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PISA 2021 CREATIVE THINKING INSTRUMENT FOR STUDENTS: PHYSICS TEACHERS' PERCEPTIONS

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ABSTRACT

Creative thinking, as one of the 21st century skills, is an ability that must be mastered by individuals, especially in this ever-changing era. Therefore, the demands of teachers are not only limited to training them in learning, but also knowing the profile of students' creative thinking abilities is also considered very important. The purpose of this study was to describe teachers' perceptions and interests about the need for creative thinking instruments with the PISA 2021 framework. A total of 30 physics teachers who teach in various provinces in Indonesia were involved as respondents in this study. Respondents are high school physics teachers with characteristics aged 20-40 years, 19 are female, and 11 are male. Based on the results of the analysis, it is known that more than 90% of respondents stated that it is very important to measure students' creative thinking skills. As many as 83% of respondents stated that they were interested in the PISA 2021 creative thinking ability framework and wanted to try to do a creative thinking ability test with the PISA framework. Thus, teachers have a positive perception of the PISA 2021 creative thinking framework. For this reason, it is recommended for teachers to develop creative thinking instruments with the 2021 PISA framework to measure students' creative thinking skills in learning.

INSTRUMEN BERPIKIR KREATIF PISA 2021 UNTUK SISWA: PERSEPSI GURU FISIKA

Kata Kunci:

Kemampuan berpikir kreatif
Instrumen
PISA 2021
Persepsi guru

ABSTRAK

Berpikir kreatif, sebagai salah satu kemampuan abad 21, merupakan kemampuan yang harus dikuasai oleh individu terutama di era yang terus berubah ini. Sehingga, tuntutan bagi guru tidak hanya terbatas pada melatihkannya dalam pembelajaran, tapi juga mengetahui profil kemampuan berpikir kreatif siswa juga dianggap sangat penting. Tujuan penelitian ini adalah untuk mendeskripsikan persepsi dan ketertarikan guru terhadap instrumen berpikir kreatif dengan *framework* PISA 2021. Sebanyak 30 guru fisika yang mengajar di berbagai provinsi di Indonesia terlibat sebagai responden dalam penelitian ini. Responden merupakan guru fisika SMA dengan karakteristik berusia 20-40 tahun, 19 berjenis kelamin perempuan, dan 11 berjenis kelamin laki-laki. Berdasarkan hasil analisis, terdapat lebih dari 90% responden menyatakan sangat penting untuk mengukur kemampuan berpikir kreatif siswa. Sebanyak 83% responden menyatakan tertarik dengan framework kemampuan berpikir kreatif PISA 2021 dan ingin mencoba melakukan tes kemampuan berpikir kreatif dengan *framework* PISA 2021. Dengan demikian, dapat disimpulkan bahwa guru

memiliki persepsi positif terhadap *framework* PISA 2021. Untuk itu disarankan kepada guru untuk mengembangkan instrumen berpikir kreatif dengan kerangka PISA 2021 untuk mengukur kemampuan berpikir kreatif siswa dalam pembelajaran.

1. INTRODUCTION

As we live in today, this era is developing very fast and often unpredictable. Some researchers even reveal that the 21st century is the most uncertain century [1]–[3]. So to be able to adapt well to changes, individuals must be able to think outside the box or think creatively [4]. The news circulating in the community about creative thinking is often exaggerated, it is said that creative thinking can only be mastered by certain people, which in fact is not [4], [5]. Sometimes, the ability to think creatively does not appear in a person because this ability is 'sleeping' and not trained enough. Like other abilities, creative thinking can be obtained through practice and habituation through the learning process [6]–[9]. Thus, teachers have a very big role in developing students' creative thinking skills by providing thinking activities in class [10], [11].

Creative thinking is considered as one of the ideal abilities that are expected to be mastered by students during the learning process [12]–[14]. Many researchers provide definitions related to creative thinking skills. Beghetto defines creative thinking as the ability to offer new perspectives, generate new and meaningful ideas, ask new questions, and generate solutions to problems [15]. While Tanggaard has a more extreme opinion regarding creative thinking, he defines creative thinking as the ability to refuse to surrender or defy an authority or rule [16]. It can also be interpreted that the ability to think creatively according to Tanggard is the ability to think freely without limits.

The development of creative thinking skills is influenced by several factors, namely individual internal factors and environmental factors [4], [17]. Environmental factors include the school and the surrounding community. School factors consist of curriculum, school atmosphere, study groups, and teachers. So, in this case, the teacher also plays an important role in developing students' creative thinking skills. Individual internal factors are factors that come from within the individual, including thinking styles, motivations, knowledge, intelligence, attitudes, character, and life experiences [18], [19].

In addition to various definitions related to creative thinking, various creative thinking models have also been developed, such as the creativity 4c model by Kaufman and Beghetto [20], treffinger indicator [21] which was very popular, and more recently, framework developed by OECD [6]. The creative thinking ability framework developed by PISA has more solid indicators.

PISA 2021 framework states each indicator of creative thinking in four expressions, written expression, visual expression, social problem solving, and scientific problem-solving. The first indicator is 'generate diverse ideas' was expressed through writing, visuals, school problem solving, and scientific problem-solving, likewise with generate creative ideas indicator and evaluating and improve ideas indicator. Thus, there are 12 main indicators in PISA's creative thinking framework.

Creative thinking skills are very important for students, especially for learning abstract concepts [22]–[24], such as science and mathematics, for example in studying physics concepts. In understanding the concept of physics, students must be able to use their imagination well so that the concept of physics can be depicted correctly in their minds. Because the concept of physics will explain natural phenomena through empirical evidence. The framework for thinking about the concept of physics in learning and its relationship to creative thinking is depicted in Figure 1.

