East Asian Journal of Multidisciplinary Research (EAJMR)
Vol. 3, No. 3, 2024 : 1231 - 1250

A Case Study at a Civil Aviation School on Using Problem-Based Learning to Enhance Creative, Critical, and Problem-Solving Skills

Bambang Bagus Harianto[1*], Bambang Suprianto[2], Arie Wardhono[3]
[1,2,3]Universitas Negeri Surabaya, Indonesia
[1]Politeknik Penerbangan Surabaya, Indonesia
Corresponding Author: Bambang Bagus Harianto bambang.19014@mhs.unesa.ac.id

A R T I C L E I N F O

Keywords: Critical Thinking, Creative Thinking, Problem-Solving Ability, Problem-Based Learning

Received : 05 February
Revised : 25 February
Accepted: 27 March

A B S T R A C T

This study aims to find out how cadets' critical thinking, creativity, and problem-solving capabilities are affected by problem-based learning methodologies. The methodology for this investigation was quasi-experimental. The population used in this research was taken from second-semester cadets from seven academic programs. The samples used were three classes selected based on random sampling techniques, namely Airport Electrical Engineering (AEE) 48 cadets, Aircraft Engineering (A.E.) 48 cadets, and Airport Civil Engineering (ACE) 48 cadets. The data analysed are descriptive and inferential statistical data, which are analysed using MANOVA. Its findings showed that the implementation of PBL (experimental class) was better than DL (control class) in improving cadet capability, with a significance level of α = 0.05.

DOI : https://doi.org/10.55927/eajmr.v3i3.8664
ISSN-E: 2828-1519
https://journal.formosapublisher.org/index.php/eajmr

INTRODUCTION

Learning is changing one's behaviour to acquire new knowledge, skills, and abilities. Learning is also the process of doing something through various experiences, such as seeing, observing, and understanding something. Cadets must actively learn and practice their thinking abilities through Learning. Thinking is the process of combining perceptions and elements in the mind, as well as the activity of mental manipulation caused by external stimulation that shapes thinking and reasoning. The thinking ability aligns with discourse and improves educational quality through a learning process that adheres to Learning objectives or outcome demands. (Anderson, 2020)(Mayer, 2014)(Mayer, 2005)

Since the industry continues to move very quickly, the trend shows that the industrial revolution has reached a new phase known as the 4.0 era. The Industrial Revolution was first marked by the mechanisation of manufacturing, second by the standardisation of qualities that accompany mass production, and third by the introduction of automation and robots. The skills of the 21st century have attracted interest in recent years and become one of the most important skills to use during the learning process. The capacity for original thought and its application to problem-solving is known as creative thinking. Fluency, adaptability, and originality are qualities of creative thinking. Cadets who can think creatively will show great curiosity, actively ask questions, try things, increase self-confidence, and try to do new experiences. Creative thinking will make cadets accustomed to critical thinking with their intuition and imagination, revealing uniquely fresh ideas that can solve problems. (Sasmoko et al., 2020)(Ana et al., 2020)(Kamble et al., 2018)(González-pérez & Ramírez-montoya, 2022)(Chang et al., 2015)(Lee et al., 2021)(Yang et al., 2016)

The educational model must overcome various problems the cadets face during the learning process. Problem-based Learning, or PBL, is a style that focuses on everything cadets do to acquire knowledge. The PBL model is expected to address real problems if used in the cadet learning process. Problems can inspire students' creative thinking. In other words, we let them discover and solve problems and convey ideas in new and appropriate ways. There are still some obstacles to learning in vocational schools related to learning limitations, namely the lack of scientific knowledge of cadets in analytical and inventive thought and abilities. The solution to this problem is general scientific skills, particularly skills each cadet has and can do to grow and develop (Savery, 2006)(Mustaffa et al., 2016) the Learning of Physics. (Fidan & Tuncel, 2019)(Raine & Symons, 2012)(Argaw et al., 2017)

PBL (Problem-Based Learning) has gained popularity in physics lectures. However, in physics education journals, the use of the PBL model in civil aviation school schools is still limited. In Indonesia, research articles on PBL in physics are few, even challenging to find. PBL is regarded as an effective teaching strategy to help students enhance their critical and creative thinking abilities and activate student participation in the learning process. With PBL, Students will perform better when trained to solve problems independently and collaborate with team members to complete assigned tasks. In aviation, solving problems becomes an essential skill that must be possessed. Therefore, efforts are needed to integrate the PBL model in physics Learning in flight schools in Indonesia. Increasing PBL research and development in physics will help teachers and students develop the skills needed in aviation. They can make a positive contribution to the development of education in Indonesia.

Learning methods have been developed to teach PBL concepts, particularly in physics subjects, to recognise the potential for problem-based Learning in which cadets perform a variety of practical exercises while studying. This study provides an overview of what the PBL method looks like. Placed and had a part to play in this period of the Fourth Industrial Revolution. Therefore, it is anticipated that the PBL approach will considerably aid in developing outstanding human resources capable of critical and creative thought and problem-solving.

THEORETICAL REVIEW

Problem-Based Learning

Problem-based Learning is a method that begins with formulating a problem and continues with problem-solving. PBL (problem-based Learning) enables students to choose and carry out surveys both within and outside of the classroom as necessary to address issues, starting with meaningful real-life problems. The PBL aims to acquire concepts and long-term Learning that leads to behaviour change. (Savery, 2006)(Kirschner et al., 2006)(Aslan, 2021a)

In PBL, students actively participate in the search for solutions to their problems. Participation and cooperation are based on the improvement of problem-solving and critical-thinking abilities. The focus is on an unstructured curriculum based on practical problem-solving and realistic stimulus materials. In other words, PBL is not a simple educational strategy. It relies on various educational activities and methods, including learning with problems, research, projects, and Case-based Education. It is definable as providing a problem-solving-based environment for learning through specific volunteer team learning activities. PBL is a convenient way to promote higher cognitive and academic performance, such as ingenuity and problem-solving capabilities. (Ioannou et al., 2016)(Sumirattana et al., 2017)(Miterianifa et al., 2019)

