Water Quality Modeling: A Project Based Learning in STEM

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Abstract. Project based learning in STEM education provides meaningful learning, sharpening skills, and competitiveness in a knowledge-based society. The issue of water quality is an exciting issue to be reviewed in life science-based projects in STEM education. This research aims to find modeling designs in water quality that provide guidance on solving problems in project-based learning. Qualitative content analysis methods were carried out in this research. This method is designed to condense data into valid interpretations. Data from water quality modeling is a project-based learning design carried out by prospective chemistry teachers explained in an interpretation. A total of 20 prospective chemistry teachers were involved in this research. The data collection technique in this research is an analysis of water quality modeling documents. The research instrument is a water quality modeling answer sheet, which is filled in by prospective chemistry teachers, who then create a project-based learning design. The results of the study indicate that constructing model, using model, evaluation model, and revision model are the modeling steps used. There are four variables that are understood and are the main focus in water quality: pH, conductivity, water turbidity and temperature. This model is then elaborated again to obtain water quality that is suitable for use. The problem context is focused on the water in the Jakabaring lake environment, which is not yet to be optimal in meeting all indicators. Prospective chemistry teachers make efforts to solve water quality problems by providing water purification designed to purify water.

Keywords: Modeling, Project Based Learning, STEM Education, Water Quality

1 Introduction

Water quality is a contextual and interesting topic to study in a science learning environment. Water is a source of life for people in everyday life, so studying it becomes substantial and important. The context of water provides an opportunity to learn the importance of analytical methods and how they affect [1]. Water quality monitoring is essential for understanding how water safety works and preventing water-related diseases [2]. Water quality can be identified by understanding the characteristics of water that suitable for health. [3], [4]. Learning procedures that apply scientific phenomena will lead to quality education, especially in water quality content [5]. Water quality material can involve various stakeholders in improving the

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overall quality of learning [6]. Environmental education and water quality monitoring can be useful in the development of educational institutions towards water quality conservation and monitoring [7], [8]. Water quality can be studied more optimally if learning is implemented based on science, technology, engineering, and mathematics. In the learning, projects that must be completed by students can be included. This helps the recommended water quality testing, training, and communication strategies to be implemented effectively to support water quality practices.

Project-based learning (PBL) has been recognized as a key strategy in the implementation of STEM education. In STEM education, projects that are systematically designed and implemented with a focus on problem solving can be an alternative solution for the future. PBL can improve skills, achievement, and competitiveness in a knowledge-based society [9], [10]. This student-centered model provides an extension of problem solving to project completion, impacting motivation, critical thinking, and science skills in the classroom [11]. In the integration of STEM modules with PBL, students' interest, engagement, and personal efforts in STEM education can be enhanced [12]. Project-based learning in STEM education fosters 21st-century learning skills such as critical thinking, creativity, collaboration, information literacy, and leadership, which are essential for addressing complex problems such as water quality. [13] In water quality, the use of project-based learning can improve critical thinking skills, real problem solving, collaborative learning in accordance with STEM education through activities such as water quality related projects [14], [15]. STEM and PBL synergize in finding new discovery gaps and can be applied to solving water quality material problems in the environment.

The challenges that must be faced in STEM education, especially in project-based learning, are about models and modeling. This is important because it provides a scheme and description in solving problems that must be solved by students. Models and modeling processes, students can bridge the gap between STEM disciplines and develop important skills to solve complex problems [16]. In practice, models and modeling are not often optimized in learning. This part is often missed because of various underlying factors, such as time, understanding of scientific concepts, technological limitations, and so on. This problem makes STEM teaching less complete. Understanding the nature and pedagogy of STEM education is key to overcoming challenges in STEM learning practices. Scientific modeling can be based on science, technology, engineering, and mathematics problem situations that are better prepared to overcome higher-level intrinsic challenges in integrated STEM learning activities [17]. One way to apply STEM modeling is to develop and apply mathematical models, which emphasize the importance of digital tools and programming in problem modeling [18]. The importance of models and modeling is an interesting thing to study, especially in water quality material which involves project-based learning.

Previous research on models and modeling in STEM has been widely reviewed. Models in STEM play a role in influencing individual perceptions and aspirations in STEM fields [19], [20], [21], [22]. Scientific modeling involves the creation and manipulation of representations that simulate real-world phenomena, aiding in prediction and scientific explanation [23]. The scientific models included are tools for predicting and explaining. In this case, students can develop a deeper understanding of scientific concepts as their understanding develops [24]. The use of this model and modeling can be used in water quality which is an issue in this study. Based on the previous description, it is concluded that finding models and modeling can find and solve problems related to water quality. STEM education with project-based learning that uses models and modeling is appropriate because it solves problems in a more structured, systematic, and dynamic way. Models and modeling can also represent the problems experienced and try to find solutions, thus providing opportunities for scientific, high-level, critical thinking based on simulations or the reality that occurs. The purpose of this study is to find a water quality modeling design that provides guidance for solving problems in project-based learning.

