LUMAT
International Journal on Math, Science and Technology Education

Research article

Fostering Students' Process and Product Creativity Through Chemistry-Based STEM-PjBL in Vocational Context

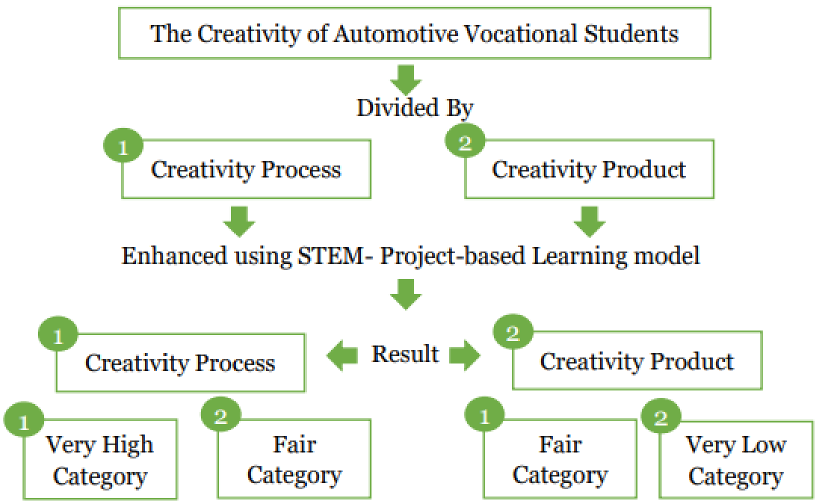
Fapriyan Wijoyo Mulyopratikno[1,2] and Antuni Wiyarsi[3]

[1] Doctoral Program in Chemistry Education, State University of Yogyakarta, Indonesia
[2] Senior High School, Al Azhar Yogyakarta World School, Indonesia
[3] Department of Chemistry Education, State University of Yogyakarta, Indonesia

Abstract: This study aims to reveal (1) the level of students' creativity (process and product), (2) description of student's product in STEM framework. This study applied pre-experimental with one-shot case study design. The samples were 38 male tenth grade students as one group. Teaching intervention was STEM integrated Project Based Learning (STEM-PjBL) model for six meetings. Rubrics of creativity process and product were used to collect the data. The level of students' creativity was analyzed with categorization descriptively. The results show that students' process creativity is very high, and a few students have a fair process creativity category. Meanwhile, product creativity is fair for students, and a few students have a very low product creativity category. Overall, the automotive vocational students' creativity level is in the Little-Creativity and Mini-Creativity category. All the products produced have integrated STEM, students are more dominant in explaining products using a scientific (chemistry knowledge) dimension, but they are weak in describing the mathematics integrated into the product.

Keywords: creativity, project-based learning, STEM, vocational school

Correspondence: antuni_w@uny.ac.id



Received 30 November 2024 / Accepted 2 July 2025 / Published 13 August 2025
Published by the University of Helsinki, Finland and LUMA Centre Finland.

1 Introduction

The development of the 21st century requires the education system to play a role in creating a generation ready to face future challenges. Students must have specific skills that can be used to face future challenges, such as creativity, critical thinking, communication, and collaboration (4C) skills (Meda, 2023; Saimon et al., 2023; Trevallion & Nischang, 2021). The 4C skills students have can help students to solve daily life problems, communicate effectively, work together productively, and create problem-solving innovation (Partnership for 21st Century Skills, 2007). Creativity skills are one of the skills used to help students develop innovative problem-solving.

Students with high levels of creativity can generate more ideas, be more active in discussions, and overcome the challenges (Wu & Wu, 2020). This makes students more confident in expressing their opinions and ideas to solve problems (Rahayu et al., 2022; Rani Satyam et al., 2022; Supena et al., 2021). Thus, creativity skills in students will encourage them to solve the problems they face by using innovative solutions. Therefore, creativity skills are one of the skills that are prioritised in the 2013 Indonesian national education curriculum (K-13).

On the other hand, there are four dimensions in a person's creativity skills influence the person to create innovative ideas or products to overcome a problem. A person's creativity skills are divided into four dimensions: person, press, process, and product (4P) of creativity (Beghetto & Kaufman, 2014; Rhodes, 1961). These dimensions influence the development of creativity in students. The person and press dimensions of creativity refer to internal and external factors that influence students' creativity skills. In contrast, the process and product of creativity refer to students' activities in producing various ideas, works, or creative solutions.

Therefore, classroom learning activities are one factor that can influence the process and product of students' creativity. When students engage in deeper learning, they generate new understandings that are meaningful to themselves and others, impacting the creative products produced by the students (Henriksen et al., 2020; Roffey & Quinlan, 2021). This happens because individual knowledge cannot be separated from the social and cultural context in which the individual is located, according to the Social Constructivism Theory proposed by Vygotsky (Amineh & Asl, 2015; Schunk, 2020; Taber, 2020; Vygotsky, 1978). Interaction with other students will provide them with learning experiences that will enable them to enhance their knowledge, so that students can produce rich and diverse creative products. However, Sudjimat's research (2016) said that the products creativity produced by Indonesian students are still simple, so the products produced cannot be used for practical purposes or sold.

Students can create innovative, diverse, and practical creative products by improving their creativity skills. Currently, there is a learning approach that can encourage students to develop problem-solving skills, enhance creativity, learning experiences, and critical thinking skills, namely the Science, Technology, Engineering, and Mathematics (STEM) approach (Hebebci & Usta, 2022; Mystakidis et al., 2022; Niancai et al., 2024; The

Minister of Education Susil Premajayantha, 2023). Implementing the STEM approach provides students with a more open learning experience because students will integrate the various knowledge they have acquired to solve problems using creativity skills (Banks & Barlex, 2014; Juškevičienė et al., 2021; Nguyen et al., 2020; Ozkan & Umdu Topsakal, 2021; Vieira et al., 2024). Therefore, applying the STEM approach in learning allows students' creativity to increase.

In addition, the STEM approach has been applied by previous studies with various learning models, such as project-based learning (PjBL), problem-based learning (PBL) and inquiry science (Baran et al., 2021; Johnson et al., 2020; Lin et al., 2021; Muzana et al., 2021; Park et al., 2018; Smith et al., 2022). The PjBL model is a more appropriate model to integrate with the STEM approach because the PjBL model emphasises project activities carried out by students so that students can create innovative problem-solving products (Tan & Chapman, 2016). Indirectly, PjBL activities will help students develop critical and creative thinking skills. This is in line with previous studies, namely that the integrated STEM approach to the PjBL model (STEM-PjBL) can improve students' critical thinking skills and creativity (Banks & Barlex, 2014; Lou et al., 2017; Mursid et al., 2022; Primadianningsih et al., 2023; Ruhana et al., 2024; Sumarni & Kadarwati, 2020). Therefore, STEM-PjBL can be integrated to help improve students' creativity skills. Unfortunately, due to the lack of chemistry teachers' knowledge in designing and implementing STEM-based learning, this implementation in Indonesia is not optimal (Fitriyana et al., 2021; Thaha et al., 2021).

