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Developing 21st Century Skills in Chemistry Classrooms: Opportunities and Challenges of STEAM Integration

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Abstract. The paper portrays the first year of two-year study in integration 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 as 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 school in topics of hydrocarbon, petroleum, solubility, and acid base in year 10 and 11. The 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 show that students have developed their critical and creative thinking, problem-solving skills, collaboration and argumentation skills, leadership and responsibility, information and literacy skills. The researchers faced the challenges 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. Integrating STEAM into chemistry learning has developed students' 21st-century skills in those three areas. Teachers also learned to develop their competencies for being facilitators and agents of change, in addition to skills development in dealing with students' differences.

INTRODUCTION

The 21st-century learning has been developed recently in relation to students' competencies in facing the challenges in their real lives. The term 21st-century skills is generally used to refer to certain core competencies such as collaboration, digital literacy, critical thinking, and problem-solving that advocates believe schools need to teach to help students thrive in globalisation world (Partnership 21, 2008). In a broader sense, 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 demonstrate the three Rs, but also 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, communication 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.

Chemical education is the incorporation of the principles of education and chemistry itself, so that the chemical education-related learning to understand the concepts of existing chemicals. According to Gabel (1999), chemistry education research focused on efforts to improve learning activities chemistry, in particular help students understand

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the concepts of chemistry and chemical creating meaningful learning. Thus, research in the field of chemical education, generally focused on learning methods, to understand how learners, as well as other aspects of learning such as curriculum and assessment.

In this context, 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 is considered as a difficult subject since its characteristic of abstract concepts and relation to students' daily lives (Sirhan, 2007). 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 education system's ability to develop and respond to this growing need of skills is central to the integrity of the education system remaining the center for job readiness for future generations of workers. This has led to a restructuring of educational curricula, teaching, and test taking, though this has yet to be a unanimous process. Examples of these changes include better curricula to support abstract knowledge on subjects, teaching that focuses on problem-based learning, and testing that can measure student's progression into their very own 21st century skills mindset. However, the process of teaching skills such as self-direction, collaboration, and creativity is not a straightforward, or fully understood, process (Rotherham & Willingham, 2009).

The application of this learning approach integrates each STEAM component in project-based learning. Project-based learning (PBL) is a student-centered pedagogy that 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. Application of the STEAM approach also encourages students to understand each STEAM component in a chemistry study. The application of this learning is done by providing a learning activity consisting of several projects by integrating STEAM components, namely science explains the knowledge where in this research is about the concept of acid and base, the technology describes the use of the latest technology that enables students in the implementation activity, engineering describes the techniques used by students during project completion, arts that will elicit students' creativity in project design, and mathematics which are the calculation formulas students use during learning activities.

The STEAM learning approach stages integrated in this project-based learning applied with five learning steps of relating, planning, developing, cooperating, and transferring. 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. Application of the STEAM approach also encourages students to understand each STEAM component in a chemistry lesson. The application of this learning is done by providing a learning activity consisting of several projects by integrating STEAM components, such as science explains the knowledge where in this research is about the concept of acid and base solutions, technology describes the use of the latest technology that enables students in the implementation, engineering describes the techniques used by students during project completion, arts that will elicit students' creativity in project design and mathematics which are the calculation using mathematics formulas during learning activities.

Based on the Attachment of the Regulation of the Minister of Education and Culture No. 70 of 2013. Curriculum 2013 embraces the pattern of learning in the form of student learning (learn-curriculum). The curriculum 2013 was developed based on 21st-century learning principles which developing students' soft skills which including career and life skills in 21st-century learning. It 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 is useful and meaningful. One of the innovations that can be done is an integration of STEAM (Science, Technology, Engineering, Art, and Mathematics) in chemistry learning. 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 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.

RESEARCH METHODOLOGY

The purpose of this study was to develop students' 21st-century skills in chemistry classroom through STEAM integration. This research employed the qualitative approach with an interview, observations, reflective journal, 21st-century rubric skills, and project assessment as data collection. The activities carried out through the phase of relating, planning, developing, cooperating, and transferring. The focus on developing the STEAM project as chemistry concepts as the basic principles. The challenges were in relating the STEAM project with the chemistry of hydrocarbon, petroleum, solubility, and acid base. The project or innovative hydrocarbon and petroleum model, solubility reactions, Goldfish Aquarium and hydroponic in acid and base. The steps of teaching methods in STEAM approach show below.