2 Method

This research was conducted on 20 prospective chemistry teachers in April-May 2024. The research used qualitative content analysis, an analysis technique that requires systematic categorization and coding of textual data to identify patterns, themes, and relationships in the data [25], [26]. This method allows researchers to explore the content of texts, understand the underlying meaning, and draw conclusions based on the data analyzed. The process of qualitative content analysis usually includes steps such as data preparation, coding, categorization, and theme development. Qualitative content analysis can gain a deeper understanding of the phenomenon being studied and produce rich insights from the textual data analyzed [25], [27]. The data collection technique in this study is the analysis of project-based learning documents and water quality modeling. This modeling document is in the form of data from https://sagemodeler.concord.org/ and field studies conducted to review water quality. The research instrument is in the form of a water quality modeling answer sheet filled out by prospective chemistry teachers, who then create a project-based learning design. Data analysis is carried out by identifying answers and patterns in the data.

3 Result and Discussion

STEM education using project-based learning can be a solution in solving problems in the water quality unit. Water quality is a theme that is relevant to everyday life. Even in several studies have emphasized that project-based learning with STEM can improve critical thinking skills and scientific work skills [15], [28]. Involving students in hands-on projects related to water treatment activities can effectively encourage the development of skills in science, technology, engineering, and mathematics [29]. In the application of water quality, it is divided into groups that compile project-based learning with the STEM education system. This group provides a design in the form of a project as in table 1 below:

Table 1. Water quality project design

PjBL Water Quality 1	PjBL Water Quality 2
Basic Questions: How healthy is the water around you?	Problem Recognition: Is the water around us safe for consumption?

How do you know if the water quality is healthy?	Are there any factors that affect water quality?
Create a Project Design: The Project Design is made by solving water quality problems that are in accordance with STEM education using scientific modeling, scientific explanation	Designing Project Planning: The project is made with STEM-PjBL. Identify water quality by comparing the quality of drinking water and the quality of water around
Create a Schedule: The project is implemented in 2 weeks	Compiling a Project Schedule: The project is implemented in 2 weeks
Monitor Project Progress: Weekly progress, monitoring progress every week	Implementation and Monitoring of the Project Conducted by lecturers, weekly progress that has been completed
Result Assessment: Assess progress, findings, and presentations	Testing the Results (Presentation): Presentation of the water quality unit influencing factors
Experience Evaluation: Evaluate the results of the water quality testing project	Evaluation and Reflection: Evaluation is carried out with project improvements and follow-up plans for water quality

From the table above, the integration of project-based learning in STEM education, especially in the water quality unit. We can see that, in the project-based learning step there is no significant difference between groups 1 and 2 in the water quality project plan. In this project, prospective chemistry teachers are faced with the quality of water around them at the stage of determining the problem or basic questions. This step is expected to be the right way for prospective chemistry teachers to solve problems that have been encountered based on projects. The application of project-based learning in STEM education has been shown to increase student creativity, problem-solving skills, and mastery of concepts [30], [31], [32]. Research shows that project-based learning is a dominant and effective strategy in implementing STEM education, because it not only improves students' skills but also prepares them to compete in a knowledge-based society [9]. Project-based learning in STEM has been shown to have a positive impact on students' attitudes and aspirations towards education [33].

STEM and project-based learning are something that can be integrated and become a relevant choice in contextual learning. Extended projects relate to real problems or questions in society, and project-based learning gives students the opportunity to investigate questions that are considered meaningful in the real world [34]. Through STEM project-based learning activities, educators can create meaningful learning experiences that influence students' future career choices and encourage active exploration of STEM topics [35]. In STEM, ongoing inquiry to explore complex and interesting phenomena in depth can be done together. Collaborative projects that address real-world problems such as water quality issues deepen understanding of STEM concepts and develop essential 21st-century skills [30]. After seeing the urgency of project-based learning in water quality. The next discussion is to see the content analysis of the answers of prospective chemistry teachers about how they model water quality using scientific modeling. There are 4 parts of constructing model, using model, evaluation model, and revision model.

3.1 Constructing Models

Water is the main source of life that is important to see its quality. However, in modeling water quality, initially prospective chemistry teachers are still fixated on seeing water physically such as smell, taste, color, clarity, and foam. In this context, they have not worked as scientists as expected in STEM education. This can be seen from the answers given by prospective chemistry teachers about water quality as seen in Table 2.