On the other hand, vocational school requires students to be able to apply chemistry concepts to their field of expertise. For example, chemistry learning in automotive vocational schools helps students to be able to apply chemical theory in the automotive world. Automotive vocational students studying hydrocarbon compounds and petroleum can help students understand the chemical compounds contained in vehicle fuels, types of vehicle fuels, and the process and impact of fuel combustion in vehicle engines (Febrianto & Wiyarsi, 2018). The STEM-PjBL model plays a role in learning activities carried out by automotive vocational students. For example, automotive students can make products to overcome the problem of used motor vehicle oil waste and air pollution due to the combustion of motor vehicle fuels and make environmentally friendly alternative fuels. Therefore, the STEM-PjBL model is very appropriate if applied in vocational schools in Indonesia, because graduates from vocational schools in Indonesia aim to create graduates who can carry out certain types of work. Unfortunately, automotive vocational students still find it challenging to connect the chemical content of hydrocarbon compounds with real-world contexts, which causes the skills possessed by automotive vocational students to be less than optimal (Wiyarsi et al., 2020). Therefore, this study aims to examine the effect of chemistry learning based on the integrated PjBL model with the STEM approach in automotive vocational schools, especially on the material of hydrocarbon and petroleum compounds. The following research questions guide this study:

a. At what level are the students' creativity in terms of process and product?
b. How do students integrate STEM into their products during learning process?

2 Context of Study

2.1 Chemistry Based STEM-PjBL Model in Vocational School

Learning is a student activity (students with students, students with teachers, students with the environment, and students with learning resources) in building or constructing knowledge based on the results of past and current learning experiences (Anderson & Krathwohl, 2001; Arends, 2012; Gilbert & Treagust, 2009). However, there are differences in learning in each educational institution, such as chemistry learning in Senior High Schools (SHS) and Vocational High School (VHS) in Indonesia. SHS focus on extending students' understanding of basic natural science, social science, and language science to prepare them for entering higher education or university, Meanwhile, VHS prepare students to have specific expertise and ready to join the workplace, so chemistry learning in VHS must support vocational competencies (students' specific expertise) in VHS (Faraday et al., 2011; Wiyarsi et al., 2020).

The learning approach teachers in VHS can use is the STEM approach, which consists of integrating Science, Technology, Engineering and Mathematics, because the STEM approach helps VHS graduates to become experts in specific fields of work (Banks & Barlex, 2014; Kiray & Shelley, 2018). The following is a description of each discipline in the STEM approach: In the science disciplines (S), students can investigate, use knowledge, revise, modify knowledge, and explain scientific phenomena using empirical evidence. Technology disciplines (T) require students to design a tool that helps represent abstract ideas and can enhance learning about complex concepts. Engineering (E) requires students to solve problems or discover innovations using scientific knowledge and models, tools, or prototypes from technology modeling and analysis using mathematics. Math (M) in STEM functions so students can think, understand problem-solving, and reason using math.

A learning model appropriate to the vocational context and can be integrated with the STEM approach is the PjBL model (Tan & Chapman, 2016). The PjBL model emphasizes learning and provides students with learning experiences through project activities (Krauss & Boss, 2014). This is because PjBL is a learning method or model that follows the constructivist learning theory (Hmelo-Silver, 2004). So, PjBL model emphasizes students' learning experience, then teachers reduce the direct instruction learning model. Beside that, the STEM-integrated PjBL model in vocational schools can develop creativity, critical thinking skills, and student motivation in chemistry classes (Rahmawati et al., 2020). The development of the STEM-PjBL model in this study was adapted from the PjBL research of Aldabbus (2018), Bilgin et al. (2015), Chiang and Lee (2016), Kızkapan and Bektaş (2017), Uziak (2016) and integrated with the STEM approach from Aydin-Gunbatar et al.

(2018), Chonkaew et al. (2016), Kiray and Shelley (2018). So, the syntax of STEM-PjBL in this study consists of five stages: selection of learning topics, designing projects, making projects, presenting projects, and evaluating.

Selection Of Learning Topics

Project work begins with the students selecting a specific topic with the teacher as an advisor. The topic is generally a problem that students can solve through experiments or observations. Project work brings opportunities for students to demonstrate their achievements. In addition, these work opportunities allow students to work together in everyday life environments and collaborate on tasks. Each student or group begins to investigate information about a specific topic.

Designing Projects

Students offer suggestions to solve the problem. These suggestions are called 'Project Plans' in schools. Then, each individual or group collects information and documents to prove or support their topic. Teachers should encourage students to use their ideas in designing the project, such as what materials to use, sources of information and how to present the final product. This stage will help students become more creative and independent learners.

Making Projects

In this stage, students conduct experiments, make observations, collect and interpret data and record the results. During the project implementation process, teachers must ensure that students have enough time and opportunity to practice skills such as effective communication, using technology, critical thinking, and solving problems related to everyday phenomena.

Presenting Projects

Finally, each group writes a report and presents their study in the classroom. Presenting the final product is the main way for students to work hard and feel proud of what they have done. So, students should be encouraged as much as possible to display their projects and talk about them with others.

Evaluating

All students and teachers discuss and evaluate the projects presented. Teachers and students work together to provide constructive feedback to each other. Students can learn from the revisions and modify their projects according to the feedback received from their teachers and peers.

Learning in vocational schools is not only learning about theory but applying the theory to solve problems in the real world (Lucas et al., 2012). So, the material on hydrocarbon compounds and petroleum in VHS Automotive aims to support the competence of students in VHS Automotive in solving problems in the real world. An example of learning hydrocarbon compounds and petroleum that can be applied to VHS Automotive is the introduction of the application of hydrocarbon compounds in everyday life in the form of fuels, such as gasoline, kerosene, and diesel (Wiyarsi et al., 2017). This learning allows students to determine the combustion reaction process in vehicle fuel, analyze the impact of burning vehicle fuel on the environment, and find solutions. Based on that, the hydrocarbon compounds and petroleum materials can be connected to the context of vehicles in Automotive VHS.

2.2 Creativity in Chemistry

Students are said to be creative if they have imagination and can produce something new from something that already exists. Therefore, students must have appropriate knowledge and critical thinking skills to become creative individuals (Kaufman & Baer, 2006). The level of a person's creativity is divided into four, namely: Big Creativity (Big-C), Pro Creativity (Pro-C), Little Creativity (Little-C), and Mini Creativity (Mini-C) (Beghetto & Kaufman, 2014; Kaufman & Sternberg, 2006). Big-C describes the work of an expert who turns science into an invention. At the same time, Pro-C is the level of creativity gained from experience and training to become a professional in a field. Little-C is an example of someone who can solve problems from problems in everyday life using something new from existing knowledge/items. At the same time, mini-C is the application of an idea/connection that someone creates.

VHS students only have two levels of creativity: Little-C and Mini-C. Therefore, vocational students' creativity level in chemistry learning can be divided into Little-C and Mini-C. The Little-C level is an activity carried out by vocational students in creating a tool/item to solve problems in everyday life using the chemistry they have learned. Then Mini-C level is a student activity in finding solutions to problems in everyday life that are faced by providing ideas based on the chemistry that has been learned.

On the other hand, increasing student creativity can be done by providing in-depth learning so that the creativity process and products can develop. The creativity process is the activity of students in solving problems using creative ideas or ideas. The creativity process is divided into four indicators: preparation, incubation, illumination, and verification (Fautley & Savage, 2007; Gruszka & Tang, 2017; Mayasari, 2017; Runco & Kim, 2018). Preparation indicators are students' activities to collect, analyze, and propose a problem at hand. In contrast, incubation indicators are student activities that help them think about the impact and solution of the problem-solving process. Illumination is an activity where students develop ideas that aim to overcome the problems at hand. Verification is an activity carried out by students to compile, test, and refine the ideas used to solve the problem at hand.

In addition, creative products are student activities that involve making products using creative ideas. Indicators of creativity products consist of novelty, usefulness, relevance, effectiveness, and practicality of the product (Fautley & Savage, 2007; Gruszka & Tang, 2017; Mayasari, 2017; Runco & Kim, 2018). Product novelty is the product's originality students create to solve a problem (Fautley & Savage, 2007). Shalley et al. (2004) said product usability is the suitability of products created by students with new ideas for the problem. Cropley et al. (2011) said product effectiveness is the success rate of products produced by students in overcoming the problems faced, while product relevance is the accuracy of the science used by students to create a tool to solve a problem. Product practicality is the ease of using/operating products students create (Widyastuti & Utami, 2018).