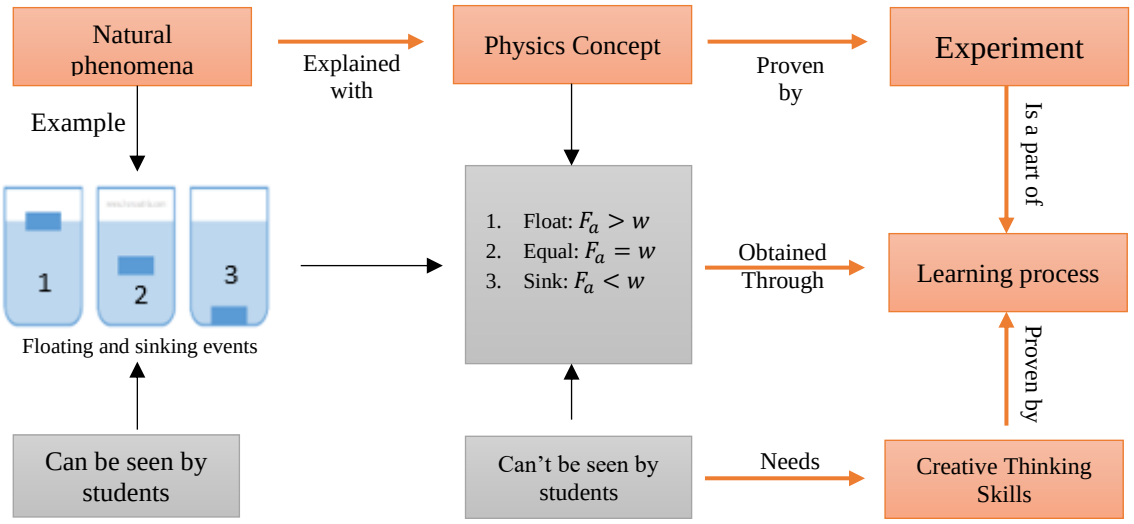


Figure 1. The framework of creative thinking skills on the concept of physics (buoyancy)

In Figure 1, it is clear that the concept of physics is needed to explain natural phenomena that occur in everyday life. However, the concept of physics cannot be seen directly, but through the process of thinking and imagining, this statement is supported by other researches which ensures that to master the concepts of physics, higher thinking skills are needed [25], [26]. As in static fluid material, for example, students can mention the concepts of sinking, floating, and floating, but to understand the concept of buoyancy, students need creative thinking skills, because buoyancy cannot be seen directly but through a process of deep thinking and observation. Therefore, mastery of creative thinking skills is very important in learning physics [27], [28].

Education practitioners from various countries have several times reported the results of measuring creative thinking in learning. In many studies on the application of learning models, learning approaches, learning strategies, and learning media, researchers report a lot of creative thinking ability test results. Several studies were also conducted to improve creative thinking skills, such as developing problem-solving-based teaching materials to improve creative thinking [29], implementing e-learning to improve creative thinking [30], applying the STEM learning approach to improve creative thinking [31]–[33], using technology as a learning medium to improve creative thinking [34]–[36], applying the creative responsibility-based teaching learning model to students' creativity [37], innovating the STEM approach in learning media to improve creative thinking [12], applying problem-based learning models to improve creative thinking [38]–[40], to utilizing Android-based learning multimedia to improve creative thinking [41].

Most of the test references use creative thinking indicators developed by Treffinger which consist of fluency, flexibility, originality, and elaboration [21]. These indicators are considered too general in expressing creative thinking skills. In 2021, PISA will develop more complex indicators to measure creative thinking ability. Along with the development of this new framework, it is necessary to know the teacher's response regarding the importance of this framework to be applied in learning in schools, including in assessment. Until now, there are not many studies that use creative thinking instruments with the PISA 2021 framework. This study aims to describe teachers' perceptions and interest in creative thinking instruments with the PISA 2021 framework.

2. METHOD

2.1 Research Design

This study uses a qualitative method with a descriptive approach. In qualitative research, most of the research focus is the reflection of human thinking [42]. In line with this qualitative view, the purpose of this study is to describe teacher perceptions regarding the need for creative thinking instruments and teacher interest in creative thinking instruments with the PISA 2021 framework. The details of the research process are depicted in the flow chart in Figure 2.

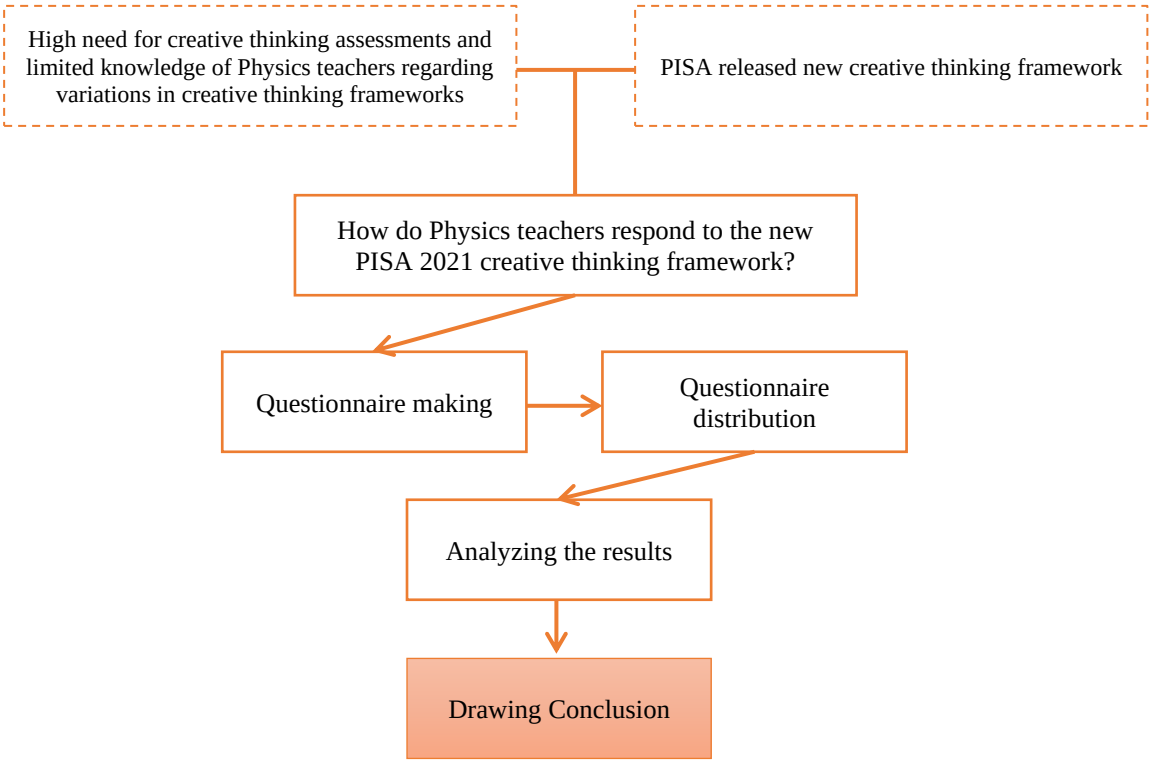


Figure 2. Research Flow

2.2 Research Instruments

The instrument used in this research is a needs analysis instrument with 3 main indicators: information related to the application of creative thinking skills in physics learning, information related to the application of the creative thinking test, and information related to the application of the creative thinking test

From the three information above, it is developed into:

1. Nine statements with a Likert scale

The example of a statements are shown in Table 1.

