



Development of creative thinking and problem-solving skill instrument of plant growth in high school

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ABSTRACT

Creative thinking and problem-solving skills are needed to face the 21st century of 4.0 industrial revolution. Improving the quality of human resources to face the era of the industrial revolution 4.0 must be developed in education. Biology as one of the subjects in high school, especially in plant growth and development matters, allows to develop creative thinking and problem-solving skills because in it there is a student project on plant growth and development. It takes the right instrument to measure the achievement of creative thinking skills and problem solving skills in Biology learning, especially on the topic of plant growth and development. Two instrument questions have been developed, namely the instrument for creative thinking skills and problem solving skills. The development of this instrument was carried out through the stages of Research and Development Borg and Gall 1983. It produced 10 essay questions measuring creative thinking skills and 8 questions measuring problem solving skills. The question gets very decent expert validation criteria with a score of 91% - 97%. The results of the validation test based on the Pearson Product Moment formula show that the ten items of creative thinking skills are valid with a significance level of 0.05. The reliability test of the two instruments has a result of 0.82, above Cronbach's Alpha coefficient, which is reliable for creative thinking skills instruments. Meanwhile, the instrument of problem solving skills showed very reliable results with Cronbach's Alpha value of 0.95.

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INTRODUCTION

Creative thinking skills and problem solving are two of several competencies needed in the 21st century (Care et al., 2018; Trilling & Fadel, 2009; Zubaidah, 2016) which is also known as the era of the industrial revolution 4.0. Creative thinking skills are needed in social life both in the present and in the future to solve new problems that arise in everyday life (Carmeli et al., 2013; Ulger, 2018; Xanthacou & Kaila, 2011). Problem solving skills are also needed to be able to deal with new problems in every field of work (Fischer & Neubert, 2016). The life of the 21st century demands quality human resources in all their efforts and results (Mardhiyah et al., 2021)

Improving the quality of Human Resources through education channels ranging from primary and secondary education to tertiary institutions is the key to being able to follow the development of the Industrial Revolution 4.0 (Mardhiyah et al., 2021). Biology as part of science taught in high school has the basic goal of educating students to be able to research, investigate, and build relationships between knowledge and everyday life (Djamahar et al., 2019). In Biology learning activities, creative thinking skills are needed to synthesize ideas, generate new ideas, and determine the effectiveness of existing ideas (Sumarni & Kadarwati, 2020; Zubaidah et al., 2017). In Biology, students are faced with phenomena in everyday life so that students' problem-solving skills are also very necessary (Muhlisin et al., 2020). Learners who are trained with creative thinking skills will be able to be flexible and see opportunities and face challenges in a world that continues to grow rapidly (Ritter & Mostert, 2017). Meanwhile, students who have the ability to solve problems can overcome change using their creative thinking framework (Isaksen et al., 2010).

One of the Biology materials in class XII SMA is plant growth and development. At SMA Pangudi Luhur II, Indonesia Servasius, learning to achieve basic material skills is carried out with an e-learning-based PjBL model in order to improve 4C skills which include creative thinking and problem solving skills. Unfortunately, the achievement of 4C skills has never been specifically measured with the right instrument. The selection of the right assessment instrument will greatly affect the objectivity and validity of the assessment results so that objective and valid information can be obtained on the achievement of learning objectives. On the other hand, errors in selecting and applying an assessment also result in invalid information regarding learning and education outcomes (Setiadi, 2016). These facts strengthen the reason for conducting a research that develops an instrument for assessing creative thinking skills and problem solving skills that are appropriate for plant growth and development materials in class XII SMA.

METHODS

Research Design

In this study, the method used is research and development (R&D) with the development model of Borg and Gall (1983) which includes the initial research and data collection stages, planning, initial product development, expert validation, and first revision, initial trial, revision. product, field testing, final product revision, and dissemination (Pahrudin et al., 2019). The stages of the research procedure of Borg and Gall (1983) model can be seen in Figure 1