Sumarni and Kadarwati (2020) explained that creativity helps students link chemistry concepts with real life, making it easier for students to understand chemistry material. In addition, student creativity helps students to think more flexibly. On the other hand, creative science learning also allows students to collaborate, share ideas or ideas, and appreciate people's perspectives; this causes students to participate more actively individually and in groups (Amrulloh & Galushasti, 2022). Creativity in chemistry learning makes it easier for students to understand chemistry material and allows students to be more actively involved in the chemistry learning provided.

3 Methodology

3.1 Research Design

This study applied a pre-experimental with a one-shot case study design, because researchers carry out treatment in one group and perform an assessment once after treatment. A pre-experimental one-shot case study is a research design conducted on one group without any comparison group (Creswell & Cresswell, 2018; Gall et al., 2003).

3.2 Samples

The sample consisted of 38 tenth-grade male students who were 15-16 years old in one class. The automotive vocational students in Yogyakarta, Indonesia, were in the Light Vehicle Engineering (LVE) department.

3.3 Intervention

The teacher taught the six meetings (6x80 minutes) using the STEM-PjBL model on hydrocarbon compounds and the petroleum topic. The STEM-PjBL model consists of activities: selecting learning topics, designing projects, presenting projects, and evaluating. The learning context of this activity is solving the problem of used oil waste from vehicles, fuel oil spills in the sea and air pollution from motor vehicle exhaust fumes using hydrocarbon compounds and the petroleum topic.

The first step of the STEM-PjBL model involves student and teacher activities. At this stage, students and teachers are to choose a problem topic related to learning hydrocarbon compounds and petroleum. Then, each student or group begins to investigate information about the topic. The second step was an activity where students offered suggestions through project designs to solve problems on the chosen topic. Then, the activity continues at the third step. At this stage, students conduct experiments, make observations, collect and interpret data, and record the results to create a prototype that can be used to solve problems. The fourth activity was carried out by students or groups, presenting the products designed to overcome the issues of the chosen topic. The last step was to discuss and evaluate the project presented by all students and teachers. The teacher and students work together to give each other constructive feedback. Students can learn from the revision results and modify their projects according to the feedback received from the teacher and their peers.

3.4 Data Collection Instruments

Rubrics of creativity process (C-Process-RI) and product (C-Product-RI) were used to collect the data. The C-Process-RI consists of 4 aspects, namely preparation, illumination, incubation, and verification, adapted from Fautley and Savage (2007), Gruszka and Tang (2017), Mayasari (2017), and Runco and Kim (2018). The creativity process rubric consists of 9 indicators with 12 sub-indicator items. The indicators of the student creativity process rubric can be seen in Table 1, while the creativity process rubric sub-indicators can be seen in the Appendix.

Table 1. Indicators of the Student Creativity Process Rubric

No	Aspects	Indicators
1	Preparation	Collecting problems
		Posing a problem
		Analyzing the problem
2	Incubation	Analyzing the impact of the problem
		Finding problem-solving solutions
3	Illumination	Solving the problem
4	Verification	Testing the product
		Compile a product development report
		Presenting the product

The C-Product-RI consists of 5 aspects, namely novelty, usefulness, relevance, effectiveness, and practicality, adapted from Fautley and Savage (2007), Gruszka and

Tang (2017), Mayasari (2017), Runco and Kim (2018). The creativity product rubric consists of 10 indicators with 10 sub-indicator items. The indicators of the student creativity product rubric can be seen in Table 2, while the creativity product rubric sub-indicators can be seen in the Appendix.

Table 2. Indicators of the Student Creativity Product Rubric

No	Aspects	Indicators
1	Novelty	Product originality
		Product uniqueness
2	Usefulness	Product usefulness
		Product suitability
3	Relevance	Accuracy of science
		Appropriateness of STEM aspect application
4	Effectiveness	The success of the product in facing the problem
		Appropriateness of selection of tools and materials
5	Practicality	Ease of product use
		Ease of product storage

In addition, the instruments used in the study were the Learning Plan, Student Worksheet, and Learning Supplement. All instruments were theoretically validated by expert judgment before being used in research. Expert judgment is two lecturers with doctoral degrees and professors in Chemistry Education at Yogyakarta State University who are experts in chemistry, especially the material of hydrocarbon compounds and petroleum.

3.5 Data Analysis

The level of students' creativity was analyzed with categorization descriptively. Students' average creativity score (process and product) is categorised based on ideal assessment by calculating the perfect mean and standard deviation (Miller et al., 2008). Then, in this study, there are 12 sub-indicators for the creativity process, so the minimum value is 12. The maximum is 48, then students are in the category of very high creativity process (>39), high (34-39), fair (28-33), low (22-27) and very low (≤21). Likewise, for the assessment of creative products, there are 10 sub-indicators, so the minimum value is 10. The maximum value is 40, so students are in the category of very high creativity products (>32.5), high (27.6-32.5), fair (22.6-27.5), low (17.6-22.5) and very low (<17.5).

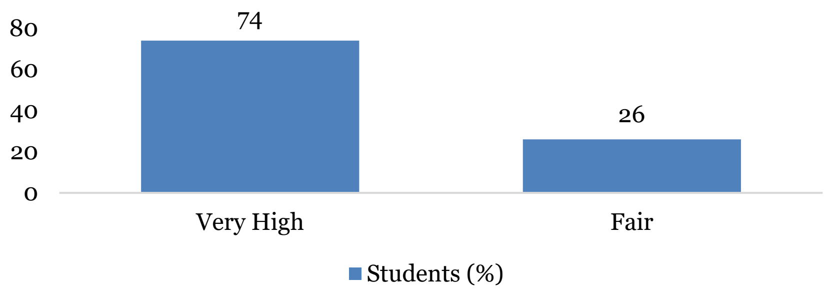
The researcher describes the products produced by students using descriptive content analysis to see the use of STEM science in the products made by students (Vaismoradi et al., 2013). First, the teacher asks students to collect products and reports of product creation carried out by students. Then, the teacher reads and understands the results of the products and reports of product creation carried out by students. After that, the teacher codes to find out the STEM disciplines integrated in the products developed. Finally, the researcher groups the coding into broader categories and reports the analysis results.

4 Results and Discussion

4.1 Students' Creativity in Process Dimension

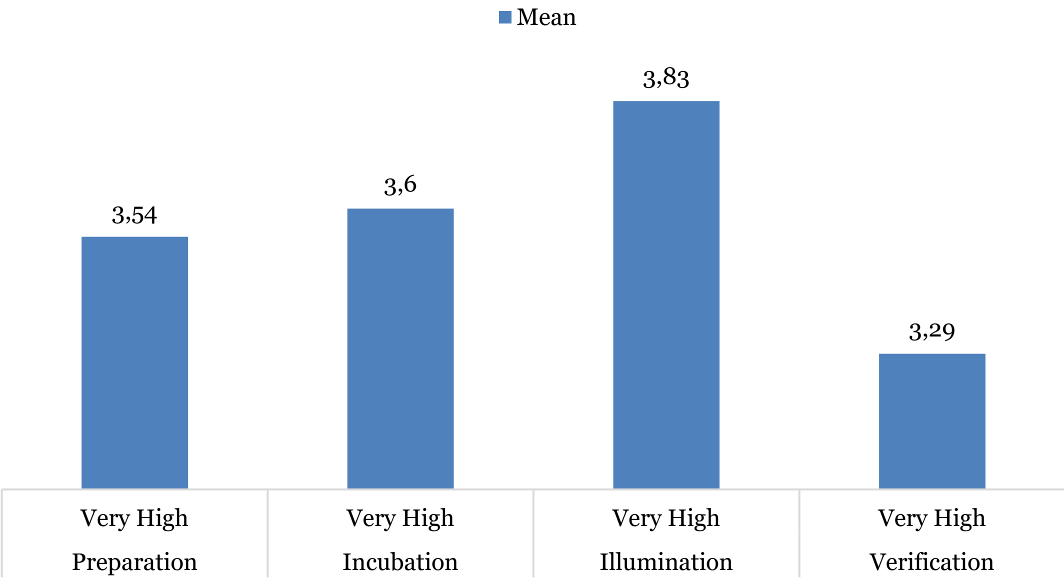
The results showed that 74% of the students' creativity in the process dimension is Very High, while 26% are in the Fair category (Figure 1). This means that applying the STEM-PjBL model in this study can improve students' creativity in the process dimension. This happens because the STEM-PjBL model encourages students to be actively involved in designing products that are used to solve real-life problems (Prajoko et al., 2023). This model makes students actively engaged in group discussions, so that students in one group can share ideas to solve the issues they face. Indirectly, this provides a direct learning experience that causes students to master learning concepts and develop creative thinking processes, so that students can develop innovative ideas/products.