Table 1. Questionnaire Items with a Likert Scale

Information	Statement	SA	A	DA	SDA
Practice creative thinking skills at school	1. You train students to get used to assembling their own experimental tools according to the experimental objectives to be achieved				
	2. In teaching physics, You direct your students to find their own various problems in everyday phenomena according to the topic being studied				

With: SA = Strongly Agree A = Agree DA = Disagree SDA = Strongly Disagree

2. Three questions with answers on a scale of 4, 3, 2, 1
   The example of a statements are shown in Table 2.

Table 2. Questionnaire items with a scale of 4, 3, 2, 1

Information	Question	4	3	2	1
Creative Thinking Test	1. How important do you think creative thinking skills are? 2. How important is it to know the profile of students' creative thinking skills?				

3. Three questions with yes or no answer choices
   The example of a statements are shown in Table 3.

Table 3. Questionnaire Items with Yes or No Options

Information	Question	Y	N
PISA 2021 creative thinking skills framework	1. Have you ever heard of the PISA 2021 creative thinking skills framework? 2. Have you used the PISA 2021 creative thinking ability framework in developing creative thinking test?		

4. One question to choose more than one answer
   The example of a statements are shown in Table 4.

Table 4. Questionnaire Item with Multiple Answer Choices

Information	Question
PISA 2021 creative thinking skills framework	3. In your opinion, from the eleventh grade physics lesson below, which material is the most appropriate for measuring creative thinking skills? (you may choose more than 1) □ Rigid Body Equilibrium □ Rotational Dynamics □ Hooke's Law □ Static Fluid □ Dynamic Fluid □ Heat and Temperatures □ Kinetic Theory of Gases □ Thermodynamics □ Mechanical Wave □ Sound Wave □ Doppler Effect □ Light Wave □ Optic □ Mirror and Lens □ Keppler Law

5. Five open-ended questions
   The example of a statements are shown in Table 5.

Table 5. Questionnaire Statements with Open-ended Question

Information	Statement
PISA 2021 creative thinking skills framework	1. If you think creative thinking skills are important in studying physics, what is the reason?
Practice creative thinking skills at school	2. If you have ever measured students' creative thinking skills, what type of questions did you use? What indicators are used?

2.3 Respondent

The respondents of this study were 30 high school physics teachers who teach eleventh grade in Indonesia. With the characteristics of 11 male physics teachers and 19 female physics teachers. In full, the demographics of the respondents involved in this study are shown in Table 6.

Table 6. Demographics of Research Respondents

Sample Category	Gender		Age		Last Education				Province			
			20-30	30-40	BPE	BP	MPE	HS	L	B	WJ	SS
N = 30	11	19	23	7	18	2	7	3	21	3	3	1

Description:

: Man

: Woman

BPE : Bachelor of Physicc Education
BP : Bacehelor of Physics
MPE : Master of Physicc Education
HS : High School (are studying in bachelor degree)
L : Lampung
B : Banten
WJ : West Java
SS : South Sumatera

The distribution of the research sample reviewed by province is shown in Figure 3.

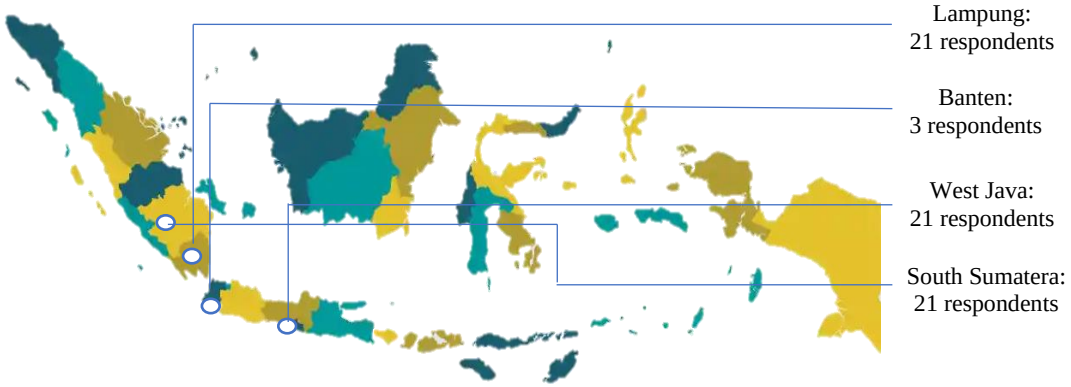


Figure 3. Distribution of Research Samples by Province

2.4 Trustworthness of the Research

There are at least four criteria for a qualitative research to say the data can be trusted, including credibility, transferability, dependability, and confirmability. One way to ensure the credibility of a study is seen from the selection of samples chosen at random. Transferability is external validity which states that research results can be applied to other objects. Dependability is reliability, and confirmability is expert judgment regarding the objectivity of the instrument [4]. In collecting research data, researchers pay attention to these four criteria. How this research meets the four criteria is discussed in Table 7.

Table 7. Trustworthness of the Research

Trustworthness Criteria	The Steps in this Research
Credibility	In this study, respondents were selected randomly by distributing forms to several teachers in several regions in Indonesia. Physics teachers who participated as respondents in this study filled out a questionnaire voluntarily.
Transferability	In qualitative research, because the object is humans, where each thought is complex and different, it cannot be generalized, so the results of this study do not have to represent the perceptions of Indonesian physics teachers as a whole.
Dependability	The research instrument is declared reliable if it can be used to test other objects under the same conditions. This research instrument was developed with this in mind.
Confirmability	In this case, the researcher involved lecturers in the physics education department at the Indonesian Education University.