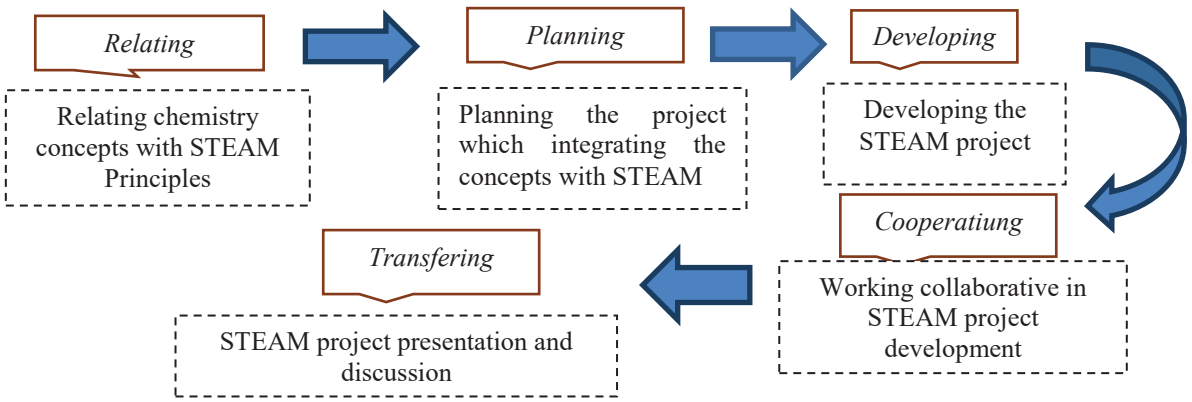

FIGURE 1. Project based learning in STEAM project

The model in integrating project-based learning in STEAM project is developed in this study. The steps focuses on the process of developing the project. The challenges are 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.

RESULTS AND DISCUSSION

In this era of teaching and learning, 21st century learning becomes one of the active methods that can support the learning process in the classroom, in the 21st century learning, most of the current generation has grown up with the technology we see all around. Having the same in the field of education will not only evoke their interest in the form of tablets and laptops, they will definitely feel more at ease using a medium that they have always seen in use, with shifting to the digital world, there are no real constraints of time and space. Combine with that interactive integration of different subject and technology which can help enhance education and the growth curve of each individual. This can be measured with students' involvement. Active involvement was simply unfeasible previously, but with digital content, that is no longer a concept.

There are challenges in education to integrate different disciplines in teaching and learning. The students also face the challenges in making connections between subjects and implementing it in the real life. The integration of STEAM (Science Technology Engineering Art and Mathematics) approach in chemistry learning with art integration in STEAM concepts. In STEAM integration, students were encouraged to observing phenomena of chemistry problems and solving the problems in daily lives which are related to the chemistry concept.

The 21 st-century learning that provides a brief illustrative overview of the knowledge, skills, work habits, and character traits commonly associated with 21st-century skills, such as: critical thinking, problem solving, reasoning, analysis, interpretation, synthesizing information, research skills and practices, interrogative questioning, creativity, artistry, curiosity, imagination, innovation, personal expression, perseverance, self-direction, planning, self-discipline, adaptability, initiative, oral and written communication, public speaking and presenting, listening, leadership, teamwork, collaboration, cooperation, facility in using virtual workspaces, information and communication technology (ICT) literacy, media and internet literacy, data interpretation and analysis, computer

programming, civic, ethical, and social-justice literacy, economic and financial literacy, entrepreneurialism, global awareness, multicultural literacy, humanitarianism, scientific literacy and reasoning, the scientific method, environmental and conservation literacy, ecosystems understanding, health and wellness literacy, including nutrition, diet, exercise, and public health and safety.