Figure 1. Level of Students' Creativity in Process Dimension



Besides that, Figure 2 shows the average score of students' creativity in the process dimension in the Very High category (mean>3,25). Based on Figure 2, it can be seen that the mean of the Illumination indicator is the highest, while the mean of the verification indicator is the lowest. This means that students can develop ideas that aim to solve the problems faced well, but students need help compiling, testing, and perfecting the solutions. This is in line with the research of Chen et al. (2022), who said that through project activities, students learn to explore new ideas and develop innovative solutions to the problems at hand.

Figure 2. Level of Students' Creativity for Each Indicator of Process Dimension



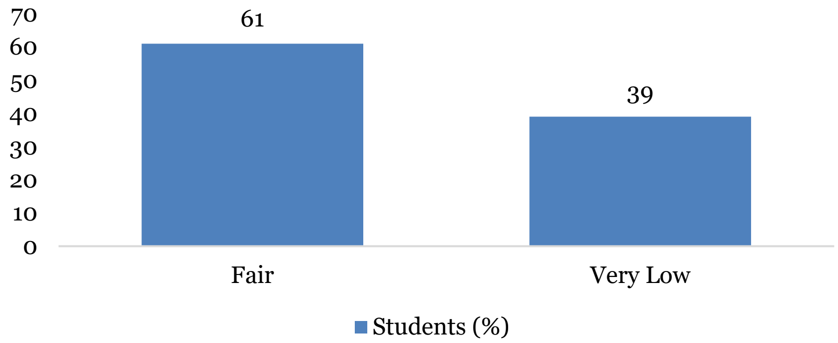
The low average of the verification indicator was due to two groups of students being unable to help compile reports and present product development. The products that could not be developed were air pollution filters and oil reservoirs developed to address the problem of the impact of vehicle exhaust emissions and used oil waste. This could have happened because the teacher did not select group members, so students made groups randomly. As a result, there were no cooperative activities between students to complete the developed product. This is in line with the research of Mahenthiran and Rouse (2000), which states that involving teachers in the selection of group members can improve the performance of group activities compared to the selection of group members by students.

Additionally, there is a possibility that socioeconomic status influenced the research sample, potentially preventing students from developing air pollution filters and oil reservoirs. Indirectly, the socioeconomic background of families will affect students' ability to learn in STEM fields (Uludüz & Çalik, 2022). Students from low socioeconomic backgrounds tend to have limited access to resources (equipment and teaching materials) that support STEM learning compared to students from higher socioeconomic backgrounds. Students from higher socioeconomic backgrounds have better access to resources when pursuing STEM studies.

4.2 Students' Creativity in Product Dimension

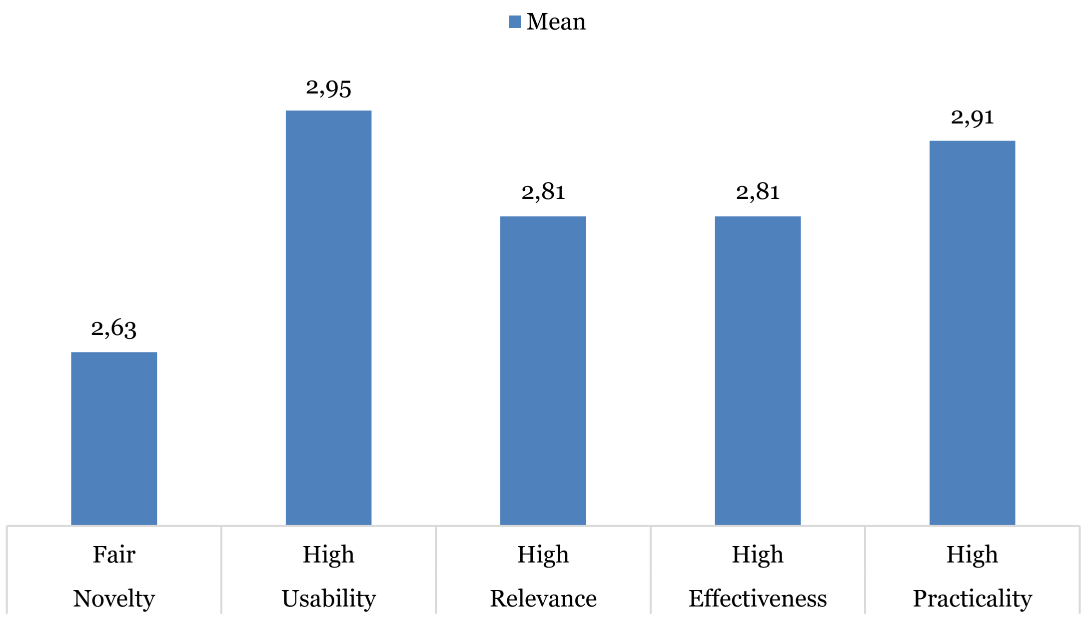
The results showed that 61% of the students' creativity in the product dimension is Fair, while 39% are in the Very Low category (Figure 3). These results indicate that implementing the intervention in this study has not impacted the products produced by students. This is because several groups said they had difficulty managing time in making products, students were not used to activities like this, and they lacked the tools and materials to make products. The shortcomings in implementing the STEM-PjBL model can potentially limit the development of student products (Baran et al., 2021). In addition, students who cannot define problems completely, manage the obstacles faced effectively, and conduct systematic product feasibility analysis will affect the quality of the products produced (Lin et al., 2021). These things may have happened in this study, so implementing the STEM-PjBL model made the students' creativity in the product dimension fall into the Fair and Very Low categories.

Figure 3. Level of Students' Creativity in Product Dimension



However, Figure 4 shows that students' creativity of product indicator, namely usability, relevance, effectiveness, and practicality, is in the High category (2.76-3.25 mean score), but the novelty indicator is in the Fair category (2.25-2.75 mean score). The figure shows that the average of the usefulness indicator is the highest, while the average of the novelty indicator is the lowest. The usability aspect of the product is the suitability of the product created by students with the problem at hand. This means that students have developed products suitable for overcoming the difficulties faced by learning hydrocarbon and petroleum compounds and taking the vocational study program. These results align with the research of Chonkaew et al. (2016), which shows that the STEM approach helps students engage, obtain, search, collect, and connect the information obtained efficiently in developing the given task. In addition, the low novelty aspect is because some of the products produced by students are not accompanied by supporting arguments. These arguments are based on the learning concepts of hydrocarbon compounds and petroleum. Meanwhile, the ability to argue in STEM-based learning can improve students' attitudes positively towards STEM learning (Saricam & Yildirim, 2021).