In its application, the PBL model has several advantages. Implementing PBL provides at least three benefits: (1) It aids students in developing their logical thinking and cognition; (2) it can encourage students to learn collaboratively; and (3) it can create students to foster practice reasoning skills based on valid evidence. The benefits of implementing PBL include (1) helping students to foster leadership skills, teamwork, communication, and problem-solving; (2) helping students to focus on the information learned; (3) Helping students to take responsibility in Learning; (4) encouraging students to have a more profound method of instruction by forcing them to discover and manipulate different levels of information, and (5) improving students' learning motivation by focusing on real-life supportive Learning across a variety of learning media (Abdullah et al., 2019)(Liu & Pásztor, 2022)(Suparji et al., 2018)(Mulyanto et al., 2018). The definition of learning through problems is explained by the following research (Fitriani et al., 2020)(Mahmood & Jacobo, 2019)(Odell et al., 2019)(Caswell, 2019)(Nor Fadzilah Binti Wan Husin et al., 2016)(Masek & Yamin, 2011)

Critical Thinking

Critical thinking skills are a part of higher-order cognitive abilities that require students to develop a process of analysing or evaluating the information on a problem using logical reasoning in making decisions, making fresh efforts, and providing a new understanding of existing concepts. The ability to think critically involves analysing or evaluating the information on a problem by applying logical reasoning before making decisions. As Fisher stated in 2009, there were six critical thinking indicators: (1) identifying problems, (2) gathering relevant information, (3) developing several alternative solutions to problems, (4) drawing conclusions, (5) expressing opinions, and (6) evaluating arguments. Meanwhile, FRISCO separated the six components of critical thinking (six) basic elements (Focus, Reason, Inference, Situation, Clarity, and Overview). The first component concerns comprehending the topic, key points, problems, and what to ask or say when Learning occurs. The second element, reason, emphasises the student's ability to provide rational reasoning before evaluating an argument. The third component is inference, which highlights the student's ability to evaluate a conclusion. The fourth element is a situation that emphasises the student's decision-making ability. The fifth factor is clarity, emphasising students' ability to explain group discussions. The sixth and final component is an overview that highlights the student's ability to verify his thinking.(Ennis, 2018)(Chan, 2013)(Lovegreen, 2020)(Haghparast et al., 2014)(Fisher, 2009)

The ability to think critically needs to be fostered, including (1) introducing students to the search for information independently according to the needs or demands of the times, (2) providing provisions to students in the face of a problem, (3) introducing students to how to see a problem from various points of view; (4) Possessing critical thinking abilities which can compete and work together to solve challenges. Students' ability to think critically is seen during discussions and arguments. Based on valid evidence, the process of disputes and ideas indicates that students have demonstrated and activated their capacity for critical thought. The criteria for critical thinking align with the findings of research by (Hursen, 2021)(Thaiposri & Wannapiroon, 2015)(Ulger, 2018)(Sukartiningsih & Jacky, 2019)(Abrami et al., 2014)(Prayogi et al., 2018)(Larsson, 2017)

Creative Thinking

Innovative thinking skills result from interaction among students, teachers, and their environment. Creative thinking is the same as expressing new ideas and solving unique learning problems. This idea is expressed mainly in common sense and logical thinking. It does not offend or blame the ideas of others. The ability to think creatively, according to (Ayyildiz & Yilmaz, 2021)(Yang et al., 2016), is formulated as an ability that reflects the following aspects: (1) the ability to think fluently, which allows somebody to do many things, ideas, answers and solutions to problems or questions, (2) the flexibility in thought or thinking abilities that allows somebody to create different ideas, answers or questions, (3) an authentic way of thinking that leads to the fact that one can generate original ideas and find innovative ways to combine parts that are commonly used. (4) Mature thinking ability enriches people with broader thoughts and ideas.(Chiang et al., 2016)(Gu et al., 2019)

One of the most crucial skills for learners is the ability to think creatively, especially in teaching and learning physics. Using one's capacity for original thought is necessary for students to understand, master, and solve the issues they face. Through creativity in physics learning, it is hoped that students will be brave to solve mathematical problems in their own way. (Miller et al., 2013)

(Pahlevi, 2018), Level 1 is poor creative thinking because it only expresses students' awareness of the need to complete their tasks. Level 2 indicates a better level of originality from students who must demonstrate how they observe the implications of their choices, such as the deployment and processing of signals or networks connected using wired systems. Level 3 is the next greater level because learners must make strategies and coordinate between different explanations in their tasks. The student must decide on the desired level of detail and how to present the sequence of actions or the logical state of the action system. Concluding the construction process's achievements and challenges and giving suggestions for improving the planning and constructing the process, his level does not pay attention to the novelty, flexibility, and fluency of individual creative thinking products, making it difficult to identify them in the learning process (Barak & Doppelt, 2000). The definition of creative thinking is in line with the studies conducted by(Diluzio & Congdon, 2015)(Wachira & Absaloms, 2017)(Hu et al., 2016)(Syahrin et al., 2019)(Cristofori et al., 2018)(Rosen et al., 2020)(Gu et al., 2019)(Chen et al., 2019).

Problem Solving

Problem-solving is a way to overcome problems by applying the knowledge that has already been gained to new and previously unknown situations. Problem-solving is a process of overcoming difficulties to achieve the expected objectives. Problem-solving is a learning approach that provides a problem and then seeks its solution through data searching until the conclusion. (Tania & Jumadi, 2021)(Singh & Dutt, 2022)(Maskur et al., 2020)(Aslan, 2021b)(Choi et al., 2014)

A problem is a situation in which an individual or group does not have a straightforward solution to find an answer. Problem-solving is the effort of individuals or groups to search for answers based on previous insights to meet the needs of unusual situations. (Lin et al., 2022)

According to (Yayuk & Husamah, 2020), there are Four indicators of problem-solving skills: (1) Recognising the issue, which includes what is known and what is requested; (2) Preparing a settlement plan, which can be realised by writing down what is learned; (3) Making a settlement; (4) Revisiting, which includes the truth answer and conclude it.

