Tadris: Jurnal Keguruan dan Ilmu Tarbiyah 7 (2): 201-219 (2022)
DOI: 10.24042/tadris.v7i2.12690

TADRIS: JURNAL KEGURUAN DAN ILMU TARBIYAH
(Tadris: Journal of Education and Teacher Training)
P-ISSN: 2301-7562 | E-ISSN: 2579-7964
ejournal.radenintan.ac.id/index.php/tadris/index

What is the Most Impressive Treatment to Foster Students' Creative Thinking Skills? A Meta-Analysis and Bibliometric Review

Nur Endah Susilowati*, Muslim, Ridwan Efendi, Achmad Samsudin
Department of Physics Education, Universitas Pendidikan Indonesia, Indonesia

Article History:
Received: June 23rd, 2022
Revised: July 6th, 2022
Accepted: August 8th, 2022
Published: December 29th, 2022

Keywords:
Creative thinking skills,
Effect size,
Meta-Analysis

***Correspondence Address:**
nurendahsusilowati@upi.edu

Abstract: Research related to learning treatment to train creative thinking skills has been frequently done. However, this has become a concern for teachers to assess which 'learning treatment' is better in developing students' creative thinking skills. This study aims to analyze the most effective treatment in improving students' creative thinking skills on science and mathematics concepts, based on data sources from international journal articles. The meta-analysis was conducted using CMA software and involving 21 published papers in international journal indexed by Scopus and or WOS. Data analysis was carried out by comparing the effect size values from the research results. According to the results of the meta-analysis, the average effect size data obtained with the learning model reached 1.075, the learning approach reached 1.627, and the learning media reached 1.575. Then based on the analysis, three 'treatments' were found that were considered as the most effective based on the effect size comparison, namely the PBL model with an effect size of 3.765, the STEM approach with an effect size of 0.90, and the use of interactive multimedia with an effect size of 0.83. The finding of this research stated that the PBL model is the most effective treatment to train students' creative thinking skills. The results of this study provide views for science and mathematics educators to consider to use PBL (learning model), STEM/AM (learning approach), and technology-based learning media to train creative thinking.

INTRODUCTION

Creative thinking, often mentioned as one of the most needed skills in this century (Akpur, 2020; Al-Momani, 2019), is one of the higher order thinking skills related to produce something original, new, different or unique, effective, meaningful, or exceeding the target limit (Beghetto, 2019; Gingl & Mingesz, 2019). However, it is not only limited to 'producing' activities, but also has a broader meaning. Refering to the creative thinking framework developed by OECD (2021), creative thinking activities are not only limited to generate different and creative 'brilliant' ideas, but also include evaluating, developing, and improving an idea.

Creative thinking is one of the ideal skills which are expected to be mastered by students during the learning process (Rusimamto et al., 2021; Saregar et al., 2020). This ability is very important for students to master, especially to learn abstract concepts (Gardiner, 2020; Sun et al., 2020), science and mathematics that contain many abstract concepts. For example, in studying physics or in understanding the concept of physics, students must be able to use their imagination well so that the concept of physics can be correctly depicted in their minds. Therefore, mastery of creative thinking skills is very important in learning physics (Batlolona, 2019; Wicaksono et al., 2017).

Because of the importance of creative thinking skills to be mastered, it is necessary to find solutions to practice creative thinking skills in everyday learning. As such, many researchers do experiments to train creative thinking skills. This is proven based on data from Scopus page, in the 2016-2021 range, there were 3,486 studies from various countries using Creative Thinking keywords.

There are several learning treatments that are often used to train creative thinking skills, such as problem-based learning models (Rahman et al., 2020), STEM learning (Parno et al., 2019; Wannapiroon & Petsangsri, 2020), or as simple as applying technology as a learning media (Aldalalah, 2020; Park & Kim, 2021). Based on the results of bibliographic analysis using Vosviewer, in each keyword, several learning treatments are often associated with creative thinking skills based on 3,486 Scopus articles as shown in Figure 1.

