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STEAM-Project Based Learning (PjBL): Efforts to Train Critical Thinking Skills for Prospective Science Teacher

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Abstract: The implementation of STEAM-PjBL integration trains students to work together to build their own knowledge, construct ideas, critical thinking in analyzing problems, then try to solve them through a project. The purpose of this study was to determine the effectiveness of STEAM-PjBL integration to train the critical thinking skills of prospective science teachers through entrepreneurship courses. This research is a descriptive study with a one short case study design. The research subjects were students of Science Education Class of 2021. The instruments used were tests of critical thinking skills and questionnaires on student responses to learning. Test result were analyzed using N-gain and paired t test, the response questionnaire was analyzed descriptively. The results showed an increase in students' critical thinking skills test scores, and positive responses with an average of >83.6%. Based on this, it can be concluded that STEAM-PjBL integration is effective in improving students' critical thinking skills.

Keywords: Critical thinking; Science teacher candidates; STEAM-PjBL

Introduction

Human resources need to have the skills to face the 21st century competition and compete with other countries. One of the efforts to prepare superior human resources is through education. The 21st century skills have been identified by *the National Education Association* as 4C skills which include *Critical Thinking*, *Creativity*, *Communication* and *Collaboration* (National Education Association, 2014). These skills are important so that students have readiness, ability to work, marketability, and competitiveness.

Learning in higher education, lecturers build a learning culture that can improve higher-level thinking skills and student character so that new habits are formed in the learning process. According to Firdaus et al. (2015) critical thinking skills must be applied and developed in the curriculum and learning process to produce students who have higher order thinking skills. This is done with practice and habituation to develop critical thinking skills.

Critical thinking skills are basically the ability to consider relevant or irrelevant information with the aim of being able to make decisions about what to do. This is in accordance with the opinion of Ennis (1996) that critical thinking emphasizes rational and reflective thinking so as to achieve a decision-making process. Therefore, critical thinking skills are an important aspect that students need to have because they are very useful for solving problems and as a provision for facing life now and in the future. Students with sufficient critical thinking skills have the potential to be able to study problems systematically, face challenges in an organized manner, formulate innovative questions, and design solutions that are seen as relatively new (Johnson, 2007). Critical thinking skills are needed in everyday life (Tax et al., 2011), because they can encourage appropriate and directed decision-making, provide logical reasons, are able to make correct conclusions, so as to achieve the desired results (Bassham et al., 2011). A critical thinker always questions sources of knowledge information, tests the validity of information, analyzes the reliability of information, in order to be able to provide appropriate

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explanations for certain situations (Brink et al., 2007; Halpern, 2014; Hong et al., 2015). Learning science can train students' critical thinking skills (Hartawati et al., 2020).

Lecturers need to examine the learning model used to shape student character and foster a learning culture that develops students' critical thinking skills. Learning that is expected to improve students' critical thinking skills is the Project-Based Learning (PjBL) learning model. Project Based Learning (PjBL) is an innovative learning model or approach that emphasizes learning through complex activities (Brink et al., 2007). The PjBL model provides opportunities for students to explore content using various ways that are meaningful to them and to conduct experiments collaboratively. Through PjBL students collaborate with their groups to work on projects that have been designed (Effendi, 2017; Iskandar et al., 2019). This is in line with research which states that PjBL has the potential to improve students' critical thinking skills (Matahari et al., 2023; Sumardiana et al., 2019; Zahroh, 2020).

The PjBL Model innovation is carried out through integration with the STEAM learning approach. The STEAM approach is a 21st century learning approach (Bayles et al., 2021; Guevara et al., 2021), which trains students how to use art and science together by involving critical, creative, and innovative thinking skills in the process understand real problems (Wilson et al., 2019). The STEAM approach is learning that is integrated with various fields of science, namely *Science, Technology, Engineering, Arts* and *Mathematics* which aims to increase student involvement, creativity, innovation, problem solving skills, and other cognitive benefits (Liao, 2016).

The STEAM learning concept emerged as a model for how to remove boundaries between academic subjects, so that science, technology, engineering, art and mathematics can be structured into an integrated curriculum (Zubaidah, 2019). PjBL learning with integrated STEAM can develop students' abilities in building *a habit of mind* from the design process to designing projects with integrated fields of Science, Technology, Engineering, Arts and Mathematics. Daniel's research (2017) shows that the PjBL model with a scientific approach makes a positive contribution to critical thinking skills in class VIII students of junior high school. The steps of the PjBL-STEAM learning model in this study have been modified according to The George Lucas Educational Foundation (2005) namely by introducing real problems that integrate STEAM through basic questions, planning STEAM projects that involve collaboration between lecturers and students, preparation activity schedules and agreeing on project completion schedules, monitor the progress of the project, ending with evaluation of the results and reflection of the project.