Problem-solving is an approach that exposes a situation faced by students that requires a solution using different strategies and problem-solving steps. Problem-solving activities begin with confrontation and end, particularly when an answer is obtained, followed by the conditions of a given problem. The definition of problem-solving is in line with the results of the research. (Choi et al., 2014)(Sarathy, 2018)(Ahdhianto et al., 2020)(Wiltshire et al., 2018)(Winkler et al., 2021)(Cahyono et al., 2019)(Araiza-Alba et al., 2021)(Suarsana et al., 2019)

METHODOLOGY

The research design was conducted using a quasi-experimental paradigm. Sugiyono (2017) asserts, "The quasi-experimental approach has a control group; therefore, it cannot wholly control outside factors that influence the experiment's results. This approach was developed to overcome the difficulties of finding a research control group. In this investigation, two groups are used: the experimental and control groups. The experiment group had a sort of treatment, Problem-based Learning. In contrast, the control group did not have any treatment at all.

Post-tests were administered to both groups to check for any differences between the experimental and control groups. Suppose the experimental group's score differs noticeably from the control group's. In that case, the post-test results will be categorised as successful if the experiment group scores significantly better than the control group prior to the research. A homogeneity test was applied to check whether the control class and the experiment were homogeneous. (Sugiyono, 2017)

The population of this study is the cadets of the Surabaya Aviation Polytechnic, consisting of 3 study programs and the cadets from the second semester of the academic year 2021–2022. In this study, the independent variable was the application of PBL in Learning and control by direct Learning (DL). The samples in this study were three classes selected using random sampling: 2 (two) classes from Airport Electrical Engineering (AEE), consisting of 48 cadets, 24 cadets of Aircraft Engineering (A.E.) and 24 cadets of Airport Civil Engineering (ACE). Through the sample selection technique, there are two experimental and one control class. The total of all four classes was 144 cadets.

The research data were collected through questionnaires on the cadets' critical thinking, creative thinking, problem-solving skills, student responses, and test results for physics subjects based on differences between the control group and the experiment. Questionnaires on critical thinking, creative thinking, and problem-solving skills were measured using Likert scale measurements. The questionnaire must first be validated by an expert or validator, which is calculated using SPPS software. The result obtained from the number of question items of critical thinking ability is (the number of reliable), the result obtained from the number of question items of creative thinking ability is (the total reliability number), and the result obtained from the number of question items of problem-solving ability is (total reliability)

Critical thinking Questionnaires are applied to find out cadets' critical thinking ability. There are 6 (six) indicator items adapted from Ennis's (Chan, 2013): (1) Focus, (2) Reason, (3) Inference, (4) Situation, (5) Clarity, and (6) Overview. Cadets' creative thinking ability can be measured by using a creative thinking ability questionnaire. The creative thinking ability questionnaire is built on proposed indicators (Runco et al., 2010), which are expressed as abilities that reflect the following aspects: (1) Fluency in thinking, which allows one to do many things, ideas, answers, solutions to problems or questions; (2) Flexibility in thinking, which allows one to create different ideas, answers, or questions; and (3) an authentic way of thinking, which leads to the generation of new and unique expressions and the discovery of unusual combinations of common elements. (4) The ability to think strategically provides people with broader perspectives and ideas. Polya's indicators are used to compile the problem-solving ability questionnaire. There are four indicators of problem-solving ability: (1) problem comprehension, (2) preparation of a settlement plan, (3) settlement, and (4) revisiting. The ability to think strategically provides people with broader perspectives and ideas.(Yayuk & Husamah, 2020)

This research analysed the data inferentially and descriptively; inferential data processing was calculated using multivariate statistical analysis or MANOVA. The descriptive analysis consists of the frequency, average, average value, standard deviation, and most significant and lowest data values obtained from the ability to critically, creatively, and solve problems. MANOVA is used to test hypotheses. Several conditions must be initially conducted before the hypothesis is tested, namely (1) the homogeneity test using Levene's Test and (2) the data distribution normality test using the Kolmogorov-Smirnov test to see whether the data is normal or not.

RESULTS AND DISCUSSION

Developing Skills through Learning Method

1. **Developing Critical Thinking Skills through Problem-Based Learning (PBL) and Direct Learning (DL)**

Table 1 shows statistical data on how critical thinking skills developed in the experimental class (R) and control class (K). We can find some information in the table, including the total number of respondents in both classes, the average critical thinking score, standard deviation, minimum and maximum scores, and a comparison of the experimental and control classes.

The analysis results show that the number of respondents in both classes is the same, which is 72 people. This shows that both classes have the same number of students, so critical thinking skills can be compared between the experimental and control classes. Furthermore, it can be seen that the experimental class had a higher average critical thinking score than the control group, which is 18.6111 and 16.6667, respectively.

Table 1. Statistical Data on the Development of Critical Thinking Skills in the Experimental Class (R) and Control Class (K)

Statistics	Critical Thinking Ability	
	R	K
N	72	72
Mean	18.6111	16.6667
Dev. Standard	1.10058	0.97223
Minimum	17.00	13.00

Maximum	20.00	18.00

The following data were obtained from the distribution of the critical thinking ability questionnaire, as many as 10 item questions: The existing instruments explain the cadets' critical thinking skills. By seeing the mean score in the two classes shown in Table 1, the mean score in the experimental class is 18.6111, and the control class is 16.6667. From the mean value, the cadets' critical thinking ability in the experimental class is higher than the cadets' critical thinking ability in the experimental class control.

The different average scores suggest that by using specific methods or approaches in Learning. It can improve the critical thinking abilities of students. In this case, the experimental class may have been given a certain treatment or method in its Learning that is different from the regulated class. The capacity for critical thought in question includes the student's ability to collect information, analyse, evaluate, and make critical and rational conclusions.

Furthermore, the deviation standard on the experiment and control class shows that the experiment class, 1.10058, is higher than the control class, 0.97223. This means there is a wider variety of critical thinking skills in the experimental class compared to the control class. Additionally, the maximum and minimum skills on thinking skills were provided. It shows that the minimum score of critical thinking ability in the experimental class is 17, while in the control class, it is 13. The maximum score of critical thinking ability in the experimental class is 20, while in the control class, it is 18. From the comprehensive information provided in Table 1, it can be concluded that using specific methods or approaches to Learning can improve students' critical thinking skills. It can be seen that the average critical thinking score is higher when compared to the control group. However, educators still have some proper strategies to be given in the classroom, especially to those with lower scores. This treatment can be done by providing unique guidance or exercises to improve students' critical thinking skills.