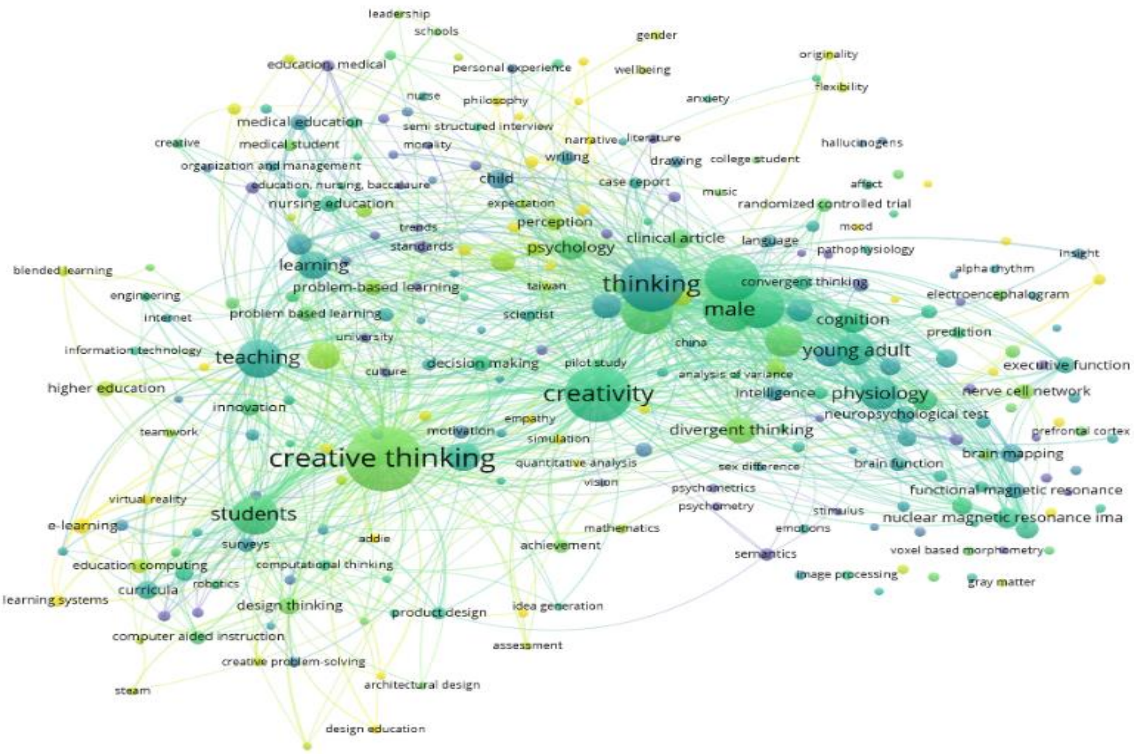

Figure 1. Variables Related to Creative Thinking

Based on the results of the bibliography, there are several research variables that are often related to creative thinking such as Problem-Based Learning models, project-based learning, design thinking models, technology-based learning, learning approaches like STEM/AM and so on.

The map also shows that just like other thinking skills, creative thinking skills can also be trained through learning (Lucas & Spencer, 2017; Tabieh et al., 2020). Thus, many educators and educational researchers try to apply varied 'treatments' in learning to train students' creative thinking skills (Batlolona et al., 2019; Saregar et al., 2020; Suryandari et al., 2018).

Many studies have proven that learning can train students' creative thinking skills. As the results, in the last three years, there have been many studies related to 'learning treatment' to train creative thinking skills. As pointed out by Suyidno et al. (2017), they found that the creative responsibility-based learning model was effective in improving students' scientific creativity skills. Saregar et al. (2020) stated that the application of the STEM approach positively affects students' creative thinking skills. The results of other studies also show that students' creative thinking skills can be improved by implementing the problem-based learning model (Batlolona et al., 2019; Nuswowati & Taufiq, 2015; Wartono et al., 2018). Shabrina & Kuswanto in 2018 have also proven that creative thinking skills can be increased through the application of Android-based learning multimedia.

