemistry is a part of science that studies the phenomena and laws of nature which focuses on the study of matter, covering the composition, properties and the energy changes that accompany such material changes (Chang, 2005). Chemical education is considered as the incorporation of the principles of education and chemistry itself, therefore the chemistry learning
focus on the learning to understand the chemistry concepts. However, chemistry with its abstract concepts is considered difficult for students in connecting it with the real-life situations (Sirhan, 2007). According to Gabel (1999), chemistry education research focused on efforts to improve learning activities chemistry, in particular help students to understand the concepts of chemistry and create meaningful learning. Thus, research in the field of chemistry education, generally focused on learning methods to help students in understanding the concepts as well as other aspects of learning such as curriculum and assessment. In this paper, chemistry teaching and learning are facing the challenges because of the fundamental concepts need to be developed in teaching and learning, meanwhile, these 21st-century skills are also important to be developed. Chemistry subject involves three representations of macroscopic, microscopic and symbolic representation (Treagust, 2015). These three representations need to be discussed by chemistry teachers in order to develop a good understanding of chemistry concepts. In addition to these characteristics, students used to teach for passing the test by memorizing the facts and ignoring the concepts. Therefore, chemistry learning becomes difficult and less meaningful.

The STEAM has been integrated with project-based learning which focuses on student-centered pedagogy and involves a dynamic classroom approach in which it is believed that students acquire a deeper knowledge through active exploration of real-world challenges and problems. According to Conley (2005), research projects should become the central part of secondary school's curricula. Application of the STEAM approach also encourages students to understand each STEAM component of science, technology, engineering, art, and mathematics in chemistry learning. The learning was provided through the activities which consisted of STEAM components such as science which explains the knowledge about the concept of acid and base, the technology describes the use of the latest technologies that enables students in the implementation activity, engineering describes the techniques used by students during the completion of project work, arts that will elicit students' creativity in project design, and mathematics which includes the calculation and formulas students use during learning activities. There are five learning steps of relating, planning, developing, cooperating, and transferring in this integration of STEAM learning. Each stage of project-based learning will encourage students to be active and thinking about completing the given project: starting with essential questions, developing project plans, preparing schedule, student monitoring and project progress, testing and assessing results, evaluation of experiences.

In Indonesia, the learning activities are conducted based on the Curriculum
2013 which embraces the pattern of learning in the form of student learning (learn-curriculum). The curriculum 2013 was developed based on 21st century learning principles of developing students' soft skills which should be implemented to all subjects, including chemistry. Chemistry should be taught contextually to encourage students to solve the real lives from chemistry perspectives, so they will find chemistry as useful and meaningful. The STEAM approach can develop students' higher order skills through integration of different disciplines. In this approach, students can understand the concepts and develop their 21st century skills that are developed through the STEAM project. According to Yakman and Lee (2012), STEAM approach can contribute to students learning of the process by developing students' understanding and creativity which has been implemented in Korea and 17 other countries. STEAM approach has provided the impact on the improvement of the quality of education, economics, industry and community welfare. Therefore, the research focusing on the implementation of STEAM and exploring the implications on students' learning are of importance now a days.

**Research Methodology**

This research employed the qualitative approach with an interview, observations and reflective journal as data collection instruments. The activities were carried out through the phase of relating, planning, developing, cooperating, and transferring. The challenges were in relating the STEAM project with the chemistry concepts which have been done in the topics of hydrocarbon, petroleum, solubility, and acid base. In this paper, the focus was on the project of Goldfish Aquarium which was related to acids and bases concept. The steps of teaching methods in STEAM approach are shown below in Figure 1.

![Figure 1. Project Based Learning in STEAM Project.](Hadinugrahaningsih, Rahmawati, & Ridwan, 2017)
The teaching model in integrating project-based learning in STEAM project was developed in this study. The challenges were integrating the STEAM into the project as in Indonesia, chemistry is not integrated in curricula with other subjects. Therefore, relating step becomes the main issue in this process. In each process, the students conduct in the classroom with the teachers as facilitator is followed by students' self-directions in completing the project.