The advantages of PjBL are that it gives freedom to students to plan learning activities, carry out projects collaboratively, and ultimately produce work products that can be presented to others (Wang et al., 2015). Learning that applies the PjBL model with STEAM approach is one of the effort implemented to improve learning outcome (Subiki et al., 2023). The application of the STEAM learning approach using the PjBL learning model is proven to be able to improve students' science process skills (Sakdiah et al., 2022). The PjBL-STEAM model allows students to own and develop students' critical thinking skills through challenging questions or problems that require them to plan a project by integrating various possible subjects (STEAM), looking for information on tools and materials that can be used so that they are expected to feel they own the project. In this way, PjBL-STEAM enables students to increase their emotional intelligence by actively participating in the learning process and allows them to produce something by cooperating with others, controlling the emotions of themselves and others, motivating themselves and others in planning to completion something project. The important difference between PjBL-STEAM and direct learning lies in the stages of presenting a problem and solving a problem. In conventional learning, the presentation of the problem is placed at the end of learning as an exercise and its completion is also the application of the concepts learned. In PjBL-STEAM student's work together to build their own knowledge, construct ideas, think critically in analyzing problems with the STEAM field and then try to solve them which are built into a project. Therefore, the STEAM-integrated PjBL model is considered capable of making a positive contribution.

The purpose of this study was to determine the effectiveness of the STEAM-PjBL model for training critical thinking skills in science teacher candidates in terms of the results of critical thinking tests.

Method

This research used a one-group pretest-posttest design. In this design, researchers measure the increase in students' critical thinking by giving a pretest to the treatment group. Then implement the STEAM-PjBL model in the context of innovative businesses from the surrounding environment and finally by giving a posttest.

Implementation of PjBL in this research follows the PjBL stages from The George Lucas Educational Foundation (2005) which consists of six steps, namely determining basic questions, designing a project plan, preparing a schedule, monitoring project activities, testing results, and evaluating experience. The projects carried out are directed to be based on STEAM, project progress reports are carried out online via Google Meet, because it is more practical and easily accessible (Firdaus et al., 2015; National Education Association, 2014).

The research subjects were 55 science teacher candidates from the Science Education Departement, consisting of 51 female students and 4 male students. The sampling technique used was purposive sampling. Instrument used in this research are lessons plans, student worksheets, critical thinking skills questions, and response questionnaires. The instruments have been validated.

The pretest-posttest results data were analyzed using the N-gain value. The N-gain value functions to determine the increase in student critical thinking skills after implementing STEAM-PjBL. The N-gain values obtained were then interpreted according to the categories in Table 1. In addition, the pretest-posttest data were also tested for normality and homogeneity as well as statistical tests using SPSS software.

Table 1. N-Gain Criteria

N-Gain	Criteria
$g \geq 0.7$	High
$0.7 > g \geq 0.3$	Medium
$g < 0.3$	Low

Results and Discussion

Validation Results

The tools used in this study were validated by two experts in science learning. The results of the learning device validation are presented in Table 2.

Table 2. Results of Device and Research Instrument Validation

Type	Criteria
Lesson Plans	Very Valid
Student Worksheet	Very Valid
Critical thinking skills test	Very Valid
Response questionnaire	Valid

Table 2 shows the validity of the tools used in the study in the very valid category for lesson plans, Student Worksheet, and critical thinking skills questions, valid categories for response questionnaires. This means that learning tools and research instruments are feasible to use.

Normality, Homogeneity, Paired Sample T-Test Results

The significance of increasing critical thinking skills is carried out by a normality test first. Based on Table 3, the results of the normality test using a significance level of 5% obtained sig = 0.61 > 0.05. This shows that the data is normally distributed. After that, a homogeneity test was carried out with a significance level of 5% and obtained sig 0.17 > 0.05. These results indicate that the data is homogeneous. Then a paired t test was carried out with a significance level of 5%=0.000<0.05. The results of the t test indicate that there are differences in students' critical thinking skills before and after the implementation of STEAM-PjBL learning.