In addition, the results of data analysis in Table 1 also show a significant difference between the experimental and control classes in terms of critical thinking ability. This indicates that the approach or method used in the experimental class is more effective in improving students' critical thinking skills. In the context of Learning, thinking critically is one of the essential abilities students should possess. Critical thinking skills can help students make decisions and produce more qualified thinking. Thinking critically can also help students solve problems more systematically and effectively.

Therefore, it is pivotal for teachers or educators to develop students' critical thinking skills in the learning process. One way to do this is to use methods or approaches to improve students' critical thinking skills. In this case, the teacher can use an active and collaborative approach, encourage students to think critically and find ways to solve issues. Hence, it should be noted that there are still variations in abilities in the classroom, and appropriate treatments are needed for students with lower abilities.

2. Developing cadet's creative thinking skills through Problem-Based Learning (PBL) in experimental classes and Direct Learning control classes (DL)

Data in Table 2 is statistical data which shows how the experimental class (R) and control class fared in terms of developing their critical thinking abilities (K). The number of respondents, average value, standard deviation, lowest and maximum scores for both groups, as well as the number of respondents were all included in the data. Based on the findings of the data analysis in Table 2, there are 72 respondents in both the experimental class and the control class. Hence, the experimental class's average creative thinking ability score was found to be more significant than the control classes, coming in at 14.4861 and 12.5694, respectively.

Furthermore, information is obtained regarding the standard deviation in both classes. The standard deviation of the experimental class is 0.91917, and the standard deviation of the control class is 0.81925. This means that the variation in the creative thinking ability score in both classes is relatively low and less evenly distributed. The data provided shows that the minimum score of creative thinking ability in the experimental class is 12, while in the control class, it is 11. The maximum score of creative thinking ability in the experimental class is 16, while in the control class, it is 14.

Table 2. Statistics on the Development of Creative Thinking Ability with Experimental Class (R) and Control Class (C)

Statistics	Creative Thinking Ability	
	R	K
N	72	72
Mean	14.4861	12.5694
Dev. Standard	0.91917	0.81925
Minimum	12.00	11.00
Maximum	16.00	14.00

Based on the data provided in Table 2, it can be concluded that using specific methods or approaches in Learning can improve students' creative thinking skills. This is evident from the average scores of creative thinking ability in the experimental class, which is higher than the control class. The ability to think creatively is essential for students because it can aid learners in discovering new ideas, developing innovations, and solving complex problems. Therefore, special attention must be given to developing students' creative thinking abilities in the learning process.

In Learning, teachers or educators can use various strategies or methods to improve students' creative thinking skills. For example, teachers can use an open and interactive approach to learn and provide a variety of challenging tasks and problems that require creative thinking from students.

Overall, from the data analysis in Table 2, it can be concluded that using specific methods or approaches in Learning can improve students' creative thinking skills. However, proper treatment is still needed to improve the creative thinking skills of students who still have low scores. Therefore, continuous efforts are required from teachers or educators to enhance students' creative thinking skills effectively and efficiently.

Additionally, as shown by the analysis's findings in Table 2, utilising particular teaching strategies can help students become more creative. In this context, specific approaches and methods used in experiment classes can inspire teachers or educators to improve students' creative thinking skills.

When selecting the best strategy to develop students' creative thinking abilities, teachers and other educators may find inspiration or guidance from the strategy or technique employed in the experimental class. In paying attention to developing students' creative thinking skills, it is essential to remember that creative thinking skills can be grown in every student. Although there are variations in abilities in the classroom, each student has potential that can be developed through proper Learning and effective strategies.

Overall, the results of the data analysis in Table 2 show that the development of creative thinking skills in students can be done through specific methods or approaches to Learning. Therefore, teachers or educators must pay special attention to choosing and applying the correct methods to improve students' creative thinking skills. In this case, it is also essential to pay attention to conditions or environments that support the development of students' creative thinking skills. All these efforts are expected to improve learning outcomes and foster quality creative thinking skills in each student.

3. Developing problem-solving skills through Problem-Based Learning (PBL) in experimental classes and Direct Learning in control (DL) classes

Table 3 shows statistical information outlining how the experimental and control classes work in terms of their ability to build problem-solving skills. The number of respondents, average score, standard deviation, minimum value, and maximum score for both classes are all listed in this table.

The experimental and control classes contain exactly 72 respondents, as shown by the results of the data analysis in Table 3. The average problem-solving skill of the experimental class was also found to be higher than that of the control class, measuring 14.7917 versus 12.5, respectively.

Table 3. Statistical Data on Problem-Solving Ability Development with Experimental Class (R) and Control Class (K)

Statistic	Problem-solving skills	
	R	K
N	72	72
Mean	14.7917	12.5000
Dev. Standard	0.82116	0.88811
Minimum	14.00	11.00
Maximum	16.00	14.00

Higher grade point averages in experimental classrooms may indicate that students' problem-solving skills have improved due to using particular teaching strategies. Additionally, the two classes' standard deviations are relatively low, suggesting that students in both the experimental and control groups have similar problem-solving skills. Both classes' minimum and maximum scores also reveal variances in students' problem-solving skills. The required minimum score for problem-solving ability in the experimental class is 14, whereas in the control class, it is 11. The experimental class has a maximum score for problem-solving abilities 16, whereas the control class has a maximum score of 14.

Regarding students' problem-solving abilities, it is essential to remember that they can be developed for every student. Although there are variations in abilities in the classroom, each student has potential that can be developed through proper Learning and effective strategies. Students need problem-solving skills since they can use them to solve issues and make wise judgments. Therefore, focusing specifically on improving students' problem-solving abilities throughout the educational process is crucial.

Overall, the data analysis findings in Table 3 demonstrate that specific teaching strategies or pedagogical techniques can help students improve their problem-solving abilities. Therefore, it requires great care for teachers or educators to select and implement the appropriate techniques to enhance students' problem-solving skills. In this situation, it is equally crucial to focus on the circumstances or settings that encourage the growth of pupils' problem-solving skills. These initiatives are anticipated to enhance student learning outcomes and develop problem-solving abilities. This is in response to research done by.

3.2. Developing Skills Through Differences in Classroom

3.2.1. Development of Critical Thinking Skills in AEE, A.E., and A.C. Classes

The critical thinking ability of each cadet is different. Data on the critical thinking ability of cadets are described in Table 4 below from the analyses performed on three classes. Development of Creative Thinking Skills in Classes AEE, A.E., and ACE

Table 4. Statistical Data on Developing Critical Thinking Skills in AEE, A.E., and ACE classes.