**RESULTS AND DISCUSSION**

In this initial study of the implications of STEAM project in students' learning focus has been on the 21st century skills. In this context, there are three main focus areas i.e. (1) learning and innovation skills, (2) information, media, and technological skills, and (3) life skills and career. As stated before, there are challenges in education to integrate different disciplines in teaching and learning. The integration of STEAM has encouraged students to observe phenomena of chemistry problems and solving the problems in daily lives which are related to the various concepts in chemistry. STEAM project was conducted with the working group. This study employed interviews, observations, and reflective journal. The STEAM approach which was integrated through project based learning has helped students to develop knowledge and skills by working for an extended period of time to investigate and respond to authentic, engaging, and complex questions, problems and challenges. Project based learning has the potential to help students' in learning and improving motivation (Blumenfeld, 2011). The implementation of STEAM in Chemistry lesson has been shown in Table 1.

**Table 1**

**STEAM Integration in Chemistry Lesson with Example of Goldfish Aquarium Project.**

<table>
<thead>
<tr>
<th>SCIENCE</th>
<th>TECHNOLOGY</th>
<th>ENGINEERING</th>
<th>ART</th>
<th>MATHEMATICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>The concept of acid and base</td>
<td>Aeration technology</td>
<td>Create aquarium</td>
<td>Decorate the aquarium according to the creativity of the students</td>
<td>Calculations in aquarium production</td>
</tr>
<tr>
<td>Testing of indicators against acidic and basic solutions</td>
<td>Using pH meter</td>
<td>Establishment of natural indicators</td>
<td>Display power point as presentation material</td>
<td>Calculations in the manufacture of solutions with a certain pH</td>
</tr>
<tr>
<td>Testing the endurance of living things</td>
<td>Using laptop, mobile phone, projector, powerpoint media as presentation material</td>
<td>Assembling the aerator</td>
<td>Make a creativity of the media</td>
<td>pH measurement</td>
</tr>
</tbody>
</table>
Based on the data in Table 1, learning with the application of STEAM provides an opportunity for students to develop the competence of hard skills and soft skills during the learning process.

The results show that students have developed their 21st century skills which focus on higher order thinking skills of critical and creative thinking, problem-solving skills, and argumentation skills, then developing the information and literacy skills, in addition to self-direction and collaborative skills.

**High Order Thinking Skills**

The higher order thinking skills have been developed in this study which are creativity, critical thinking, and problem-solving skills. The challenge of developing the project and relate it with STEAM basic principles has stimulated students in developing creativity and critical thinking. Project based learning is a learning model that improves students' ability (Larmer, 2010). Students have to find and solve the problems after understanding the chemistry concepts. They tried to find out different resources, including Internet and books, besides involving art in designing the projects. The students explored different resources and asked critical questions in completing the project.

> I asked questions and explored different information to complete the project. The teachers have stimulated my thinking of what was the water condition to keep the Goldfish alive

*(Student Interview, Mei 20, 2016)*

> I am stimulated by the questions of my friends and colleagues about the Goldfish and its relation to acid base concepts

*(Student Reflective Journal, June 3, 2016)*

The results show that were opportunities for further development of higher order thinking skills with STEAM integration in chemistry learning. However, teachers play important roles to stimulate the process. The learning process has been illustrated in Figure 2.

![Figure 2. Students Developing their Critical Thinking Skills.](image-url)
The results are relevant to the findings that integration of STEAM into learning activities has led students to develop problem-solving, critical thinking skills and collaborative skills (Messier, 2015). In this study students were able to continuously develop their critical thinking. Wade (1995) identifies eight characteristics of critical thinking which involves asking questions, defining a problem, examining evidence, analyzing assumptions and biases, avoiding emotional reasoning, avoiding oversimplification, considering other interpretations, and tolerating ambiguity. STEAM approach has helped students in finding the ways to solve the problem, because the students use the knowledge to relate with their environment, including solving the environmental problems (Jeon & Lee, 2014). Therefore, STEAM approach could engage students in developing critical thinking, communication, collaboration, and creativity. Learning and innovation skills which are developed as 21st century skills are adaptability, complex communication skills, non-routine problem solving, self-management, and systems-thinking which are essential skills in the 21st century workforce. The most effective way to prepare students for the workforce and college is to integrate core concepts with key skills.