Figure 4. Level of Students' Creativity for Each Indicator of Product Dimension



4.3 STEM Framework Description of Students' Product

The results showed that six student groups successfully designed the developed product prototype after they follow the treatment that was carried out. However, only four groups completed the prototype product development. So, four groups have Little-Creativity level, and two groups have Mini-Creativity level. This is because four groups can design and develop problem-solving products, while two groups can only design problem-solving products (Beghetto & Kaufman, 2014; Kaufman & Sternberg, 2006). The prototype designs developed were used oil distillation prototype, oil boom and oil screamer, vacuum vehicle fume sucker, oil filter, air pollution filter, and waste oil container. The successfully developed products were prototypes of used oil refiners, oil boom and oil screamers, vacuum vehicle fume suction, and oil filters.

4.3.1 Product Prototype of Used Oil Distillation

Applying the chemistry of hydrocarbon and petroleum compounds in the context of automotive vocational studies, especially in used oil waste, students can use this knowledge to overcome used oil waste due to vehicle repairs. This study shows that students try to make products that can process used oil waste into alternative fuel oil. This prototype is used to deal with unused, used oil waste. This prototype aims to convert used oil into renewable fuel oil.

Figure 5. Design and Prototype of Used Oil Distillation Product

(a) (b)

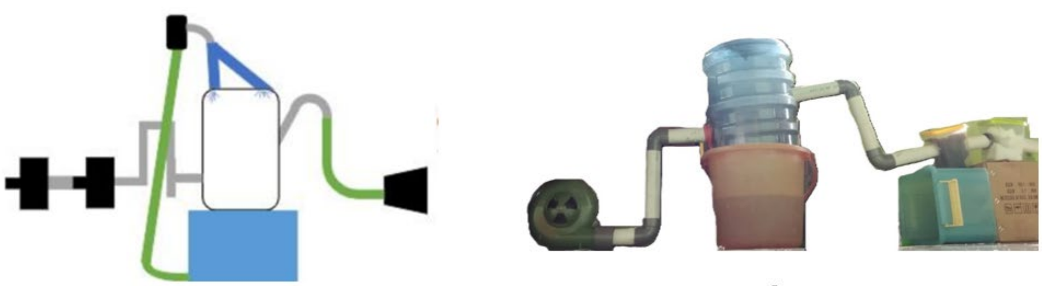
Figure 5 is the design of the used oil refinery product (a) and the prototype of the used oil refinery product (b). The science discipline (especially chemistry) used in the prototype is the principle of petroleum chain breaking using high temperature (Cracking Thermal Process) (Chang, 2010). The process breaks the carbon chain bonds of oil ($C_{18}H_{38}$) into diesel oil ($C_{14}H_{30}$), kerosene ($C_{11}H_{24}$), naphtha (C_6H_{14}), gasoline (C4H10), as well as some alkene compounds (>C=C<).

The technology discipline used in developing the prototype is the development of a prototype using the working principle of homemade multistage distillation. The engineering discipline in this project is the design used in manufacturing tools that adapt petroleum processing designs. The basic materials for making the tool are from a mixture of aluminum metals, such as milk cans and wafer cans. Integrating mathematics discipline in developing the prototype allows students to estimate the desired gasoline production from the used oil. Based on the carbon chain breaking reaction, the initial knowledge is obtained: 1 mole of $C_{18}H_{38}$ (oil) equals 1 mole of C_4H_{10} (gasoline). It can be known that the density of oil is about 0.8 grams/L. Therefore, we can calculate the production of gasoline.

4.3.2 Product Prototype of Motorcycle Fume Suction

The application of the chemistry of hydrocarbon and petroleum compounds in the context of automotive vocational studies, especially in the processing of vehicle exhaust, students can use this knowledge to overcome air pollution caused by motor vehicles. This study shows that students try to make products that can filter air pollution when motor vehicles are repaired in the workshop. Therefore, the workshop uses this prototype to address air pollution caused by motor vehicle exhaust.

Figure 6. Design and Prototype of Vehicle Fume Vacuum Suction Product



(a) (b)

Figure 6 is a picture of the motor fume suction design (a) and the prototype of the motor fume suction product (b). The mechanism of action of the tool, namely motor smoke containing C, CO, CO_2, SO_2, H_2O, and NO_2, is sucked by vacuum and channeled into a tube containing a sprayer and activated carbon. After that, the smoke can react with water and create artificial acid rain or be trapped by the activated carbon in the prototype.

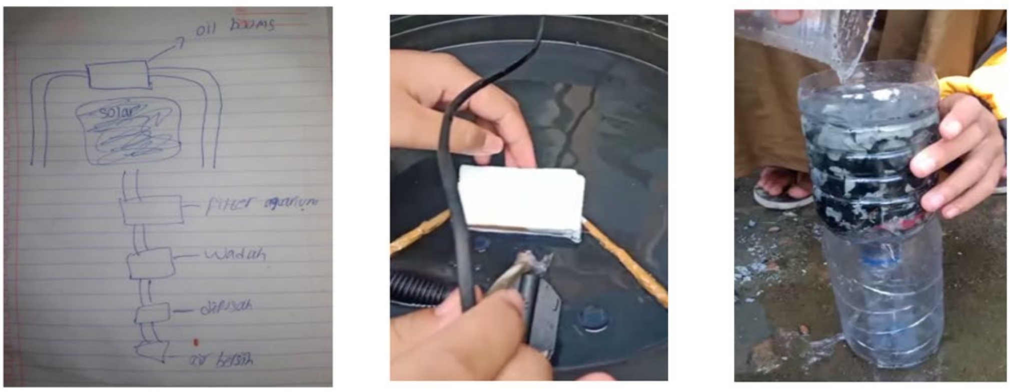
Integrating science discipline in the prototype allows students to determine the gases resulting from the combustion process in vehicle fuels from perfect combustion and incomplete combustion reactions, namely Carbon, CO gas, and CO_2 gas. In addition, when burning gasoline in a motor engine, there is a reaction between Sulfur (S) attached to the fuel and Nitrogen (N) in the air with oxygen, resulting in SO_x and NO_x gases.

The integration of technology discipline in the prototype helps the engineer avoid being polluted by pollutants released when servicing the motor. Engineering discipline integration in the prototype is that the prototype uses a vacuum cleaner designed to have adsorbents and parts that can make acid rain. The materials used to make the prototype are unused. Mathematics discipline can be used in the prototype because students can calculate the volume of motor exhaust gas generated by burning gasoline.

4.3.3 Product Prototypes of Oil Screamer Oil Boom and Oil Screamer

The oil boom is a prototype developed to deal with oil spills in water areas, while the oil screamer is used to suck up oil spills in water areas. In addition, students in this group also made a simple oil spill filtration basin. Figure 7 is an example of the product design of the oil boom, oil screamer, oil spill filter tub (a), and prototype of the oil boom and oil screamer (b) and oil spill filter tub (c).

Figure 7. Design and Product Prototype of Oil Boom, Oil Scremmer, and Oil Spill Filter Tank



(a) (b) (c)

The working mechanism of the prototype is that oil spills in the waters are captured using an oil boom so that the oil does not spread everywhere. An oil screamer is used to suck the spilled oil and put the oil into a storage container. Then, the water and oil spills are filtered in the oil spill filter tub to clean the polluted water. The integration of science disciplines in this prototype is that students use the principle of mixture separation by adsorbing oil spills using adsorbents. The adsorbents used are charcoal, zeolite, coconut fiber, and cloth. Zeolite adsorbs oil spills, while coconut fibers and cloth filter out impurities in the water and oil spills.

