Developing 22nd century skills through the integration of STEAM into smoke absorber project

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Abstract. This study aimed to develop 22nd century skills through the integration of STEAM (Science, Technology, Engineering, Art, and Mathematics) project in chemistry learning. The study involved the thirty-three students of 11 year. The STEAM integration was implemented in the teaching of colloidal system through a project-based learning. The study employed qualitative approach to explore the integration of STEAM in chemistry and students’ 22nd century skills development. Data were collected through classroom observations, interviews, reflective journals, and chemistry concept test. Students designed an innovation project with the integration of STEAM in developing smoke absorber as the solution of the smoke pollution. The data were then analysed based on the themes pattern found in multiple data sources. It shows that STEAM improved students’ critical thinking, creativity, collaboration and communication skills, and caring of environmental problems (5C), in addition to information, media, and technology skills. However, this study remains challenging since STEAM integrated chemistry learning requires more empowering student, time resources, and learning contexts in order to explore and to raise the students’ environmental awareness.

1. Introduction
Chemistry, one of the learning subjects in high school, is considered as difficult matter for students. According to [1], students experiences many difficulties in learning chemistry because it is abstract, not easy to understand and not directly related to their lives. Hudson in [2] states that chemistry teaching must not only transmit knowledge, but also must be relevant to daily life, so students can find the merit of chemistry in daily life.

Chemistry learning in the Indonesian curriculum now a days require students to develop their abilities in term of hard skills and soft skills. Education in 21st century aims to develop student’s collaboration, communication, creativity and critical thinking skills (4Cs). Since the 22nd century will come really soon, students need new Cs to face and to survive in 22nd century such as 1) care, to helps students to understand and to act from an ethic of care, 2) connection, to help students act on the desire to authentically connect with other, 3) culture, to create spaces of genuine positivity, and 4) community, to help students act on the value of involving all voices in the process.

STEAM (Science, Technology, Engineering, Art and Mathematics) is an approach that is designed to integrate the five disciplines that encourage student’s curiosity to express their own knowledge [3]. The integration of these fields of science is expected to increase the meaningfulness of chemistry concepts so it will easy accepted, attractive and empower students’ soft skills. Learning with STEAM
integration refers to constructivism learning theory [4] where students will actively build their own knowledge through pleasant learning experiences. Students will actively create strategies independently for the learning process. On the previous study, STEAM can developed students’ soft skills such as critical thingking, problem solving, and collaboration skills [5].

Various studies of STEAM application in Indonesia have an impact on motivation and the development of students' soft skills. Several studies on STEAM in Indonesia are related to various focuses, such as multiple intelligence [6], students’ attitudes [7], and learning material concept [8-9] performance evaluation [10], 21st century skills [11], chemistry learning [12-13], and the marker space approach [14]. Therefore, this study focuses on the implementation STEAM in teaching chemistry to develop 22nd century skills students need in the present and future.

2. Methods
This study aimed to develop 22nd century skills through the integration of STEAM project in chemistry learning. The qualitative research was employed with multiple data collections of interview, classroom observations, reflective journal, and chemistry concept test. This study was held four times and involved thirty-three students of 11 grade. The stages of STEAM integration in chemistry learning carried out through five phases as shown in figure 1.

![Figure 1. Project-Based Learning in STEAM Project](image)

In the project, students have tried to assemble a device that can draw smoke and filter it with the absorption’s principle. In each process, teachers play important roles as facilitators, then students’ working collaboratively in completing the project. The collected data were analysed through three stages namely data reduction, data display, and conclusions [14]. Data were reduced by grouping, selecting, focusing, and removing unnecessary items based on the 22nd century skills aspect. Data were presented in the form of tables, graphs, and narrative texts, and the conclusions, then verified by checking its consistency and compatibility with other data collected.

