JTK: Jurnal Tadris Kimiya 7, 1 (June, 2022): 121-134
Website: http://journal.uinsgd.ac.id/index.php/tadris-kimiya/index
ISSN 2527-9637 **(online) ISSN** 2527-6816 **(print)**

Development of 21st Century Skills in Acid-Base Learning Through STEAM Projects

Achmad Ridwan[1*], Chinthia Fatimah[1], Tritiyatma Hadinugrahaningsih[1], Yuli Rahmawati[1] and Alin Mardiah[1]
[1]Chemistry Education, Faculty of Mathematics and Natural Science, Jakarta State University, East Jakarta, 23111, Indonesia
[*]E-mail: achmadridwan@unj.ac.id

Received: 13 December 2019; Accepted: 21 June 2022; Published: 30 June 2022

Abstract

This study aimed to develop students' 21st century skills by integrating STEAM projects (Science, Technology, Engineering, Art, and Mathematics) in learning chemistry on acid and base solutions. Interdisciplinary learning was designed to allow students involved actively in learning through project development activities to see the relevance of learning content and its application in real life. This study involved 35 students of natural science 11th grade, consisting of 14 boys and 21 girls, in one of public senior high schools in DKI Jakarta Province. Researchers used qualitative methods to understand students' experiences and the implications of learning on their 21st century skills. The researcher collected data through semi-structured interviews, observation, journal reflective, and 21st century skills questionnaires. The results showed that each stage of STEAM learning integrated with project-based learning encouraged students to develop 21st century skills, namely learning and innovation skills, skills using information, media, technology, and life and career skills. Students reflected their abilities in using information and technology, the ability to work together, communication, and thinking at higher levels, as well as adaptability and leadership. In addition, students were also faced with challenges in changing the paradigm of teachers and students and managing the learning process.

Keywords: 21st century skills, acid-base, chemistry learning, project based learning, STEAM approach

DOI: https://doi.org/10.15575/jtk.v7i1.4913

1. Introduction

As a developing country, Indonesia now has more challenges, one of them is the existence of the ASEAN Economic Community (AEC). Indonesia joined AEC since the end of 2014. The existence of AEC open up greater opportunities for participating at free markets among ASEAN countries. Increasingly open free market allows countries to easily sell goods and services to other countries throughout Southeast Asia so that competition will be even more intense. One way to reduce the unemployment rate due to increasingly fierce competition is to prepare generations who have competitiveness in skills. Skills are the capital necessary in future life. Indonesia seeks to develop skills that needed in the 21st century through the 2013 curriculum which states that integrative thematic learning emphasizes character education and looks at processes for skilled up (Alismail, 2015).

Education is a forum to prepare a generation who compete in knowledge, attitudes, and skills. In the 21st century, the skills in education is very important for students to be competitive in the future. This is in accordance with 21st century learning which has three aspects of skills, which are learning and innovating, using information, media and technology as well as life and career skills (Trilling & Fadel, 2009). 21st century skills arise from the assumption that today individuals live in an environment familiar with technology, abundant information, very rapid technological advances, and the necessity of communicating and collaborating (Partnership for 21st Century Skills, 2008). ATCS (Assesment and Teaching for 21st Century Skills) concluded four main things related to 21st century skills, which are how to think, how to work, work tools, and life skills (Pacific Policy Research Center, 2010). To optimally develop 21st century skills, needs support from all fields of teaching and learning, including chemistry.

Chemistry is a part of sciences which important to be understood by students. There are a lot of phenomena in life closely related to chemistry (Bhargava, 2016; Roy, 2016), so that the learning of chemistry cannot be separated from its context in real life (Majid & Rohaeti, 2018). The process of learning chemistry often faces challenges due to the need for the development of basic concepts. On the other hand, it is also necessary to consider the development of 21st century skills. Chemistry is also considered a subject that is difficult for students to understand because of the abstract characteristics of the concept (Sirhan, 2007). Therefore, in order to have a complete understanding, students are encouraged to have an understanding of the three levels of representation of chemical sciences, which are macroscopic, sub-microscopic, and symbolic (Johnstone, 1991). In addition to these characteristics, chemistry learning emphasizes the process of memorizing facts and ignoring concepts so as to make them less meaningful (Hadinugrahaningsih et al., 2017).

STEAM is a relatively new educational paradigm that emphasizes interdisciplinary, creative, contextual, problem- or project-based learning (Henriksen et al., 2019). Therefore, in the last decade, STEAM has become an increasingly in demand subject in the field of scientific and educational studies (Khine & Areepattamannil, 2019). STEAM approach is a development of STEM approach, the addition of "Art" elements to STEM will develop creativity, collaboration, and innovation (Davis & Long II, 2017; Lee et al., 2016). The addition of "Art" helps learners who have different views in finding relationships between disciplines to develop comprehensive knowledge in solving problems (Rahmawati et al., 2022; Wilson et al., 2021). The integration of "the Art" dimension is carried out to ensure the active involvement of learners in the learning process to develop interdisciplinary thinking and assist them in building a self-profile by considering the differences between learners. (Başaran & Erol, 2021).