Integrating technology disciplines in this prototype allows students to use the working principle of oil booms and oil screamers designed to overcome oil spills in the waters. In addition, students developed an oil spill filter basin to separate the spilled water and oil mixture. Integrating engineering disciplines in this prototype allows students to design three tools: an oil boom, an oil screamer, and an oil spill filter basin.

The design is homemade and uses cheap materials. The oil boom can be made using a rubber base material, and the goal is for the rubber to form a hollow float inside. The cavity is used to insert air into the oil boom so that the oil boom can float. The oil screamer is designed like an air suction vacuum, while the oil spill filter tub is designed like a water purification tub. The filtration basin can be given a hole so clean water can flow directly.

The integration of math disciplines in the development of tools allows students to measure the length of the oil boom by calculating the circumference of the polluted area. In addition, students can calculate the volume of oil spilled in the reservoir. The oil's density is lighter than water's, so the oil spill is above the water. Therefore, students can calculate the volume of oil spilled in the collection tube.

4.3.4 Product Prototype of Oil Filter

The oil filter prototype was developed to make it easier for students to filter dirty oil. The results of filtering dirty oil can be resold to used oil collectors because the quality is better than before filtering. Figure 8 shows the design of the oil filter product (a) and the prototype of the oil filter product (b). The working mechanism of the tool is that dirty oil is poured into the oil filter and allowed to flow down to the oil reservoir. The oil filter will adsorb the impurities carried by the dirty oil.

Figure 8. Oil Filter Design (a) and Oil Filter Prototype Product (b)

(a) (b)

The integration of science disciplines in this prototype is that students make oil filters using the principle of adsorption. The adsorbents used are coconut fiber, clay, cloth, sponge, palm fiber, and charcoal. Coconut fibers and palm fibers are used to filter out dirt and pebbles mixed with used oil. Cloth and sponge absorb water mixed with used oil, while clay is used as a lead adsorbent in used oil. Clay and activated charcoal can be used to adsorb metal-metal cations in oil.

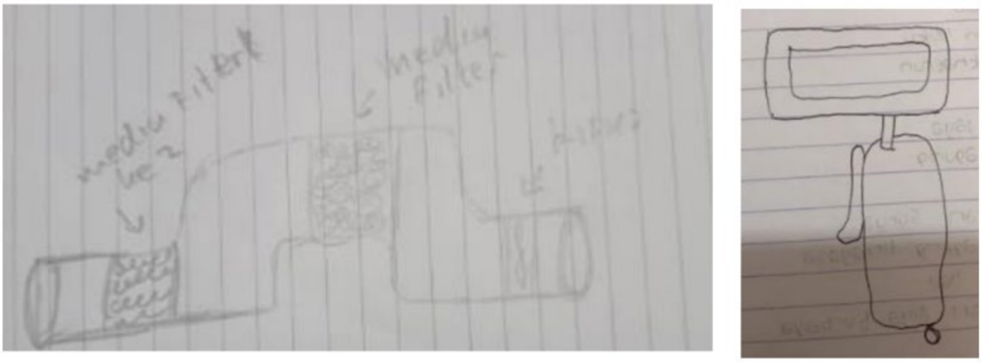
The integration of technology disciplines in the development of this prototype is that the prototype is used to reduce used oil waste that has been used and make it easier for students to reprocess used oil. The hope is that filtering used oil produces high-quality base oil that can be sold back to used oil collectors. The integration of engineering disciplines in developing this prototype is achieved by students designing prototypes using the principle of dirty water filtration. Students provide additional adsorbents such as sponges and cloth.

The integration of the discipline of mathematics in this development allows students to measure the volume of used oil resulting from used oil filtration. In addition, students can measure the time used in the used oil filtration process. Students can also calculate the profit of selling the base oil produced.

4.3.5 Prototype Design of Air Pollution Filter and Used Oil Collection Tank

The development of the prototype air pollution filter and the use of the oil reservoir only reached the design stage. Figure 9 shows the design of the air pollution filter prototype (a) and the design of the used oil container (b). The air pollution filter prototype filters air pollution, while the oil reservoir collects used oil. At this stage, the STEM sciences integrated in the prototype design are science and engineering.

Figure 9. Product Design of Air Filter (a) and Used Oil Container (b)



(a) (b)

The integration of science disciplines in developing air pollution prototype design is that students utilize the air filtration principle to design air pollution filter prototypes. This means that students can analyze the impact of air pollution on the environment and health. The integration of engineering disciplines used is that students design a prototype with two air filter rooms and an air suction room. The air filter room is used to adsorb gases from air pollution, while the air suction room contains a fan that is used to suck air.

The integration of science disciplines in developing the used oil reservoir prototype design allows students to isolate waste oil because used oil waste contains heavy metals such as lead. This means that students can analyze the impact of used oil on the environment and health. Integrating engineering disciplines allows students to design a prototype of a used oil catch basin, but students need to explain the parts of the used oil catch basin.

Limitations in the research that has been carried out, namely the assessment of the level of student creativity, are only carried out in classes that apply for STEM-based hydrocarbon and petroleum compounds programs with PjBL models integrated with vocational contexts. The application of the STEM-based hydrocarbon and petroleum compounds chemistry program integrated with the vocational context could be more optimal because it is done online. Students are unfamiliar with the project activities, so several groups still need to complete the assigned project activities.

6 Conclusions

This study concludes that vocational students' creativity levels are in the Little-Creativity and Mini-Creativity categories. In addition, students' creativity in the process dimension is in the Very High and Fair categories. The Illumination students' creativity in the process indicator is the highest category. Meanwhile, the verification is the lowest category. But, students' creativity in the product dimension is in the Fair and Very Low category. The usability students' creativity in the product indicator is the highest category, while the novelty is the lowest category.

This research implies that the hydrocarbon and petroleum compounds chemistry program based on STEM integrated with vocational context can be used to foster students' creativity ability in automotive vocational schools. The study results can be considered for choosing other chemistry programs to measure students' creativity skills in vocational schools. The researchers' suggestion for further research is to design project-based learning activities more carefully so that project tasks can be done thoroughly. Other researchers can design better Student Worksheets to measure students' creativity skills more optimally. Other researchers can better supervise groups that perform project tasks to see how much students carry out the project development. Other researchers can analyze the creativity ability in both groups (experimental and control) to compare the results of students' creativity abilities after applying the STEM-PjBL-based chemistry program integrated with the vocational context.

Acknowledgement

The authors thanks to The Ministry of Research, Technology and Higher Education, which has financially supported this study within the Master Thesis Research program 2020.

References

Aldabbus, S. (2018). Project-Based learning: Implementation and Challanges. *International Journal of Education, Learning and Development*, *6*(3), 71–79.

Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9–16.

Amrulloh, M. S., & Galushasti, A. (2022). Professional development teacher to improve skills of science process and creativity of learners. *Journal of Education and Learning (EduLearn)*, *16*(3), 299–307. https://doi.org/10.11591/edulearn.v16i3.20404

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for Learning, Teaching, and Assesing: A Revision of Bloom's Taxonomy of Educational Objectives. Diterjemahkan oleh Agung Prihantoro*. Addison Wesley Longman, Inc.

Arends, R. I. (2012). Learning to Teach 9th Edition. In *McGraw-Hill*.