Table 2. Water quality (Modeling 1)

Indicator	Good Water Quality	Poor Water Quality
Smell	Odorless	Smells like earth, rotten
Taste	Tasteless (provides a taste when drunk)	There is a metallic, bitter taste
Color	Colorless	Brown, red, green, black
Clarity	Clear/colorless	Cloudy
Froth	Non-foaming	There is foam, lots of air bubbles

Based on the answers above, prospective chemistry teachers divide water quality into two categories, namely good and bad quality water. The focus of the answers given is the physical description of the water seen. This initial modeling has not provided factual data on the expected water quality as a scientist would. The answers above are general modeling that even laypeople can answer. Modeling must be based on the problem situation of science, technology, engineering, and mathematics to be better prepared to overcome higher-level intrinsic challenges in integrated STEM learning activities [17]. Modeling water quality involves a variety of approaches that can be used to understand, predict, and manage water conditions in an ecosystem [36]. The use of modeling was then carried out and returned to the prospective chemistry teachers. They were faced with the question "How do experts determine water quality? What can we do to determine water quality?" This is a driving question that is expected to provide an update from the previous modeling. The use of scientific models and modeling mechanisms can be used as a major aspect of the transformation of global science education to improve the perception and cognition of scientific principles [37]. This activity is the beginning of modeling, namely constructing a model, which is then continued with the use of the model.

3.2 Using the model

The use of the model begins with a discussion of the previous answers made by prospective chemistry teachers. They began to find several terms that are closely related to the field of chemistry. These terms are what they then concluded as water quality variables. The requirements of this variable are that it can be measured by simulation, and the data is known when the field test is carried out. In the first variable, prospective chemistry teachers agree on the selection of the degree of acidity, commonly known as pH. In the second variable, prospective chemistry teachers determine the presence of temperature as a variable that affects water quality. In the third variable, prospective teachers try to find a scientific term for clarity which then gets the name Total Dissolved Solid (TDS). Next, from the colored water, they try to find out about the case of colored water that it is possible that it contains metals that can conduct electricity. From various literatures, this fourth variable is chosen, conductivity. Even prospective chemistry teachers also submitted one example of water quality again, namely O_2 in water. Finally, five water quality variables were obtained, namely pH, temperature, TDS, conductivity, O_2 in water. Scientific modeling involves the reconstruction of models for scaffolding learning and conceptual understanding, emphasizing the importance of metaknowledge, and practical elements in the process [38]. The prospective chemistry teachers then began to design scientific modeling to help the PjBl process that would be carried out. The revised answer modeling obtained from prospective chemistry teachers is summarized as follows in

Table 3. Water quality (revised modeling)

Variabel	Good Water Quality	Poor Water Quality
pH	6,5-8,5	Too sour (1-5), Too Basal (10-14)
conductivity	0-200 μS/cm (low conductivity)	201-1000 μS/cm (mid-range conductivity)
TDS	0-100 ppm	101-500 ppm
Temperature	10-25 C	Cloudy
Dissolved O2	6-8 mg/L	5 mg/L dangerous, 3 mg/L critical, 1 mg/L organism death

The study was conducted by prospective chemistry teachers to find the standard of each variable that indicates that the water quality is good. The degree of acidity of pH so that the majority of aquatic organisms can live in a water condition ranges from 6.5-8.5. Too acidic pH containing metal will have a bad impact on aquatic organisms [39]. On the other hand, water with high pH levels that are too alkaline can also pose challenges for aquatic organisms. Carbonate alkalinity, salinity, and pH are significant stressors for aquatic animals and impact aquatic plants [40], [41]. Conductivity affects water quality. Conductivity is the ability of a material or solution to conduct electricity, the higher the ion content in water the higher the electrical conductivity. In the environment, conductivity measurements are essential for evaluating freshwater and saltwater mixing, flow hydrographs, and mapping contaminated groundwater. [42]. TDS is the total amount of dissolved solids in a solution, usually water. These dissolved solids include inorganic salts (such as calcium, magnesium, potassium, sodium, bicarbonate, chloride, and sulfate) as well as some organic matter dissolved in water. The presence of TDS in water sources, often from sources such as sewage, can significantly contaminate drinking water, posing a risk to public health [43]. Monitoring TDS levels is essential to differentiate between clean and polluted water sources, thus helping in establishing an effective water quality monitoring system [13]. Water quality is influenced by temperatures that are not too hot and not too cold because it has an impact on organisms and the ecosystem in it. Water temperature is an important factor that influences water quality parameters and aquatic ecosystems

[44]. Temperature variations can affect water quality by influencing the behavior of natural parameters [45]. Dissolved oxygen is the amount of free oxygen available in water. Dissolved oxygen is essential for aquatic life, including fish, invertebrates, and microorganisms. Dissolved oxygen levels are affected by factors such as temperature, atmospheric pressure, biological activity, and pollution. Changes in temperature can have a direct impact on key indicators of water quality such as dissolved oxygen (DO) and biochemical oxygen demand (BOD) [46]. River water temperature (RWT) and dissolved oxygen (DO) are important indicators for assessing the health of river ecosystems [47].