Research related to the implementation of the STEAM approach in various countries has shown implications for the development of various skills. Gardner & Tillotson (2019); Patterson & Muna (2019) reports that learners' involvement in collaborative learning from real-life problems encourages them to develop their procedural abilities. The application of STEAM has been assessed as one of the learning approaches that significantly encourages the development of student creativity (Khamhaengpol et al., 2021; Shen et al., 2021), solving various problems in a creative and integrative way by increasing understanding and interest in knowledge, processes and natural tourism in a variety of different fields related to science technology (Kim, 2011). In addition, the application of STEAM encourages students' curiosity and motivation in independent learning, problem solving, project-based learning, and challenge-based learning (Park et al., 2016; Rahmawati et al., 2021). STEAM helps learners be aware of how to learn and focus by emphasizing logical, mathematical and scientific thinking, while increasing learners' learning motivation by generating curiosity about the concepts they have learned with real life (Adriyawati et al., 2020; Rahmawati et al., 2020).

Based on the various implications of STEAM learning above, this approach has great potential in the development of 21st century skills. Therefore, this study aims to develop the skills of 21st century learners in chemistry learning. The topic of acids and bases is chosen because it is one of the popular chemistry learning concepts due to its wide application in life (Saglam et al., 2011).

However, in practice, to bring learners into the realm of application is still rarely done. Thus, in this study, students are directed to be able to produce a STEAM project as an application of the concept of acids and bases.

2. Research Method

This research used qualitative methods to describe as a whole and in depth the development of students' 21st century skills through the implementation of STEAM projects in acid and base learning.

2.1. Research Design

The study involved 35 students of natural science 11th grade, consisting of 14 men and 21 women in one of public senior high schools in DKI Jakarta. The research was carried out through three stages: preparation, implementation, and the final stage shown in Figure 1.

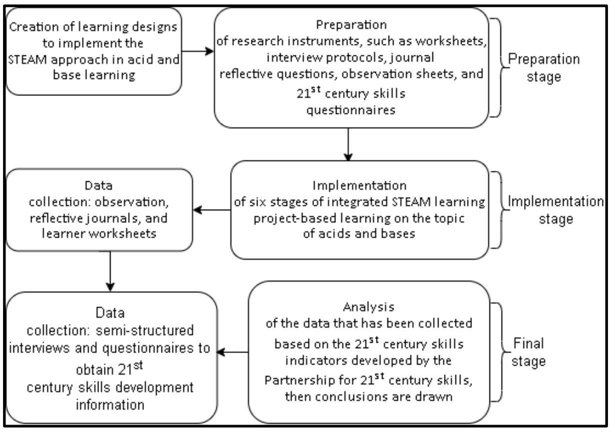

Figure 1. Research Flow

In the preparation stage, researchers compiled acid and base learning plans through material analysis, STEAM-PjBL literature, and student characteristics. In addition, researchers also prepared the necessary instruments in the study, such as worksheets, reflective journals, interview questions, observation sheets, and 21st century skills questionnaires. The STEAM-PjBL was carried out in eight meetings through six learning steps shown in Figure 2.

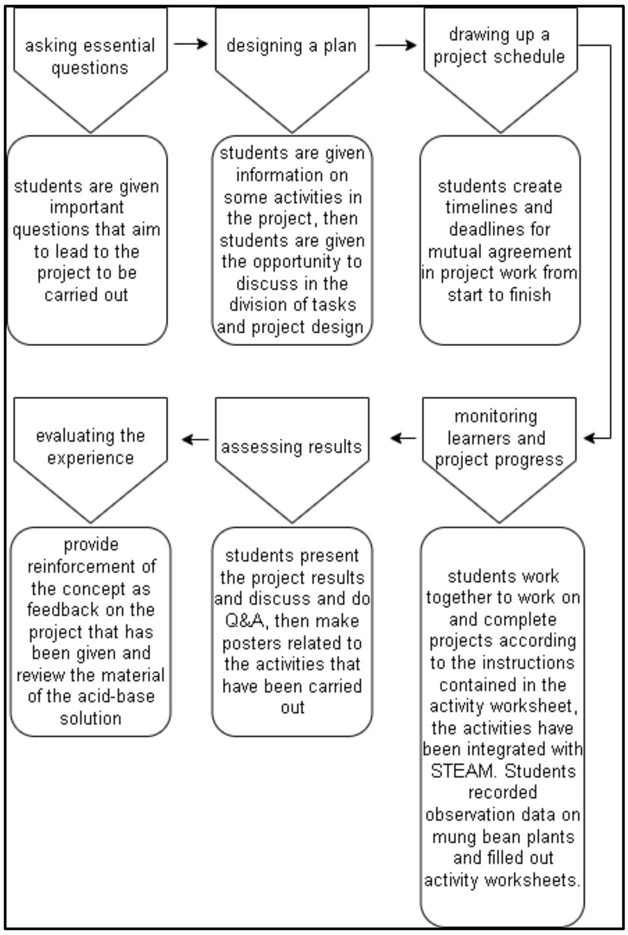

Figure 2. STEAM Learning Stages Integrated with Project-Based Learning

The STEAM project developed related to acid and base learning was the activity of growing mung beans. Students in groups made pots from clay with designs according to their creations. Then painted and decorated the pot using watercolors. They also made acid and base solutions with a certain pH from natural ingredients and materials available in the laboratory. Furthermore, they carried out a series of activities, such as planting mung beans, measuring soil pH using a soil tester, observing the growth of mung bean plants, and making posters as a communication medium for the activities that have been carried out.

