Journal of Turkish Science Education, 2025, *22*(3), 488-507.
DOI no: 10.36681/tused.2025.025

Journal of Turkish Science Education
http://www.tused.org
© ISSN: 1304-6020

Ethno-STEAM science learning to improve prospective teachers' creative thinking and problem-solving skills

Woro Sumarni[1], Sri Kadarwati[2], Endang Susilaningsih[3]

[1]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, Corresponding author, worosumarni@mail.unnes.ac.id, ORCID ID: 0000-0002-5865-087X*
[2]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0002-4530-1996*
[3]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0002-7427-1562*

ABSTRACT
This study was aimed at improving the creative thinking and problem-solving skills of prospective teachers and to identify the relationship between those skills during science learning using the Ethno-STEAM approach. The quantitative study was carried out with a pre-experimental design. The research design was a one-shot case study. The research subjects were 80 prospective teachers from two universities. The research instrument used was a test to measure creative thinking skills and problem-solving. The data were analysed using the N-gain test. The Pearson product moment correlation test was used to determine the relationship between creative thinking skills and problem solving. The results of the study showed that the students' creative thinking and problem-solving skills increased after the application of science learning with the Ethno-STEAM approach with the N-gain value in the medium category. A fair relationship between creative thinking and problem-solving skills was observed (r = 0.679).

RESEARCH ARTICLE

ARTICLE INFORMATION
Received: 14.10.2023
Accepted: 10.06.2024
Available Online: 22.09.2025

KEYWORDS:
Creative thinking, ethno-STEAM, problem solving, science learning.

To cite this article: Sumarni, W., Kadarwati, S., & Susilaningsih, E. (2025). Ethno-STEAM science learning to improve prospective teachers' creative thinking and problem-solving skills. *Journal of Turkish Science Education, 22*(3), 488-507. http://doi.org/10.36681/tused.2025.025

Introduction

The ability of the teacher to think creatively is directly tied to the level of success achieved by pupils in their educational endeavours in the classroom. Creative teachers will become initiators in developing creative thinking skills for their pupils through the learning designs they prepare and implement (Erdogan, 2019). Accordingly, prospective teachers need to be trained in creative thinking so that they may fulfil their roles effectively and educate individuals who are capable of creative thinking (Ramdani, et al., 2021). Teachers who have advanced creative thinking skills have an impact on the achievement of creative thinking of their pupils and increase their interest in science (Ernawati et al., 2022; Zubaidah et al., 2017). The results of previous research have found that creative thinking skills and problem-solving need to be foci for systematic training in the course of the learning process (Kiraga, 2023).

Problem-solving abilities are closely related to creative thinking abilities, and both are essential (Montag-Smit & Maertz, 2017). Teachers with good problem-solving and creative thinking skills can help learners learn how to build their knowledge and use it in creative ways (Yulianti et al., 2020). On the other hand, if teachers lack the ability to think creatively and solve problems, they will be unable to train their pupils to do so, and their pupils may be less able to solve the complicated difficulties they encounter in the real world (Ratnasari et al., 2019; Ulger, 2018).

Attempts are being made to raise this level of expertise through the introduction of novel science educational strategies that forge connections between scientific study and the cultural traditions of the surrounding area. The term "ethno-scientific approach" refers to a method of teaching and learning that integrates learners' cultural backgrounds with scientific concepts (Sarwi et al., 2019). Indonesia is a country of various tribes, religions and cultures, indeed every region in Indonesia has a diversity of cultures that have been passed down from their ancestors. Knowledge in the fields of arts, culture, health, agriculture, agriculture, culinary and others should be used by teachers to improve the learning process and learning outcomes. The ethnoscience approach conditions pupils to learn from the environment, society, and culture that prevail around where they live. The ethno-scientific approach is part of local wisdom and is based on Vygotsky's theory. This theory confirms that cognitive knowledge is acquired through interpersonal and intrapersonal (Sumarni, 2018).

Learning that draws on the scientific expertise of a community has been shown to enhance the critical and creative reasoning abilities of future teachers (Sumarni et al., 2022). Students' favourable attitudes toward science, their creative thinking in the classroom, and their problem-solving skills were all enhanced by the use of an ethnoscience approach during teaching and learning process as previously reported (McCarthy, 2018).

STEAM, which is an acronym for Science, Technology, Engineering, Arts and Mathematics, is a collaborative approach to encourage learners to be able to think broadly about problems that exist in the real world (Costantino, 2018). STEAM develops according to the needs of the times which aims to provide convenience and effective assistance to the community. One of the benefits of STEAM learning is that it helps learners think at a higher level, especially when it comes to being able to think critically about different kinds of information, think creatively when solving a problem, and make decisions supported by good arguments (Ozkan & Topsakal, 2021; Chung et al., 2018).

To develop high order thinking skills (HOTs) in science education, it needs to be supported by a learning system that is able to accommodate the rapid development of technology along with the changing times (Liline et al., 2024). This condition is a strong indication for the world of education to reform its learning strategies. One of the reforms carried out is the application of the STEAM learning model where participants are taught to learn to process through observing, fun activities, recognising patterns and practising creative thinking as well as becoming more skilled in collaborating and communicating in completing a task (Perignat & Katz-Buonincontro, 2018; Quigley et al., 2017; Kim & Bolger, 2017).

Previous studies have reported that ethnic crafts could be integrated in the teaching and learning activities to develop the students' creative thinking, critical thinking and problem-solving skills. The bamboo crafts in Hong Kong have been reported as a good tools to help learners to gain a proper mentality, through cultivating their 21st century skills (Ho & Shih, 2023). The bamboo crafts could appear as the daily life appliances such as cookware, containers and building techniques. In addition, the crafts could also occasionally appear in seasonal festivals or funerals such as bamboo theatres, offerings and lion-dance. One previous study has also reported that the Batik crafts as a traditional in Indonesia could improve pupils' creative thinking skills (Nursalim, 2020). Furthermore, the utilisation of the Batik crafts in the teaching and learning process could also courage the learners to work collaboratively with their friends, in addition to train them to be more critical, particularly in making decisions and solving problems (Rozie et al., 2021).

Bringing indigenous knowledge and practices especially the ethnic crafts into the teaching and learning dynamic has been reported in previous studies. The local culture of Troso woven fabric has been identified as being able to enable pupils to better understand scientific concepts such as compounds and mixtures, heat and energy transfer, including measurement processes (Khusniati et al., 2023). The integration of such teaching and learning activities with STEAM education could be beneficial and have a big impact on the development of 21st century skills. The traditional game Pesapean in Madura culture has been reported to be able to develop the collaborative skills (Qomaria & Wulandari, 2022). The skill aspects were contribution, motivation, time-management and problem-solving skills, group dynamics, and interaction with other group members. The exploration of STEAM aspects in the traditional festival in Bali was also studied and the results could be used during the teaching and learning of social arithmetic – a mathematical subject that studies social life, such as buying and selling activities (Puspadewi et al., 2022). The traditional musical instrument Kacaping was reported to be able to enhance problem-solving skills and learners' motivation towards preserving local wisdom in South Sulawesi. Ethno-science-integrated STEAM provides a framework for integrating these various fields. The science learning programme incorporating the ethno-STEAM approach provides for learning the basic science concepts inherent in indigenous science on aspects of science, environment, technology, art and mathematics. The ethno-STEAM approach is also used as the basis for this research to improve these skills through learning that connects formal science concepts (science in schools) with science in society. The ethno-STEAM approach in the science learning as the integration of local wisdom and STEAM approach has not been reported before. This approach offers a holistic and systematic approach in developing learners' creativity and problem-solving skills. On the one hand, the creative thinking and problem-solving skills of prospective teachers during the teaching and learning process using the ethno-STEAM approach need to be clearly corelated. This study aimed to determine the increase in creative thinking skills and problem-solving skills, if any, after prospective teachers took part in science learning with the Ethno-STEAM approach and the relationship between these skills.