3. Result and Discussion
The results show that the STEAM integration in chemistry learning has developed students’ 22nd century skills which known as 5Cs, namely communication, collaboration, creativity, critical thinking, and care. In chemistry learning, students face challenges in making connection between concepts and implementing it in real life situation. The integration of STEAM in chemistry learning encouraged students to observe phenomena and solve the problem related to chemistry concept. Project-based learning method has been applied to raise students’ engagement [15] and improve students’ motivation [16].

Smoke is a colloidal system consists of a solid dispersed in a gas. Smoke absorber is a simple device made as a solution to the problem of air pollution with mechanical fan and activated carbon fiber as an adsorbent. It is used to reduce the harmful smoke by removing bad odor and combustion
products. The following table 1 provides the information of STEAM aspects mapping on smoke absorber project.

Table 1 STEAM Integration in Smoke Absorber Project

| Science | Technology | Engineering | Art | Mathematics |
|---------|------------|-------------|-----|-------------|
| Application of colloid system in everyday life such smoke | Making a device to reduce negative impact of smoke | Designing a device | Decorate the device according to the creativity of the students | Calculation in device production |
| Smoke absorption process use activated carbon fibers | Using laptop, handphone, projector, and powerpoint as media presentation | Assembling the tools | Display powerpoint as presentation material | Calculate time for project making |
| | | Arranging the activated carbon as an absorber in the device | Making a creative media | Calculate the size of activated carbon filter to match the size of the device |

Table 1 shows that STEAM provides the opportunities for students to develop the competence of hard skills and soft skills during learning process. In this study, students not only understand the application of colloidal systems in everyday life and skilled in operating computer and other electronics devices, but also they can develop the skills needed in the 22nd century which are explained in the following discussion.

3.1. Communication and Collaboration

The application of STEAM in chemistry learning can improve students' skills in conveying arguments, communicating ideas, develop the ability to solve problems by discuss and collaborate between group members in completing projects. It can be seen on students' conversation below.

Student 19: In the tools we make, there is activated carbon which functions as an absorber. But from the video about the steps of making smoke absorber that your group presented, I don't see any activated carbon in there. Then how do you filter the smoke?

Student 12: Let's look at the video once again, in the tube as the exist air placed the activated carbon, so there is still absorption process of smoke (Classroom observation, 24 April 2019)

The result above indicated that student learn to develop different way of learning by asking the question and another student as the presenter give the opinion regarding the project. According to [17] the students had opportunities to give their opinion related to their learning experiences. Beside that, the students also developed their ability to give their sight in discussion to solve the problem.

From the problems given, we discussed by giving the opportunity to all group members to express their opinions to solve the problem. We discuss to determine the easiest and most relevant solutions based on the opinions we have discussed (Student’s interview, Student 12, 24 April 2019)

STEAM approach was implemented in chemistry classroom through project-based learning provide the opportunity for student to obtain deep chemical understanding and engaged students in investigation of authentic problems by working in team for an extended period of time [11]. So students developed their collaborative skill through STEAM project by discussing the complex question, and how to work in a team to accomplish the project well.
We share tasks and help each other when someone has difficulty working on their parts (Reflective journal, Student 20, 22 April 2019)

There are no difficulties in working together because we help each other and provide feedback (Reflective journal, Student 18, 15 April 2019)

I feel comfortable with my group, because all members of the group are communicative and can be invited to work together (Reflective journal, Student 30, 22 April 2019)

STEAM has helped the students in finding the way to solve the problem using their knowledge to relate it with the phenomena in everyday lives, including solve the environmental problem by discuss [18]. Therefore, STEAM integration in chemistry learning can lead students to develop their communication and collaboration skills. The results of this study are relevant to the finding STEAM approach could help student have the collaboration skills [5].

3.2. High Order Thinking Skills
The higher order thinking skills refers to students’ ability to use cognitive processes to solve a complex problem [19]. The HOTs have been developed in this study are creativity, critical thinking and problem solving skills. The challenge facing of completing the project and relate it with STEAM discipline has stimulated students to develop creativity and critical thinking skills [20].