Tabel 3. Normality, Homogenity, and Paired Sample T-Test Results

Normality	Homogeneity	Paired Sample T test
Sig 0.61>0.05	Sig 0.17>0.05	Sig 0.000<0.05

Improving Students' Critical Thinking Skills through the Implementation of STEAM-PjBL

The effectiveness of the STEAM-PjBL learning model to improve critical thinking skills can be seen through the results of tests carried out before and after learning, which are shown by the results of Ngain's calculations. The results of calculating the average critical thinking skill test are presented in Table 4.

Table 4. Average Pretest, Posttest Scores, and N-gain of Critical Thinking Skills with STEAM-PjBL

Average pretest	Average postest	N-gain	Criteria
65.20	79.6	0.40	Medium

Based on Table 4, the average pretest score is 65.2 and the average posttest score is 79.6. The pretest and posttest results of all students were then analyzed using the N-gain test to determine the increase in students' critical thinking skills after implementing STEAM-PjBL. Based on the calculation results, the overall N-gain value is 0.40. These results indicate that the overall increase in students' critical thinking skills is at medium criteria. This is in accordance with research results which state that the integration of STEAM PjBL together can create innovation to generate creative and critical ideas and solutions, making it easier to solve a problem (Suliyanthini et al., 2023).

This study found that the STEAM-PjBL learning model improves students' critical thinking skills. The results of this research show that the STEAM-PjBL learning model can improve students' critical thinking skills. This is in line with research which shows that critical thinking skills can be improved through providing experience (Khairati et al., 2021), by implementing PjBL and connecting it with contextual problems (Rushiana et al., 2023; Wahyudiati et al., 2022). In this research, students identify business opportunities that come from their surroundings. From the business ideas obtained, students develop a business plan and the products to be produced. The resulting product must comply with STEAM rules, the process of which is carried out through a project with the group. One of the student projects used as an example is the making of BORING (Bonggolan KERING), which is a typical Gresik dish made from milkfish. This project was chosen by students as an effort to take advantage of the abundance of milkfish during the main harvest. Milkfish is processed and served in a dry version like crackers so that it can be enjoyed for a longer time. The target market is college students, school students, and the general public so boring is produced in various flavors.

The stages of the student activity project in making BORING, which is learning by integrating STEAM-PjBL in entrepreneurship courses are presented in Figure 1.