Methods

Research Design

The quantitative study was carried out with a pre-experimental design. The research design was carried out with a one-shot case study.

Participants

The subject of this study was the students of the Bachelor of Science Education programme in the 5th semester who have pursued the General Chemistry, Local Wisdom in Science Learning, Integrated Science and its Learning, STEM and Conservation Education courses. The participants of this study were 80 prospective teachers from two universities with the same curriculum. The sampling technique used was the purposive sampling technique. The respondent profile can be seen in Table 1.

Table 1

The profile of the participants involved in this study

Characteristic	University	
	A	B
Male	10	12
Female	35	23
Semester	5	5
Age	20-22 years	20-22 years
Residency	Central Java	Central Java

Learning Activities

The study was carried out in the Chemistry course 'Concepts and applications' learning activities for which are listed in Table 2.

In this study, the overall learning activities were in accordance with the syntax of the project-based learning. This was due to previous findings showing the success of project-based learning, i.e., enhancing the students' creativity, improving the students' learning outcomes and higher-order thinking skills (Ariyatun, 2021; Chung et al., 2022; Habibi et al., 2020). Moreover, the project-based learning integrated with the ethno-STEM aspects could help to improve the students' critical and creative thinking skills science literacy. During the learning, the students were positioned in the condition of posing the problems as the initial stage in collecting and integrating the new knowledge based on their prior knowledge in their daily lives.

Table 2

The learning stages during the teaching and learning activities using ethno-STEAM approach

Meeting	Learning stage	Online	Offline
1	Start With the Essential Question	The students are organised into groups. They are required to read various learning sources related to the Colloidal concept and its application, as well as Polymers and their applications.	The teaching and learning process was started by essential questions that required the students to conduct activities. The topics chosen were closely related to the reality of local wisdom of the community in the students' surrounding, i.e. pottery crafts and traditional Batik.
2	Designing a Plan for the Project and Creating a Schedule	The planning of learning was collaboratively conducted between the lecturers and students through discussion forum available in the e-learning ELENA. The plan consisted of the rules and the selection of activities that could support the project accomplishment.	The lecturers and students collaboratively developed the schedule of activities in accomplishing the project. The activities in this stage were preparing a timeline, deciding the due date when the project should be finished, and providing directions to the students to start the activity with a deep investigation through a primary source person regarding the local wisdom of making pottery and Batik. Supervisors intervened if students went off-track. They were questioned about the ethno-science, ethno-technology, ethno-engineering, ethno-art, and ethno-mathematics on both ethnic crafts.
3-6	Monitor the Students and the Progress of the Project	The lecturers made sure that the students' activities and the progress of the group project were well-monitored through ELENA. The students practised making traditional pottery and Batik. A progress report was submitted through a documentation using Powerpoint® slides and video blog. The monitoring process was conducted using a matrix to record all important activities.	The students presented the progress of their group project, as well as the results of the construction of society's indigenous knowledge related to STEAM in order to be observed by three experts for validation. The class discussion related to the colloidal system concepts and its properties, either directly or indirectly related to the project.
7	Assess the Outcome and Evaluate the Experiences	The students uploaded the project results to be graded. The lecturers evaluate and grade the project results to measure the standard of achievement and provide the feedback regarding the students' understanding level.	The students presented their project results either individually or in groups. In this stage, the students were asked to reveal their feelings and experiences during the project execution. The discussion was performed to improve their communication skills and draw conclusions as a solution towards the problems raised at the first stage.

Learning activities combined online and offline learning. Online learning facilitates inquiry planning, and offline learning activities are conducted to do group investigations. The investigations were carried out by the students in groups involving the local wisdom in some Central Java areas, i.e., traditional Batik crafts and local ceramic industry and then integrated into learning as is shown in Table 3.

Table 3

Local wisdom integrated into learning (pottery and Batik crafts)

Pottery Crafts	
Pottery is often also referred to as ceramics. Pottery/ceramic crafts are works of art made by human hands that use clay as the main raw material which has gone through a burning process. The word ceramic comes from the Greek, namely keramos. This means that glassware is made of clay that has gone through a burning process.	
Ethno-science	
Clay is a complex hydraaluminum silica with the chemical formula $Al_2O_3.nSiO_2.kH_2O$ where n and k are the numerical values of the bonded molecules and vary for the same mass. Clay is used to make various ceramic products such as decorative ceramics, roof tiles, bricks, sinks, kitchen utensils etc. Ceramics are products made from a mixture of inorganic, non-metallic minerals (clay and its admixtures) processed at high temperatures, and shows a crystalline, non-crystalline or a mixture of both structures. One of them for cement materials has the compound formula $Al_2O_3.K_2O.6SiO_2.2H_2O$. Clay mineral particles are usually negatively charged so that clay particles are almost always hydrated, that is, they are surrounded by layers of water molecules which are referred to as adsorbed water. This layer is generally two molecules thick and is therefore called a double diffusion layer. The double diffusion layer is a layer that can attract water molecules or cations around it. This layer will disappear at temperatures higher than 600^oC to 1000^oC and will reduce the natural plasticity. Water can also be lost simply by air drying. When the plastic ceramic body is dried, 3 important processes will occur: (1) Water in the layers between the clay particles diffuses to the surface, evaporates, until finally the particles touch each other and shrinkage stops; (2) Water in the pores is lost without shrinkage; and (3) the water adsorbed on the surface of the particles is lost. These steps explain why the drying process must be carried out slowly to avoid cracking, especially in stage 1. Processing in a too fast way would cause a cracking due to the sudden loss of water without being balanced by the perfect arrangement of the clay particles, which would result in a sudden shrinkage.	
Ethno-technology	
 	Traditional equipment are a printing tool and turntable. Burning was done in an open kiln using a shallow clay pit with a burning grass fire. This pottery-making technique is still used today by some ceramic artists in Indonesia.
Ethno-Engineering	
The stages in making ceramics were interrelated with one another. If the initial process was done well, it would produce a good product, and vice versa; errors in the early stages of the process would produce a low-quality product. Material processing The purpose of processing this material is to process raw materials from various materials that are not ready to use into ready-to-use plastic ceramic bodies. In the processing of materials there are certain processes that	

must be carried out, including reducing grain size, filtering, mixing, stirring, and reducing the water content. Grain size reduction can be done by pulverizing or grinding. Screening is intended to separate materials with inhomogeneous sizes. The commonly used size is 60 – 100 mesh. Mixing and stirring aims to obtain a homogeneous mixture of ingredients. Reducing the water content is carried out in the wet process, where the resulting mixture of materials in the form of sludge is carried out in a further process, namely thickening to reduce the amount of water contained so that it becomes a plastic ceramic body. This process can be done by aerating on a plaster table or by using a filter press. The final stage is homogenising the mass of the clay body and free air bubbles that may be trapped. The ceramic body mass that has been kneaded is stored in a closed container, then cured to obtain maximum plasticity.

Formation

There are 3 formation techniques: hand-building, throwing, and casting. In making ceramics by hand-building, there are several well-known methods, namely: pinching, coiling (to raise or enlarge the ceramics being made), and slabbing (to make square or cylindrical ceramics). Rotary technique is used to produce spherical or cylindrical ceramics. The stages of formation in the rotary technique are: centering, coning, forming, rising, refining the contour. Another technique uses the help of molds made from gypsum. This technique is used to produce ceramics in large quantities with the same shape and size. Printing techniques can be done in 2 ways: solid printing and pouring printing.

Drying technique

The drying technique is carried out to remove plastic water bound to the ceramic body. In order to avoid drying too fast, ceramic objects are allowed to air dry at room temperature in the early stages. After there is no shrinkage, drying in direct sunlight or drying machines can be done.