The above water quality modeling cannot be simulated yet, it is still focused on the concept of variables that affect water quality. Various modeling approaches have been developed to simulate and predict water quality parameters, helping the decision-making process related to water quality management. One of them is the use of the SageModeller platform, which integrates various modeling techniques to analyze and predict conditions. The SageModeller platform allows the integration of various modeling methods, such as moving averages, dynamic changes, and static water quality [48]. The software is content-free, meaning that students can create complete models that will run, even if the model is inconsistent with the scientific explanation of the phenomenon being modeled. SageModeller can provide comprehensive insights into water quality dynamics and facilitate the development of optimal management strategies for water interception systems [49]. SageModeller allows simulation of various water quality parameters, including dissolved oxygen, nutrients, organic matter, and pH, in different water systems such as lakes, reservoirs, and rivers [50], [51]. The SageModeller platform offers a versatile and comprehensive approach to water quality modeling, integrating a variety of techniques, and models to effectively analyze, predict, and manage water quality parameters. Water quality modeling is shown in Figure 1 below:

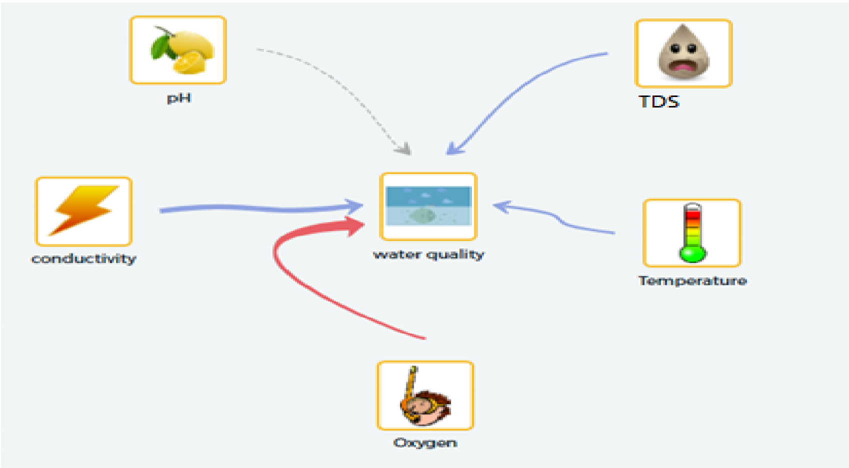

Fig. 1. Modelling water quality in sagemodeler

Sagemodeler above is designed with a representation of pH, conductivity, oxygen, temperature, and TDS with various images according to the display above. This representation is to facilitate the identification of the project or the next step. Sagemodeler is also practical in modifying the variables in it. Model analysis is still focused on the first level of variables that affect water quality. Furthermore, this model will be tested in the field, and then move on to the model evaluation stage.

3.3 Evaluation Model

Evaluation Model is carried out by prospective chemistry teachers on previously created models. This evaluation provides changes and improvements to the model compared to before [52]. In the evaluation of the model, there was a change in the number of variables to only 4 because for the Dissolve Oxygen test there was no tool that supported the field test, so a reduction was carried out to only 4 variables. The previous driving question also triggered questions again from prospective chemistry teachers if the variables could still be influenced by other causes because there is a causal relationship in each phenomenon. Finally, reformulating what things affect the four previous variables can be seen in Figure 2.

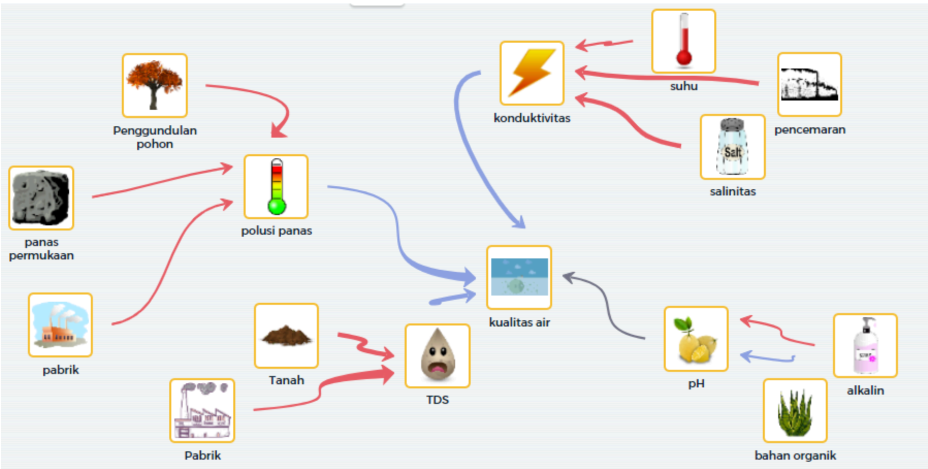

Fig 2. Evaluation modelling water quality

The prospective chemistry teachers finally reformulated the modeling. This evaluation resulted in a simple and systematic modeling. [53]. This water quality modeling: 1. Heat pollution occurs due to deforestation, surface heat and the presence of factories, 2. TDS increases due to dissolved soil and factories, 3. High conductivity occurs due to increased temperature, salinity, water pollution, 4. The pH is not neutral because the environment is too alkaline due to alkaline materials and the presence of organic materials that are acidic.[54]. After completing the simulation modeling, the project is continued to conduct practical testing. Practical testing provides reinforcement for previous evaluations for model improvement [55].