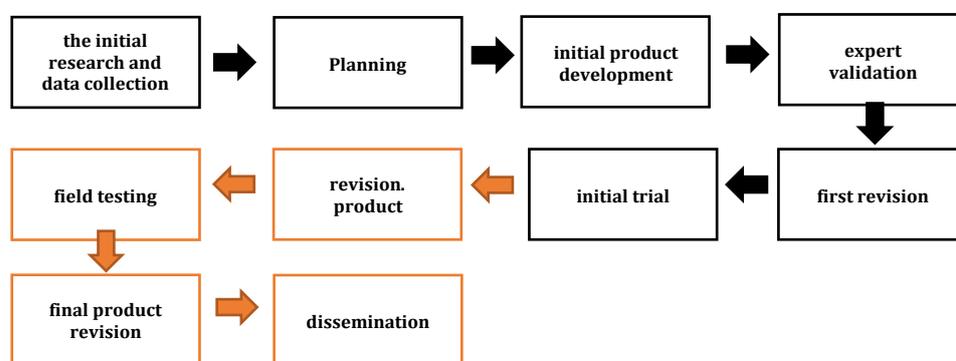


Figure 1. The stages of the research of Borg and Gall (1983)

In the initial research and data collection stage, observations were made at Pangudi Luhur II Servasius High School which applied the PjBL learning model with collaborative subjects with the aim

of improving creative thinking and problem solving skills. The results to be achieved cannot be seen because the instruments developed have not referred to indicators of creative thinking and problem solving skills. At the planning stage, material selection is carried out by looking for sources of reference for creative thinking skills and problem solving skills, then making a grid of questions based on predetermined indicators. The next stage is initial product development. At this stage, 10 questions about creative thinking skills and 8 questions about problem solving skills were developed based on the grid. In addition to questions, rubrics and scoring guidelines are also made to facilitate the assessment process. After all the questions have been made, an expert validation test is carried out. In accordance with the corrections and input from the experts, the item revision process was carried out. Furthermore, at the initial trial stage, validation and empirical reliability tests were completed with 10 students as samples. In this article, the Borg and Gall stages are only executed until the initial trial, the next stage will be accomplished in further research.

Population and Samples

The research was conducted at Pangudi Luhur II Servasius High School in September 2021. The research was quantitative and involved 10 students of class XII class 2020-2021 in testing the validity of the instrument. The population of this study were students of class XII MIPA at SMA Pangudi Luhur II Servasius which consisted of 3 classes. The research sample was chosen randomly, namely students of class XII MIPA 2.

Instrument

Participants were given 10 descriptive questions related to creative thinking skills and 8 questions about problem solving skills. Creative thinking skills questions are made based on creative thinking indicators, namely fluency, flexibility, originality, elaboration and metaphorical thinking (Yusnaeni et al., 2017). Problem solving skills are made based on 4 problem solving indicators, namely identifying problems, seeking information and making designs, providing solutions and maintaining solutions (Muhlisin et al., 2020). Each indicator is made into 2 questions. The grid of creative thinking and problem solving skills can be seen in [Table 1](#) and [Table 2](#).

Table 1.
Grid Question of Creative Thinking Skills

No	Indicator	Number of Problem	Amount of questions
1	Fluency Able to generate ideas, ways, suggestions, questions, and alternative answers smoothly within a certain time	1, 2	2
2	Flexibility Able to generate various ideas, answers, or questions, where the idea or answer is obtained from a different point of view by changing the way of thinking and approach used	3, 4	2
3	Originality able to generate phrases, ways, or ideas to solve problems or create combinations of unusual and unique parts or elements that no one else thought of	5,6	2
4	Elaboration able to enrich, develop, add, describe, or specify details of objects, ideas, products, or situations to make them more interesting	7,8	2
5	Metaphorical thinking able to use comparisons or analogies to make new connections	9,10	2
Total			10

The expert validation stage is carried out to determine whether the product is developed for further use and it is carried out on three experts consisting of two lecturers and one education practitioner. The assessment criteria consist very worthy, eligible worth enough, not eligible very unworthy (Arikunto & Jabar, 2010) shown in [Table 1](#)

Table 2.

Grid Question of problem-solving skills

No	Indicator	Number of Problem	Amount of questions
1	Identifying problems Learners can describe the problem clearly accompanied by data related to learning materials.	1, 2	2
2	Find information and create plans can find and provide several related sources of information and create troubleshooting stages	3, 4	2
3	Provide solutions have some viable solutions and can provide clear reasons	5, 6	2
4	Elaboration able to enrich, develop, add, describe, or specify details of objects, ideas, products, or situations to make them more interesting	7, 8	2
Total			8

Table 3.