Burning stage

Burning

Combustion is the heart of making ceramics in that it transforms a brittle mass into a solid, hard, and strong mass. Combustion is carried out in a high temperature furnace. The burning process is carried out continuously in the furnace, for 1 day (12 h). With a temperature range of 600 ºC to 1300 ºC. This temperature must be adjusted to the type of clay. For example, clay which is rather hard does not require a very high burning temperature. On the other hand, clay which is still somewhat soft requires a higher temperature for firing. In addition to making ceramics not easily crushed, the burning process is also intended to make this craft more solid and watertight. During firing, the ceramic body undergoes several important reactions, loss/appearance of mineral phases, and weight loss.

Burning of biscuit/bisque

Burning biscuit/bisque is a very important stage because through this burning an object can be called a ceramic. Biscuit is a term to refer to ceramic objects that have been fired at a temperature range of 700–1000 ºC. Burning biscuits is enough to make something strong, hard, waterproof. For glazed ceramic objects, baking biscuits is the initial step so that the object to be glazed is strong enough and able to absorb the glaze optimally.

Art

Ceramic shapes and motifs

To get an attractive pottery, one of the things a pottery maker does is to give the pottery a decorative motif

Ethno-mathematics

The mathematical concepts contained in pottery can be used as innovative culture-based teaching materials so that students can more easily understand mathematics in everyday life. Mathematical concept of 'mortar' pottery: the mortar seen from above is a circular shape, the mortar seen from the side is a parabolic curve, while the parabolic curve is formed from the slice of a cone.

Other examples of pottery are flower pots, umbrella holders and jars. In this pottery, in addition to the concept of a circle, it can also be used to explain the concept of geometric transformation, namely reflection, because if one centre line is taken, the right side will be the same as the left side. For large flower pots it consists of a combination of parabolic curves, tubes and circles. For the body where the umbrella can also be used to describe the shape of a tube with one part uncovered. There is also a jar shape which is a combination of a circle and a spherical space. The bricks contain the concept of rectangles and blocks.

Mathematical concepts can also be identified in pottery craftsmen's activities which include counting activities, measuring activities, and designing activities. Ethno-mathematics in counting activities appears when the craftsman determines the ratio of raw materials for the mixture or clay and when the craftsman determines the clay needed to make a pottery item. Ethno-mathematics in the counting activity appears when the craftsmen use the term fist to estimate the amount of clay needed. Ethno-mathematics in measuring activities appears when the craftsmen determine the diameter of the base and lid and the height of the pottery. With the activity of calculating the composition of the material, the concept of percent and equivalent of comparisons will emerge.

Batik Crafts

Batik is the art of dyeing cloth with a barrier dyeing technique using wax. Batik is one of the popular ancient art forms in Indonesia which has gone worldwide and is recognized by many countries. Batik has been designated by UNESCO as Masterpieces of the Oral and Intangible Heritage of Humanity since October 2, 2009.

Ethno-science

Raw materials for making batik:

1) 'mori' cloth, which is a white material made of cotton (cellulose),
2) melted wax (a mixture of paraffin, microcrystalline and beeswax used to cover parts of the fabric that will be left plain/undyed).
3) starch liquid is a type of colloidal sol (solid in liquid)
4) Peanut oil solution belongs to the colloidal type of water-in-oil emulsion,
5) dyes natural belong to the type of colloidal sol (solid in liquid).
6) The smoke produced from burning wood in the process of pelorodan/boiling to remove batik wax is a type of colloidal aerosol (solid in gas)
7) *'lerak'* soap to remove dirt without fading the color of the batik

Ethno-technology

making batik uses more traditional tools passed down by the ancestors. Equipment in the batik process include: 1) *'canthing'* is a tool made of copper and the handle is made of bamboo. Used to take liquid wax from the pan to be etched on the surface of mori. Wax is the main ingredient used to make motifs on cloth. 2) a small frying pan as a container for heating the wax so that it melts, 3) *'Anglo'* (furnace for heating wax), and 4) *'gawangan'*. *'Gawangan'* is a tool for placing mori when batik is made. It is made of wood or bamboo so it is light and easy to move around.

Ethno-Engineering

Several things must be considered in order to obtain good batik cloth, starting from the preparation of the material. The processing of 'mori' into batik cloth is divided into 2 processes, namely the preparation process and the process of making batik. The preparation process is a series of work on mori so that it becomes a cloth that is ready to be made into batik. This preparatory work includes *'Nggirah'* (washing) and *'Ngetel'*. *'Ngetel'* is removing starch from the mori by wetting the mori with a solution of peanut oil, ash soda, typol and enough water, then drying it. This process is done so that the dye can seep into the fabric fibers perfectly.

When making batik, the temperature of the wax must be hot enough so that the wax seeps into the pores of the fabric.

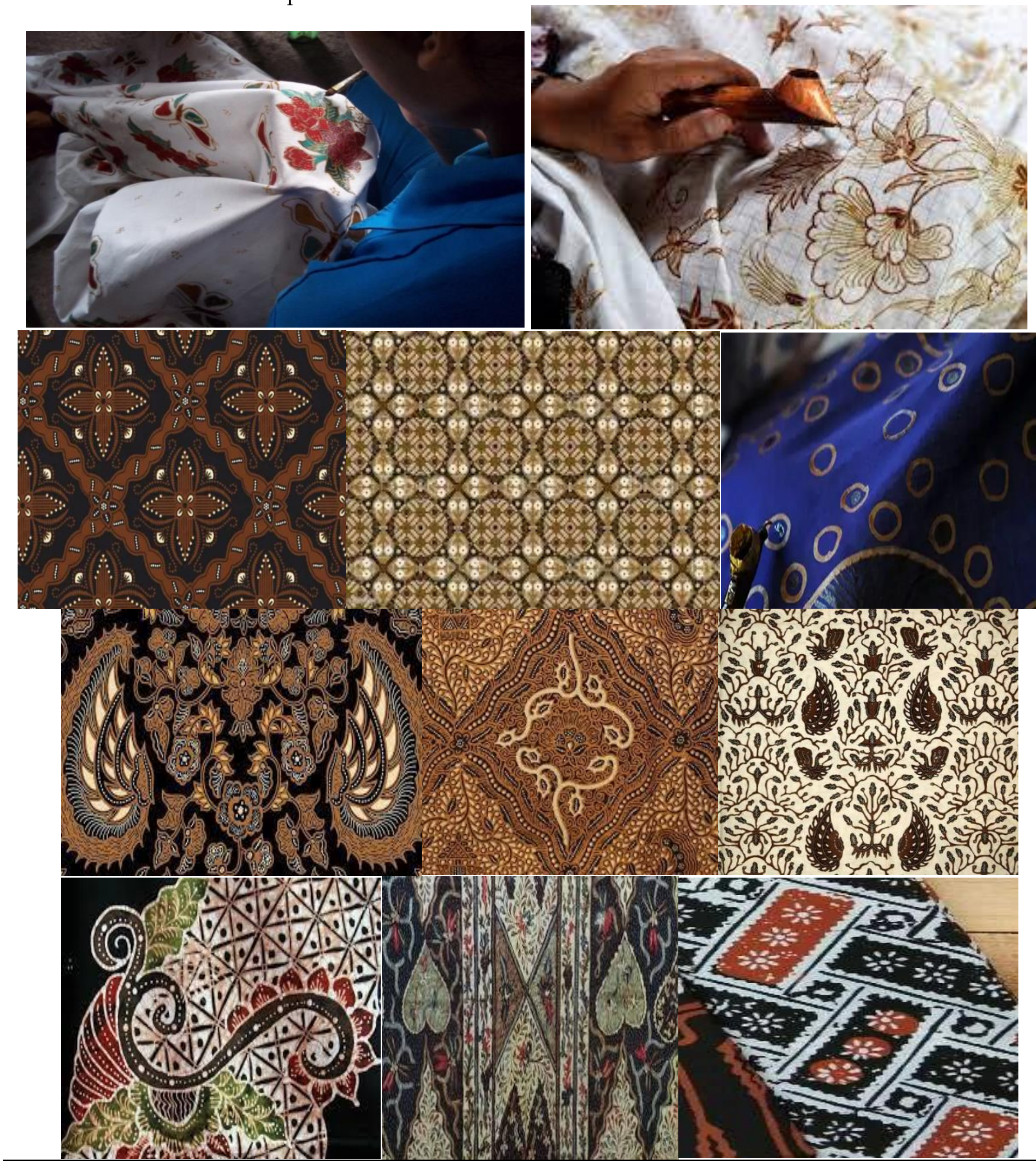
In the coloring process, batik dyeing starts from the lightest color and ends with the darkest color.