Statistics	Critical Thinking Ability		
	AEE	AE	ACE
N	48	48	48
Mean	17.5417	17.6667	17.7083
Dev. Standard	1.52927	1.43413	1.32019
Minimum	13.00	15.00	15.00
Maximum	20.00	20.00	20.00

Based on data from Table 4, the average critical thinking score for cadets in the AEE class is 17.5417, while A.E. gets a score of 17.6667. AEE received an average score of 17.7083, indicating that ACE class cadets have a more substantial capacity for critical thought than AEE and A.E class cadets.

3.2.2. Developing Creative Thinking Skills in AEE, A.E., and A.C. Classes

Table 5 shows statistical data on cadets' creative thinking abilities in classes AEE, A.E., and ACE.

Table 5. Statistical Data on Developing Creative Thinking Skills in AEE, A.E., and ACE classes.

Statistics	Creative Thinking Ability		
	AEE	AE	ACE
N	48	48	48
Mean	13.5000	13.5147	13.5147
Dev. Standard	1.28824	1.33621	1.28756
Minimum	11.00	11.00	11.00
Maximum	16.00	16.00	16.00

Based on the data from Table 5, the average score of creative thinking ability of AEE class cadets is 13.5000, and A.E. gets an average score of 13.5147. AEE got an average score of 13.5147, so it can be concluded that the creative thinking ability of A.E. and ACE class cadets has the same or equivalent and higher abilities compared to the skills of AEE class cadets.

3.2.3. Problem-Solving Skills Development in AEE, A.E., and A.C. Classes

Table 6 shows statistical data on the problem-solving capabilities of cadets in classes AEE, A.E., and ACE.

Table 6. Statistical Data on Developing Creative Thinking Skills in AEE, A.E., and ACE Classes

Statistics	Problem-solving ability		
	AEE	AE	ACE
N	48	48	48
Mean	13.6458	13.6458	13.6458
Dev. Standard	1.50869	1.42156	1.39130
Minimum	11.00	11.00	11.00
Maximum	16.00	16.00	16.00

Based on Table 6, the average problem-solving ability score of cadets in classes AEE, A.E., and ACE is 13.6458, so it can be concluded that the problem-solving abilities of cadets in classes AEE, A., and ACE have the same or equivalent skills.

3.3. The Influence of the Learning Method

This study used one independent variable and three dependent variables, with 144 cadets as research subjects. Learning methods have two categories: Learning using PBL and Learning using DL. There were two methods used in hypothesis testing in this study, the first using MANOVA and the second to see the effects on dependent variables, namely (1) critical thinking ability, (2) creative thinking ability, and (3) problem-solving ability.

3.3.1. Analyse with MANOVA

Before conducting a hypothesis test with MANOVA, several requirements must be met: (1) a homogeneity test using the Levene test, (2) a normality test using the Kolmogorov-Smirnov test to see whether the distributed data is standard. All these tests use SPSS. The first test tests homogeneity. The Levene test uses a significance level = 0.05. MANOVA says that the dependent variables are the same in every class. Levene's test on the critical thinking ability of cadets with a significance score of 0.387, creative thinking ability of 0.346, and problem-solving ability of 0.578, the significance score of the three dependent variables above = 0.05, so it can be concluded that the null hypothesis in this study is accepted. So, we can continue this research because the whole variable is homogeneous.

The second test tested the normality of the data using the Kolmogorov-Smirnov test with a significance level = 0.05. Kolmogorov Smirnov's test on the critical thinking ability of cadets has a significance score of 0.000, creative thinking ability of 0.000, and problem-solving ability of 0.000, the significance score of the three dependent variables is below = 0.05 so that the null hypothesis is rejected, but different results are obtained at a calculated F score that shows strong (strong) results so that this study can continue.

3.3.2. Hypothesis Testing

Based on the influence of learning methods, the significance scores in the last column of Table 7 showed a comparison of the results of the significance criteria = 0.05, which was calculated by using the Pillai's Trace, Wilks' Lambda, Hotellings' Trace, and Roy's Largest Root tests. It shows that the data support the hypothesis that the influence of learning methods affects dependent variables, or it can be said that the influence of learning methods can improve critical thinking ability, creative thinking skills, and problem-solving abilities whose score can be seen as a whole in Table 8

Table 7. The effect of learning method

Factor	Test	Value	F	Sig.
Metode (strategi)	*Pillai's Trace*	0.801	187.445^b	0.000
	Wilks' Lamda,	0.199	187.445^b	0.000
	Hotelling's Trace	4.017	187.445^b	0.000
	Roy's Largest Root	4.017	187.445^b	0.000

Table 8. Influence among Dependent Variables Based on Learning Methods

Learning Ability	df	Mean Square	F	Sig.
Critical Thinking	1	136.111	126.234	0.000

Creative Thinking	1	132.250	174.468	0.000
Problem-Solving	1	189.063	258.454	0.000

The first claim is that, with a significance score of 0.000 = 0.05, using the Problem-Based Learning (PBL) learning technique is preferable to using the Direct Learning (DL) learning method to develop critical thinking skills. The findings of the hypothesis are consistent with the research data in Table 1. It shows that the average score of the experimental class is 18.6111, and the control class is 16.6667. This means that the experimental class's cadets' critical thinking abilities have a more significant influence than the control class's. According to the results of this hypothesis, which had a significance level of 0.05, critical thinking skills in PBL-using classrooms are superior to those in DL-using classes. The second hypothesis, the development of creative thinking ability cadets, using the Problem-Based Learning (PBL) learning method is better than using the Direct Learning (DL) learning method with a significance score of 0.000 < = 0.05. The research data in Table 2 shows the average score of the experimental class, 14.4861, and the control class, 12.5694. This means that the experimental class's cadets' creative thinking ability score is greater than the control class's. The results of this hypothesis with a significance level = 0.05 show that students who use PBL have higher levels of creativity than students who utilise DL.