Aydin-Gunbatar, S., Tarkin-Celikkiran, A., Kutucu, E. S., & Ekiz-Kiran, B. (2018). The influence of a design-based elective STEM course on pre-service chemistry teachers' content knowledge, STEM conceptions, and engineering views. *Chemistry Education Research and Practice*, *19*(3), 954–972. https://doi.org/10.1039/c8rp00128f

Banks, F., & Barlex, D. (2014). Teaching STEM in the Secondary School. In *Teaching STEM in the Secondary School*. Routledge. https://doi.org/10.4324/9780429317736

Baran, M., Baran, M., Karakoyun, F., & Maskan, A. (2021). The Influence of Project-Based STEM (PjbL-STEM) Applications on the Development of 21st-Century Skills. *Journal of Turkish Science Education*, *18*(4), 798–815. https://doi.org/10.36681/tused.2021.104

Beghetto, R. A., & Kaufman, J. C. (2014). Classroom contexts for creativity. *High Ability Studies*, *25*(1), 53–69. https://doi.org/10.1080/13598139.2014.905247

Bilgin, I., Karakuyu, Y., & Ay, Y. (2015). The Effects of Project Based Learning on Undergraduate Students' Achievement and Self Efficacy Beliefs Towards Science Teaching. *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(3).

Chang, R. (2010). *Chemistry 10th Edition*. McGraw-Hill.

Chen, S. Y., Lai, C. F., Lai, Y. H., & Su, Y. S. (2022). Effect of project-based learning on development of students' creative thinking. *International Journal of Electrical Engineering and Education*, *59*(3), 232–250. https://doi.org/10.1177/0020720919846808

Chiang, C. L., & Lee, H. (2016). The Effect of Project-Based Learning on Learning Motivation and Problem-Solving Ability of Vocational High School Students. *International Journal of Information and Education Technology*, *6*(9).

Chonkaew, P., Sukhummek, B., & Faikhamta, C. (2016). Development of analytical thinking ability and attitudes towards science learning of grade-11 students through science technology engineering and mathematics (STEM education) in the study of stoichiometry. *Chemistry Education Research and Practice*, *17*(4), 842–861. https://doi.org/10.1039/c6rp00074f

Creswell, J. W., & Cresswell, D. C. (2018). *Fifth Edition Research Design Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publication.

Cropley, D. H., Kaufman, J. C., & Cropley, A. J. (2011). Measuring creativity for innovation management. *Journal of Technology Management and Innovation*, *6*(3), 13–40. https://doi.org/10.4067/s0718-27242011000300002

Faraday, S., Overton, C., & Cooper, S. (2011). *Effective teaching and learning in vocational education*. LSN. www.lsnlearning.org.uk

Fautley, M., & Savage, J. (2007). *Creativity in secondary education*. British Library Catoluguing in publication data.

Febrianto, & Wiyarsi, A. (2018). *Bahan Ajar Kimia Hidrokarbon dan Minyak Bumi untuk Sekolah Menengah Kejuruan (SMK) Teknik Otomotif*. UNY Press.

Fitriyana, N., Wiyarsi, A., Pratomo, H., Marfuatun, Krisdiyanti, A., & Adilaregina, W. (2021). In-Service Chemistry Teachers' Prior Knowledge Regarding STEM Integration in High School Chemistry Learning. *Proceedings of the 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)*, *528*(Icriems 2020), 218–230. https://doi.org/10.2991/assehr.k.210305.033

Gall, M. D., Gall, J. ., & Borg, W. R. (2003). *Educational Research: An Introduction (7th ed.)*. Pearson Education, Inc.

Gilbert, J. K., & Treagust, D. (2009). *Multiple Representations in Chemical Education*. Springer.

Gruszka, A., & Tang, M. (2017). *Handbook of the management of creativity and innovation: theory and practice chapter 3rd*. World Scientific Press.

Hebebci, M. T., & Usta, E. (2022). The effects of integrated STEM education practices on problem solving skills, scientific creativity, and critical thinking dispositions. In *Participatory Educational Research*. dergipark.org.tr. https://dergipark.org.tr/en/pub/per/article/1170048

Henriksen, D., Richardson, C., & Shack, K. (2020). Mindfulness and creativity: Implications for thinking and learning. *Thinking Skills and Creativity*, *37*(June), 1–10. https://doi.org/10.1016/j.tsc.2020.100689

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, *16*(3), 235–266.

Johnson, C. C., Mohr-Schroeder, M. J., Moore, T. J., & English, L. D. (2020). *Handbook of Research on STEM Education*. Routledge. https://doi.org/10.4324/9780429021381-3

Juškevičienė, A., Dagienė, V., & Dolgopolovas, V. (2021). Integrated activities in STEM environment: Methodology and implementation practice. *Computer Applications in Engineering Education*, *29*(1), 209–228. https://doi.org/10.1002/cae.22324

Kaufman, J. C., & Baer, J. (2006). *Creativity and Reason in Cognitive Development*. Cambridge University Press.

Kaufman, J. C., & Sternberg, R. J. (2006). *The International Handbook of Creativity*. Cambridge University Press.

Kiray, A., & Shelley, M. (2018). *Research Highlights in Stem Education*. ISRES Publishing.

Kızkapan, O., & Bektaş, O. (2017). The Effect of Project Based Learning on Seventh Grade Students' Academic Achievement. *International Journal of Instruction*, *10*(1), 37–54.

Krauss, J., & Boss, S. (2014). *Thinking through project-based learning: Guiding deeper inquiry*. Corwin Press.

Lin, K. Y., Wu, Y. T., Hsu, Y. T., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. *International Journal of STEM Education*, *8*(1), 1–15.

Lou, S. J., Chou, Y. C., Shih, R. C., & Chung, C. C. (2017). A study of creativity in CaC 2 steamship-derived STEM project-based learning. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(6), 2387–2404. https://doi.org/10.12973/EURASIA.2017.01231A

Lucas, B., Spencer, E., & Claxton, G. (2012). How to Teach Vocational Education : A Theory of Vocational Pedagogy. *Centre for Real-World Learning, University of Winchester*, *Dec*, 133. http://www.skillsdevelopment.org/PDF/How-to-teach-vocational-education.pdf

Mahenthiran, S., & Rouse, P. J. (2000). The impact of group selection on student performance and satisfaction. *International Journal of Educational Management*, *14*(6), 255–264. https://doi.org/10.1108/09513540010348043

Mayasari, T. (2017). *Efektivitas program perkuliahan ipa terapan melalui pembelajaran berbasis proyek dengan pendekatan stem untuk meningkatkan kreativitas, literasi stem dan penguasaan konsep calon guru*. Universitas Pendidikan Indonesia.

Meda, L. (2023). *Effective Pedagogical Skills for a 21st Century Teacher Reflections, Theories and Practice*. Nova Science Publishers.

Miller, M. D., Linn, R. L., & Gronlund, N. E. (2008). *Measurement and assessment in teaching*. Prentice Hall.

Mursid, R., Saragih, A. H., & Hartono, R. (2022). The Effect of the Blended Project-based Learning Model and Creative Thinking Ability on Engineering Students' Learning Outcomes. *International Journal of Education in Mathematics, Science and Technology*, *10*(1), 218–235. https://doi.org/10.46328/ijemst.2244

Muzana, S. R., Jumadi, Wilujeng, I., Yanto, B. E., & Mustamin, A. A. (2021). E-STEM project-based learning in teaching science to increase ICT literacy and problem solving. *International Journal of Evaluation and Research in Education*, *10*(4), 1386–1394. https://doi.org/10.11591/IJERE.V10I4.21942

Mystakidis, S., Christopoulos, A., & Pellas, N. (2022). A systematic mapping review of augmented reality applications to support STEM learning in higher education. In *Education and Information Technologies* (Vol. 27, Issue 2). Springer US. https://doi.org/10.1007/s10639-021-10682-1

Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability (Switzerland)*, *12*(21), 1–16. https://doi.org/10.3390/su12218865

Niancai, L., Zhuolin, F., & Qi, W. (2024). Education in China and the World. In W. Qi (Ed.), *Education in China and the World*. Shanghai Jiao Tong University Press. https://doi.org/10.1007/978-981-99-5861-0

Ozkan, G., & Umdu Topsakal, U. (2021). Exploring the effectiveness of STEAM design processes on middle school students' creativity. *International Journal of Technology and Design Education*, *31*(1), 95–116. https://doi.org/10.1007/s10798-019-09547-z

Park, D. Y., Park, M. H., & Bates, A. B. (2018). Exploring young children's understanding about the concept of volume through engineering design in a STEM activity: A case study. *International Journal of Science and Mathematics Education*, *16*(2), 275–294. https://doi.org/10.1007/s10763-016-9776-0

Partnership for 21st Century Skills. (2007). *Framework for 21st Century Learning*. *2019*. Ohio Department of Education.