The final stage of the study included the processing of data obtained during the research, data analysis, and drawing conclusions related to the implications of

STEAM-PjBL practice on the development of learners 21st century skills.

2.2. Data Collection Techniques

Data collection in this study was carried out through several techniques including interviews, observations, reflective journals, and 21st century skills questionnaires. Researchers were assisted by two observers to observe in depth the various phenomena that occur during the research process and to obtain information on the involvement of learners in STEAM-PjBL. At the end of each meeting, learners were asked several reflective questions to gain an exploration of the understanding, feelings, and challenges they face during learning. The example of the question asked is as follows; (1)How did you feel after doing various activities in STEAM learning today?; (2)What benefits have you felt from the learning that has been done?

After the acid and base learning ends, semi-structured interviews were conducted both individually and in groups through focus group discussions (FGD). The purpose of the interview was to obtain more in-depth information related to the experience of students in chemistry learning which was carried out using STEAM-PjBL. In addition to the interviews, learners also filled out a 5-likert scale questionnaire as a self-assessment of the of 21st century development skills they feel. Here are some examples of statement items in the questionnaire filed. (1) I was able to create my own creative ideas with observations or experiences that I have experienced, (2) I was able to ask questions that were important to gather information, (3) I was able to divide my time, make plans and complete tasks on time.

2.3. Data Analysis Techniques

Data analysis in this study was carried out through three stages: data reduction, data presentation, and conclusion drawing (Miles & Huberman, 1994). Data reduction was carried out by focusing attention on the simplification and transformation of raw data obtained during the study with the aim of setting aside irrelevant data or information. The relevant data were then presented in matrix or coding tables based on the categorization of STEAM-PjBL implementation stages and 21st century skills aspects. Furthermore, the implications of STEAM-PjBL learning practices on the development of learners' 21st century skills in chemistry learning were analyzed.

2.4. Data Validity Techniques

Data validity technique used in this study was trustworthiness (Guba & Lincoln, 1989). To test trustworthiness, credibility criteria were used to verify data in drawing conclusions that included prolonged engagement, persistent observation, progressive subjectivity, and member checking (Miles & Huberman, 1994). Prolonged engagement was carried out by involving researchers directly in the research process to understand the context, explore student involvement, and implement STEAM-PjBL in chemistry learning over a period of time. At the same time, persistent observation was carried out by deeply observing each phenomenon that occurs continuously assisted by two observers. Progressive subjectivity was carried out to monitor the development of students' 21st century skills based on records obtained during the study. Member checking was carried out to ensure the accuracy of the data by reconfirming ambiguous data to the research subject.

3. Result and Discussion

3.1. Implementation of STEAM Approach Integrated with Project-Based Learning (PjBL)

The first stage in the STEAM approach integrated with project-based learning was to provide essential questions related to the project to be given. These essential questions were to stimulate and direct learners to the project to be worked on. The essential question that led to the project related to the application of acids and bases in everyday life. Some of the essential questions given are: (1) What do you know about acids and bases?; (2) How do the properties of acidic solutions and alkaline solutions differ?; (3) How to find out a solution is acidic or alkaline?; (4) Do you know the benefits or applications of acids and bases in everyday life?

The questions asked in this early stage of learning encourage the inquiry process of learners to be able to evaluate, synthesize, and analyse problems so as to encourage their curiosity (Hawari & Noor, 2020). Essential questions lead learners to the application of various skills and understanding of content to effectively develop multidisciplinary projects (MacMath et al., 2017).

Table 1. Activity Mapping in the STEAM Approach

Activities	Planting Mung Beans on Soils that have different pH
Science	1. Acids and Bases 2. Plant Resistance to the Environment (pH) 3. The science of farming
Technology	1. Soil tester (smart easy to use 4 in 1 soil survey instrument) *2. Handphone* 3. Laptop
Engineering	1. Planting technique: hollowing out, selection of seedlings, watering 2. The technique of making pots out of clay
Arts	1. Sketch of the shape of the pot 2. Paint and decorate the pot with paint so that it has aesthetic value
Mathematics	1. Measurement of pH and plant growth 2. Making a solution with a certain pH

The second stage in the STEAM-PjBL was planning the project. Researchers assigned projects through activities, namely planting mung beans in soil that has a different pH. Researchers provided information on several activities in the project such as making pots from clay, making acid and alkaline solutions with a certain pH from natural materials and materials available in the laboratory, planting plants, painting, observing plant growth and making posters as a communication medium of the activities carried out. Students were given the opportunity to discuss in the division of tasks and design projects. In addition, before planning the project, students were asked to do literacy regarding mung bean plants. The activities provided have five elements of STEAM, namely science, technology, engineering, arts, and mathematics (Table 1).