Natural dyes are used in traditional batik, especially dyes derived from plants, such as those found in wood, bark, roots, root bark, seeds, seed coats, leaves and flowers. Plants commonly used for batik dyes include mengkudu root (*Morinda citrifolia*) which produces a red color, tegeran wood (*Cudrania javanensis*) which produces a yellow color, tingi wood (*Ceriops tagal*) which produces a brown color, indigo or indigo leaves (Indigofera sp.) which produces a blue color, and mango leaves (*Mangifera indica*) which produces a green color. Besides that, there are jolawe (elaocorpus folium), tegeran (Cudraina javanensis), Jati (*Tectonagrandis*), secang (*Caesalpinia sappan* Flem.), mengkudu (*Morinda citrifolia*), coconut (*Cocos nucifera*), durian (*Durio zibethinus* L.), mangrove (*Rhizophora mucronata*), and mangosteen (*Gracinia mangostana*).

One of the techniques carried out as an effort to prevent the color of batik from fading and maintaining its quality, when drying batik cloth, is best done in the shade and when washing batik cloth, do not use detergent, but use soap/'*lerak*'.

Art

Art in various written batik patterns



Ethno-mathematics
The process of making batik, if it is connected with mathematics, includes counting, measuring, and counting activities. Mathematical concepts contained in Batik motifs, for example, are straight lines, curved lines, parallel lines, symmetry, points, angles, rectangles, triangles, circles, parallelograms and the concept of congruence. The ethnomathematics contained in Jember batik motifs is geometric transformation which includes translation, rotation, reflection and dilation (Milenia et al., 2022).
The Kangkung Setingkes batik motif, if it is related to mathematics, it is one of the geometrical motifs. The geometric elements in the Kangkung Setingkes batik motif are in the form of points, lines, angles, congruence, congruence, and geometric transformations. One element in the Kangkung Setingkes batik motif can be arranged based on the concept of geometric transformation, namely translation, rotation, dilation, and reflection.
The mori needed is adjusted to the desired short length of cloth, usually rectangular in shape. There is no exact measure of the length of mori cloth because usually the cloth is measured traditionally. The traditional size is called *'kacu'*. *'Kacu'* is a handkerchief, usually square in shape. So, what is called "*sekacu*" is the square size of the mori, taken from the width of the mori. Therefore, the *'sekacu'* length of one type of mori will be different from the *'sekacu'* length of other types of mori. But nowadays, this measure is rarely used. It is easier for people to use the square meter measurement to determine the length and width of mori cloth. The national size is 1 piece of cloth 2.1 x 1.15 m.

Data Collection Tools

The data collection tools used in this study were the assessment instruments for creative thinking and problem-solving skills, as well as in-depth interviews about local wisdom of batik and ceramics. Evaluation of creative thinking and problem-solving abilities was done by using a standardised testing procedure.

Instruments to Assess Creative Thinking Skills

The open-ended test instrument for creative thinking skills consisted of 6 items and problem-solving consists of 10 items that had been declared valid by Indonesian experts and tested. In this study, creative thinking skills were assessed on four aspects: fluency, flexibility, originality and elaboration, while problem-solving skills were assessed through understanding, planning, implementing plans and evaluating problem plans. The aspects of fluency include the ability to solve problems and provide many answers to these problems; or provide many examples or statements related to a particular concept or context. The aspects of flexibility include skills of using a variety of problem-solving strategies; or providing various examples or statements related to a particular concept or situation. The aspects of authenticity include the ability to use new, unique, or unusual strategies to solve problems; or provide the new, unique, or unusual examples or statements. The detail aspects of elaboration included the ability to explain certain procedures, answers or situations in detail, coherently and coherently. These explanations used the appropriate concepts, representations, terms or formulae.

Calculation of test reliability using Alpha Cronbach showed the reliability of the creative thinking test instrument with alpha values of 0.812 and 0.714 for problem solving test items. The time allotted to complete this test is 120 min.

Data Collection Procedure

The data collection was carried out after the learning activities had been completed. The test was given to 80 students who were taking the course of "Chemistry: Concepts and Applications using an ethno-STEAM approach". To collect the data, a "paper and pencil" test was used. The test included an evaluation of students' creative thinking and problem-solving skills.

Data Analysis

The data collected from both tests and interviews were analysed using descriptive statistics and content analysis. The experts' validation was used as the main consideration in deciding whether a local wisdom-containing activity that was explored by the students could be categorized as an ethno-science, ethno-engineering, ethno-technology or ethno-mathematics. Three experts in ethno-STEM-based education have been involved in this study to make validation on the results of exploration and reconstruction of the indigenous knowledge in relation with the STEM activity performed by the students. The obtained quantitative data from the test was analysed using normalised gain values and statistical techniques to identify the Pearson correlation between creative thinking and problem-solving skills.

The gain value was calculated according to Hake (1998) using the equation (1). N-gain (%) obtained by each student both as a whole and per indicator are categorised as in Table 4.

$$N - gain\ (\%) = \frac{score\ postest - score\ pretest}{score\ maximal - score\ pretes}\ x\ 100\% \quad (1)$$

Table 4

Category for increasing the ability to think creatively and solve problems

Percentage (%)	Category
70 < % ≤ 100	High
29 < % ≤ 70	Medium

Table 5

Interpretation of the correlation coefficient

r value	Interpretation
0.00-1.199	Very weak
0.20-0.399	Weak
0.40-0.599	Medium
0.60-0.799	Strong
0.80-1.000	Very strong

The qualitative data collected from interviews was analysed using content analysis to obtain information regarding students' insight into local wisdom around them in relation to STEAM. This analysis aims to reveal students' views on efforts to strengthen local wisdom values in the digital era, as well as factors that influence the understanding and application of local wisdom values in everyday life.

Findings

The Impact of Ethno-STEAM Learning on Improving Creative Thinking Skills

The average value of N-gain for creative thinking skills is presented in Table 6. Table 6 shows that the average N-gain of creative thinking skills is in the moderate category. The magnitude of this N-gain indicates that ethno-STEAM learning positively influences students' creative thinking abilities. The results of calculating the average score for each aspect of creative thinking skills are presented in Figure 1.