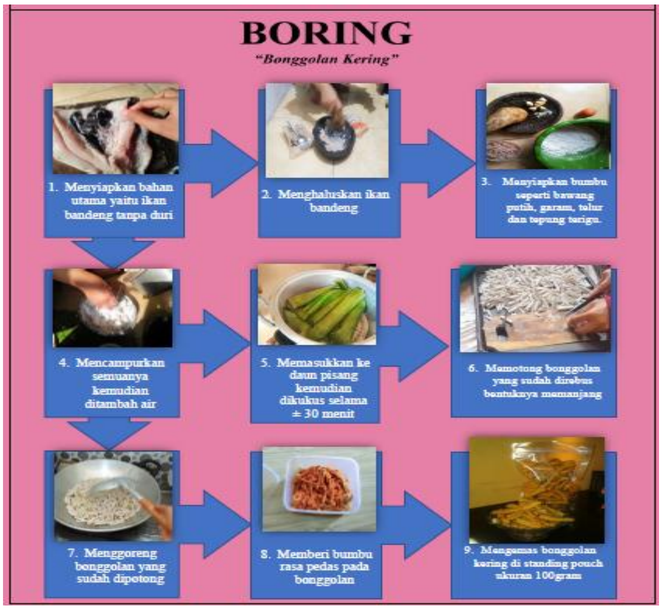

Figure 1. BORING manufacturing project

Figure 1 shows one of the student business ideas to utilize the abundance of raw materials in the form of milkfish into processed food. Students have foresight in reading the potential of the surrounding environment to increase income. The abundant harvest of milkfish causes the price of milkfish to be cheap, so it is necessary to think about efforts to increase the selling value of milkfish, namely by processing it into a nutritious snack, namely dried lumps which are named 'BORING' or dried lumps. Processing of humps into snacks causes a longer shelf life. Processed fish products contain protein that is useful for the body, so it is very good for all ages to consume. Processing of fresh fish is added with spices and tapioca flour, then through the steaming process to produce a chewy texture with the smell of fish. Milkfish was chosen as a raw material for processed lumps because of its abundant amount and rich source of protein (20-24%), amino acids, fatty acids, minerals and vitamins. The highest amino acid composition was glutamate at 1.386% (fresh water) and 1.268% (brackish water). The highest unsaturated fatty acid is 31-32% oleic, the macro minerals in milkfish meat are: Ca, Mg, Na and K. The micro minerals consist of Fe, Zn, Cu, and Mn. The vitamin content of milkfish meat includes vitamins A, B1 and B12 (Hafiludin, 2015). Innovation of hump food ingredients into chips can support improving the economy and people's welfare (Muthmainah, 2021). Dry cobs are more promising for business opportunities because they are more durable.

Response Questionnaire Results

The results of student responses to learning using STEAM-PjBL in entrepreneurship courses are presented in Table 5. Responses include student responses to the learning process, project assignments, lecturer responses to students and project results, suitability of the material being studied with the STEAM-PjBL model. Based on Table 5, the statement regarding lecturers providing full support to learning with STEAM-PjBL shows the highest percentage (100%), which means that lecturers position themselves as facilitators in learning, whose job is to guide and activate students to learn. Lecturers manage learning effectively so that they can achieve learning goals, se (Dewi et al., 2021)**.** This is consistent with research using the STEAM approach which can increase student motivation (Nkulikiyinka et al., 2020), whereas with the PjBL model student activity in learning has increased (Elisabet et al., 2019; Pratiwi et al., 2018). The combination of STEAM-PjBL makes learning more systematic and innovative (Dewi et al., 2021).

Table 5. Student Responses to Learning with STEAM-PjBL

Statement	Percentage (%)
Enjoy learning with the STEAM-PjBL model	98.40
Challenged with the steps of the STEAM-PjBL model	95.10
Feel left out if you don't follow the lesson	86.90
Feeling worried if the lecturer is not present	83.60
Enthusiastic in working on projects	86.90
Actively involved in the group	98.40
Can't wait for the lecturer's feedback	95.10
Lecturers provide full support for learning with STEAM-PjBL	100
Be confident when studying with STEAM-PjBL	90.20
Understanding learning material	98.40
Don't be pressured when asking the lecturer	83.60
Enjoy working on projects	98.40
With STEAM-PjBL the motivation to study reaches home	91.80
Challenged to dig up more detailed information	98.40
Complete assignments on time	95.10

The lowest percentage of student response questionnaires was 83.6%, namely students really need the presence of lecturers in learning, to provide guidance during project-based learning. The results of the student response questionnaire to learning as a whole are visualized in the form of a diagram in Figure 2.

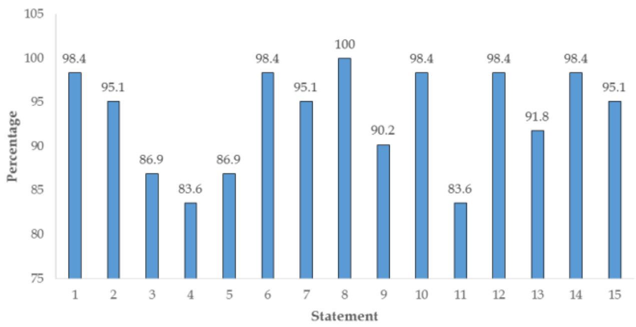

Figure 2. Questionnaire results of student responses to learning with STEAM-PjBL

Conclusion

Based on the results of research conducted, it shows that learning using the PjBL-STEAM model is effective for training the critical thinking skills of science teacher's candidates. This is shown by an increase in students' critical thinking skills test results with a significance level of 0.000<0.05. Average N-gain in the medium category. Science teacher candidates gave positive responses to learning by applying STEAM-PjBL to explore business ideas from the environment.

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Author Contribution

All authors contribute to the process of completing research and writing articles. The concept of research, preparation of instruments, validation, data collection, analysis and interpretation of data and drafting of articles. Conceptualization: Dyah Astriani; Arrangement of instruments: An Nuril Maulida Fauziah; Instrument validation: Martini; data collection: Dyah Astriani and Laily Rosdiana; data analysis and interpretation: Dyah Astriani and Aris Rudi Purnomo; writing–original draft: Dyah Astriani, writing–review& editing: Dyah Astriani, Aris Rudi Purnomo. All authors reviewed the results and approved the final version of the article manuscript.