The third stage was to compile a schedule, students made a timeline and deadlines by mutual agreement in working on the project from start to finish. The preparation of the time for the activity and how long the observation was obtained was based on the results of a mutual agreement between the researcher and the students. The fourth stage was monitoring the project, students worked together to work on and complete the project according to instructions and reported progress in writing through worksheets. Students work in groups with great enthusiasm to develop their projects. Researchers supervised the progress of the project, monitored and asked how the mung bean plant grows. Activities in creating projects can make learners develop 21st century skills (Figure 3).

Figure 3. Activity in Creating a Project

The documentation in figure 3 showed students communicating and collaborating together to produce a product. In addition, students are more skilled in using a tool that has never been used before such as universal indicator paper and soil tester. The build of acid and base solutions with a variety of pH trains critical thinking and problem-solving skills.

The fifth stage was to assess the results, the researcher assessed the results of the products produced from the project given to the learners. Students presented the project results and discussed and did question and answer, then made posters related to the activities that have been carried out. The product produced from the given project, namely the mung bean plant, can be seen in Figure 4.

Figure 4. Products Produced by the STEAM Approach

The last stage in the STEAM approach integrated with project-based learning was to evaluate the experience to find out what students got from learning using the STEAM approach on acid and base solution materials. In addition, at this stage, the researcher provided reinforcement of the concept as a feedback on the project that has been given and reviewed the material of acid and base solutions. Here is an example of a dialogue between researcher and learners:

Student 9	:	*Mam, studying chemistry can apparently be attributed to other subjects, such as Biology and Mathematics?*
Teacher	:	*What do you think it looks like?*
Student 9	:	*Yes, we observe plant growth such as its height per day, whether it continues to grow or not if it is watered with various solutions whose pH varies.*
Teacher	:	*Learning with the STEAM approach is indeed related to various fields of science, so that your knowledge is getting wider, interesting or not?*
Student 9	:	*Interesting mam, more real learning.*

The passage of the dialogue above was the result of interviews with students, showing that students can feel not only learning chemistry but also learning another lesson, namely biology, chemistry and biology included in Science (Yakman & Lee, 2012). Learners can describe which parts include biology lessons. Learners also get a connection between the material studied and the problems that exist in life, thus obtaining important information and preparing life skills for future skills (Alismail & McGuire, 2015). Some experiences about learning with the STEAM approach are also felt by students, including:

The highly communicative and interactive STEAM teaching system is useful for students in Indonesia whose education system is limited.
(Student 25, Interview, 6 February 2017)

What I feel when learning using STEAM, we feel more practice. The advantages of using the STEAM approach can help me to better understand the true meaning of learning. The use of the STEAM method is very pleasant during learning.
(Student 10, reflective journal, 1 February 2017)

Can process learning values better, better application, can develop as, thoughts, creativity, can be more efficient and can design things well.
(Student 6, reflective journal, 1 February 2017)

The results of the above interview showed some of the learners' responses about the STEAM approach. Responses about the STEAM approach include communicative and interactive, fun and can hone skills.

Researchers feel that linking certain chemicals to the application of the STEAM approach is a challenge for researchers. Acid-base material in general has a dimension of conceptual knowledge, thus providing challenges in the application of the STEAM approach in learning. The application of the STEAM approach with activity makes the dimensions of knowledge on the material of acid and base solutions more varied. Another challenge faced is that learning takes time longer than traditional learning.

3.2. 21st Century Skills Development

The application of learning with the STEAM approach through project-based learning using activities directed at a project has the potential to make students have skills. Skills needed in the future as listed in 21st century skills. 21st century skills are divided into 3 large groups, namely learning and innovating skills, skills to use information, media and technology, and life and career skills. The main assessment of 21st century skills is the way of thinking, the way of working, tools of work and life skills. (Pacific Policy Research Center, 2010).

21st century skills include learning and innovating skills consisting of critical thinking and problem solving, creativity and innovation, communication and collaboration. Information, media and technology skills consisting of information literacy, media literacy, and technological literacy. Life and career skills consist of flexibility and adaptability, self-initiative and direction, social and cross-cultural interaction, productivity and accountability, and leadership and responsibility. The results of the development of students' 21st century skills were obtained by researchers through questionnaires, interviews, and journal reflective. The results of the 21st century skills questionnaire (Figure 5) showed the most significant skills including communication and collaboration skills, social and cross-cultural interaction and flexibility and adaptability.