The third hypothesis, the development of cadet problem-solving abilities, using the Problem-Based Learning (PBL) learning method is better than using the Direct Learning (DL) learning method with a significance score of 0.000 < = 0.05. The results of the hypothesis are supported by the research data in Table 3, which explains why the control class's average score is 12.5000, and the experimental class's average score is 14.7917. It suggests that the problem-solving abilities of the cadets in the experimental class are more influential than those of the cadets in the control class. Based on the findings of this hypothesis, with a significance level of 0.05, it can be concluded that students are more able to solve problems in PBL classes than in DL classes.

CONCLUSIONS AND RECOMMENDATIONS

Based on the data analysis from inferential and descriptive statistical tests of the implementation of the Problem-Based Learning (PBL) learning method and its impact on the ability of cadets, this study found that the ability of cadets using the Problem-Based Learning (PBL) learning method is better than using the Direct Learning (DL) method. The descriptive data supports this: the increase in the cadet ability in the experimental class is higher than that in the control class.

In addition, the cadet's ability is also viewed using mean data from mean data. It can be seen that the experimental class using PBL is better than the average score in the control class using DL. The descriptive data of each class showed different results, including the critical thinking ability of cadets in the ACE class was higher than in the other classes, the creative thinking ability of the A.E. and ACE classes was higher than that of the AEE class, and the problem-solving ability of the third class had the same value.

FURTHER STUDY

The proposed further study includes comparative studies across academic programs within civil aviation schools, longitudinal studies to observe the long-term effects of PBL on cadets, qualitative analysis of perceptions towards PBL, research on technology integration within PBL, and cross-cultural studies to understand cultural factors in PBL implementation. By advancing these investigations, a deeper understanding of the potential and limitations of PBL in enhancing critical thinking, creativity, and problem-solving skills within the context of civil aviation education will be attained.

REFERENCES

Abdullah, J., Mohd-Isa, W. N., & Samsudin, M. A. (2019). Virtual reality to improve group work skill and self-directed learning in problem-based learning narratives. *Virtual Reality*, *23*(4), 461–471. https://doi.org/10.1007/s10055-019-00381-1

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, A., Persson, T., Bernard, R. M., Waddington, D. I., & Wade, C. A. (2014). *Strategies for Teaching Students to Think Critically: A Meta-Analysis*. https://doi.org/10.3102/0034654314551063

Ahdhianto, E., Marsigit, Haryanto, & Nurfauzi, Y. (2020). Improving fifth-grade students' mathematical problem-solving and critical thinking skills using problem-based learning. *Universal Journal of Educational Research*, *8*(5). https://doi.org/10.13189/ujer.2020.080539

Ana, A., Kustiawan, I., Ahman, E., Zakaria, S., Muktiarni, M., Dwiyanti, V., Saripudin, S., & Kahoerunnisa, I. (2020). Defining Vocational Teacher Competencies in Industry 4.0 from the Perspective of Policymakers. In *Journal of Engineering Education Transformations* (Vol. 34).

Anderson, J. R. (2020). *Cognitive Psychology and Its implications* (2nd ed., Vol. 9). Worth Publisher.

Araiza-Alba, P., Keane, T., Chen, W. S., & Kaufman, J. (2021). Immersive virtual reality as a tool to learn problem-solving skills. *Computers and Education*, *164*(July 2020), 104121. https://doi.org/10.1016/j.compedu.2020.104121

Argaw, A. S., Haile, B. B., Ayalew, B. T., & Kuma, S. G. (2017). The effect of problem based learning (PBL) instruction on students' motivation and problem solving skills of physics. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(3), 857–871. https://doi.org/10.12973/eurasia.2017.00647a

Aslan, A. (2021a). Problem- based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers and Education*, *171*. https://doi.org/10.1016/j.compedu.2021.104237

Aslan, A. (2021b). Problem- based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers and Education*, *171*. https://doi.org/10.1016/j.compedu.2021.104237

Ayyildiz, P., & Yilmaz, A. (2021). 'Moving the Kaleidoscope' to see the effect of creative personality traits on creative thinking dispositions of preservice teachers: The mediating effect of creative learning environments and teachers' creativity fostering behavior. *Thinking Skills and Creativity*, *41*, 100879. https://doi.org/10.1016/j.tsc.2021.100879

Barak, M., & Doppelt, Y. (2000). Using Portfolios to Enhance Creative Thinking. *Journal of Technology Studies*, *26*(2), 16–25.

Cahyono, B., Kartono, Waluyo, B., & Mulyono. (2019). Analysis critical thinking skills in solving problems algebra in terms of cognitive style and gender. *Journal of Physics: Conference Series*, *1321*(2). https://doi.org/10.1088/1742-6596/1321/2/022115

Caswell, C. A. (2019). *Courses for Second Language Teacher Education The Interdisciplinary Journal of Problem-based Learning SPECIAL ISSUE : UNPACKING THE ROLE OF ASSESSMENT IN PROBLEM- AND PROJECT-BASED LEARNING Recursive Reflective Reports : Embedded Assessment in PBL Courses*. *13*(2).

Chan, Z. C. Y. (2013). A systematic review of critical thinking in nursing education. In *Nurse Education Today* (Vol. 33, Issue 3, pp. 236–240). https://doi.org/10.1016/j.nedt.2013.01.007

Chang, Y., Li, B. di, Chen, H. C., & Chiu, F. C. (2015). Investigating the synergy of critical thinking and creative thinking in the course of integrated activity in Taiwan. *Educational Psychology*, *35*(3), 341–360. https://doi.org/10.1080/01443410.2014.920079

Chen, S. Y., Lai, C. F., Lai, Y. H., & Su, Y. S. (2019). Effect of project-based learning on development of students' creative thinking. *International Journal of Electrical Engineering Education*. https://doi.org/10.1177/0020720919846808

Chiang, F., Chiu, C., & Su, Z. (2016). Using digital storytelling to enhance elementary school students' creative thinking. *2016 International Conference on Advanced Materials for Science and Engineering (ICAMSE)*, 505–508. https://doi.org/10.1109/ICAMSE.2016.7840183

Choi, E., Lindquist, R., & Song, Y. (2014). Effects of problem-based learning vs. traditional lecture on Korean nursing students' critical thinking, problem-solving, and self-directed learning. *Nurse Education Today*, *34*(1), 52–56. https://doi.org/10.1016/j.nedt.2013.02.012

Cristofori, I., Salvi, C., Beeman, M., & Grafman, J. (2018). The effects of expected reward on creative problem solving. *Cognitive, Affective and Behavioral Neuroscience*, *18*(5). https://doi.org/10.3758/s13415-018-0613-5

Diluzio, R., & Congdon, C. B. (2015). Infusing the creative-thinking process into undergraduate STEM education: An overview. *ISEC 2015 - 5th IEEE Integrated STEM Education Conference*, 52–57. https://doi.org/10.1109/ISECon.2015.7119945

Ennis, R. H. (2018). Critical Thinking Across the Curriculum: A Vision. *Topoi*, *37*(1), 165–184. https://doi.org/10.1007/s11245-016-9401-4

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers and Education*, *142*. https://doi.org/10.1016/j.compedu.2019.103635

Fisher, A. (2009). *Berpikir kritis sebuah pengantar.* (4th ed.). Erlangga.