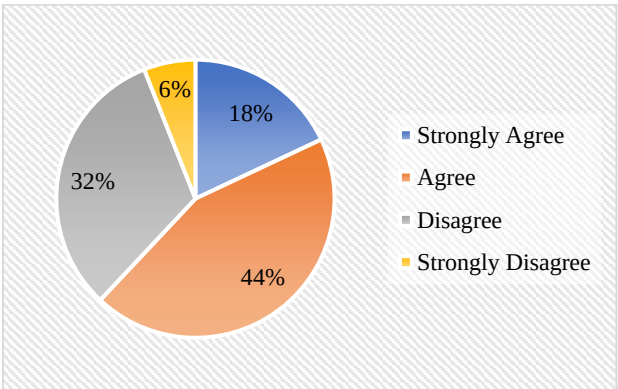
2.5 Data Analysis

Data were analyzed by interactive analysis by Miles and Huberman [43], with the steps:

1. Data collection. At this stage, a questionnaire was distributed to high school physics teachers in Indonesia. Distribution is done within 1 week (1 December-12 December 2021).
2. Data Reduction. At this stage, the researcher collects and calculates the results, discards unnecessary data, leaving the data needed to be presented.
3. Data presentations. At this stage, the researcher presents the data in the form of presentations, tables, and graphs.

3. RESULTS AND DISCUSSION

Measuring students' creative thinking skills is as important as practicing creative thinking skills in learning. Therefore, knowing the perception of teacher needs regarding what kind of creative thinking instrument is needed is also important. However, before knowing this, researchers must know the profile of learning that occurs in the classroom, whether teachers in Indonesia have implemented learning that can train creative thinking skills. These results are presented in graphical form in Figure 4.



Gambar 4. The Percentage of Respondents who have and haven't Applied Creative Thinking in Class Learning

A total of 62% of respondents (19 teachers) have implemented learning that can train creative thinking skills. So it can be said that the majority of teachers have trained their creative thinking skills through learning physics in class. Although they feel that they have implemented learning that trains creative thinking skills, not all teachers think that their

learning is effective, such as the results of the questionnaire that was filled out by respondent C14 which stated that the respondent has 'directed students to find their own various problems in everyday phenomena', yet 'more than 50% of students have not been able to find a solution to a physics problem in a creative way'. This indicates that active learning is only perceived in one direction, namely from the teacher. In contrast to what was stated by respondent C1, the respondent stated that C1 has 'directed students to find their own various problems in everyday phenomena', therefore' more than 50% of students are able to find a solution to a physics problem in a creative way'. After being confirmed through a questionnaire on the application of the creative thinking test, respondent C14 stated that he had never tested students' creative thinking skills, while respondent C1 stated that he had tested students' creative thinking skills once in 1 semester. Complete data regarding the percentage of respondents who have and have never measured students' creative thinking skills can be seen in Figure 5b.

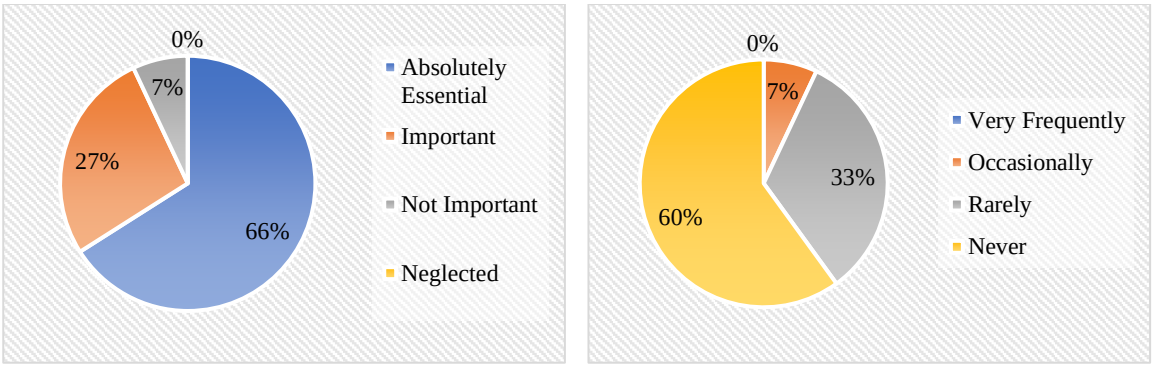


Figure 5. (a) The Teacher's Perception of the Importance of Knowing the Profile of Students' Creative Thinking Skills and (b) The Frequency of Testing Creative Thinking Skills

Description:
Very Frequently : more than 3 times in 1 semester
Occasionally : 2-3 times in 1 semester
Rarely : only once in 1 semester
Never : have never done a special creative thinking ability test

Figure 5 shows that most respondents consider knowing the profile of students' creative thinking skills is important. Based on figure 5 (a), 7% respondents who stated that knowing the profile of students' creative thinking skills was not important were respondents C24 and C28. In the open-ended question, respondents stated several reasons related to things that made them think that doing creative thinking ability tests was not important, as shown in Table 8 below.

Table 8. Respondents' Responses to the Creative Thinking Ability Test

Code	Gender	Province	Response
			Contra
C24		South Sumatera	I feel that doing a creative thinking test in particular is not needed because it is inefficient, besides that the exam questions have been integrated with the HOTS, so that a creative thinking ability test is not specifically needed.
C28		Lampung	It is true that creative thinking skills are included in the 21st century skills that are important to be trained, but the government has provided an assessment that takes into account the 4C abilities, so there is no need to do individual tests.

			Pro
C03		Lampung	It's very important. Because creative thinking is one of the 21st century abilities that is demanded as a learning outcome, so knowing the profile of students' creative thinking is very important.
C07		South Sumatera	Measuring creative thinking skills can't just be observed during learning, so a separate test is needed to find out the profile of students' creative thinking.

Although more than 90% of respondents agree that it is important to do a creative thinking ability test (see Figure 5a), 60% of them have never done a creative thinking ability test independently. Regarding this, several respondents shared their reasons as seen in Table 9.

Table 9. Respondents' Responses Regarding the Reasons for not doing the Creative Thinking Test

Kode	Gender	Province	Reason
C05		Lampung	Don't have enough ability to make creative thinking instruments
C18		West Java	There is not enough time to do and develop a creative thinking ability test
C11		Lampung	Don't have a creative thinking ability test draft, don't have time to make your own creative thinking ability test
C25		South Sumatera	Couldn't make a good creative thinking ability test

Based on some of the responses in Table 9, physics teachers actually want to test creative thinking skills, but due to the unavailability of creative thinking instruments, they have never tested creative thinking skills on students. 40% respondents (12 respondents) stated that they had done a creative thinking ability test on students. As a follow-up question, through an open-ended question, the researcher explores the types of tests and indicators of creative thinking ability used by teachers to measure students' creative thinking abilities. The results are presented in Table 10.