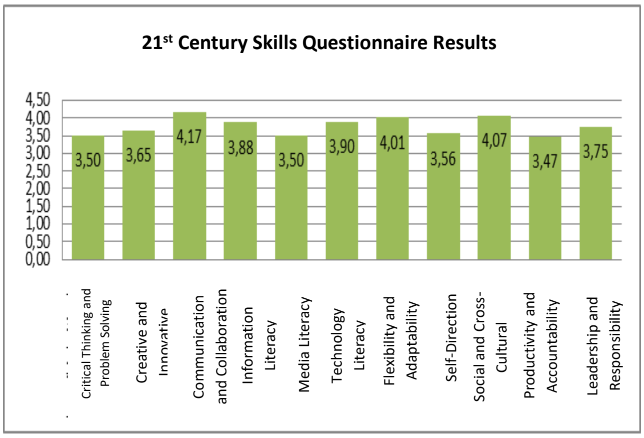

Figure 5. 21st Century Skills Questionnaire Results

Skills that also showed significant development were technological literacy skills, information literacy, leadership and responsibility, creativity and innovation, as well as self-initiative and direction. Other skills that also developed well were critical thinking and problem solving, media literacy, and productivity and accountability.

3.2.1. Learning and Innovating Skills

Learning and innovation skills consist of critical thinking and problem-solving, creative and innovative skills, and communication and collaboration. These three skills support the way of thinking and the way of working to be able to be competitive in the future.

Learning by applying the STEAM approach through a project gives students the opportunity to find knowledge and explore knowledge to produce products. The main activity given was planting mung beans which were given two different treatments. Learners think what happens to the growth of plants that were given different treatment and compare them so as to practice critical thinking and problem-solving skills.

Student 13 can answer the problem of acidic pH that inhibits the growth of mung bean plants because with acidic pH it will stimulate abscisic acid hormone which is a growth-inhibiting hormone.
(Observation, 31 January 2017)

Students observed the problems that occur, compared observations so that they can solve the problems that occur. Therefore, the STEAM project led learners to be involved in the thought process to stimulate the development of students' critical thinking skills and creativity. (Wilson et al., 2021). The given project not only trained critical thinking and problem-solving skills but also led learners to produce work. The creation of works was the result of creativity and innovation together in groups. STEAM encourages learners to develop skills of creativity and innovation including in the way of thinking, how learners produce products, then visualized in a tangible form (Lu et al., 2021; Y. Rahmawati et al., 2019).

Student 24	:	*Why is the bottle cap hollowed out?*
Student 20	:	*So that it is easy when watering the plants, just spray it like a shower, there is no need to open the bottle cap again.*
Student 24	:	*Oh yes, that's right, to make it more practical.*

The above dialogue could be analyzed that learners use creative ideas and convey ideas with clear goals and are accepted as an innovation in project work. Creative ideas can appear in project creation, creativity and innovation here as a way of thinking of learners when given a project with a set time.

The success of learners in developing STEAM projects reflects that communication and collaboration are well established (Nurramadhani et al., 2021). These skills have implications for the way learners work in teams and produce a product together. The following statement of student 13 indicates that work management in the team is going very well.

Working together, as when planting, we share tasks, some make solutions, take soil, and paint. We have our own strengths and weaknesses so that we complement each other.
(Student 13, Interview, 31 January 2017)

Based on the interview above, it showed that there was good communication and collaboration taking place within the group. The involvement of learners in information exchange activities, discussions and providing input, encourages them to practice communication and cooperation skills with peers. (Adriyawati et al., 2020; Ridwan et al., 2020).

3.2.2. Skills in Using Information, Media, and Technology

Skills in using information, media, and technology consist of information literacy, media literacy and technological literacy. These three skills are included in the working tool. Information literacy skills are needed in project creation, how learners use information and process information to produce products.

Student 3 convey the information obtained about green bean plants such as the optimum pH of green bean plant growth, green bean plants can grow on loose and dry soil types. If the soil is dry then the watering time is more than 2 times.
(Observation, 17 January 2017)

The results of the interview above illustrated that students were able to choose and use information well. This reflects that project-based learning encourages learners to look for information related to the activities carried out and apply relevant information in the learning process (Cioc et al., 2022).

Media literacy skills are also needed in project creation, media literacy skills are included in the tools of work, and how students develop media from the information obtained.

Group 3 can develop learning media from the activities that have been carried out, namely making posters with a green gradation background, listed titles, goals, plant characteristics, broad treatment, and conclusions, also accompanied by photos.
(Observation, 2 Februari 2017)

The results of the interview above showed that students could develop posters as a communication medium for the products that have been made. This shows that the integration of art in STEM provides opportunities for students to be creative in developing products and media as a means of sharing information (Tome & De Abreu, 2022).

Another skill that emerged from the implementation of a project-based learning integrated STEAM approach in chemistry learning is technological literacy. Learners used technological literacy in completing projects and helping them acquire knowledge. Technological literacy skills include tools work, how learners use technology and develop technology to produce products.

The use of a soil tester in this activity, makes more understand about how to use it.
(Student 27, Reflective Journal, 24 January 2017)

The reflective journal above described learners gaining updated knowledge through tools used in a given project and gaining the ability to use it correctly. Technology can help visualize outcomes and predict with observational data from the growth of mung bean plants (Kuhn, 2015).