**Information and Literacy Skills**

In a globalized world, information, media, and technology skills are important in the 21st century. In STEAM project, students learn to find out information and manage it for developing the project and solve the problems. The students explored different resources to develop the project of Goldfish. In developing the aquarium, they used different pH to determine the best pH conditions for goldfish as shown in Figure 3.

![Figure 3. Students Applied the Concept of Acid and Base.](image)

Applications of integrated STEAM approach in project-based learning can be ascertained by providing learning activities like the endurance test of goldfish which is influenced by pH of solution. Giving several projects on learning helped in developing the students' critical thinking skills that can be observed during the process of implementation of learning activities. Implications of this project have been stated by students below:
I tried to find out different resources, including Internet, not only the Goldfish, but also the concepts of acid and base.  

(Student Interview, May 13, 2016)

It’s exciting to have opportunity to use the technology and discuss my findings with my group. We tried to enrich our knowledge in completing the project.  

(Student Reflective Journal, May 20, 2016)

Students have faced the challenges in looking up different information to solve the problems in the project. They understood that the information which is widely provided on the Internet, sometimes it is not considered as valid information. Therefore, they not only learnt to explore the information, but also to evaluate it.

Self-Direction and Collaboration Skills

Self-direction and collaboration skills are the necessary 21st century skills in life and career. Davies, Csette and Poon (1999) further indicated that recent graduates viewed the important skill sets of adaptability and flexibility as receiving low attention in their academic experience. In group working, students have to deal with other students' differences. They have to adapt to each other for a couple of weeks for completing the project. The students also developed the leadership of managing the project with the problems and challenges. In this context, the self-direction is also important as they have their own responsibility.

It's challenging to manage my team as some of them are not performing well. However, I learnt to divide the tasks and monitor the progress.

(Student Interview, May 23, 2016)

Sometimes, we get confused to decide what we have to do. However, we need to decide the project steps, therefore, we need to collaborate.

(Student Reflective Journal, May 20, 2016)

I learnt to collaborate with others and complete my task well.

(Student Interview, May 13, 2016)

Based on the results and discussions, STEAM approach has several advantages of in developing 21st century skills in students' without ignoring knowledge development. It also helps students to solve the problems through collaborating with one another.

Finally, the STEAM approach has helped students to relate the chemistry concepts and different disciplines of mathematics, science, technology, inquiry
and art through application of knowledge into everyday life. Besides the challenges of relating the chemistry concepts and time management, the benefits of the STEAM approach include helping students understand the team working on real-life projects, taking into account the following matters: a) students can use knowledge and skills from all subjects to support their project work and start to see how content is used in real lives and why it is important to know about it, b) students are encouraged to acknowledge and respect the skills and interests of themselves and others. They learn how to organize the team based roles in the group. The learning process through 21st century skills is also beneficial for students to begin thinking about their thinking, or in other words, begin conscious and active self-reflection and questioning, which some evidence suggests is an important first step for students. Becoming a critically conscious student will surely play a pivotal role in this important developmental stage of student's academic and professional career. Therefore, in Indonesian context, the STEAM integration in chemistry learning has provided the opportunity in developing students' competences in relation to the curriculum 2013.

**CONCLUSION**

The study explored that STEAM approach can be integrated into chemistry learning through projects related to the chemistry curricula. The important elements of 21st century skills are learning and innovation skills, information, media, and technological skill, life and career skills which have been stimulated in the study. The study found that STEM integration can be implemented to develop higher order thinking skills, information and literacy skills, self-direction and collaborative skills. The researchers faced the challenge of integrating STEAM within the chemistry curricula, empowering students, and managing the teaching and time resources. Students have started to challenge their critical and creative thinking within the existing learning environments. It is also the challenge to provide a collaborative learning experience to students who are inclined to learn and work on their own as well as relate to chemistry concepts (Scott, 2010). However, further research can be conducted in exploring the challenges of implementing the STEAM in chemistry learning.

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