Expert Validation Criteria

Interval Category	Criteria
81%-100 %	Very Worthy
61% - 80%	Eligible
41% - 60%	Worth Enough
21% - 40%	Not Eligible
0% - 20%	Very Unworthy

Procedure

In the first stage, preliminary research was carried out at Pangudi Luhur II Servasius High School to achieve basic plant growth and development competencies through PjBL for several subjects (including Biology) with the aim of improving 21st century skills (4C). However, so far, the achievement of 4C skills (which includes creative thinking and problem-solving skills) has never been specifically measured. The next stage is planning, which is choosing material for plant growth and development. This material was chosen because based on the basic competencies that must be achieved, students must carry out a plant growth project so that it is suitable for this research. Creative thinking and problem-solving skills are needed to deal with problems in everyday life (Fischer & Neubert, 2016) one of which is doing plant growth projects.

In the next stage, the initial product development is carried out by making description questions. The description questions were chosen because the description questions instrument demanded creative answers that could measure students' creative thinking skills (Marwiyah et al., 2015). In answering the description questions, students can present their own ideas (Suwanto, 2010) to see the creative process and their ways to solve problems. This instrument is then equipped with an assessment rubric in accordance with the indicators of creative thinking and problem solving that are measured.

The expert validation stage is carried out to determine whether the product is developed for further use, and it is carried out on three experts consisting of two lecturers of plant physiology and one education practitioner. One education practitioner is a P4TK (instructor of learning strategies, assessments, and evaluations of science learning). With the background of expert validators in the field of evaluation of learning and plant physiology, the validators are considered competent to assess the creative and problem solving skills instrument on aspects of presentation, language, and content (BSNP, 2014). After the validation stage, the first revision is carried out in accordance with the input of the expert validator. After the first revision, the initial test of instruments was conducted on 10 students of class XII Class 2020-2021 who had obtained the material of growth and development of plant to get data on validity and reliability. The next stage has not been done in this study and will be done in the next research.

Data Analysis Techniques

Test the validity of the problem item with the Pearson Product Moment Formula, if r calculates $> r$ table of the problem item is declared valid (Widiyanto, 2012). Reliability with Alpha Cronbach's is used to parametrically test instruments of creative thinking skills and problem-solving skills. Instrumen is said to be reliable if Alfa Cronbach's reliability coefficient is more than 0.70 ($r_i > 0.70$)(Murti, 2011)

RESULTS AND DISCUSSION

Three experts validated the creative thinking skill instrument by giving a score on a scale of 1-5. Then, the results of the assessment of the three experts are sought for the average value. Besides the instrument, a scoring grid and rubric are also included to be corrected by expert validators. The results of the validation of the three experts can be seen in Table 4.

Table 4.
Expert Validation Results on Creative Thinking Skills Instruments

	Aspects examined	Number of Question									
		1	2	3	4	5	6	7	8	9	10
A. Material/ Content											
1	Problems in accordance with basic competencies	4.7	4.7	5.0	4.7	5.0	5.0	4.7	4.7	5.0	4.7
2	Problems in accordance with the indicator of creative thinking skills measured	5.0	4.7	4.7	4.7	5.0	4.7	5.0	4.7	4.7	4.7
3	Problems according to the cognitive level measured	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
4	Problems in accordance with learning materials	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
5	Problems in accordance with the characteristics of high school students	4.7	4.7	4.3	4.7	4.7	4.3	4.7	4.7	4.3	4.7
B. Contruccion											
1	The subject matter is clearly formulated	4.7	4.3	4.3	5.0	4.7	4.7	4.7	5.0	4.7	4,7
2	The image used (if any) on the problem is clearly presented	4.7	4.7	4.3	-	-	5.0	5.0	5.0	-	5.0
C. Language											
1	Use language that is in accordance with the rules of Indonesian	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
2	Using communicative language	4.3	4.0	4.3	4.3	4.7	4.7	4.3	4.7	4.3	4.0
3	Use clear and easy to understand sentences	4.3	4.3	4.3	4.7	4.7	4.7	5.0	5.0	4.3	4.7
Value of each question item		4.6	4.5	4.5	4.7	4.7	4.7	4.7	4.8	4.6	4.6
In Percent (%)		93	91	91	93	95	94	95	95	92	93
Criteria		Very Worthy									