3.4 Revising Model

Revising the model is done by monitoring the water quality in Jakabaring Lake. This monitoring is part of a project that must be completed. After seeing the simulation with SageModeler, they tried to find a phenomenon that could be obtained from water quality tests in the field. The results of this water quality test are real tests and the data can be seen in table 4.

Table 4. Water quality test results

Location	Point 1	Point 2	Point 3	Point 4	Point 5
Colour	Deep green	Green	Brown	Yellow	Green
Stream	Stagnant water	Stagnant water	Stagnant water	Stagnant water	Stagnant water
Soil	Brown	Brown	Brown	Brown	Brown
Organism	-	Fish, Reeds	Water Hyacinth, Lotus, Reeds	Water Hyacinth, Cogongrass	Lotus, Water Hyacinth, Reeds
Ph	4,14	4,12	4,37	4,21	6,31
ns/cm	215	225	278	212	187
TDS	113	113	135	106	93
Temperature (°C)	31,2	30,4	31,5	31,2	30,5
Oil	No	No	No	Yes	No

Based on the data above, the analysis was carried out qualitatively and quantitatively. Qualitative can be seen from the color of the water, flow, surrounding soil, and organisms on the surface of the water flow. The selected quantitative data was then focused on four main variables, namely pH, Conductivity, TDS, and Temperature as evidence that it is the basis for identifying water quality. Field analysis also found that variables that affect water quality are also influenced by other factors. This is what makes it necessary to revise the final model in order to obtain modeling results that are appropriate for water quality testing. This modeling revision produces water quality, as shown in the table below:

Table 5. Water quality (Revising Modeling)

Variable	Revision Modeling
pH	1. The pH of water is affected by organic materials/organisms around the lake flow. Dead organisms/plants will produce acid which will affect the pH of the water 2. The pH of water is affected by alkaline compounds spilled into the water due to home industries, washing activities and so on. 3. The recommended pH for water quality is 6.5-8.5
Conductivity	1. Conductivity is affected by temperature, the higher the temperature the greater the increase in conductivity 2. Conductivity is affected by salinity, salinity is directly proportional to the increase in conductivity

	3. Conductivity is affected by factory activity
TDS	1. TDS is influenced by dissolved soil, the more dissolved soil the higher the TDS 2. TDS is influenced by industrial activities in the surrounding area which can increase pollution so that it is directly proportional to TDS 3. TDS is influenced by household activities which produce household waste, the more it affects the quality of TDS.
Temperature	1. Temperature is affected by the deforestation of trees/plants around the stream, the more cases of deforestation there are, the more it is directly proportional to the increase in temperature. 2. Temperature is affected by factory activities, factory activities that produce production waste can increase the temperature in water/water. 3. Temperature is affected by surface heat, the higher the surface heat, the more it is directly proportional to the increase in temperature.

This modeling shows that there are four variables that affect water quality. These variables are also influenced by the surrounding conditions which are correlated with the results of water tests. The method in this modeling is in line with the principles of constructivism, emphasizing active student involvement, and social interaction to achieve learning objectives [56]. Project-based learning has been shown to be effective in improving scientific attitudes, problem-solving skills, and levels of self-efficacy [57], [58], [59]. Modeling in scientific modeling gives students the opportunity to work collaboratively, manage resources effectively, be actively involved in the learning process, and foster participatory thinking [60]. In project-based learning, it is expected that there will be engineering products used in solving problems from the modeling above. Prospective chemistry teachers make efforts to overcome water quality problems by providing a water purification design that is useful for purifying water. This design is in the form of filtration that can filter solids and purify water better than before [61].

4 Conclusion

Project-based learning can be an option in STEM learning because it promotes various interdisciplinary learning objectives. This learning enhances critical thinking skills through analysis of water quality variables, trains scientific investigation skills through model testing and revision, integrates theoretical knowledge with simulation and field practice. PjBL has been successful and aligned with STEM because it achieves a comprehensive understanding of water quality and the interdisciplinary learning process. Model construction looks at water quality physically such as smell, taste, color, clarity, and foam. Using Models can be used to understand the relationship between phenomena, finally obtaining water quality variables, namely pH, conductivity, temperature, TDS, Dissolved Oxygen. Evaluation model is carried out by further simulation with SageModeler by looking at the factors that affect water quality variables. Condition adjustments are made by reducing dissolved oxygen because there are no measuring instruments for field tests. Model revision is carried out by practicing in Lake Jakabaring to see the variables that affect water tests and organoleptic tests of water quality. The results of this water quality test are continued by revising the final stage model. The final variables in the revision are pH, conductivity, temperature, TDS. The follow-up project carried out is the refinement of the product engineering to be designed. A prospective chemistry teacher tries to solve the water quality problem by providing a water purifier designed to purify water.