Fitriani, A., Zubaidah, S., Susilo, H., & al Muhdhar, M. H. I. (2020). The effects of integrated problem-based learning, predict, observe, explain on problem-solving skills and self-efficacy. *Eurasian Journal of Educational Research*, *2020*(85). https://doi.org/10.14689/ejer.2020.85.3

González-pérez, L. I., & Ramírez-montoya, M. S. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. In *Sustainability (Switzerland)* (Vol. 14, Issue 3). MDPI. https://doi.org/10.3390/su14031493

Gu, X., Dijksterhuis, A., & Ritter, S. M. (2019). Fostering children's creative thinking skills with the 5-I training program. *Thinking Skills and Creativity*, *32*, 92–101. https://doi.org/10.1016/j.tsc.2019.05.002

Haghparast, M., Nasaruddin, F. H., & Abdullah, N. (2014). Cultivating Critical Thinking Through E-learning Environment and Tools: A Review. *Procedia - Social and Behavioral Sciences*, *129*, 527–535. https://doi.org/10.1016/j.sbspro.2014.03.710

Hu, R., Wu, Y. Y., & Shieh, C. J. (2016). Effects of virtual reality integrated creative thinking instruction on students' creative thinking abilities. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(3). https://doi.org/10.12973/eurasia.2016.1226a

Hursen, C. (2021). The Effect of Problem-Based Learning Method Supported by Web 2.0 Tools on Academic Achievement and Critical Thinking Skills in Teacher Education. *Technology, Knowledge and Learning*, *26*(3), 515–533. https://doi.org/10.1007/s10758-020-09458-2

Ioannou, A., Vasiliou, C., & Zaphiris, P. (2016). Problem-Based Learning in Multimodal Learning Environments. *Journal of Educational Computing Research*, *54*(7), 1022–1040. https://doi.org/10.1177/0735633116636755

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*, *117*, 408–425. https://doi.org/10.1016/j.psep.2018.05.009

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1

Larsson, K. (2017). Understanding and teaching critical thinking—A new approach. *International Journal of Educational Research*, *84*(May), 32–42. https://doi.org/10.1016/j.ijer.2017.05.004

Lee, Y. F., Lin, C. J., Hwang, G. J., Fu, Q. K., & Tseng, W. H. (2021). Effects of a mobile-based progressive peer-feedback scaffolding strategy on students' creative thinking performance, metacognitive awareness, and learning attitude. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2021.1916763

Lin, P. C., Hou, H. T., & Chang, K. E. (2022). The development of a collaborative problem solving environment that integrates a scaffolding mind tool and simulation-based learning: an analysis of learners' performance and their cognitive process in discussion. *Interactive Learning Environments*, *30*(7), 1273–1290. https://doi.org/10.1080/10494820.2020.1719163

Liu, Y., & Pásztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. *Thinking Skills and Creativity*, *45*. https://doi.org/10.1016/j.tsc.2022.101069

Lovegreen, V. (2020). Critical Thinking Pedagogy and Quality Assurance in the United States. *Emerald Publishing Limited*, 13–28. https://doi.org/https://doi.org/10.1108/978-1-83867-106-820201004

Mahmood, D., & Jacobo, H. (2019). Grading for growth: Using sliding scale rubrics to motivate struggling learners. *Interdisciplinary Journal of Problem-Based Learning*. https://doi.org/10.7771/1541-5015.1844

Masek, A., & Yamin, S. (2011). The Effect of Problem Based Learning on Critical Thinking Ability: A Theoretical and Empirical Review. *International Review of Social Sciences and Humanities*, *2*(1), 215–221. www.irssh.com

Maskur, R., Sumarno, Rahmawati, Y., Pradana, K., Syazali, M., Septian, A., & Palupi, E. K. (2020). The effectiveness of problem based learning and aptitude treatment interaction in improving mathematical creative thinking skills on curriculum 2013. *European Journal of Educational Research*, *9*(1), 375–383. https://doi.org/10.12973/eu-jer.9.1.375

Mayer, R. E. (2005). *Multimedia Learning* (Vol. 2). Cambridge University Press.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In *The Cambridge Handbook of Multimedia Learning, Second Edition* (pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Miller, L. D., Soh, L.-K., Chiriacescu, V., Ingraham, E., Shell, D. F., Ramsay, S., & Hazley, M. P. (2013). Improving learning of computational thinking using creative thinking exercises in CS-1 computer science courses. *2013 IEEE Frontiers in Education Conference (FIE)*, 1426–1432. https://doi.org/10.1109/FIE.2013.6685067

Miterianifa, Trisnayanti, Y., Khoiri, A., & Ayu, H. D. (2019). Meta-analysis: The effect of problem-based learning on students' critical thinking skills. *AIP Conference Proceedings*, *2194*. https://doi.org/10.1063/1.5139796

Mulyanto, H., Gunarhadi, G., & Indriayu, M. (2018). The Effect of Problem Based Learning Model on Student Mathematics Learning Outcomes Viewed from Critical Thinking Skills. *International Journal of Educational Research Review*, *3*(2), 37–45. https://doi.org/10.24331/ijere.408454

Mustaffa, N., Ismail, Z., Tasir, Z., & Said, M. N. H. M. (2016). The Impacts of Implementing Problem-Based Learning (PBL) in Mathematics: A Review of Literature. *International Journal of Academic Research in Business and Social Sciences*, *6*(12). https://doi.org/10.6007/ijarbss/v6-i12/2513

