The development of chemistry students’ 21 century skills through a STEAM project on electrolyte and non-electrolyte solutions

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Abstract. This paper portrays a study into the integration of a Science, Technology, Art, Engineering, and Mathematics (STEAM) project in chemistry learning of electrolyte non-electrolyte solutions for developing 21st-century skills. Thirty-two, year-10 students engaged in the study. The research employed qualitative methodology with multiple modes of data collection via semi-structured interviews; classroom observations, reflective journals, and documentation were guided by a 21st-century skills rubric. In addition, the project was assessed against the criteria of project development, STEAM integration, and product quality. Students designed an innovative project, integrating STEAM in developing and making a miniature LED by using the natural electrolyte solution sources, such as lemon, lime, apples, and salt water. Students created posters and video projects for presentation in a project exhibition. Students were able to integrate their knowledge from various fields to solve problems and create new innovations. The students used the 21st-century skills of collaboration, communication, critical thinking, creativity and innovation alongside technology as a tool for learning. The engaging learning environment encouraged students to develop their skills and chemistry conceptual understanding.

1. Introduction

21st-century learning is a term related to student competencies when faced with real-life challenges [1]. The Partnership for the 21st-century skills [2] proposes that students in today’s world must have essential skills to be successful in the 21st-century life and workplace, such as information, media and technology skills, communication and collaboration skills, and critical thinking and problem solving skills [3]. Educating students with the 21st-century skills will contribute to society by make them more productive [4].

Learning STEAM also provides opportunities to turn abstract science and mathematics concepts into concrete real-life applications. STEM education mostly combines problem solving, analytical, critical, creative thinking, teamwork, and communication skills as a pedagogical strategy [5,6].

In Indonesia, STEM research projects are becoming more evident as indicated by the increased emphasis on research in national and international seminars, and provision of both private and government research grants in STEM topics. STEM research projects have been conducted in primary and secondary schools, including: projects focusing on a multiple intelligences approach [7], student
attitude [8], and scientific literacy [9], projects related to learning resources used a virtual laboratory for junior high school students [10] and STEM learning materials for physics in secondary schools [11,12], performance assessment in STEM [13], integration of art in STEM education conducted through STEAM education in chemistry learning for 21st-century learning skills [1]. STEM and disaster [14]. STEM education in chemistry [15]. A maker space approach to STEM learning in elementary schools [16]. The researchers faced the challenge of integrating STEAM within the chemistry curricula, empowering students, and managing the teaching and time resources.

2. Method
The research employed qualitative research with multiple data collection methods via semi-structured interviews, classroom observations, reflective journals, and documentation, guided by a 21st-century skills rubric [17]. Thirty-two year-10 students participated in the project. The teaching method used stages of relating, planning, developing, cooperating, and transferring as figure 1 below.

![Figure 1](image.png)

Figure 1. Project based learning in STEAM project [1].

This paper describes a STEAM approach used in the chemistry learning of electrolyte and non-electrolyte solutions. Students designed an innovation STEAM project by developing a miniature LED circuit using natural electrolyte solution sources, such as lemon, lime, apples, and salt water. Students created posters and video projects for presentation in the project exhibition.

3. Result and discussion
The results show that STEAM integration in Electrolyte Non-Electrolyte Solutions project helped developed 21st-century skills through collaboration, communication, higher order thinking skills of creative and critical thinking, creativity, innovation, and in using the technology as a tool for learning.

3.1. Collaboration and communication
The STEAM project encouraged students to express their opinions, communicate their ideas and improve their ability to discuss through the stages of project development and project exhibition. Students also had to collaborate within the group to solve problems and to complete the project. The sample below captures the conversation between a student presenting and another student asking a question:

*Student 8*: The lights in your group project were difficult to light up, why does that happen?
Students 33 : We think, it was because when we to cut the lemon in wrong way, too much lemon water came out of the lemon, it caused the electrolyte solution volume from the lemon decreases, so the light did not turn on.

Students 5 : Was there any differences between lemon that you cut as pieces and the whole lemon without you cut it?

Students 2 : We tried first with whole lemon without cut it, and Aldan gave a suggestion to cut it. So we tried to cut it and some light came out, so we decided to cut the lemon to press and make it effective.

One of the visitors to the exhibition asked why the LED lights could light up using fruit, then the students answered the reason why the lights could light up, because in lemons there are vitamin C and citric acid which can be weak electrolytes, lemons also have rich content such as potassium, calcium and magnesium so that the fruit can be an electrolyte solution that can turn on the LED lights (Students 9, classroom observation, 2 February 2018).

The results of the interview and classroom observation above show that learning with STEAM gives students the opportunity to develop their communication and collaboration skills, not only learning in concepts, but also in socializing and trying to communicate ideas to the general public. Chemistry learning is also expected to educate graduates who are able to interact socially within the school environment, and with the broader community [18]. The results are relevant in demonstrating that STEAM learning integration may lead students to develop collaborative skills [19]. The results of the rubric collaboration and communication skills are 4.1.