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References

1. Mandler, D., Blonder, R., Yayon, M., Mamlok-Naaman, R., Hofstein, A.: Developing and implementing inquiry-based, water quality laboratory experiments for high school students to explore real environmental issues using analytical chemistry. *Journal of Chemical Education* **91**(4), 492–496 (2014)
2. Peletz, R., Kumpel, E., Bonham, M., Rahman, Z., Khush, R.: To what extent is drinking water tested in sub-Saharan Africa? A comparative analysis of regulated water quality monitoring. *International Journal of Environmental Research and Public Health* **13**(3), 275 (2016).
3. Chung, P.L., Chung, C.Y., Liao, S.W., Miaw, C.L.: Assessment of the school drinking water supply and the water quality in Pingtung County, Taiwan. *Environmental Monitoring and Assessment* **159**(1–4), 207–216 (2009).
4. Cradock, A.L., Jones, S.E., Merlo, C.: Examining differences in the implementation of school water-quality practices and water-access policies by school demographic characteristics. *Preventive Medicine Reports* **14**, 100823 (2019).
5. Elzagheid, M.I.: Jubail industrial college (JIC) educational quality assurance and management procedures: Chemical and process engineering technology department as an example. *European Journal of Educational Research* **8**(3), 659–669 (2019).
6. Çoban, G.Ü., Akpınar, E., Küçükcankurtaran, E., Yıldız, E., Ergin, Ö.: Elementary school students' water awareness. *International Research in Geographical and Environmental Education* **20**(1), 65–83 (2011).
7. Júnior, A.P., Morales, G.P., Beltrão, N.E.S., Dias, Y.A.S., de Azevedo Sadeck, C.C., Santos, L.B.: The use of geotechnology in environmental education and water quality monitoring: O uso da geotecnologia na educação ambiental e na conservação ou monitoramento da qualidade da água. *Concilium* **23**(6), 405–419 (2023).
8. Mochtar, J., San, G.S.: Challenges in quality assurance: A ten-year journey. *PhD Thesis*. EDP Sciences (2020).
9. Mustafa, N., Ismail, Z., Tasir, Z., Mohamad Said, M.N.H.: A meta-analysis on effective strategies for integrated STEM education. *Advanced Science Letters* **22**(12), 4225–4228 (2016). https://doi.org/10.1166/asl.2016.8111
10. Wahono, B., Chang, C.Y.: Assessing teacher's attitude, knowledge, and application (AKA) on STEM: An effort to foster the sustainable development of STEM education. *Sustainability* **11**(4), 950 (2019). https://doi.org/10.3390/su11040950
11. Keiler, L.S.: Teachers' roles and identities in student-centered classrooms. *International Journal of STEM Education* **5**, 1–20 (2018). https://doi.org/10.1186/s40594-018-0131-6
12. Krishnan, K., Nasri, N.M., Sadan, M.K.B.: STEM approaches in teaching and learning process: Systematic literature review (SLR). *International Journal of Academic Research in*