From the results above, it can be seen that items 1 to 10 based on material, construction and language aspects are included in the very feasible criteria to be used with the lowest results being 91% for questions number 1, 2 and the highest results for questions numbers 5,7 and 8. on instruments no. 4,5 and 9 there are no pictures, then the assessment column is empty. In addition to providing an assessment, the experts also provide input which is then revised. Inputs and revisions for item 2 can be seen in Figure 2.

Questions before revision	Questions after revision
Pay attention to images of durian plants of the same type, with an experience different treatment.	Look at the following picture:

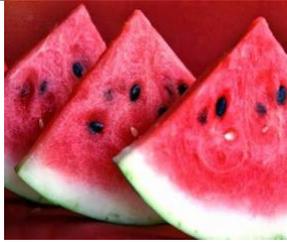
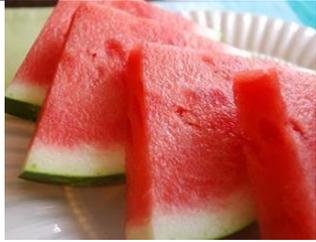
Questions before revision		Questions after revision	
			
Conventional	Biotechnology	Conventional	Biotechnology
Write down ideas, ways, suggestions, questions (along with alternative answers) related to the internal growth factors that can be manipulated to fruit plant on the picture.		Write down ideas, ways, suggestions, questions (along with alternative answers) related to the internal growth factors that can be manipulated to fruit plant on the picture.	

Figure 2. Question number 2 before and after revision

Based on the input of the expert validators, they said that the image is not clear enough and the reader cannot see the purpose of the image. One of the expert suggested to use seeded watermelons image compared to seedless watermelons image. The inputs from two expert validators is also given for question no. 3. Here is the revision for question no. 3 before and after revision.

Questions before revision		Questions after revision	
See the different of the following plants:		See the different of the following plants:	
	Both plants are the same type of succulents and has the same age, but showing different growths. Beside the different of light intensity please give possibilities three different ideas		Both plants are the same type of succulents and has the same age, but showing different growths. Beside the different of light intensity please give possibilities three different ideas regarding to the
regarding to the growth of image number 1.		growth of image number 1	

Figure 3. Question item no. 3 before and after revision

In the point of question no. 3 revision is given on the basis of input that the image of problem no. 3 is unbalanced and less shows the desired conditions to be solved by the student. The pots in both images are not the same and the plants are difficult to compare. Improvements are made by looking for other image sources that are more balanced and can show the intended condition.

In questions no. 2 and 3, there are revisions to the pictures presented in the questions. This is because the pictures on the two questions are not clear enough so that they can produce different interpretations for each student. This is not in accordance with the construction rules for writing description items where the image should be clear and have a function (BNSP, 2010). In addition, the purpose of image media to attract attention, clarify ideas, illustrate facts to attract students' attention so that it is easy to remember the information (Arqam, 2019) will not be achieved if the images displayed instead confuse students. Correction and input from one of the expert validators is also given in the point of question no. 7. Question item no. 7 before and after the revision can be seen in Figure 4.

Questions before revision	Questions after revision
Here is a video link on how to secure a unique plant by paying attention to the external factors that <u>plants need</u> https://youtu.be/cO9YX4Cdesw . After seeing the video provides an idea to enrich / develop / add to the idea of farming by providing detailed	Here is a video link on how to secure a unique plant by paying attention to the external factors that <u>plants need</u> https://youtu.be/cO9YX4Cdesw . After seeing the video provide one idea to enrich / develop / add to the idea of farming by providing detailed specifications about the

specifications about the ideas, ways *and products* *ideas, ways and products produced have better growth produced to become more interesting.* *and productivity.*

Figure 4. Question item no. 7 before and after revision

Question point no. 7 is revised in the last sentence based on the input that the resulting product should not only be interesting but rather have better growth and productivity. The challenge to make plants more productive than just making plants more pleasing to the eye will stimulate students to think more elaborately, especially on plant growth material.