3.2. Higher order thinking skills

The challenges of developing a project and relating it to STEAM basic principles stimulated students to develop creativity and critical thinking skills. Project-based learning is a model that improves student ability to solve problem [20]. Students had to solve the problem of finding natural material that can turn up light as related to their understanding chemistry concepts.

Students 28 : Teacher, my group does not carry zinc. I will use a can of drinks, then I will cut the cans into small pieces. Can it replace zinc teacher?

Researcher : Yes, just try it.

Students 36 : Teacher, why does this lamp not turn on?

Researcher : Try to correct the circuit, what should be corrected?

Student 36 : We will try to replace the shorter cable, then strengthen the copper and zinc coil and also maybe we have to change the lemon, because the water of lemon has been wasted, so the electrolyte of the lemon decrease.

In addition to the length of cable used, the parts that must be inserted with the electrodes and village circuit allow it to keep the lights on. Students tried to answer questions using different resources, including the internet and books. Art was also used in designing the projects.

"Aluminum foil as a negative pole, the coin as a positive pole, so when connected the lights will turn on because there is a current there, and there is a medium that sends it cardboard which has been put into vinegar water, so even though the cardboard is insulator but because there is a solution electrolyte, so the cardboard can deliver electricity" (Students 20, Interview, 8 February 2018).
The sample from the reflective journal and interview above shows that students tried to problem solve and use their knowledge about chemistry concepts in a real-life scenario. The integration between STEAM learning and project-based learning not only makes students learn basic theories in project completion techniques, but students will also learn problem solving skills, critical thinking and collaboration skills [19]. The results of the critical thinking skills rubric given to students showed significant improvement in results, namely 4.03 on a scale of 5.

3.3. Creativity and Innovation

Strategies for developing students' creativity and designing learning systems helped students develop their creativity [21]. For example, providing opportunities for learners to experience and practice their own creativity through stimulating, relevant, and authentic learning experiences their subject matter field. Students were also given problems in the project which allow them to practice developing creativity and active inquiring [18].

Previously we wanted to make the lights for Iron Man to be the coolest, but the circuit was difficult after trying and had to use natural materials, but we tried again and again and finally we decided to make the LED lights made into a light with apple resources (Students 14, interview, January 27, 2018).

The results of the classroom observation above show that students can change their way of thinking to provide alternative solutions to some problems. The results of the questionnaire show development of creativity and innovation skills given to students obtained an average value of 4.1 on a scale of 5. The STEAM with art component greatly stimulated students' creativity and innovation. Students collaborated with each other in creating designs and decorating their projects. They not only learnt chemistry concepts but they also integrated art into their learning. In addition, students also made posters and videos to present the project. At the end of the lesson, a project exhibition was held where students presented their results, answered questions and communicated with teachers, students from the school community.

3.4. Using the technology as a tool for learning

Students learnt to use technology such as the LED lights lit by natural sources, without using batteries. According to Trilling and Fadel, technology skills refer to the use of technology to create media through innovation [22]. The students had to work out the best design needed to make the LED light up which required scientific understanding and knowledge of engineering design.

We use apples to make the LED lights turn on, before I think it won't work but it turns out it works, because after I learnt about electrolyte, I think that apples also have a vitamin C and maybe some of citric acid, so we use apples to turn on the LED lights that we made as a decoration for the lights (Students 24, Interview, 16 February 2018).

The results of the interview above show that students applied and develop their knowledge about chemistry concepts to find an innovative solution to make something that can used as a technology. Students not only develop their 21st skills but also understood the chemical concepts of electrolyte and non-electrolyte solutions that were taught. The rubric criteria, using the technology as a tool for learning, showed that students obtained an average value of 4 on a scale of 5.
Throughout the project, the STEAM approach helped develop students’ 21st-century skills and provided opportunities for students to understand working on real-life scenarios through the project in Figure 2. Students applied the knowledge of chemistry concepts to a real life and the STEAM approach provided students with a student-centered approach to learning chemistry.

4. Conclusion
The 21st-century skills of collaboration, communication, critical thinking, creativity and innovation, combined with using technology as a tool for learning, were used in this study. The STEAM project to make natural chemical lights engaged students in designing an innovation project with the integration of STEAM in building a miniature LED by using natural electrolyte solution sources, such as a lemon. Students learnt chemistry concepts about electrolyte and non-electrolyte solutions, chemistry bonding in electrolyte and non-electrolyte solutions, and about cathode and electrode uses in chemistry. Students started to challenge their critical and creative thinking within their existing learning environment. A continuing challenge for educators is how to provide a collaborative learning experience for students who prefer to learn and work on their own as well as understand chemistry concepts [23].

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