Progressive Education and Development **12**(4) (2023). Available at: https://ijarped.com/index.php/journal/article/view/829
13. Sulaiman, S., Imran, A., Hidayat, B.A., Mashuri, S., Reslawati, R., Fakhrurrazi, F.: Moderation religion in the era society 5.0 and multicultural society: Studies based on legal, religious, and social reviews. *Linguistics and Culture Review* **6**(S5), 180–193 (2022). https://doi.org/10.21744/lingcure.v6nS5.2106
14. Hussin, H., Jiea, P.Y., Rosly, R.N.R., Omar, S.R.: Integrated 21st-century science, technology, engineering, mathematics (STEM) education through robotics project-based learning. *Humanities and Social Sciences Reviews* **7**(2), 204–211 (2019)
15. Oyewo, O.A., Ramaila, S., Mavuru, L.: Harnessing project-based learning to enhance STEM students' critical thinking skills using water treatment activity. *Education Sciences* **12**(11), 780 (2022)
16. Hallström, J., Schönborn, K.J.: Models and modelling for authentic STEM education: Reinforcing the argument. *International Journal of STEM Education* **6**(1), 22 (2019).
17. Dong, Y., Wang, J., Yang, Y., Kurup, P.M.: Understanding intrinsic challenges to STEM instructional practices for Chinese teachers based on their beliefs and knowledge base. *International Journal of STEM Education* **7**, 1–12 (2020).
18. Frejd, P., Bergsten, C.: Mathematical modelling as a professional task. *Educational Studies in Mathematics* **91**, 11–35 (2016).
19. Diekman, A.B., Steinberg, M., Brown, E.R., Belanger, A.L., Clark, E.K.: A goal congruity model of role entry, engagement, and exit: Understanding communal goal processes in STEM gender gaps. *Personality and Social Psychology Review* **21**(2), 142–175 (2017).
20. González-Pérez, S., Mateos de Cabo, R., Sáinz, M.: Girls in STEM: Is it a female role-model thing? *Frontiers in Psychology* **11**, 564148 (2020).
21. Kompella, P., Gracia, B., LeBlanc, L., Engelman, S., Kulkarni, C., Desai, N., Clark, G.: Interactive youth science workshops benefit student participants and graduate student mentors. *PLoS Biology* **18**(3), e3000668 (2020). https://doi.org/10.1371/journal.pbio.3000668
22. Shin, J.E.L., Levy, S.R., London, B.: Effects of role model exposure on STEM and non‐STEM student engagement. *Journal of Applied Social Psychology* **46**(7), 410–427 (2016).
23. McNeill, K.L., Krajcik, J.: Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student learning. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching* **45**(1), 53–78 (2007).
24. Schwarz, C.V., Reiser, B.J., Davis, E.A., Kenyon, L., Achér, A., Fortus, D., Krajcik, J.: Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching* **46**(6), 632–654 (2009).
25. Assarroudi, A., Heshmati Nabavi, F., Armat, M.R., Ebadi, A., Vaismoradi, M.: Directed qualitative content analysis: The description and elaboration of its underpinning methods and data analysis process. *Journal of Research in Nursing* **23**(1), 42–55 (2018).
26. Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K., Kyngäs, H.: Qualitative Content Analysis: A Focus on Trustworthiness. *SAGE Open* **4**(1), 215824401452263 (2014).
27. Lebni, J.Y.: The Consequences of Methamphetamine Use in Tehran: Qualitative Content Analysis (2020)
28. Devanda, B., Elizar, E.: The effectiveness of the STEM project-based learning approach in physics learning to improve scientific work skills of high school students. *International Journal of Humanities Education and Social Sciences* **2**(4) (2023)

29. Sujud, R., Rahmawati, Y., Utami, A.D.: Development of science literacy through group choice STEM-PjBL projects integrated with matter state changes. *Jurnal Penelitian Pendidikan IPA* **10**(5), 2552–2564 (2024)
30. Hakim, L., Sulatri, Y., Mudrikah, A., Ahmatika, D.: STEM project-based learning models in learning mathematics to develop 21st-century skills. *Proceedings of the International Conference of Science and Technology for the Internet of Things* (2019).
31. Sutaphan, S., Yuenyong, C.: Enhancing grade eight students' creative thinking in the water STEM education learning unit. *Cakrawala Pendidikan: Jurnal Ilmiah Pendidikan* **42**(1), 120–135 (2023).
32. Widiyanti, Y., Arum, J.W., Sukenti, E., Alfidayani, A., Herawati, D.: Implementation of lesson study-based STEM learning to students' creativity and concept mastery through joint project. *Journal of Learning Improvement and Lesson Study* **2**(1), 46–52 (2022).
33. Beier, M.E., Kim, M.H., Saterbak, A., Leautaud, V., Bishnoi, S., Gilberto, J.M.: The effect of authentic project‑based learning on attitudes and career aspirations in STEM. *Journal of Research in Science Teaching* **56**(1), 3–23 (2019).
34. Miller, E.C., Krajcik, J.S.: Promoting deep learning through project-based learning: A design problem. *Disciplinary and Interdisciplinary Science Education Research* **1**(1), 7 (2019).
35. Lou, S.-J., Tsai, H.-Y., Tseng, K.-H., Shih, R.-C.: Effects of implementing STEM-I project-based learning activities for female high school students. *International Journal of Distance Education Technologies (IJDET)* **12**(1), 52–73 (2014).
36. Novak, A.M., Krajcik, J.S.: A case study of project‑based learning of middle school students exploring water quality. In: Moallem, M., Hung, W., Dabbagh, N. (eds.) *The Wiley Handbook of Problem‑Based Learning*, pp. 551–572. Wiley, New York (2019).
37. Wang, Z., Wang, J., Jia, M.: Case study on the development and implementation of STEM projects: 'DIY traffic lights'. *Research in Education Assessment and Learning* **7**(2) (2022).
38. Boon, M., Orozco, M., Sivakumar, K.: Epistemological and educational issues in teaching practice-oriented scientific research: Roles for philosophers of science. *European Journal for Philosophy of Science* **12**(1) (2022).
39. Rostern, N.T.: The effects of some metals in acidified waters on aquatic organisms. *Fish Ocean Open Journal* **4**(4), 555645 (2017).
40. Bhuyan, J.M., Sharma, P.: A study on the water quality and the change detection of aquatic vegetation of Satajaan Beel, North Lakhimpur, Assam (2023).
41. Ge, Q., Li, J., Wang, J., Li, Z., Li, J.: Characterization, functional analysis, and expression levels of three carbonic anhydrases in response to pH and saline–alkaline stresses in the ridgetail white prawn *Exopalaemon carinicauda*. *Cell Stress and Chaperones* **24**(3), 503–515 (2019)
42. Hayashi, M.: Temperature-electrical conductivity relation of water for environmental monitoring and geophysical data inversion. *Environmental Monitoring and Assessment* **96**(1–3), 119–128 (2004). doi: 10.1023/B:EMAS.0000031719.83065.68
43. Daud, M. K.: Drinking water quality status and contamination in Pakistan. *BioMed Research International*, 1–18 (2017). doi: 10.1155/2017/7908183
44. Safari, H., Chen, H., Lagat, E., Mbuge, D.: Implications of dynamic interactions between meteorological patterns and surface water quality on environmental health—A case study of the Nairobi River. *Journal of Geoscience and Environment Protection* **12**(5), 113–146 (2024)
45. Pantelić, M., Dolinaj, D., Stankov, U., Leščešen, I.: Correlation analysis of impact of natural parameters on water quality of the River Danube near Novi Sad for the period 2004–2011. *Geographica Pannonica* **17**(3), 74–78 (2013)
46. Rehana, S., Mujumdar, P. P.: River water quality response under hypothetical climate change scenarios in Tunga-Bhadra River, India. *Hydrological Processes* **25**(22), 3373–3386 (2011). doi: 10.1002/hyp.8057