Factory smoke trigger for respiratory disorders because it is colloid which contains particulates such as lead (Pb) and Carbon monoxide which will bind hemoglobin in the blood, so it will be a lack of oxygen in the body (Test Result, Answer of Student 31, 29 April 2019)

Student 7 : Do you think the device that have been made can be used if the source of the smoke is large?
Student 21 : Yes it can, if we use a large vacuum that has big power, so we can suck all the gases, but this time we just learned to make a miniature model of smoke absorber, so the device that we make cannot filter smoke if the source is too large (Classroom observation, 24 April 2019)

According to [21], critical thinking is indicated by students able to propose the critical question and explored different resources in the project. This result study is relevant to [5] that STEAM integration in chemistry learning helped students to develop their critical thinking skills.

STEAM with art aspect has stimulated the students’ creativity. According to [22] discussed the designing strategies and learning systems to help students develop their creativity. 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 this study, students develop their creativity by designing and decorating the smoke absorber project.

Figure 2. Smoke absorber models prepared by students’ creativity
We decorate it by making a shape like a house with the roof (Reflective journal, Student 28, 24 April 2019)

We decorate smoke absorber device by drawing using markers on the surface of the device (Reflective journal, Student 19, 24 April 2019)
This results are relevant to the finding STEAM integration in chemistry learning develop students’ creativity and critical thinking [23]. Students’ creativity and critical thinking have been stimulated in smoke absorber project as students have to find and solve the problems of smoke within their understanding of colloidal system concepts. Students need to have creative thinking as a logical and divergent thinking to produce something new. This is related to curriculum 2013 that requires students to be able to interact socially with the school environment, society, and environment.

3.3. Care
To face new challenges in the coming 22nd century, education is required to develop skills that are more profound than 21st century skills. According to Altin, Bacanli and Yildiz in [24] stated that science education has the aim to raise environmental awareness of the students with improved attitudes and behaviors with regards to environmental protection. In this study, students are faced with the problem of air pollution in the form of smoke which has a negative impact on human health.

> In my opinion, to overcome the problem of air pollution, we have to reduce our ego, which means that even if we have private vehicles, for daily activities we should use public vehicles such as the MRT or transjakarta (Student’s interview, Student 21, 24 April 2019)

> In my opinion, current air pollution such as the production of smoke from factories and vehicles can be overcome by making an absorber to filter dirty air. In addition, industries can apply the physical coagulation concept by using a cottrel machine (Test Result, Answer of Student 20, 29 April 2019)

This results study indicated that students develop their caring of environmental problem by giving their opinion about the solution to reduce the harmful of the air pollution. This results are relevant to [25] stated the contextual learning cultivate the students’ environmental awareness.

Besides, the integration of STEAM in this study has developed students’ caring to each other. This finding proven by student’s interview and reflective journal below.

> The project that my group made was brought by my friend but it broke and it had to be recreated, when I called her but she could not be contacted, I felt she did not dare to tell. At first I wanted to call her father, but I was worried she would be more depressed, so I waited for her to contact me if she needed my help (Student’s interview, Student 21, 24 April 2019)

> When did group work and my friend feels sad I cheer her up and listened to her story, I'm not good at giving advices but at least I'm a good listener. Take pleasure, take a meal, invite to play (Reflective journal, Student 19, 24 April 2019)

The results above indicated if students have developed their care skills. These results are relevant to the finding of the integration of project-based learning that has been developed students empathy and appreciated the opportunity to work with other students through collaborative learning [26].

4. Conclusion
This study explored that STEAM approach can be integrated to chemistry learning within real-lives situation. The important of 22nd century skills such collaboration, communication, critical thinking, creativity, and care (5C) have been found in this study. Smoke absorber as STEAM project is designed to solve the air pollution problem occur in Jakarta. Students have developed their critical thinking and creativity with implement their chemistry knowledge to solve the environmental problem. Students have developed their communication and caring to each other in collaborative learning through STEAM project making. The challenges of integrating STEAM in chemistry learning with in empowering student, time resources and also the challenges to provide the contextual learning to raise the students’ environmental awareness need to be explored.
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