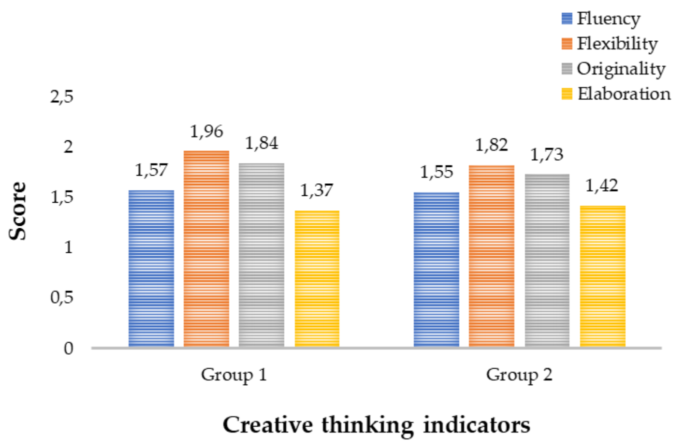
Table 6

The average value of N-gain creative thinking skills

Variable	Subject	Pretest mean	Posttest mean	Gain average score	Achievement level
Creative thinking	Group 1	1.33	6.36	0.3020	Moderate
	Group 2	0.35	5.75	0.3047	Moderate

Figure 1

Indicators of creative thinking skills



Based on Figure 1, it appeared that of the four aspects measured, the aspect of flexibility got the highest average score, followed by fluency and originality, and the lowest was elaboration/detail. This result followed the research by Ramdani et al. (2021) and Hidayati et al. (2023), where the increase in creative thinking in the elaboration aspect was the lowest after the highest originality, flexibility, and fluency. Different results were found by (Habibi, et al., 2020), which stated that the achievement of creative thinking skills in the originality aspect was the lowest, while the elaboration aspect was the highest. In the context of educational assessment, it is unlikely that students will generate completely new ideas that have never been generated before. Thus, in this research, an idea although not new in an absolute sense, can still be considered creative. For example, a student was considered to have produced an original idea when the idea generated is different when compared to the ideas of their classmates (Heard et al., 2025; Lucas, 2016).

The research results on flexibility for groups 1 and 2 obtained an average of 1.89 from the maximum value scale of 3. The aspect of flexibility obtained the highest average score compared to other aspects. This is as conveyed by Kenett et al., (2018). An indicator of flexibility in creative thinking is that students can provide alternative ideas/solutions with different and correct answers to solve the problem of clay scarcity because many clay quarrying locations have turned into housing or industrial areas. The average experimental class students could provide answers that varied from one to another of the four alternative answers given. Prospective teachers are presented with water pollution problems due to dyes and other materials from batik industry waste. The solution is to treat waste before it is discharged into the waters, bioremediation in rivers and waters, and ask the industry to pay attention to the waste disposal process, using natural dyes in the colouring process. Examples of ideas conveyed by prospective teachers vary from one to another.

The Impact of Ethno-STEAM Learning on Improving Problem-Solving Skills

Gain scores of problem-solving skills are presented in Table 7. Table 7 shows that the problem-solving skills obtained through the ethno-STEAM approach science learning programme are in the medium category. Learning programmes that present problems found in everyday life and involve students in finding solutions to problems can train them in problem-solving thinking skills. Problems with pottery and batik craftsmen are related to raw materials, the decreasing number of artisans, and efforts to increase creativity so that products are competitive and of good quality. The problem of pollution in the environment of the batik and pottery industry also requires thought so that it is not harmful to living things and their environment. These problems were explored by prospective teachers who conducted investigations to find solutions based on STEAM aspects in this study (Bertrand & Namukasa, 2023). The results of the analysis of the achievement of each aspect of problem-solving skills are obtained as presented in Figure 2.

Table 7

Problem-solving score gain

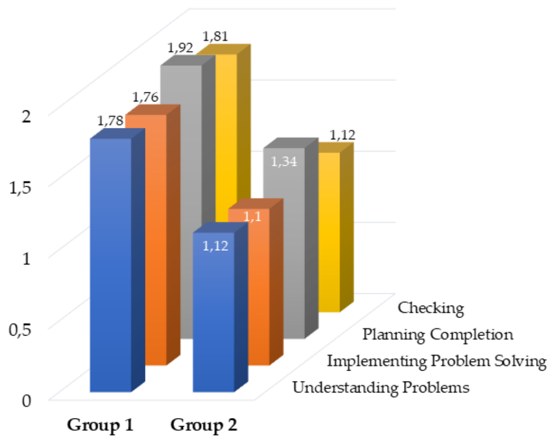
Variable	Subject	Pretest mean	Post-test mean	Gain average score	Achievement level
Problem-solving	Group 1	14.50	29.77	0.31	moderate
	Group 2	3.75	21.50	0.30	moderate

The results of the research indicator of understanding the problem on average are 1.45, with a maximum score of 3. The indicator of understanding the problem is the highest compared to other indicators. Students can write questions about polluted rivers and waters due to batik waste. On average, students can understand the problems marked by students being able to write science concepts, formulate questions, determine the main factors, and map problems. The study's results showed that the indicator for planning a solution averaged 1.63 out of a maximum score of 3. The indicator for planning for solving problems was the lowest compared to other indicators. Students only mentioned answers to science concepts but did not explain the relationship between concepts in the problem.

Individual characteristics in problem-solving are applying and using the right mathematical equations following the concepts, principles, rules, formulae and laws to solve problems (Ida et al., 2021). The study's results showed that the indicator of carrying out problem-solving averaged 1.43 out of a maximum score of 3. The indicator of carrying out problem-solving had the third highest acquisition. On the whole, students can write science concepts to solve river and water pollution problems due to batik waste. Those results indicate that the students able to implement problem-solving.

Figure 2

The average score of the problem-solving skill aspects



Correlation between Creative Thinking Ability and Problem-Solving Skills

Table 8 presents the findings of the correlation test conducted between creative thinking and problem-solving skills. The results of the correlation test between the variables of problem-solving and creative thinking skills are shown in Table 6, and they indicate a link with a value of 0.679. According to the interpretation of the correlation table, the correlation between the capacity to creatively think and the ability to solve problems falls into a category that is classified as very strong. Thus, it can be inferred that there is a positive and very substantial link between creative thinking and problem-solving skills. This correlation follows the findings of other researchers who found that there is a positive relationship between creative thinking and problem-solving skills (Meitiyani, et al., 2021).

Table 8

Correlation test of creative thinking and problem-solving skills

		Problem-solving	Creative thinking
Problem-solving	Pearson Correlation	1	0.679
	Sig. (2-tailed)		0.001
	N	80	80
Creative thinking	Pearson Correlation	0.679	1
	Sig. (2-tailed)	0.001	
	N	80	80

*** Correlation is significant at the 0.01 level (2-tailed).*

Discussion

Ethno-STEAM is a learning approach as an integration of two learning approaches, i.e., ethno-science approach and STEM aspects. Ethnoscience includes an activity to explain the indigenous science (knowledge developing in a society) in the scientific science point of view. In this case, if the teachers and lecturers wanted to implement the ethnoscience-integrated learning, they were required to understand and recognise the local practices and its potencies to be utilised during the learning process. STEAM is a learning approach relating the science, technology, engineering, art and mathematics strongly emphasized in the 21st century learning.

Scientifically, a learning could be categorized as a ethno-STEAM learning should fulfil the followings.

a. In the context of learning, the ethno-STEAM is a project-based learning model that could be used by the students to overcome the challenges and problems, as well design the problem solving.
b. This model integrates the methodological and conceptual aspects/elements to direct the students in designing and solving the problems using a practical approach.
c. This process is modelled based the stages similar to an engineering design process. First, the students are directed to identify the problems or needs that are essential to be solved, provide an initial understanding to the objectives of the project. After a while, the students would learn to collect/gather the relevant information and data through research and analysis. The subsequent process would involve the concept formulation; the students are invited to creatively think and result various design ideas as potential and effective solutions. In addition, the students are required to evaluate and do some improvements on the solution.
d. During the implementation of learning, the lecturers accommodate the formation of constructive learning environment; the lecturers as widely as possible would facilitate the information search on the local wisdom and analysis of the concepts containing in the local wisdom.
e. The lecturers as a facilitator, motivator, manager and supervisor should provide the students with motivation and feedback regarding the progress of the project they are working on.