3.2.3. Life Skills and Career

Life and career skills consist skills of flexibility and adaptability, self-initiative and direction, social and cross-cultural interaction, productivity and accountability, and leadership and responsibility. These five skills are included in the way of working and life skills. Flexibility and adaptability skills are very useful for dealing with changes that always occur when completing projects that are being worked on. Both of these skills are important so that learners have an effective and efficient way of working.

I just accept it if I am given a jobdesc, but I also see in advance whether I can do it or not, if I can't do it, I ask for another jobdesc or I ask for direction so that it can be done together.
(Student 30, Interview, 14 February 2017)

The results of the interview above showed that collaborative activities open up opportunities for students to develop flexibility and adaptability at work (Hadinugrahaningsih et al., 2017). In addition, the projects provided encourage students to be more initiative and to improve their knowledge and abilities to be more skilled. Initiative and self-direction are also very important when working within a group.

I accept the jobdesc given but sometimes also I take my own initiative to work on something I can.
(Student 22, Interview, 8 February 2017)

From the above interviews it could be concluded that learners can initiatively organize themselves in groups to carry out tasks. It is based on an inquiry process in project development that leads learners to find answers to essential questions, find the right project, reflect on the process, and evaluate projects based on criticism (Grossman et al., 2019)

Social and cross-cultural interactions are also very important when working in groups to build good communication, learners must be able to interact with different character members of the group. Activities directed to a project gave learners the opportunity to be able to build social interaction, respect the opinions of other group members in completing the project.

Student 27:	*Why at the time we check the pH of the soil is 7 while we have flushed the soil with an alkaline solution?*
Student 28:	*the soil should also be alkaline because the solution being watered has a pH of 9*
Student 25:	*Maybe it is because it is just been watered so it has not absorbed all, plus in the soil there are many elements, there may be a reaction.*
Student 27:	*Oh yes, that's right, it could have happened.*

Based on the dialogue above, it could be concluded that there was interaction between 3 learners in their group. Group work activities facilitate learners to develop their social interaction by giving friends the opportunity to speak, respecting opinions, and receiving opinions from friends. (Chu et al., 2019). Effective interaction opens up opportunities for good collaboration for learners to complete their projects. In this study, the resulting project was in the form of planting mung beans. The following statements of student 15 reflect the occurrence of good project management in their cooperation.

The purpose of this project is to find out the consequences resulting from the growth of plants that are given different treatment. First, we plant a mung bean plant in two different pots, the first pot with water, and the second pot with an acidic solution, then observed for 5 days and noted the growth and development that occurred over 5 days, measured the pH of the soil using a soil tester. (Student 15, Interview, 6 February 2017)

From the results of the above interviews it could be concluded that learners 15 understand the project and manage the project in an organized manner and can name the steps carried out. Good project management is also based on the development of a sense of responsibility and leadership experienced by students.

Incidentally, when asked about the dynamics of the group, I am the group leader, in the group I use one-way coordination so I coordinate the jobdesc according to their ability, then they accept and carry out the assigned tasks, we all learn to be the best. (Student 25, Interview, 6 February 2017)

The statement of learner 25 above reflected that he has a leadership spirit as the head of the group who is tasked with coordinating all members and providing opportunities for them to develop into the best. This showed that the implementation of the STEAM approach integrated with project-based learning encourages students to have a sense of collective responsibility to be able to solve project development challenges well (Tenhovirta et al., 2021). As well as encouraging them to demonstrate their critical ability to be successful, both in school learning and careers (Holmes, 2017).

4. Conclusion

Based on the description of the research results above, it reflected that the implementation of the STEAM approach that is integrated with project-based learning in chemistry learning is effective in developing the 21st century skills of students. Project-based learning trains learners to actively engage their thinking skills in order to solve problems through the development of creative and innovative projects. Work activities in teams encourage them to communicate clearly so that they can collaborate effectively. Learners also reflect the development of their skills in seeking information and using technology to be able to work together flexibly, interact across socio-cultures, increase productivity, and accountability. In addition, STEAM project development activities lead learners to develop themselves into independent learners characterized by the emergence of self-initiative, responsibility, and training their leadership attitudes.

Learning using STEAM approach provides a more meaningful learning experience by directly practicing the application of acid and base solution materials in everyday life. The STEAM approach is able to provide a memorable experience. The varied responses from learners regarding the STEAM approach to learning show that the STEAM approach is fun, not boring, can hone and develop skills as well as interactive and communicative.