Table 10. Types of Creative Thinking Ability Tests used by Teachers

Code	Gender	Province	Education	Test Type
C01		Lampung	B PE	Multiple choice with reason Treffinger model: fluency, flexibility, originality, elaboration I got the test from the internet, assessment bank, and sometimes i tried to make them myself
C02		Lampung	HS	Multiple choice I looked for the test in the HOTS book
C03		Lampung	M PE	Multiple choice with reason Flexibility, fluency, elaboration, originality I develop my own assessment and collaborate with fellow teachers and college friends who also develop creative thinking skills
C04		Lampung	B PE	Essay Flexibility, fluency, originality and elaboration I develop my own assessment, I have experience developing creative thinking assessment when I was in bachelor degree
C06		Lampung	B PE	Multiple choice with reason With indicators of fluency, flexibility, originality, and elaboration.

				I use a creative thinking assessment that I have developed as a result of a training.
C07		Sumatera Selatan	B PE	Essay Fluency, flexibility, elaboration, originality, and problem solving. The test that I use is the result I developed myself as a coursework when I was in S1, I used this test to test 3 different classes.
C08		Jawa Barat	B PE	Multiple choice and Essay Fluency, flexibility, elaboration, originality, and problem solving. I developed my own assessment and sought references from training handouts and HOTS books.
C09		Lampung	HS	Multiple choice I looked for assessments on the internet and HOTS books.
C10		Lampung	B PE	Essay and Multiple choice Originality, elaboration, fluency I am looking for references from the internet and HOTS books
C14		Banten	M PE	Essay Treffinger indicator I use the test developed by my friend when I was in bachelor degree.
C16		West Java	B PE	Essay Fluency, flexibility, elaboration, originality I have developed creative thinking skills when I was undergraduate, sometimes I also searched in the internet and books
C20		Banten	B PE	Multiple choice with reason Fluency, flexibility, originality, elaboration I developed creative thinking skills with fellow teachers.

Table 10 describes the types of creative thinking ability tests that have been used by the twelve respondents. Based on the survey results, there are 3 types of questions that are often used by respondents, reasoned multiple choice, essay, and ordinary multiple choice. Based on the indicators, the average respondent uses creative thinking indicators developed by Treffinger, namely flexibility, fluency, originality, elaborative, and problem solving.

Judging from how to get the problem, there are four classifications, the instrument source chart is shown in Figure 6 below. A total of 8 respondents said that they developed their own creative thinking instrument that they used. 6 respondents said they got questions from books, 4 people said they got questions from the internet, and 2 people said they got questions from other sources, other sources referred to are the results of friends development and results from workshops.

Regarding the creative thinking framework, when asked whether the respondents knew about the PISA 2021 creative thinking framework, 93% of respondents said they did not know, the other 7% claimed to have heard of it but had never known the form of the instrument. 83% of respondents stated that they wanted to try using the PISA framework to test students' creative thinking skills but did not know how to develop it. Respondent C03 stated that he hoped for the development of creative thinking ability tests through this new framework.

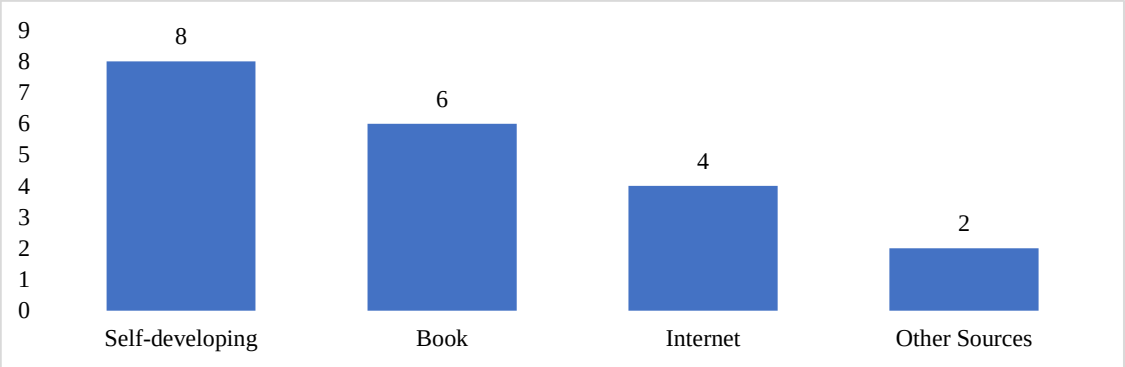


Figure 6. Source of Instruments

Physics topics that are most suitable to be used to measure creative thinking skills, the teacher gives a vote on 15 physics topics in class 11 High School. The result is shown in Figure 7.