STEAM project was conducted with the group working to integrate STEAM into the chemistry concepts. This study uses the rubric of 21st-century skills to measure the skills of the students. This rubric developed into the material as well as the observation of the student, interview, reflective journal, and the student questionnaire. The STEAM approach was integrated through project-based learning. Project Based Learning help students to gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge. Project-based learning is a comprehensive approach to classroom teaching and learning that is designed to engage students in investigation of authentic problems. Project based learning have the potential to help people learn, indicate factors in project design that affect motivation and thought, examine difficulties that students and teachers may encounter with the projects; and describe how technology can support students and teachers as they work on projects, so that motivation and thought are sustained (Blumenfeld, 2011). Chemistry learning based STEAM is done by an effort to develop students' abilities according to 21st-century learning. The implementation of STEAM in Chemistry lesson shown in this table.

TABLE 1. STEAM integration in chemistry lesson, example in goldfish aquarium project

SCIENCE	TECHNOLOGY	ENGINEERING	ART	MATHEMATICS
The concept of acid and base	Aeration technology	Create aquarium	Decorate the aquarium according to the creativity of the students	Calculations in aquarium production
Testing of indicators against acidic and basic solutions	Using pH meter	Establishment of natural indicators	Display power point as presentation material	Calculations in the manufacture of solutions with a certain pH
Testing the endurance of living things	Using laptop, mobile phone, projector, powerpoint media as presentation material	Assembling the aerator	Make a creativity of the media	pH measurement

Based on the above table, 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.

In the 21st century learning, people explore, experience, and understand the world around them in many new and different ways. Learning and education is no exception with technology providing access to virtually any information at the touch of a screen. With access to all of this information, it would seem that newer generations would be pushing the envelope on what is considered to be intellectually competent. However, despite endless access to information, students and early-career professionals are falling short. Many employers have found that the younger generation of applicants are lacking key skills, such as critical thinking, problem solving, and communication, thus causing what many people call a skills gap. Studies suggest that this gap in higher-order thinking skills is growing. Luckily, leading educational companies are tackling this growing skills gap by addressing educational strategies to help students develop sharper 21st century skills. Addressing the benefits of 21st century skills, however, is one of the easiest places to begin.

The results show that students have developed their critical and creative thinking, problem-solving skills, collaboration and argumentation skills, leadership and responsibility, information and literacy skills. Integrating STEAM into chemistry learning has developed students' 21st century skills in those three areas of (1) learning and innovation skills, which include ways of thinking and how to work; (2) Information, Media, and Technological Skill, which includes the tools used in the work; (3) Life skills and career, which includes skills to live in the world includes skills to live in the world.

Learning and innovation skills

Learning and innovations skills are developed in this study which are creativity, critical thinking, and problem-solving skills. The challenges of developing the project and relate it in 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. It also involves art in designing the projects.

We actively delivered creative ideas in group assignments such as finding different problem solutions and developing creative design
(Student Interview, April 20, 2016)

I kept finding the information, questioning information from different resources and friends, then criticize and review the results
(Student Interview, April 25, 2016)

In addition, there are some students faced difficulties in learning engagement:

I felt confused with what to do in the project
(Student Reflective Journal, May 9, 2016)

It is difficult to develop creative thinking without understanding the project aims
(Student 33, Reflective Journal, May 9th, 2016)

Based on the result, there were opportunities and challenges of STEAM integration in chemistry learning, especially in developing 21st-century skills. Teachers play important roles as a facilitator in teaching and learning.

FIGURE 2. Students developed the aquarium

The results are relevant to the findings that STEAM learning integration will lead students to develop problem-solving, critical thinking skills and collaborative skills (Messier, 2015). In this study students can increase the critical thingking, Wade (1995) identifies eight characteristics of critical thinking. Critical thinking 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 developed in 21st-century skills is adaptability, complex communication skills, non-routine problem solving, self-management, and systems-thinking are essential skills in the 21st-century workforce. The most effective way to prepare students for the workforce and college is to implement and scale what is already known about effective learning and teaching, content vs process wars should be ancient history, based on the evidence from the learning sciences. Integrating core concepts with key skills will prepare students for the

workplace and college. We need to move past mile-wide and inch-deep coverage of ever-expanding content in the classroom. Developing skills in the context of core concepts is simply good practice for polarizing debates, consider the evidence, and get to work.