The Impact of Ethno-STEAM Learning on Improving Creative Thinking Skills

From Figure 1, it can be seen that the aspects of fluency in groups 1 and 2 attain an average of 1.56 from the maximum value scale of 3. The aspect of fluency in creative thinking got the second highest rank after flexibility. This aspect of flexible thinking was shown by students being able to write down creative ideas to solve the problem of environmental damage due to pottery making by providing correct, complete, systematic, and acceptable explanations to all groups. On average, students can provide answers to more than three solutions to problems. Creative ideas for teacher candidates arose when given the problem of the difficulty of obtaining raw materials for making pottery. Apart from that, other ideas presented were innovations in shapes, colours, and motifs. The answers given by more than one student indicating that prospective teacher students in general already have fluent thinking (Larraz-Rábanos, 2021).

The originality aspect is measured when prospective teachers are presented with the problem of pottery craftsmen delaying the production process due to the rainy season so that the pottery they produce does not dry quickly. As a result, pottery production has decreased. The idea conveyed by prospective teachers regarding this problem is to use technology to dry pottery to fulfil the value of authenticity. Making an oven around the printing process is one of the original ideas because, so far, this technology has not been applied by craftsmen. The research results showed that originality aspect data for groups 1 and 2 obtained an average of 1.76 from a maximum value scale of 3. The indicator of originality in creative thinking has the third-highest score. The original indicator of creative thinking is that students can write down creative ideas to solve problems faced by pottery and batik craftsmen correctly and have original (unique/out of the box) characteristics (Ariyatun, 2021). The average student of the experimental class can provide unique answers.

For the elaboration aspect, the data from groups 1 and 2 obtained an average of 1.40 from the maximum value scale of 3. The detail indicator in creative thinking has the smallest gain compared to other indicators. The detailed indicator of creative thinking is that students can correctly write creative ideas to solve batik colouring problems accompanied by detailed explanations. The average student in the experimental class can provide detailed/detailed answers. Prospective teachers are presented with the problem of air pollution for people close to pottery kilns. Their suggestion was to build a chimney and a kiln far from residential areas. These ideas are explained in detail about the shape of a chimney for pottery craftsmen. This indicates that prospective teachers were able to explain their ideas as a solution to these problems.

The increase in the four indicators of creative thinking in this study was not optimal based on the average acquisition being below a value of 2 out of a maximum range of 3. The lack of optimal improvement in creative thinking skills was suspected because students were not used to being given non-routine problems and real problems faced by society. In addition, this learning programme is designed for seven meetings, and students may need more time to develop their thinking skills optimally. According to DeHaan (2009) and Gube & Lajoie (2020) that students tended only to be able to solve problems that they often or have encountered (routine problems) and experience difficulties when facing unusual problems (non-routine problems) so that they can solve routine problems in the form of memorisation and difficulty solving problems that are reasoning. As the results, the learning could help students to produce and develop unique ideas (Ariyatun, 2021; Gube & Lajoie, 2020).

The Impact of Ethno-STEAM Learning on Improving Problem-Solving Skills

Self-evaluation of problem-solving skills involved the activity of re-checking of previous problem-solving and analysing the weaknesses and strengths of problem-solving (OECD, 2014). The results showed that the average problem-solving evaluation indicator for the experimental class was 1.55 out of a maximum score of 3. The second-highest problem-solving evaluation indicator was smaller than the problem-understanding indicator and higher than the other two indicators. This research is in line with what was conveyed by Joynes et al. (2019) that using the ethno-STEAM approach, students' abilities in defining problems, exploring problems, determining alternative solutions, and planning solutions with quite good category. Students were not accustomed to solve problems, especially those requiring linkages between science, technology, and engineering Students also still have difficulty if given complex problems. As seen in the research results, the increase in the problem-solving ability of prospective teachers was only in the moderate category (Wijayati et al., 2019). However, when viewed from the ability to plan and implement strategies, it is still low, possibly due to a common understanding of the science concepts (Yulianti et al., 2020).

Table 6 and Table 7 show that the average N-gain of the research subjects was in the moderate category, both in creative thinking skills and problem-solving skills. The magnitude of this N-gain indicates that Ethno-STEAM learning positively influences students' creative thinking and problem-solving skills. STEAM is the right learning model to provide a holistic competence for students in order to prepare for future challenges dominated by the use of technology, while still appreciating traditional culture (Chung et al., 2022). The increase in problem-solving and creative thinking skills that applies to Ethno-STEAM learning is due to learning activities designed to facilitate processes that develop these two thinking skills (Rohmantika & Kurniawan, 2021). Ethno-STEAM learning in this study presented the community's practices in making pottery and batik by linking science, technology, engineering, art and mathematics. In order to come up with the most effective response, the issue is analysed in groups. Students investigate STEAM-related facets of the community's conventional knowledge as part of the process of determining the best solution. In the local wisdom of making pottery, the colloid concept is associated with the technology of making handicrafts from clay with high-firing techniques. The pottery results from the heating process at high temperatures will produce pottery with a high selling value, especially if it is designed with a unique model and has a varied colour appearance.

Thus, learning that presents problems and carries out investigations to find solutions facilitates the emergence of creative and problem-solving thinking processes (Nur et al., 2020). Teachers may urge pupils to do autonomous research activities or encourage divergent thinking in scientific process skills in order for them to acquire creativity and problem-solving skills via discovery activities. As previously reported, that factors like a) experience in solving problems which can be viewed from memory, problem solving structure, speed and efficiency, and metacognitive monitoring skills; b) self-regulation related to thinking strategies in solving problems; c) the ability to identify problems and breadth of insight; d) the ability to use certain symbols or objects; e) the ability to identify goals, rules, criteria, and assess the correctness of the solutions created; and f) insight/knowledge of the problems (Maltin, 1994). Meanwhile, four factors influencing the students' problem-solving skills are knowledge, beliefs and affect, control and sociocultural factors could influence the problem-solving skills (Carson, 2007).

Correlation between Creative Thinking Ability and Problem-Solving Skills

One context that supports the growth of creative thinking skills is a problem-solving activity. Students need the ability to solve problems, especially complex ones, creatively. The ability to think creatively is a cognitive skill to provide a solution to a user problem and to provide a novelty from simple ideas (Gube & Lajoie, 2020). Problem-solving skills train individuals who take information and use it, criticise, ask questions, and solve problems creatively. Experience, knowledge and intuition applied simultaneously to a single problem are the products of creative thinking that can be quickly and effectively used in problem-solving (Nurita et al., 2017).

Teaching science based on the scientific method could enhance students' degree of creative thinking, academic accomplishment, and attitude toward gaining science information (Cook & Bush, 2018). Learning activities that present challenges, exploring them, and discovering answers to them enhance creative thinking skills. Learning scientific process skills in schools is critical for encouraging creative thinking and developing science professionals' potential and prospects.

Deeper engagement with mathematics at each stage of learning encourages learners to construct in-depth understanding of concepts, while increasing their rigor. During the learning process, the teacher encourages pupils to be involved in the use of mathematical concepts, such as measurement, calculation and the use of tables or graphs (Bertrand & Namukasa, 2020). When they solve problems creatively, they practice fact-based mathematical concepts such as addition, subtraction, division and multiplication of numbers, rotating with angles specific measures, measure/calculate the circumference, area and volume.

In this study, the prospective teacher students were trained to analyse data, create, discover, explore, imagine, present, apply, and alter scientific knowledge. Learners' ability to think creatively in science may be nurtured via the introduction of inquiry-based activities and process skills. Prospective teachers' capacity for original thought and problem solving is honed via exercises drawn from the community's local knowledge and an examination of existing challenges. Students' creative thinking, problem-solving abilities, and curiosity were all found to rise, and a deeper awareness of the world and its possibilities was gained (Sumarni & Kadarwati, 2020; Sumarni et al., 2022).