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Conflicts of Interests

The authors declare no conflict of interest.

References

Bassham, G., Irwin, W., Nardone, H., & Wallace, J. M. (2011). *Critical thinking: a student's introduction*. McGraw-Hill.

Bayles, J., Peterson, A. D., Pitts, S. J., Bian, H., Burkholder, S., Hegde, A. V, & Stage, V. C. (2021). Food-Based Science, Technology, Engineering, Arts, and Mathematics (STEAM) Learning Activities May Reduce Decline in Preschoolers' Skin Carotenoid Status. *Journal of Nutrition Education and Behavior*, *53*(4). https://doi.org/10.1016/j.jneb.2020.10.017

Brink, R. V. D., & Budgen. (2007). *Critical Thinking for Students: Learn the Skills of Critical Assessment and Effective Arguments*. How to Books Ltd.

Daniel, F. (2017). kemampuan berpikir kritis siswa pada implementasi Project Based Learning (PJBL) berpendekatan saintifik. *JPMI (Jurnal Pendidikan Matematika Indonesia)*, *1*(1), 7–13. https://doi.org/10.26737/jpmi.v1i1.76

Dewi, N. P. L. K., Astawan, I. G., & Suarjana, I. M. (2021). STEAM-PJBL Approach Learning Tool on Theme 2 Always Save Energy. *Journal of Pedagogy and Learning*, *4*(2), 222–232. https://doi.org/10.23887/jp2.v4i2.36725

Effendi, M. (2017). Pembelajaran berbasis proyek (PjBL) untuk mengembangkan kemampuan berpikir kritis mahasiswa PGMI IAIN Ponorogo. *Cendekia*, *15*(2), 305–318. https://doi.org/10.21154/cendekia.v15i2.1098

Elisabet, E., Relmasira, S. C., & Hardini, A. T. A. (2019). Increasing Motivation and Learning Outcomes in Science by Using the Project Based Learning (PjBL) Learning Model. *Journal of Education Action Research*, *3*(3), 285. https://doi.org/10.23887/jear.v3i3.19451

Ennis, R. H. (1996). Critical Thinking Dispositions: Their Nature and Assessability. *Informal Logic*, *18*(2), 165–182. https://doi.org/10.22329/il.v18i2.2378

Firdaus, F., Kailani, I., Bakar, M. N. B., & Bakry, B. (2015). Developing Critical Thinking Skills of Students in Mathematics Learning. *Journal of Education and Learning (EduLearn*, *9*(3), 226–236. https://doi.org/10.11591/edulearn.v9i3.1830

Guevara, J. L., Patel, R., & Trivedi, J. (2021). Optimization of steam injection in SAGD using reinforcement learning. *Journal of Petroleum Science and Engineering*, 4. https://doi.org/10.1016/j.petrol.2021.108735

Hafiludin. (2015). Analysis of Nutritional Content in Milkfish from Different Habitats. *Marine Journal*, *8*(1), 37–43. https://doi.org/10.21107/jk.v8i1.811

Halpern, D. F. (2014). *Thought and Knowledge: An Introduction to Critical Thinking*. Taylor&France.

Hartawati, Y., Harjono, A., & Verawati, N. N. S. P. (2020). Momentum and Impulse Critical Thinking Skills Viewed From Learners' Learning Styles with the 5E Learning Cycle Model. *ORBIT: Journal of Research Results, Innovations, and Applications of Physics Education*, *6*(1), 181–187. https://doi.org/10.31764/orbita.v6i1.1515

Hong, Y., & Choi, I. (2015). Assessing reflective thinking in solving design problems: The development of a questionnaire. *British Journal of Educational Technology*, *46*(4), 848–863. https://doi.org/10.1111/bjet.12181

Iskandar, I., & Mulyati, S. (2019). The use of project based learning method in developing students' critical thinking. *Indonesian Journal of Learning and Instruction*, *2*(01), 71–78. https://doi.org/10.25134/ijli.v2i01.1686

Johnson, E. B. (2007). *Contextual teaching & learning: making teaching and learning activities fun and meaningful*. MIC.