One of the expert validators also provides input for problem item number 10 whose revised results can be seen in [Figure 5](#).

Questions before revision	Questions after revision
<p>This image shows indoor lettuce farming technology that has been done in Japan and China. This technology was developed to overcome the lack of land.</p>	<p>This image shows indoor lettuce farming technology that has been done in Japan and China. This technology was developed to overcome the lack of land.</p>
	
<p>In this agricultural system light, nutrients, temperature and humidity are regulated so that lettuce growth can be optimal. Sunlight replaced LED lights with certain wavelengths suitable for plant photosynthesis needs, as well as temperature and humidity so as not to depend on weather and climate. Nutrition is measured analytically in water media (such as hydroponic farming in general) so that waste of water and nutrients can be avoided. Vertical growth (verticulture) can anticipate the lack of land in urban areas.</p> <p>Based on the illustrations and explanations above analogize the system above for human growth. If the next 200 years the earth is very dense, the barren land cannot be planted with plants, the food chain does not last, the climate and weather are not supportive while there are still human babies who can be saved to grow and develop. As a researcher what can you prepare to still meet the factors of growth externally?, use your imagination accompanied by scientific facts that you get from the literature.</p>	<p>This agricultural system of light, nutrients, temperature and humidity is regulated so that lettuce growth can be optimal. Sunlight replaced LED lights with certain wavelengths suitable for plant photosynthesis needs, as well as temperature and humidity so as not to depend on weather and climate. Nutrition is measured analytically in water media (such as hydroponic farming in general) so that waste of water and nutrients can be avoided. Vertical growth (verticulture) can anticipate the lack of land in urban areas.</p> <p>Based on the illustrations and explanations above analogize the system above for human growth. If the next 200 years the earth is very dense, the barren land cannot be planted with plants, the food chain does not last, the climate and weather are not supportive while there are still human babies who can be saved to grow and develop. As a researcher what can you prepare to still meet its growth factors externally?, use your imagination accompanied by scientific facts that you get from the literature <i>but still consider the ethical and moral aspects.</i></p>

Figure 5. Question point no. 10 before and after revision

The input of an expert validator for question point number 10 is to include ethical and moral aspects in the student's metaphorical thinking skills. To answer question no 10, students have to think metaphorically about the future by utilizing their knowledge of Biotechnology. Biotechnology is one of the markers of advances in science and technology in the 21st century that affect human life. Considering moral and ethical aspects is important because humans who behave ethically are one of the competencies of 21st century human resources that must be formed and developed through learning that includes ethical studies (Huda, et al [2016](#)), one of which is Biology. After expert validation the next process is a test of validity and reliability in a small group of students of 10 respondents. The assessment

is based on the creative thinking skills assessment rubric with the lowest point 1 and the highest point 4 if all the criteria according to the creative thinking skills indicators are fulfilled (table 1). The value obtained by students is the total points obtained multiplied by 5 so that the highest score is 100. After the score is obtained, an empirical validation test is carried out. The results of the creative thinking skills instrument validity test can be seen in Table 5.

Table 5.

The results of the test of the validity of the creative thinking skills instrument.

Number of Question	Pearson Correlation Value	Criteria
1	0.81	highly valid
2	0.68	valid
3	0.66	valid
4	0.21	invalid
5	0.68	valid
6	0.64	valid
7	0.64	valid
8	0.45	invalid
9	0.61	invalid
10	0.82	valid

Empirical validation results were obtained through a trial on 10 respondents who had obtained plant growth and development materials. The data obtained is calculated by the Pearson Product Moment validation formula. For n the sum of 10 at the significance level of 0.05 is 0.62 while for the significance level 0.01 is 0.77. The question item is declared valid if r calculates the > r of the table. People show that the ten points are a problem. Table 5 it can be seen that the harmony of the problem item has a calculated $r > r$ table at the signification level of 0.05 so that all have valid criteria. In the item of problem no r table $> r$ calculates at significance 0.01 and is stated to have very valid criteria. In Table 5 it can be seen that there is 1 question having very valid criteria and 6 questions having valid criteria. These results indicate that seven of the ten creative thinking skills instruments can produce a measure that reflects the creative thinking skill variable being measured. The opposite results are found in the other 3 questions that get invalid results. The reason is that in questions no. 4 and 8, most of the students gave almost the same answers, while in question 9, students did not understand the meaning of the analogy, giving rise to different interpretations. The next stage is the reliability test using Cronbach's Alpha Coefficient, the instrument is declared reliable if the reliability coefficient is greater than or equal to 0.7. From the calculation obtained the value of Cronbach's Alpha 0.82, this value shows that the instrument of creative thinking skills is reliable to use because it can provide consistent measurement results. Expert validation tests are also performed for problem-solving skills instruments. Besides the instrument, a scoring grid and rubric are also included to be corrected by expert validators. The average results of the three expert validators can be seen in Table 6.