Conclusion and Recommendations

It can be inferred from the foregoing analysis and discussion that prospective teachers were in the moderate range for critical thinking and problem-solving skills. It may benefit from a more in-depth understanding of scientific concepts by adopting an ethno-STEAM approach to their teaching and learning process. Science education with an ethno-STEAM focus has been shown to help moderately-competence teachers in increasing their capacities for creative thought and problem solving, as shown by the findings and discussions previously presented. The STEAM approach facilitated students to find related concepts in order to solve problems that exist in everyday life. Incorporating STEAM into the classroom helps students make connections between what they study and the actual world, leading to more relevant science education.

In the case of the students' creative thinking skills, the students were observed to not be well acquainted with complex and real problems. They seemed needed more time to get accustomed with the problems and to develop their thinking skills. In this study, it was clearly shown that the non-routine problems introduced to the students could produce unique ideas and thoughts. Meanwhile, in the case of the problem-solving skills, the ethno-STEAM approach in this study could help students to solve more complex problems, especially those requiring linkages between science, technology and engineering. Moreover, the students' conceptual understanding of the basic concepts could help the students in improving their problem-solving skills.

In addition, in the case of the correlation between creative thinking and problem-solving skills, the students' ability to think creatively in science may be nurtured via the introduction of inquiry-based activities and process skills. Prospective teachers' capacity for original thought and problem solving is honed via exercises drawn from the community's local knowledge and an examination of existing challenges. Students' creative thinking, problem-solving abilities, and curiosity were all found to rise, and a deeper awareness of the world and its possibilities was gained. From the ethno-STEAM learning activities, all students explained that they felt happy, excited through the process, wanted to learn more and received challenges that would not be obtained through the learning they were used to.

For educators, researchers and policy makers, the authors recommend applying the ethno-STEAM learning approach as proposed in this study to equip students with immersive learning experiences in science, technology, engineering and mathematics as well as local culture. It is highly recommended that the educators (lecturers and teachers) could use this learning model with the ethno-STEAM approach as an alternative to train the students' creative thinking and problem-solving skills in studying science or other fields of study to address 21st century challenges. In general, the students' creativity would be hampered if students do not have an adequate mathematical basis and do not routinely think correctly. These thinking routines are useful for sparking questions and thoughts about a topic. Questions that should arise as a start include: Why… What is the reason… What if…… would it be different if… Other researchers in ethno-STEAM education could conduct the continued research the learning model with STEAM approach focusing on the improvement of effectiveness and flexibility in various educational contexts. In addition, examining the effectiveness and the suitability of the learning model with ethno-STEAM approach at various educational level; either at middle schools, higher education, or other educational levels.

Acknowledgments

The authors would like to thank the Directorate of Research, Technology and Community Services of the Directorate General of Higher Education, Research and Technology for the financial support for this study as the Letter of Agreement for Assignment for Implementation of the Research Program Number: 61.20.6/UN37/PPK.10/2023, June 20th, 2023. The authors would also like to extend the gratitude to the lecturers and students involving in this study for the great support, help and collaboration during this study.

References

Ariyatun. (2021). Analysis of project based-learning integrated with ethno-STEM on students' critical and creative thinking skills. *Journal of Educational Chemistry (JEC), 3*(1), 35-44. https://doi.org/10.21580/jec.2021.3.1.6574.

Bertrand, M. G., & Namukasa, I. K. (2023). A pedagogical model for STEAM education. *Journal of Research in Innovative Teaching & Learning*, *16*(2), 169-191. https://doi.org/10.1108/JRIT-12-2021-0081.

Bertrand, M., & Namukasa, I. (2020). STEAM education: student learning and transferable skills. *Journal of Research in Innovative Teaching and Learning, 13*(1), 43-56, https://doi.org/10.1108/jrit-01-2020-0003.

Chung, C., Lin, C., & Lou, S. (2018). Analysis of the learning effectiveness of the STEAM-6E special course—a case study about the creative design of IoT assistant devices for the elderly. *Sustainability, 10(9)*, 1-16. https://doi.org/10.3390/su10093040.

Chung, C.-C., Huang, S.-L., Cheng, Y.-M., & Lou, S.-J. (2022). Using an iSTEAM project-based learning model for technology senior high school students: Design, development, and evaluation.

International Journal of Technology and Design Education, 32(2), 905–941. https://doi.org/10.1007/s10798-020-09643-5.

Cook, K., & Bush, S. (2018). Design thinking in integrated STEAM learning: surveying the landscape and exploring exemplars in elementary grades. *School Science and Mathematics, 118*, 93-103. https://doi.org/10.1111/ssm.12268.

Costantino, T. (2018). STEAM by another name: transdisciplinary practice in art and design education. *Arts Education Policy Review, 119*(2), 100-106. https://doi.org/10.1080/10632913.2017.1292973.

DeHaan, R. L. (2009). Teaching creativity and inventive problem solving in science. *CBE Life Sci Educ. 8*(3), 172–181. https://doi.org/10.1187/cbe.08-12-0081.

Erdogan, V. (2019). Integrating 4C skills of 21st century into 4 language skills in EFL classes. *International Journal of Education and Research, 7*(11), 113–124.

Ernawati, M. D., Sudarmin, S., Asrial, A., Muhammad, D., & Haryanto, H. (2022). Creative thinking of chemistry and chemistry education students in biochemistry learning through problem-based learning with scaffolding strategy. *Jurnal Pendidikan IPA Indonesia, 11*(2), 282-295. https://doi.org/10.15294/jpii.v11i2.33842.

Gube, M., & Lajoie, S. (2020). Adaptive expertise and creative thinking: A synthetic review and implications for practice. *Thinking Skills and Creativity, 35, 100630*, https://doi.org/10.1016/j.tsc.2020.100630.

Habibi, Mundilarto, Jumadi, Gummah, S., Ahzan, S., & Prasetya, D. S. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education (IJERE), 9*(2), 415-420. https://doi.org/10.11591/ijere.v9i2.

Hidayati, N., Fitriani, A., Saputri, W., & Ferazona, S. (2023). Exploring university students' creative thinking through digital mind maps. *Journal of Turkish Science Education, 20*(1), 119-135. https://doi.org/10.36681/tused.2023.007.

Ho, S.H. & Shih, Y.-Y. (2023, September 7-8). *Enhance cultural competence and creative abilities through innovation education of traditional techniques*. [Paper presentation]. *The 25th International Conference on Engineering and Product Design Education (E&PDE 2023).* Elisava University School of Design and Engineering, Barcelona, Spain. https://doi.org/10.35199/EPDE.2023.26.

Ida, S., Aziz, R., & Irawan, W. (2021). Critical and creative thinking skills for math story problem instruction at elementary schools. *Jurnal Tatsqif, 19*(2), 98-113. https://doi.org/10.20414/jtq.v19i2.4069.

Joynes, C., Rossignoli, S., & Fenyiwa Amonoo-Kuofi, E. (2019). *21st Century skills: evidence of issues in definition, demand and delivery for development contexts (K4D Helpdesk Report).* Institute of Development Studies. https://assets.publishing.service.gov.uk/media/5d71187ce5274a097c07b985/21st_century.pdf.

Kenett, Y. N., Levy, O., Kenett, D. Y., Stanley, H. E., Faust, M., & Havlin, S. (2018). Flexibility of thought in high creative individuals represented by percolation analysis. *Proceedings of the National Academy of Sciences of the United States of America, 115*(5), 867–872. https://doi.org/10.1073/pnas.1717362115.

Khusniati, M., Heriyanti, A. P., Aryani, N. P., Fariz, T. R., & Harjunowibowo, D. (2023). Indigenous science constructs based on Troso woven fabric local wisdom: a study in ethnoscience and ethnoecology. *Journal of Turkish Science Education*, *20*(3), 549-566. https://doi.org/10.36681/tused.2023.031.

Kim, D., & Bolger, M. (2017). Analysis of Korean elementary pre-service teachers' changing attitudes about integrated STEAM pedagogy through developing lesson plans. *International Journal of Science and Mathematics Education, 15*(4), 587–605. https://doi.org/10.1007/s10763-015-9709-3.