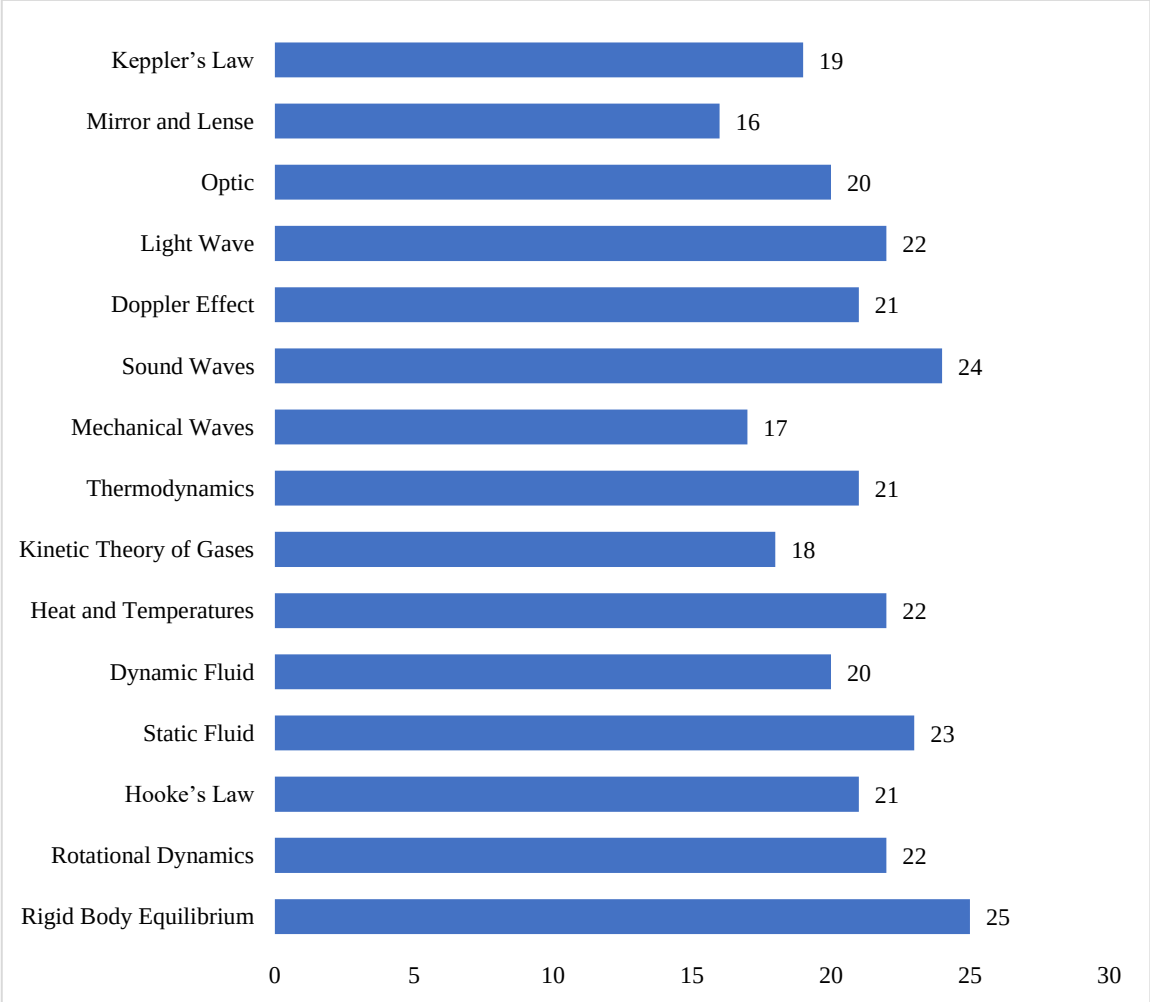


Figure 7. The most Suitable Topics to Measure Students' Creative Thinking Skills

Based on the results above, it is known that the three major materials considered by phyisics teachers to be the most appropriate for measuring creative thinking skills are rigid body equilibrium, sound waves, and static fluid. Several previous studies have also acknowledged this, as stated by several previous studies, sound wave is indeed a difficult

topic to study [44]–[47], and rigid body equilibrium is also a complicated concept [48]–[50]. The finding of this study shows that physics teachers are aware of the importance of measuring creative thinking skills in students, however many teachers have never done this specifically. In addition, not many teachers are aware of the PISA 2021 creative thinking framework, and even the majority of teachers have not been able to develop their own creative thinking assessment. Assessment for thinking skills must be continuously updated because students' thinking skills must continue to develop [51]–[56]. And as times advance, the importance of making creative assessments also increase [57]–[61].

This study provides an overview of the teacher's views regarding the assessment of creative thinking and the latest creative thinking framework from PISA 2021. The results showed that 93% of the teachers stated that it was very important to measure students' creative thinking skills, and 83% of respondents said they were interested to learn more about this. The results also found that not all teachers measure creative thinking skills through observations during the learning process and through tests. The questions used to test the ability to think creatively come from various sources, including self-developing, books or question banks, the internet, and other sources such as developing questions from colleagues and workshops. However, most of the respondents do not know how to develop a good creative thinking assessment and they do not even know about the latest creative thinking framework proposed by PISA. Therefore, it is important to provide workshops to train teachers in developing creative thinking assessments and introduce the PISA 2021 creative thinking framework. It is also important to develop creative thinking instruments that utilize the PISA 2021 creative thinking framework.

4. CONCLUSION

Research has been conducted to describe teachers' perceptions regarding the need for creative thinking instruments and teacher interest in creative thinking instruments with the PISA 2021 framework. The results showed that 93% of respondents stated that it was very important to measure students' creative thinking skills and 83% of respondents said they were interested with the PISA 2021 creative thinking ability framework and want to try to test creative thinking skills with the PISA framework.

The finding also revealed that most teachers have measure creative thinking skills through observations during the learning process and through tests. About 40% of respondents have done a creative thinking ability test independently (not through exam questions). The questions used to test the ability to think creatively come from various sources, including self-developing, books or question banks, the internet, and other sources such as developing questions from colleagues and workshops. Respondents also shared their thoughts regarding what physics topics are suitable for measuring creative thinking skills, the 3 topics with the most votes were the equilibrium of rigid bodies, sound waves, and static fluids.

Furthermore, this study provides a detailed description of information related to teachers' perceptions of the need for creative thinking instruments and teacher interest in creative thinking instruments with the PISA 2021 framework. So for further research, the researchers suggest developing creative thinking instruments with the PISA 2021 framework with the topic of equilibrium. rigid bodies, sound waves, or static fluids.

REFERENCES

[1] G. A. Callanan, D. F. Perri, and S. M. Tomkowicz, "career management in uncertain times: challenges and opportunities," *Career Dev. Q.*, vol. 65, no. 4, pp. 353–365, 2017.