References

Adriyawati, Utomo, E., Rahmawati, Y., & Mardiah, A. (2020). Steam-project-based learning integration to improve elementary school students' scientific literacy on alternative energy learning. *Universal Journal of Educational Research*, *8*(5), 1863–1873. https://doi.org/10.13189/ujer.2020.080523

Alismail, H. A., & McGuire, P. (2015). 21 St Century Standards and Curriculum: Current Research and Practice. *Journal of Education and Practice*, *6*(6), 150–155. http://files.eric.ed.gov/fulltext/EJ1083656.pdf

Başaran, M., & Erol, M. (2021). Recognizing aesthetics in nature with STEM and STEAM education. *Research in Science & Technological Education*, 1–17. https://doi.org/10.1080/02635143.2021.1908248

Bhargava, S. (2016). Role of Chemistry in Everyday Life. *Journal of Chemistry and Chemical Sciences*, *6*(2), 192–198. Retreieved from http://chemistry-journal.org/dnload/Sunita-Bhargava/CHEMISTRY-JOURNAL-CHJV06I02P0192.pdf

Chu, H.-E., Martin, S. N., & Park, J. (2019). A Theoretical Framework for Developing an Intercultural STEAM Program for Australian and Korean Students to Enhance Science Teaching and Learning. *International Journal of Science and Mathematics Education*, *17*(7), 1251–1266. https://doi.org/10.1007/s10763-018-9922-y

Cioc, C., Haughton, N., Cioc, S., & Napp, J. (2022). A Model for incorporating information literacy and collaboration in a project-based learning pedagogical exercise with application to a fluid mechanics course. *International Journal of Mechanical Engineering Education*, 030641902210814. https://doi.org/10.1177/03064190221081450

Davis, S., & Long II, R. L. (2017). Using STEAM to Increase Engagement and Literacy Across Disciplines. *The STEAM Journal*, *3*(1). Retreieved from https://web.archive.org/web/20180720184412id_/http://scholarship.claremont.edu/cgi/viewcontent.cgi?article=1148&context=steam

Gardner, M., & Tillotson, J. W. (2019). Interpreting integrated STEM: sustaining pedagogical innovation within a public middle school context. *International Journal of Science and Mathematics Education*, *17*(7), 1283–1300. https://doi.org/10.1007/s10763-018-9927-6

Grossman, P., Dean, C. G. P., Kavanagh, S. S., & Herrmann, Z. (2019). Preparing teachers for project-based teaching. *Phi Delta Kappan*, *100*(7), 43–48. https://doi.org/10.1177/0031721719841338

Guba, E. G., & Lincoln, Y. (1989). *Fourth Generation Evaluation*. SAGE Publications.

Hadinugrahaningsih, T., Rahmawati, Y., & Ridwan, A. (2017). *Developing 21st century skills in chemistry classrooms: Opportunities and challenges of STEAM integration*. 030008. https://doi.org/10.1063/1.4995107

Hawari, A. D. M., & Noor, A. I. M. (2020). Project Based Learning Pedagogical Design in STEAM Art Education. *Asian Journal of University Education*, *16*(3), 102–111. https://doi.org/10.24191/ajue.v16i3.11072

Henriksen, D., Mehta, R., & Mehta, S. (2019). Design Thinking Gives STEAM to Teaching: A Framework That Breaks Disciplinary Boundaries. In M. Khine & S. Areepattamannil (Eds.), *STEAM Education* (pp. 57–78). Springer International Publishing. https://doi.org/10.1007/978-3-030-04003-1_4

Holmes, V. R. (2017). Capital One Dream On/STEAM On Initiative: Preparing Students for STEAM College and Careers through Project-based Learning, 2016-2017. *In Research: Educational Program Report*. HISD (Houst on Independent School District). Retreieved from https://eric.ed.gov/?id=ED603543

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75–83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Khamhaengpol, A., Sriprom, M., & Chuamchaitrakool, P. (2021). Development of STEAM activity on nanotechnology to determine basic science process skills and engineering design process for high school students. *Thinking Skills and Creativity*, *39*, 100796. https://doi.org/10.1016/j.tsc.2021.100796

Khine, M., & Areepattamannil, S. (2019). *STEAM Education* (M. S. Khine & S. Areepattamannil (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-04003-1

Kim, J. (2011). A Cubic Model for STEAM Education. *Korean Journal of Technology Education*, *11*(2), 124–139. Retreieved from https://link.springer.com/article/10.1007/s10763-015-9709-3

Kuhn, M. (2015). Encouraging Teachers to W.A.I.T Before Engaging Students In Next Generation Science Standards STEAM Activities. *STEAM*, *2*(1), 1–6. https://doi.org/10.5642/steam.20150201.15

Lee, J.-C., Wang, C.-L., Yu, L.-C., & Chang, S.-H. (2016). The effects of perceived support for creativity on individual creativity of design-majored students: A multiple-mediation model of savoring. *Journal of Baltic Science Education*, *15*(2), 232–245. https://doi.org/10.33225/jbse/16.15.232

Lu, S.-Y., Lo, C.-C., & Syu, J.-Y. (2021). Project-based learning oriented STEAM: the case of micro–bit paper-cutting lamp. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-021-09714-1

MacMath, S., Sivia, A., & Britton, V. (2017). Teacher perceptions of project based learning in the secondary classroom. *Alberta Journal of Educational Research*, *63*(2), 175–192. https://doi.org/10.11575/ajer.v63i2.56345

Miles, M., & Huberman, A. (1994). *Qualitative Analysis: An Expanded Source Book* (2nd ed.). SAGE.