From a bunch of studies previously mentioned, it tiggers a question for us regarding what is exactly the most effective learning treatment for training students' creative thinking skills? To answer such question, the researcher made a research design to analyze what learning models, approaches, and media had the most impressive results in training students' creative thinking skills. The analysis was carried out in two stages, namely the first was the bibliographic analysis with Vosviewer software, and the second was statistical analysis through the Comprehensive Meta-Analysis software. (Borenstein et al., 2017).

Based on the previous research, meta-analysis provided accurate results supported by strong statistical data in making conclusions from some studies. The meta-analysis conducted by Ritchie & Tucker-Drob (2018), for instance, this study succeeded in proving that education with a longer duration (additional duration) has a better effect than education with a shorter duration. Then, the meta-analysis conducted by Adesope et al. (2017) also succeeded in proving that the claims related to exams can hinder learning, in fact, are false. This study presents concrete conclusions based on the strong statistical analysis over the most impressive learning treatment to train students' creative thinking skills in Physics subjects. More specifically, this meta-analysis aims to truly answer the following research questions: What research treatments are most often used to practice creative thinking skills?; Does the difference in learning treatment give different results in creative thinking skills?; What learning treatment is most effective in improving students' creative thinking skills?

METHOD

This research is a quantitative research with a Meta-Analysis approach (Adesope et al., 2017; Mathiesen et al., 2021). Meta-analysis is used because this research aims to find and synthesize various relevant study results related to effective learning treatments to train students' creative thinking skills (Suparman et al., 2021).

Article Sample Selection Details

When searching on the scopus.com page, there are more than 13,000 articles related to creative thinking. However, this research is merely limited to the articles published in 2016-2021, and limited to the journal articles. In addition, the sample of articles were also obtained through manual searches in the Web of Science journals. In this study, two analytical processes were carried out. The first is bibliographic analysis to see some learning treatments which are frequently associated with the keyword 'thinking creatively'. The second, after getting the data, the articles were selected and then processed by utilizing CMA software. Details of the article selection process are described in Figure 2.