Khairati, K., Artika, W., Sarong, M. A., Abdullah, A., & Hasanuddin, H. (2021). Implementation of STEM-Based Experiential Learning to Improve Critical Thinking Skills on Ecosystem Materials. *Jurnal Penelitian Pendidikan IPA*, *7*(4), 752–757. https://doi.org/10.29303/jppipa.v7i4.850

Liao, C. (2016). From Interdisciplinary to Transdisciplinary: An Arts-Integrated Approach to STEAM Education. *Art Education*, *69*(6), 44–49. https://doi.org/10.1080/00043125.2016.1224873

Matahari, D. B., Nurohman, S., & Jumadi, J. (2023). Research trends in project-based learning models in facilitating 21st century skills: systematic literature review. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 1607–1614. https://doi.org/10.29303/jppipa.v9i4.2544

Muthmainah, N. (2021). *Restoring Healthy Consumption Behavior for Local Communities in Ujungpangkah Gresik Village*. Sunan Ampel State Islamic University Surabaya.

National Education Association. (2014). *Preparing 21st Century Students for a Global Society: An Educator's Guide to the "Four Cs*. Washington, DC.

Nkulikiyinka, P., Yan, Y., Güleç, F., Manovic, V., & Clough, P. T. (2020). Prediction of sorption enhanced steam methane reforming products from machine learning based soft-sensor models. *Energy and AI*, 2. https://doi.org/10.1016/j.egyai.2020.100037

Pratiwi, I. A., Ardianti, S. D., & Kanzunnudin, M. (2018). Increasing Collaboration Capability Through the Project Based Learning (Pjbl) Model Assisted by the Edutainment Method in Social Science Subjects. *Educational Reflections: Educational Scientific Journal*, *8*(2). https://doi.org/10.24176/re.v8i2.2357

Rushiana, R. A., Sumarna, O., & Anwar, S. (2023). Efforts to Develop Students' Critical Thinking Skills in Chemistry Learning: Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1425–1435. https://doi.org/10.29303/jppipa.v9i3.2632

Sakdiah, H., Ginting, F. W., Rejeki, N. S., & Miranda, A. (2022). STEAM Learning Against Science Process Skills Viewed from the Scientific Attitude of Students in the Vocational Physics Study Course. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2531–2536. https://doi.org/10.29303/jppipa.v8i5.2313

Subiki, S., Elika, E. T. P., & Anggraeni, F. K. A. (2023). The Effect of the Project-Based Learning Model with the STEAM Approach on Learning Outcomes of High School Students the Subject of Material Elasticity. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 745–751. https://doi.org/10.29303/jppipa.v9i2.2926

Suliyanthini, D., & Yulianur, F. (2023). The Effect of Project-Based STEAM Acquire on Student Creativity in Science Learning During the Pandemic Period. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 2423–2430. https://doi.org/10.29303/jppipa.v9i5.3746

Sumardiana, H., A., & Parno. (2019). Kemampuan berpikir kritis pada model project based learning disertai STEM siswa SMA pada suhu dan kalor. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *4*(7), 874–879. https://doi.org/10.17977/jptpp.v4i7.12618

Tax, O. A. E., & SB, O. (2011). *Contemporary issues in curriculum* (5th ed.). Pearsons. Retrieved from http://books.google.com/books?id=pM1XAAAAYAAJ

Wahyudiati, D., & Qurniati, D. (2022). The Effect of Project-Based Learning on Pre-Service Chemistry Teachers' Self-Efficacy and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2307–2311. https://doi.org/10.29303/jppipa.v8i5.1834

Wang, B. T., Teng., C. W., & Lin, Y. H. (2015). Let's Go Traveling–Project-Based Learning in a Taiwanese Classroom. *International Journal of Information and Education Technology*, *5*(2). https://doi.org/10.7763/IJIET.2015.V5.481

Wilson, B., & Hawkins, B. (2019). Art and Science in a Transdisciplinary Curriculum. *MAGAZINE: STEAM EDITION*, *27*. Retrieved from http://www.circesfu.ca

Zahroh, F. (2020). Pengaruh model pembelajaran project based learning terhadap kemampuan berpikir kritis siswa pada materi elektrokimia. *Jurnal Phenomenon*, *10*(2), 191–203. https://doi.org/10.21580/phen.2020.10.2.4283.

Zubaidah, S. (2019). STEAM (Science, Technology, Engineering, Arts, and Mathematics): Pembelajaran untuk Memberdayakan Keterampilan Abad ke-21. *Seminar Nasional Matematika Dan Sains Dengan Tema "STEAM Terintegrasi Kearifan Lokal Dalam Menghadapi Era Revolusi Industri 4.0."* Retrieved from https://rb.gy/bz7cd