Information, Media, and Technological Skills

Information, media, and technology skills are important in the 21st century, as means in globalization world. However in this context, is not only using the technology, but also in implementing the science itself. In STEAM project, students learn to find out the information and manage it to be useful information for developing the project and solve the problems. The students use different resources to develop the project. In this study the students experiment on a goldfish aquarium, where students perform different pH tests to determine the best pH conditions for goldfish, students also learn to make hydroponic plants with different pH in order to obtain maximum pH for plants to grow well.

FIGURE 3. Students finalize the project of goldfish aquarium

Application of integrated STEAM approach in project-based learning is done by providing a learning activity that is the endurance test of living creature that is goldfish which is influenced by pH of solution, where in the activity consist of several project. Giving several projects on learning will be able to know the development of students' critical thinking skills that can be observed during the process of implementation of learning activities. The students project shown in this picture below:

In the other project of developing the model of hydrocarbon and concept of hydrolysis of using technology also implemented. The project itself also using the technology, not only computer but also in design thinking as part of engineering in STEAM approach. The students already have technology skills, however, the project has stimulated them to develop their project.

We're searching on YouTube for the concept and ideas to relate to chemistry concepts.
(Student Interview, May 23, 2016)

I learned to use the technology of computer application and share my work with my group.We also designed the project planning which needs creative ideas
(Student Reflective Journal, May 16, 2016)

In STEAM project, students developed ICT literacy, however it's challenging in differentiating between engineering and technology. Technology should be integrated into the project as the principle of STEAM.

Life Skills and Career

Life and career skills are one of the necessary skills in dealing with the 21st century which preparing students to live in challenging works. The students learned to develop flexibility, adaptability, initiative, self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility. Davies, Csette, 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 for developing the project, students have to deal with other students differences. They have to adapt each other for couple weeks in completing the project. The students also

developed the leadership of managing the project within the problems and challenges. In this context, the self-direction also important as they have their own responsibility.

It's challenging to manage my team as some of them are not well-performed. However, I learned to divide the tasks and monitor the progress
(Student Interview, May 23, 2016)

We initially do not know what to do, starting to plan, each of team member shares the ideas. We have differences, but we need to make decision
(Student Interview, May 23, 2016)

However, there was a challenge for students in engaging in the STEAM project, as student statement bellow.

I found it's difficult to include art in the project, we also have limited time and tried to manage team members
(Student Interview, May 23, 2016)

Based on the result and discussion, STEAM approach has several advantages of students' 21st-century skills without ignoring knowledge development, such as: engaging students as partners in their own learning, harnessing the capacity of technology to engage learners and to optimize and amplify student learning and achievement, creating more teacher-student learning partnerships through real world, authentic learning tasks enabled by technology, emphasizing and teaching important higher-order skills such as critical thinking, communication, collaboration, creativity and entrepreneurship, supporting educators in preparing our students for a rapidly changing, technology-driven, globalized world.

Based on the learning process, 21 century-learning has several advantages in the learning process that the students learned to solve the problems with critical and creative thinking skills through technology. The STEAM approach has helped to relate abstract concepts and different disciplines of mathematics, science, technology, inquiry and art. Students can apply the knowledge into everyday life. 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 start to see how content used in reality 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 on their roles in the group.

Learning process in 21st-century skills 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. It is also important for all students, especially those with few academic resources. The greater the initiative students make in learning about 21st century skills and how to develop their own, the greater the advantage they will have over their peers in developing and utilizing these skills in their years of schooling and careers to come, people with well-founded critical thinking, problem-solving, and communication skills are far more likely to hold administrative positions and are more likely to be promoted. Becoming a critically conscious student will surely play a pivotal role in this important developmental stage of student's academic and professional career.

CONCLUSION

STEAM approach can be integrated into chemistry learning through projects that related to chemistry concepts. The important elements of 21st-century skills are learning and innovation skills, information, media, and technological skill, life and career skills. The study found that STEM integration can be implemented to develop critical thinking, communication, motivation, creativity, respectful, disciplined, collaborative, responsible, adaptation, and leadership, as well as information and media literacy. The researchers faced the challenges 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 challenges of how 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).

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