Kiraga, F. (2023). Literature Review: Efforts to improve creative thinking ability in science learning. *Integrated Science Education Journal, 4*(2), 77-83. https://doi.org/10.37251/isej.v4i2.330.

Larraz-Rábanos, N. (2021). Development of creative thinking skills in the teaching-learning process. in U. Kayanipar. *Teacher education – new perspectives*. Intech Open. https://doi.org/10.5772/intechopen.97780.

Liline,S., Tomhisa, A., Rumahlatu,D., & Sangur, K. (2024). The Effect of the Pjb-HOTS learning model on cognitive learning, analytical thinking skills, creative thinking skills, and metacognitive skills of biology education students. *Journal of Turkish Science Education*, *21*(1), 175-195. https://doi.org/10.36681/tused.2024.010

Lucas, B. (2016). A five-dimensional model of creativity and its assessment in schools. *Applied Measurement in Education, 29*(4), 278–290. https://doi.org/10.1080/08957347.2016.1209206.

McCarthy, J. (2018). Do creative thinking and creative problem-solving have a place in counseling curricula? *Journal of Creativity in Mental Health, 13*(3), 306–317. https://doi.org/10.1080/15401383.2018.1433092.

Meitiyani, Elvianasti, M., & Dharma, A. (2021, October 21). *Correlation between students creative thinking ability in solving environmental problem with achievement of environmental education*. 1st Annual International Conference on Natural and Social Science Education (ICNSSE 2020), Universitas Muhammadiyah Prof Dr. Hamka. https://doi.org/10.2991/assehr.k.210430.042.

Milenia, B. B., Suryaningrum, C. W., & Rhomdani, R. W. (2022). Using ethnomathematics from batik Jember to create electronic moduls. *Jurnal Pendidikan Matematika (JUPITEK), 5*(2), 132-137. https://doi.org/10.30598/jupitekvol5iss2.

Montag-Smit, T., & Maertz, C. P. (2017). Searching outside the box in creative problem solving: The role of creative thinking skills and domain knowledge. *Journal of Business Research, 81*, 1–10. https://doi.org/10.1016/j.jbusres.2017.07.021.

Nur, S., Zubaidah, S., Mahanal, S., & Rohman, F. (2020). ERCoRe learning model to improve creative-thinking skills of preservice biology teachers. *Journal for the Education of Gifted Young Scientists, 8*(1), 549–569. https://doi.org/10.17478/jegys.673022.

Nurita, T., Hastuti., P., & Sari., D. (2017). Problem solving ability of science students in optical wave course. *Jurnal Pendidikan IPA Indonesia, 6(2)*, 341—345. https://doi.org/10.15294/jpii.v6i2.8184.

Nursalim, A. (2020, September 18-19). *Developing students' creative response in batik craft subject (higher order thinking-based learning implementation in art education).* The 2nd International Conference on Arts and Design Education (ICADE 2019), Universitas Pendidikan Indonesia. https://doi.org/10.2991/assehr.k.200321.062.

OECD. (2014). Students' strengths and weaknesses in problem solving, in PISA 2012 Results: Creative Problem Solving (Volume V): Students' skills in tackling real-life problems, OECD Publishing, Paris. https://doi.org/10.1787/9789264208070-en.

Ozkan, G., & Topsakal, U. U. (2021). Investigating the effectiveness of STEAM education on students' conceptual understanding of force and energy topics. *Research in Science & Technological Education, 39(4)*, 441-460. https://doi.org/10.1080/02635143.2020.1769586.

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: an integrative literature review. *Thinking Skills and Creativity, 31*(March 2019), 31-43. https://doi.org/10.1016/j.tsc.2018.10.002.

Puspadewi, K.R., Wulandari, I.G.A.P.A., Paraniti, A.A.I. & Safitri, N.K. 2022. Eksplorasi STEAM pada sarana upakara tumpeng kering. *Jurnal Derivat Jurnal Matematika dan Pendidikan Matematika, 9*(2), 236-245. https://doi.org/10.31316/jderivat.v9i2.3869.

Qomaria, N. & Wulandari, A.Y.R. 2022. Pengembangan keterampilan kolaboratif siswa melalui pembelajaran dengan pendekatan ethno-STEAM project konteks Pesapean. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 11*(2), 1306-1318. https://doi.org/10.24127/ajpm.v11i2.4586.

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics, 117*(1–2), 1–12. https://doi.org/10.1111/ssm.12201.

Heard, J., Ramalingam, D., Scoular, C., Anderson, P., & Duckworth, D. (2025). *Creative thinking: Skill development framework*. 2nd ed. Australian Council for Educational Research. https://doi.org/10.37517/978-1-74286-753-3.

Ramdani, A., Artayasa, I., Yustiqvar, M., & Nisrina, N. (2021). Enhancing prospective teachers' creative thinking skills: A study of the transition from structured to open inquiry classes. *Cakrawala Pendidikan, 40(3)*, 637-649. doi: 10.21831/cp.v40i3.41758.

Ratnasari, D., Suciati, S., & Maridi, M. (2019). Empowering scientific thinking skills through creative problem solving with scaffolding learning. *Jurnal Pendidikan Biologi Indonesia, 5(1)*, 61–68. https://doi.org/10.22219/jpbi.v5i1.7135.

Rohmantika, N., & Kurniawan, E. (2021). Using of ethno-STEM based teaching materials to increase the creativity of students in learning physics. *Jurnal Geliga Sains (JGS): Jurnal Pendidikan Fisika, 9(2)*, 129-138. https://dx.doi.org/10.31258/jgs.9.2.,129-138.

Rozie, F., Wulandari R., & Ningsih, P.R. (2021, November 26). *Ethnomathematics: electronic math module based on Madura batik in improving creative thinking skills*. The 1st International Conference on Mathematics and Mathematics Education (ICMMED 2020), Universitas Pattimura. https://doi.org/10.2991/assehr.k.210508.074

Sarwi, Alim, Fathonah, S., & Subali, B. (2019). The analysis of ethnoscience-based science literacy and character development using guided inquiry model. *Journal of Physics: Conference Series 1567, 022045*. https://doi.org/10.1088/1742-6596/1567/2/022045.

Sumarni, W. (2018). The Influence of ethnoscience-based learning on chemistry to the chemistry's literacy rate of the prospective teachers. *Unnes Science Education Journal, 7*(2), 198-205. https://doi.org/10.15294/USEJ.V7I2.23722.

Sumarni, W., Rumpaka, D., Wardani, S., & Sumarti, S. (2022). STEM-PBL-local culture: can it improve prospective teachers' problem-solving and creative thinking skills? *Journal of Innovation in Educational and Cultural Research (JIECR), 3*(2), 70-79. https://doi.org/10.46843/jiecr.v3i2.65.

Sumarni, W. & Kadarwati, S. (2020). Ethno-STEM project-based learning: its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia, 9*(1), 14-21. https://doi.org/10.15294/jpii.v9i1.21754.

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-Based Learning, 12(1)*, 3-6. https://doi.org/10.7771/1541-5015.1649.

Wijayati, W., Sumarni, W., & Supanti, S. (2019). Improving student creative thinking skills through project-based learning in UNNES international conference on research innovation and commercialization. *KnE Social Sciences,* 408–421. https://doi.org/10.18502/kss.

Yulianti, D., Wiyanto, W., Rusilowati, A., & Nugroho, S. E. (2020). Student worksheets based on Science, Technology, Engineering and Mathematics (STEM) to facilitate the development of critical and creative thinking skills. *Journal of Physics: Conference Series, 1567, 022068*, https://doi.org/10.1088/1742-6596/1567/2/022068.

Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving creative thinking skills of students through differentiated science inquiry integrated with mind map. *Journal of Turkish Science Education, 14*(4), 77–91. https://doi.org/10.12973/tused.10214a).