Nurkholis Majid, A., & Rohaeti, E. (2018). The effect of context-based chemistry learning on student achievement and attitude. *American Journal of Educational Research*, *6*(6), 836–839. https://doi.org/10.12691/education-6-6-37

Nurramadhani, A., Kumala, F., & Permana, I. (2021). STEAM-based project learning: the effect to middle school's student's collaboration competences. *Journal of Physics: Conference Series*, *2098*(1), 012038. https://doi.org/10.1088/1742-6596/2098/1/012038

Pacific Policy Research Center. (2010). *21st Century Skills for Students and Teachers.* Kamehameha Schools, Research, & Evaluation Division.

Park, H., Byun, S., Sim, J., Han, H.-S., & Baek, Y. S. (2016). Teachers' Perceptions and Practices of STEAM Education in South Korea. *EURASIA Journal of Mathematics, Science and Technology Education*, *12*(7). https://doi.org/10.12973/eurasia.2016.1531a

Partnership for 21st Century Skills. (2008). *21st Century Skills, Education & Competitiveness*.

Patterson, A., & Muna, N. (2019). 3-D printing as a STEAM tool for bridging artistic and technical design perspectives. *Steam*, *4*(1), 1–2. https://doi.org/10.5642/steam.20190401.10

Rahmawati, Y., Ridwan, A., Hadinugrahaningsih, T., & Soeprijanto. (2019). Developing critical and creative thinking skills through STEAM integration in chemistry learning. *Journal of Physics: Conference Series*, *1156*(1). https://doi.org/10.1088/1742-6596/1156/1/012033

Rahmawati, Y., Ridwan, A., Mardiah, A., & Afrizal. (2020). Students' chemical literacy development through STEAM integrated with dilemmas stories on acid and base topics. *Journal of Physics: Conference Series*, *1521*(4). https://doi.org/10.1088/1742-6596/1521/4/042076

Rahmawati, Yuli, Hadinugrahaningsih, T., Ridwan, A., Palimbunga, U. S., & Mardiah, A. (2021). Developing the critical thinking skills of vocational school students in electrochemistry through STEM - Project-based learning (STEM-PjBL). *AIP Conference Proceedings*, *2331*. https://doi.org/10.1063/5.0041915

Rahmawati, Yuli, Taylor, E., Taylor, P. C., Ridwan, A., & Mardiah, A. (2022). Students' Engagement in Education as Sustainability: Implementing an Ethical Dilemma-STEAM Teaching Model in Chemistry Learning. *Sustainability*, *14*(6), 3554. https://doi.org/10.3390/su14063554

Ridwan, A., Rahmawati, Y., Mardiah, A., & Rifai, A. (2020). Developing 22nd century skills through the integration of STEAM into smoke absorber project. *Journal of Physics: Conference Series*, *1521*(4). https://doi.org/10.1088/1742-6596/1521/4/042077

Roy, S. (2016). Chemistry in Our Daily Life : Preliminary Information . International Journal of Chemistry in our daily life : Preliminary information. *International Journal of Home*, *2*(3), 361–366. Retreieved from https://www.homesciencejournal.com/archives/2016/vol2issue3/PartF/2-3-26.pdf

Saglam, Y., Karaaslan, E. H., & Ayas, A. (2011). The impact of contextual factors on the use of students' conceptions. *International Journal of Science and Mathematics Education*, *9*(6), 1391–1413. https://doi.org/10.1007/s10763-010-9269-5

Shen, S., Wang, S., Qi, Y., Wang, Y., & Yan, X. (2021). Teacher Suggestion Feedback Facilitates Creativity of Students in STEAM Education. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.723171

Sirhan, G. (2007). *Learning Difficulties in Chemistry: An Overview*. *4*(2), 2–20. http://www.tused.org

Tenhovirta, S., Korhonen, T., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2021). Cross-age peer tutoring in a technology-enhanced STEAM project at a lower secondary school. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-021-09674-6

Tome, V., & De Abreu, B. S. (2022). Crossing Steam and Media Literacy at Preschool and Primary School Levels: Teacher Training, Workshop: Planning, its Implementation, Monitoring and Assessment. *Media Literacy and Academic Research*, *5*(1), 161–177. Retreieved from https://www.ceeol.com/search/article-detail?id=103767

Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. John Wiley & Sons.

Vreeburg Izzo, M., Yurick, A., Nagaraja, H. N., & Novak, J. A. (2010). Effects of a 21st-century curriculum on students' information technology and transition skills. *Career Development for Exceptional Individuals*, *33*(2), 95-105. Retrieved from https://journals.sagepub.com/doi/abs/10.1177/0885728810369348

Wilson, H. E., Song, H., Johnson, J., Presley, L., & Olson, K. (2021). Effects of transdisciplinary STEAM lessons on student critical and creative thinking. *The Journal of Educational Research*, *114*(5), 445–457. https://doi.org/10.1080/00220671.2021.1975090

Yakman, G., & Lee, H. (2012). Exploring the Exemplary STEAM Education in the U.S. as a Practical Educational Framework for Korea. *Journal of The Korean Association For Science Education*, *32*(6), 1072–1086. https://doi.org/10.14697/jkase.2012.32.6.1072