47. Rajesh, M., Rehana, S.: Impact of climate change on river water temperature and dissolved oxygen: Indian riverine thermal regimes. *Scientific Reports* **12**(1), 9222 (2022)
48. Wang, Y., Lv, F.: ARIMA-GRU water quality prediction method based on wavelet decomposition. *Second International Conference on Electronic Information Engineering, Big Data, and Computer Technology (EIBDCT 2023)*, SPIE, **11**, 117–123 (2023)
49. Ma, C.-Y., Huang, Y.-C., Kao, C.-M.: Development of optimal management strategies for the interception system using river water quality modeling. *Matec Web of Conferences*, EDP Sciences, **11** (2024)
50. Lap, B. Q., Mori, K., Inoue, E.: A one-dimensional model for water quality simulation in medium- and small-sized rivers. *Paddy and Water Environment* **5**(1), 5–13 (2007).
51. Ziemińska-Stolarska, A., Skrzypski, J.: Review of mathematical models of water quality. *Ecological Chemistry and Engineering S* **19**(2), 197–211 (2012).
52. Novak, A.M.: Using technologies to support middle school students in building models of stream water quality. In: *Proceedings of the 2017 Annual Meeting of the National Association for Research in Science Teaching (NARST)*, pp. 22–25 (2017).
53. Stachowiak, H.: General model theory. Springer, New York (1973).
54. Sulistia, S., Septisya, A.C.: Analisis kualitas air limbah domestik perkantoran. *Jurnal Rekayasa Lingkungan* **12**(1) (2019).
55. McCarty, G.W.: Water quality and conservation practice effects in the Choptank River watershed. *Journal of Soil and Water Conservation* **63**(6), 461–474 (2008).
56. Kokotsaki, D., Menzies, V., Wiggins, A.: Project-based learning: A review of the literature. *Improving Schools* **19**(3), 267–277 (2016). https://doi.org/10.1177/1365480216659733
57. Lestari, H., Rahmawati, I.: Integrated STEM through project-based learning and guided inquiry on scientific literacy abilities in terms of self-efficacy levels. *Al Ibtida: Jurnal Pendidikan Guru* **7**(1), 19–32 (2020).
58. Setiyadi, M.W., Sudiatmika, A.I.A.R., Suma, K., Suardana, N.: Meta-analysis: The effect of project-based learning on science process skills. *Jurnal Pembelajaran Dan Biologi Nukleus (JPBN)* **10**(1), 52–62 (2024).
59. Tika, I.N., Agustiana, I.G.A.T.: The effect of a blended learning project-based learning model on scientific attitudes and science learning outcomes. *Jurnal Ilmiah Sekolah Dasar* **5**(4), 557–566 (2021).
60. Warni, W., Afria, R.: Implementation and its effect of project-based learning (PjBL) model on increasing learning output in philology course. *Indo-MathEdu Intellectuals Journal* **4**(2), 1155–1163 (2023).
61. Coenraad, R., Karelius, K.: Perancangan filter penjernih air Sungai Kahayan berbasis pasir silika dan lempung alam asal Kalimantan Tengah: Design of Kahayan River water treatment filter-based silica sand and natural clay of Central Kalimantan. *Jurnal Jejaring Matematika dan Sains* **1**(2), 70–76 (2019).