Nor Fadzilah Binti Wan Husin, W., Nor Fadzilah WAN HUSIN, W., Mohamad Arsad, N., Othman, O., Halim, L., Sattar RASUL, M., Osman, K., & Iksan, Z. (2016). Fostering students' 21st century skills through Project Oriented Problem Based Learning (POPBL) in integrated STEM education program. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 17, Issue 1). https://www.researchgate.net/publication/349195017

Odell, M. R. L., Kennedy, T. J., Stocks, E., Odell, M. R. L., Kennedy, T. J., & Stocks, E. (2019). The Impact of PBL as a STEM School Reform Model The Interdisciplinary Journal of Problem-based Learning SPECIAL ISSUE : UNPACKING THE ROLE OF ASSESSMENT IN PROBLEM-AND PROJECT-BASED LEARNING The Impact of PBL as a STEM School Reform Model. *Interdisciplinary Journal of Problem-Based Learning*, *13*(2). https://doi.org/10.7771/1541-5015.1846

Pahlevi, A. S. (2018). Lateral Thinking De Bono Dalam Perancangan Desain. *Journal of Art, Design, Art Education And Culture Studies (JADECS)*, *3*(1), 45–51.

Prayogi, S., Yuanita, L., & Wasis, L. (2018). Critical inquiry based learning: A model of learning to promote critical thinking among prospective teachers of physic. *Journal of Turkish Science Education*, *15*(1), 43–56. https://doi.org/10.12973/tused.10220a

Raine, D., & Symons, S. (2012). Problem-based learning: undergraduate physics by research. *Contemporary Physics*, *53*(1), 39–51. https://doi.org/10.1080/00107514.2011.615162

Rosen, Y., Stoeffler, K., & Simmering, V. (2020). Imagine: Design for creative thinking, learning, and assessment in schools. *Journal of Intelligence*, *8*(2). https://doi.org/10.3390/jintelligence8020016

Sarathy, V. (2018). Real world problem-solving. *Frontiers in Human Neuroscience*, *12*. https://doi.org/10.3389/fnhum.2018.00261

Sasmoko, Noerlina, Indrianti, Y., & Wahid, N. H. A. (2020). Indonesian vocational engagement (I-vocatie): A new concept in improving teacher competencies 4.0. *Journal of Technical Education and Training*, *12*(3 Special Issue), 97–105. https://doi.org/10.30880/jtet.2020.12.03.010

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1). https://doi.org/10.7771/1541-5015.1002

Singh, S., & Dutt, S. (2022). Effecting the Change: Problem Based Learning (PBL) as a Pedagogy to Improve Achievement in Physics in Relation to Cognitive Styles. *ECS Transactions*, *107*(1), 8361–8382. https://doi.org/10.1149/10701.8361ecst

Suarsana, I. M., Lestari, I. A. P. D., & Mertasari, N. M. S. (2019). The effect of online problem posing on students' problem-solving abilitiy in mathematics. *International Journal of Instruction*, *12*(1). https://doi.org/10.29333/iji.2019.12152a

Sugiyono. (2017). *Metode Penelitian Kuantitatif, Kualitatif, Dan R&D*. Alfabeta.

Sukartiningsih, S., & Jacky, M. (2019). What is Discovery Learning Can Grow CriticalThinking Skills? *The IndonesianJournal of Social Studies*, *2*(2), 87–94. https://journal.unesa.ac.id/index.php/jpips/index

Sumirattana, S., Makanong, A., & Thipkong, S. (2017). Using realistic mathematics education and the DAPIC problem-solving process to enhance secondary school students' mathematical literacy. *Kasetsart Journal of Social Sciences*, *38*(3), 307–315. https://doi.org/10.1016/j.kjss.2016.06.001

Suparji, S., Nurlaela, L., & Putra, B. (2018). Strategy to Develop the Ability of Creative Thinking Using Problem-Based Learning Model in Light Vehicle Engineering Competences of Vocational Education. *Proceedings of the International Conference on Indonesian Technical Vocational Education and Association (APTEKINDO 2018)*, 83–86. https://doi.org/10.2991/aptekindo-18.2018.18

Syahrin, A., Dawud, Suwignyo, H., & Priyatni, E. T. (2019). Creative thinking patterns in student's scientific works. *Eurasian Journal of Educational Research*, *2019*(81). https://doi.org/10.14689/ejer.2019.81.2

Tania, R., & Jumadi. (2021). The Application of Physics Learning Media Based on Android with Learning Problem Based Learning (PBL) to Improve Critical Thinking Skills. *Proceedings of the 7th International Conference on Research, Implementation, AndEducation of Mathematics and Sciences*. https://doi.org/10.2991/assehr.k.210305.085

Thaiposri, P., & Wannapiroon, P. (2015). Enhancing Students' Critical Thinking Skills through Teaching and Learning by Inquiry-based Learning Activities Using Social Network and Cloud Computing. *Procedia - Social and Behavioral Sciences*, *174*, 2137–2144. https://doi.org/10.1016/j.sbspro.2015.02.013

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). https://doi.org/10.7771/1541-5015.1649

Wachira, K., & Absaloms, H. O. (2017). A raspberry-pi centred quasi-flipped learning model to trigger creative-thinking in electrical engineering students. *2017 IEEE AFRICON: Science, Technology and Innovation for Africa, AFRICON 2017*, 688–693. https://doi.org/10.1109/AFRCON.2017.8095566

Wiltshire, T. J., Butner, J. E., & Fiore, S. M. (2018). Problem-Solving Phase Transitions During Team Collaboration. *Cognitive Science*, *42*(1). https://doi.org/10.1111/cogs.12482

Winkler, R., Söllner, M., & Leimeister, J. M. (2021). Enhancing problem-solving skills with smart personal assistant technology. *Computers and Education*, *165*(March 2020). https://doi.org/10.1016/j.compedu.2021.104148

Yang, K. K., Lee, L., Hong, Z. R., & Lin, H. S. (2016). Investigation of effective strategies for developing creative science thinking. *International Journal of Science Education*, *38*(13), 2133–2151. https://doi.org/10.1080/09500693.2016.1230685

Yayuk, E., & Husamah, H. (2020). The difficulties of prospective elementary school teachers in item problem solving for mathematics: Polya's steps. *Journal for the Education of Gifted Young Scientists*, *8*(1). https://doi.org/10.17478/jegys.665833