Prajoko, S., Sukmawati, I., Maris, A. F., & Wulanjani, A. N. (2023). Project based learning (PjBL) model with STEM approach on students' conceptual understanding and creativity. *Jurnal Pendidikan IPA Indonesia*, *12*(3), 401–409. https://doi.org/10.15294/jpii.v12i3.42973

Primadianningsih, C., Sumarni, W., & Sudarmin, S. (2023). Systematic literature review: analysis of ethno-STEM and students chemistry literacy profile in 21st century. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 650–659. https://jppipa.unram.ac.id/index.php/jppipa/article/view/2559

Rahayu, S., Setyosari, P., Hidayat, A., & Kuswandi, D. (2022). The effectiveness of creative problem solving-flipped classroom for enhancing students' creative thinking skills in online physics educational learning. *Jurnal Pendidikan IPA Indonesia*, *11*(4), 649–656. https://doi.org/10.15294/jpii.v11i4.39709

Rahmawati, Y., Andanswari, F. D., Ridwan, A., Gillies, R., & Taylor, P. C. (2020). STEM project-based learning in chemistry: Opportunities and challenges to enhance students' chemical literacy. *International Journal of Innovation, Creativity, and Change*, *13*(7), 1673–1694.

Rani Satyam, V., Savić, M., Cilli-Turner, E., El Turkey, H., & Karakok, G. (2022). Exploring the role of students' views of creativity on feeling creative. *International Journal of Mathematical Education in Science and Technology*, *53*(1), 151–164.

Rhodes, M. (1961). An Analysis of Creativity. *The Phi Delta Kappan*, *42*(7), 305–310. www.oster.erd/stbnjl/

Roffey, S., & Quinlan, D. (2021). Positive education with disadvantaged students. In *The Palgrave Handbook of Positive Education*. https://doi.org/10.1007/978-3-030-64537-3_25

Ruhana, F., Rochmah, E. Y., Pada, A., Suryani, Y., & Rizki, A. M. (2024). Developing creativity and innovation in STEM curriculum: Project-based approach In secondary education. *Educational Administration: Theory and Practice*, *30*(5), 7188–7195. https://doi.org/10.53555/kuey.v30i5.4123

Runco, A. M., & Kim, D. (2018). *Reference Module in Neuroscience and Biobehavioral*. Elsevier inc.

Saimon, M., Lavicza, Z., & Dana-Picard, T. (Noah). (2023). Enhancing the 4Cs among college students of a communication skills course in Tanzania through a project-based learning model. *Education and Information Technologies*, *28*(6), 6269–6285. https://doi.org/10.1007/s10639-022-11406-9

Saricam, U., & Yildirim, M. (2021). The effects of digital game-based STEM activities on students' interests in STEM fields and scientific creativity: Minecraft case. *International Journal of Technology in Education and Science*, *5*(2), 166–192.

Schunk, D. H. (2020). *Learning Theories: An Educational Perspective Eight Edition*. Pearson Inc.

Shalley, C. E., Zhou, J., & Oldham, G. R. (2004). The effects of personal and contextual characteristics on creativity: Where should we go from here? *Journal of Management*, *30*(6), 933–958. https://doi.org/10.1016/j.jm.2004.06.007

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of problem-based learning (PBL) in STEM education: Using expert wisdom and research to frame educational practice. *Education Sciences*, *12*(10). https://doi.org/10.3390/educsci12100728

Sudjimat, D. A. (2016). Implementation of project based learning model in mechanical machining skills package of vocational high school. *AIP Conference Proceedings*, *1778*(030024), 1–7. https://doi.org/10.1063/1.4965758

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11–21. https://doi.org/10.15294/jpii.v9i1.21754

Supena, I., Darmuki, A., & Hariyadi, A. (2021). The influence of 4C (constructive, critical, creativity, collaborative) learning model on students' learning outcomes. *International Journal of Instruction*, *14*(3), 873–892. https://doi.org/10.29333/iji.2021.14351a

Taber, K. S. (2020). Mediated Learning Leading Development-The Social Development Theory of Lev Vygotsky. *Science Education in Theory and Practice: An Introductory Guide to Learning Theory*, 277–291. https://doi.org/10.1007/978-3-030-43620-9_19

Tan, J. C. L., & Chapman, A. (2016). *Project-Based Learning for Academically-Able Students*. Sense Publishers.

Thaha, H., Fitriyana, N., & Mulyopratikno, F. (2021). the Comprehension of Chemistry Teacher Toward Stem Integration in Chemistry Learning. *Jurnal Kependidikan: Penelitian Inovasi Pembelajaran*, *5*(1), 85–97. https://doi.org/10.21831/jk.v5i1.36336

The Minister of Education Susil Premajayantha. (2023). *STEM education method implemented in 96 countries in the world is included in the education system of this country*. The Minister of Education Sri Langka. https://moe.gov.lk/2023/03

Trevallion, D., & Nischang, L. C. (2021). The creativity revolution and 21 st century learning. *International Journal of Innovation, Creativity and Change*, *15*(8), 1–25. https://www.ijicc.net/images/Vol_15/Iss_8/15800_Trevallion_2021_E_R.pdf%0Awww.ijicc.net

Uludüz, Ş. M., & Çalik, M. (2022). A thematic review of STEM education for disadvantaged students. *Canadian Journal of Science, Mathematics and Technology Education, 22*(4), 938–958. https://doi.org/10.1007/s42330-022-00247-w

Uziak, J. (2016). A project-based learning approach in an engineering curriculum. *Global Journal of Engineering Education*, *18*(2).

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing and Health Sciences*, *15*(3), 398–405. https://doi.org/10.1111/nhs.12048

Vieira, M., Kennedy, J. P., Leonard, S. N., & Cropley, D. (2024). Creative self-efficacy: Why It matters for the future of STEM education. *Creativity Research Journal*, *00*(00), 1–17. https://doi.org/10.1080/10400419.2024.2309038

Vygotsky, L. S. (1978). *Mind in Society: The Develpment of Higher Psychological Processes*. President and Fellows of Harvard College.

Widyastuti, R., & Utami, I. S. (2018). Development of product-based job sheet as instructional media in vocational education. *Journal of Educational Science and Technology (EST)*, *4*(2), 119–125. https://doi.org/10.26858/est.v4i2.6064

Wiyarsi, A., Partana, C. F., & Sulistyo, B. (2017). *Pedoman Kurikulum Kimia terintegrasi Konteks Kejuruan untuk SMK Program Teknik Otomotif*. LPPM Universitas Negeri Yogyakarta.

Wiyarsi, A., Pratomo, H., & Priyambodo, E. (2020). Vocational high school students' chemical literacy on context-based learning: A case of petroleum topic. *Journal of Turkish Science Education*, *17*(1), 147–161. https://doi.org/10.36681/tused.2020.18

Wu, T. T., & Wu, Y. T. (2020). Applying project-based learning and SCAMPER teaching strategies in engineering education to explore the influence of creativity on cognition, personal motivation, and personality traits. *Thinking Skills and Creativity*, *35*(May 2019), 100631. https://doi.org/10.1016/j.tsc.2020.100631