[2] A. Craft, *creativity and education futures: learning in a digital age*. London: Trentham Books, 2010.
[3] D. Geltner and R. D. Neufville, "Uncertainty, flexibility, valuation and design: How 21st century information and knowledge can improve 21st century urban development – part ii of ii," *Pacific Rim Prop. Res. J.*, vol. 18, no. 3, pp. 251–276, 2012.
[4] S. T. Akyıldız and V. Çelik, "Thinking outside the box: Turkish EFL teachers' perceptions of creativity," *Think. Ski. Creat.*, vol. 36, no. January, 2020.
[5] S. Davis, "Creativity and the cybernetics of self: drama, embodied creation and feedback processes," in *Creativity Theory and Action in Education*, Switzerland: Springer, 2018.
[6] OECD, "PISA 2021 creative thinking framework (third draft)," *Oecd*, vol. 53, no. 9, pp. 1689–1699, 2021.
[7] B. Lucas and E. Spencer, T*eaching creative thinking: developing learners who generate ideas and can think critically*. United States of America: Crown House Publishing Limited, 2017.
[8] A. A. S. Tabieh, M. M. Al-Hileh, H. M. J. Abu Afifa, and H. Y. Abuzagha, "The effect of using digital storytelling on developing active listening and creative thinking skills," *Eur. J. Educ. Res.*, vol. 10, no. 1, pp. 13–21, 2020.
[9] Q. Zhou, "Development of creative thinking skills through aesthetic creativity in middle school educational music course," *Think. Ski. Creat.*, vol. 40, 2021.
[10] T. Hardianti and H. Kuswanto, "Difference among levels of inquiry : process skills improvement at senior high school in Indonesia," *Int. J. Instr.*, vol. 10, no. 2, pp. 119–130, 2017.
[11] F. Permata Sari, S. Nikmah, H. Kuswanto, and R. Wardani, "Development of physics comic based on local wisdom: Hopscotch (engklek) game android-assisted to improve mathematical representation ability and creative thinking of high school students," *Rev. Mex. Fis. E*, vol. 17, no. 2, pp. 255–262, 2020.
[12] A. Saregar, S. Latifah, M. N. Hudha, F. Susanti, and N. E. Susilowati, "STEM-inquiry brainstorming: Critical and creative thinking skills in static fluid material," *Period. Tche Quim.*, vol. 17, no. 36, pp. 491–505, 2020.
[13] K. C. Suryandari, S. Sajidan, S. B. Rahardjo, Z. K. Prasetyo, and S. Fatimah, "Project-based science learning and pre-service teachers' science literacy and creative thinking," *Cakrawala Pendidik.*, vol. XXXVII, no. 3, pp. 345–355, 2018.
[14] E. Istiyono, "Measuring creative thinking skills of senior high school male and female students in physics (CTSP) using the IRT-based PhysTCreTS," *J. Turkish Sci. Educ.*, vol. 17, no. 4, pp. 578–590, 2020.
[15] R. A. Beghetto, "Does creativity have a place in classroom discussions? Prospective teachers' response preferences," *Think. Ski. Creat.*, vol. 2, no. 1, pp. 1–9, 2007.
[16] L. Tanggaard, "Stories about creative teaching and productive learning," *Eur. J. Teach. Educ.*, vol. 34, no. 2, pp. 219–232, 2011.
[17] E. O. Bereczki and A. Kárpáti, "Teachers' beliefs about creativity and its nurture: A systematic review of the recent research literature," *Educ. Res. Rev.*, vol. 23, no. October 2017, pp. 25–56, 2018.
[18] J. Lee and H. Choi, "What affects learner's higher-order thinking in technology-enhanced learning environments? The effects of learner factors," *Comput. Educ.*, vol. 115, pp. 143–152, 2017.
[19] Z. Liu *et al.*, "Neural and genetic determinants of creativity," *Neuroimage*, vol. 174, pp. 164–176, 2018.

[20] J. C. Kaufman and R. A. Beghetto, "Beyond big and little: The four C model of creativity," *Rev. Gen. Psychol.*, vol. 13, no. 1, pp. 1–12, 2009.
[21] S. M. Ritter *et al.*, *Assessing Creativity: A Guide for Educators*, no. December. United States of America: The National Research Center on the Gifted and Talented, 2002.
[22] M. Sun, M. Wang, and R. Wegerif, "Effects of divergent thinking training on students' scientific creativity: The impact of individual creative potential and domain knowledge," *Think. Ski. Creat.*, vol. 37, no. September 2019, pp. 1–10, 2020.
[23] P. Gardiner, "Learning to think together: Creativity, interdisciplinary collaboration and epistemic control," *Think. Ski. Creat.*, vol. 38, no. December, 2020.
[24] H. Caldwell, E. Whewell, and R. Heaton, "The impact of visual posts on creative thinking and knowledge building in an online community of educators," *Think. Ski. Creat.*, vol. 36, no. November 2019, p. 100647, 2020.
[25] F. P. Sari, "Development of physics comic based on local wisdom: Hopscotch (engklek) game android-assisted to improve mathematical representation ability and creative thinking of high school students," *Rev. Mex. Fis. E*, vol. 17, no. 2, pp. 255–262, 2020.
[26] E. S. Kurniawan, "Synectic HOTS oriented: Development of teaching materials for high school physics learning," *Univers. J. Educ. Res.*, vol. 8, no. 11, pp. 5547–5554, 2020.
[27] I. Wicaksono, Wasis, and Madlazim, "The effectiveness of virtual science teaching model (VS-TM) to improve student's scientific creativity and concept mastery on senior high school physics subject," *J. Balt. Sci. Educ.*, vol. 16, no. 4, pp. 549–561, 2017.
[28] J. Batlolona, "Creative thinking skills students in physics on solid material elasticity," *J. Turkish Sci. Educ.*, vol. 16, no. 1, pp. 48–61, 2019.
[29] M. Aulia Rahman, Suparman, and Y. Hairun, "Design of teaching material for problem-based learning to improve creative thinking skills," *Univers. J. Educ. Res.*, vol. 8, no. 2, pp. 559–565, 2020.
[30] P. Yaniawati, R. Kariadinata, N. M. Sari, E. E. Pramiarsih, and M. Mariani, "Integration of e-learning for mathematics on resource-based learning: Increasing mathematical creative thinking and self-confidence," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 6, pp. 60–78, 2020.
[31] Parno, E. Supriana, L. Yuliati, A. N. Widarti, M. Ali, and U. Azizah, "The influence of STEM-based 7E learning cycle on students critical and creative thinking skills in physics," *Int. J. Recent Technol. Eng.*, vol. 8, no. 2 Special Issue 9, pp. 761–769, 2019.
[32] N. Wannapiroon and S. Petsangsri, "Effects of STEAMification model in flipped classroom learning environment on creative thinking and creative innovation," *TEM J.*, vol. 9, no. 4, pp. 1647–1655, 2020.
[33] G. Ozkan and U. Umdu Topsakal, "Exploring the effectiveness of STEAM design processes on middle school students' creativity," *Int. J. Technol. Des. Educ.*, vol. 31, no. 1, pp. 95–116, 2021.
[34] E. J. Park and M. J. Kim, "Visual communication for students' creative thinking in the design studio: Translating filmic spaces into spatial design," *Buildings*, vol. 11, no. 3, pp. 1–19, 2021.
[35] O. M. A. Aldalalah, "The Effectiveness of Infographic via Interactive Smart Board on enhancing Creative Thinking: A Cognitive Load Perspective," *Int. J. Instr.*, vol.