Table 6.

Expert Validation Results on Problem-Solving Skills Instruments

Validated Aspects	Number of question							
	1	2	3	4	5	6	7	8
A. Material/ Content								
1 Problems in accordance with basic competencies	5.0	5.0	5.0	4.7	5.0	5.0	5.0	5.0
2 Problems in accordance with the indicator of problem-solving skills measured	4.7	4.7	4.7	5.0	4.7	5.0	4.7	5.0
3 Problems according to the cognitive level measured	5.0	5.0	4.7	5.0	5.0	4.7	5.0	5.0
4 Problems according to the cognitive level measured	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
5 Problems according to the cognitive level measured	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7

Validated Aspects	Number of question							
	1	2	3	4	5	6	7	8
B. Construction								
1 The subject matter is clearly formulated	4.7	4.7	5.0	4.7	5.0	5.0	4.7	5.0
2 The image used (if any) on the problem is presented	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
C. Language								
1 Use language that is in accordance with the rules of Indonesian	4.0	4.3	4.3	4.3	4.3	4.0	4.3	4.3
2 Using communicative language	4.0	4.0	4.3	4.3	4.3	4.7	4.3	4.7
3 Use clear and easy to understand sentences	4.3	4.7	4.3	4.3	5.0	4.7	4.7	5.0
Average	4.6	4.7	4.7	4.7	4.8	4.7	4.7	4.8
In Percent (%)	93	93	93	93	95	95	94	97
Criteria	Very Worthy							

In Table 6, it appears that all eight questions based on the three experts are very suitable for use. The highest value is 97% which is in problem item number 8 and the lowest value is 93, namely in the point of problem number 1, 2,3, and 4. In the instrument of problem solving skills, the three validators do not provide input related to the content of the problem, but more on redaction and language use. After expert validation, the next process is a test of validity and reliability in a small group of students of 10 respondents. The assessment is based on the rubric of problem-solving skills assessment with the lowest point 1 and the highest point 4 if all the criteria according to the problem-solving skill indicators are fulfilled (Table. 2). The value obtained by students is the total points obtained multiplied by 6.25 so that the highest score is 100. After the value is obtained, an empirical validation test is carried out. The results of the test validity of problem solving skills instruments can be seen in Table 7.

Tabel 7.

The results of the test of the validity of the Problem Solving Skills instrument.

Number of Question	Pearson Correlation Value	Criteria
1	0.94	Highy Valid
2	0.93	Highy Valid
3	0.91	Highy Valid
4	0.79	Highy Valid
5	0.72	Valid
6	0.88	Highy Valid
7	0.78	Highy Valid
8	0.83	Highy Valid

In Table 7, it can be seen that the whole item of the problem has r calculate $> r$ table at the signification level 0.01 so it has a very valid criterion except item no. 5 which has a valid criterion because it has r calculates $> r$ table at significance level 0.05. These results indicate that all problem-solving skills instruments can produce a measure that reflects the measured problem-solving skills variable. The next stage is the reliability test using Cronbach's Alpha coefficient. The result obtained is 0.95. This value shows that the skilled instrument to solve the problem has high reliability.

CONCLUSION

Intrument to measure creative thinking skills and problem-solving skills in plant growth and development materials can be developed in a description problem that allows students to present their own ideas. Based on the results of empirical validation of 10 creative thinking skills instruments, 3 of them were declared invalid and required revision if they want to be used, while the entire problem solving skill instrument was declared valid and feasible to use. Both instruments about creative thinking skills and problem solving are both reliable.

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