14, no. 1, pp. 345–364, 2020.
[36] S. Atun and V. P. S. Latupeirisa, "Science KIT teaching aid for the earthquake in improving students' collaboration skills and creative thinking in junior high school," *Eur. J. Educ. Res.*, vol. 10, no. 1, pp. 187–197, 2021.
[37] N. Suyidno, Y. M., P. L., B. K., and B. Jatmiko, "Effectiveness of creative responsibility based teaching model on basic learning physics to increase student's scientific creativity and responsibility," *J. Balt. Sci. Educ.*, vol. 17, no. 1, pp. 136–151, 2017.
[38] W. Wartono, M. Diantoro, and J. R. Bartlolona, "Influence of problem based learning learning model on student creative thinking on elasticity topics material," *J. Pendidik. Fis. Indones.*, vol. 14, no. 1, pp. 32–39, 2018.
[39] J. R. Batlolona, M. Diantoro, Wartono, and E. Latifah, "Creative thinking skills students in physics on solid material elasticity," *J. Turkish Sci. Educ.*, vol. 16, no. 1, pp. 48–61, 2019.
[40] M. Nuswowati and M. Taufiq, "Developing creative thinking skills and creative attitude through problem based green vision chemistry environment learning," *J. Pendidik. IPA Indones.*, vol. 4, no. 2, pp. 170–176, 2015.
[41] Shabrina and H. Kuswanto, "Android-assisted mobile physics learning through indonesian batik culture: Improving students' creative thinking and problem solving," *Int. J. Instr.*, vol. 11, no. 4, pp. 287–302, 2018.
[42] K. M. Kim and R. Md-Ali, "Geogebra: Towards realizing 21st century learning in mathematics education," *Malaysian J. Learn. Instr.*, no. Specialissue, pp. 93–115, 2017.
[43] M. B. Miles, A. M. Huberman, and J. Saldana, *Qualitative data analysis a methods sourcebook*, 3rd editio. Los Angeles: Sage, 2014.
[44] A. Dedetürk, A. Kırmızıgül, and H. Kaya, "The effects of STEM activites on 6th grade studets' conceptual development of sound," *J. Balt. Sci. Educ.*, vol. 20, no. 1, pp. 21–37, 2021.
[45] A. Dedetürk, A. S. Kırmızıgül, and H. Kaya, "The effects of stem activities on 6th grade students' conceptual development of sound," *J. Balt. Sci. Educ.*, vol. 20, no. 1, pp. 21–37, 2021.
[46] J. J. Zhao and S. Y. Zhao, "Creativity and innovation programs offered by AACSB-accredited U.S. colleges of business: A Web mining study," *J. Educ. Bus.*, 2021.
[47] J. Li, Z. Fu, Y. Gu, and Q. H. Qin, "Recent Advances and Emerging Applications of the Singular Boundary Method for Large-Scale and High-Frequency Computational Acoustics," *Adv. Appl. Math. Mech.*, vol. 14, no. 2, pp. 315–343, 2022.
[48] Z. Z.gagić, S. J. Skuban, B. N. Radulović, M. M. Stojanović, and O. Gajić, "The implementation of mind maps in teaching physics: Educational efficiency and students' involvement," *J. Balt. Sci. Educ.*, vol. 18, no. 1, pp. 117–131, 2019.
[49] A. Sanchez-Gonzalez, J. Godwin, T. Pfaff, R. Ying, J. Leskovec, and P. W. Battaglia, "Learning to simulate complex physics with raph networks," in *Proceedings of the 37th International Conference on Machine Learning*, pp. 1–10, 2020.
[50] S. M. Hosseini, M. Mohammadi, A. Rosemann, T. Schröder, and J. Lichtenberg, "A morphological approach for kinetic façade design process to improve visual and thermal comfort: Review," *Build. Environ.*, vol. 153, no. November 2018, pp. 186–204, 2019.
[51] D. Henriksen, E. Creely, M. Henderson, and P. Mishra, "Creativity and technology

in teaching and learning: a literature review of the uneasy space of implementation," *Educ. Technol. Res. Dev.*, vol. 69, no. 4, pp. 2091–2108, 2021.

[52] T. Shechter, S. Eden, and O. Spektor-Levy, "Preschoolers' Nascent Engineering Thinking During a Construction Task," *J. Cogn. Educ. Psychol.*, vol. 20, no. 2, pp. 83–111, 2021.

[53] Y. Yang, Y. Long, D. Sun, J. Van Aalst, and S. Cheng, "Fostering students' creativity via educational robotics: An investigation of teachers' pedagogical practices based on teacher interviews," *Br. J. Educ. Technol.*, vol. 51, no. 5, pp. 1826–1842, 2020.

[54] S. Ndiung, Sariyasa, E. Jehadus, and R. A. Apsari, "The effect of treffinger creative learning model with the use rme principles on creative thinking skill and mathematics learning outcome," *Int. J. Instr.*, vol. 14, no. 2, pp. 873–888, 2021.

[55] S. Maksić and S. Jošić, "Scaffolding the development of creativity from the students' perspective," *Think. Ski. Creat.*, vol. 41, 2021.

[56] A. J. Khoiriyah and H. Husamah, "Problem-based Learning: Creative Thinking Skills, Problem-solving Skills, and Learning Outcome of Seventh Grade Students," *J. Pendidik. Biol. Indones.*, vol. 4, no. 2, pp. 151–160, 2018.

[57] S. Rahimi and V. J. Shute, "First inspire, then instruct to improve students' creativity," *Comput. Educ.*, vol. 174, 2021.

[58] K. Biswas, P. Rajput, A. Gupta, B. Bhattacharya, and T. Gupta, "A User-Centric Design Thinking Approach for Advancement in Off-Line PM Air Samplers: Current Status and Future Directions," *Aerosol Sci. Eng.*, vol. 4, no. 4, pp. 239–259, 2020.

[59] S. Kim, I. Choe, and J. C. Kaufman, "The development and evaluation of the effect of creative problem-solving program on young children's creativity and character," *Think. Ski. Creat.*, vol. 33, no. September, pp. 1–11, 2019.

[60] K. Ulger, "The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education," *Interdiscip. J. Probl. Learn.*, vol. 12, no. 1, pp. 1–21, 2018.

[61] A. A. Kholmurzaev and I. K. Tokhirov, "The active participation of students in the formation of the educational process is a key to efficiency," *Acad. An Int. Multidiscip. Res. J.*, vol. 11, no. 4, pp. 435–439, 2021.