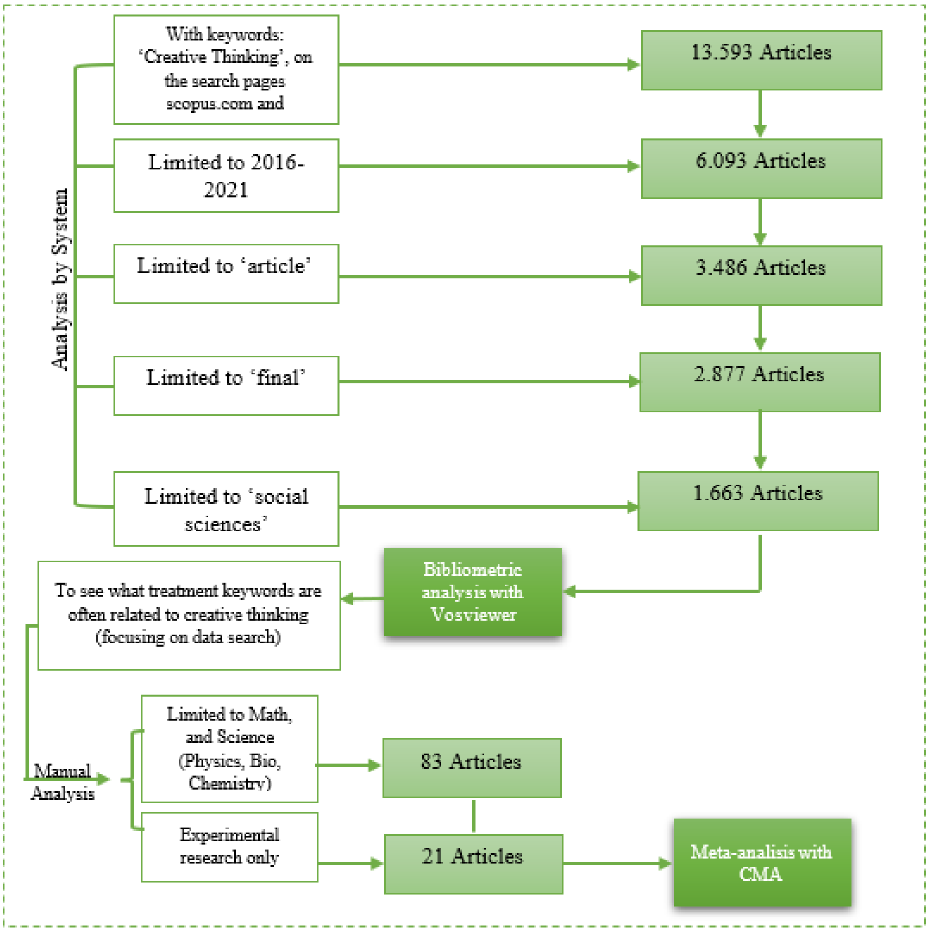

Figure 2. Article Sample Selection Process

Bibliographical Analysis on Keywords

A bibliographic analysis is a process of listing a collection of bibliographic articles to describe a relationship from broad sections (Jiménez et al., 2021). In this study, keywords mapping (bibliography) was used to see the most popular and most frequently associated variables with creative thinking skills based on keywords from 1,663 scopus indexed journal articles and the Web of Science. Through this mapping, learning treatments will be selected in the form of learning models, learning approaches, and learning media that are most often studied along with creative thinking skills. This selection intends to make meta-analysis more focused and easier. The analysis was conducted with the help of vosviewer software.

Meta-Analysis with CMA

After the most popular learning treatment data were obtained, manual analysis was carried out to select the appropriate articles to be tested for meta-analysis with CMA V3. This software facilitates the application of complex concepts with the real data, helping researchers to see the power of the meta-analysis process. Comprehensive Meta-Analysis is easy to learn and use with a clear and friendly interface. The criteria for articles which are selected manually to be processed by using CMA software are: 1) The experimental research; 2) Science and Mathematics Learning; 3) With PBL, Design thinking, STEM/STEAM, and technology-based media variables; 4) There is a sample, mean and standard deviation, or t-value, or p-value. The list of articles processed by meta-analysis can be seen in Table 1.

Table 1. Article Sample List

Treatment	Code	Title	Author Name and Publication Year	Variable	Journal	Index S*/WoS*
Learning Model	A01	Using desing thinking to cultivate the next generation of female STEAM thinkers	Kijima et al. (2021)	Design thinking	International Journal of STEM Education	S/Q1
	A02	Backward Instructional Design based Learning Activites to Developing Students' Creative Thining with Literal Thinking Technique	Srikongchan et al. (2021)	Design thinking	International Journal of Instruction	S/Q2
	A03	The Effects of Design Thinking in High School Chemistry Classes	Yang et al. (2020)	Design thinking	Journal of the Korean Chemical Society	S/Q3
	A04	Influence of Problem Based Learning Model on Student Creative Thinking on Elasticity Topics	Wartono et al. (2018)	PBL	Jurnal Pendidikan Fisika Indonesia	WOS/ ESCI
	A05	Creative Thinking Skills Students in Physics on Solid Material Elasticity	J. R. Batlolona et al. (2019)	PBL	Journal of Turkish Science Education	S/Q2
	A06	Developing Creative Thinking Skills and Creative Attitued through Problem-based Green vision Chemistry Environment Learning	Nuswowati & Taufiq, (2016)	PBL	Jurnal Pendidikan IPA Indonesia	S/Q2
	A07	Implementation of Problem-based Learning With Green Chemistry Vision to Improve Creative Thinking Skill and Students' Creative Actions	M. Nuswowati et al. (2017)	PBL	Jurnal Pendidikan IPA Indonesia	S/Q2
	A08	The Effectiveness of Problem-based Learning and Aptitude Treatment Interaction in Improving Mathematical Creative Thinking Skills on Curriculum 2013	Maskur et al. (2020)	PBL	European Journal of Educational Research	S/Q3
	A09	Problem-based Learning Strategy: Its Impact on Students' Critical and Creative Thining Skills	Kardoyo et al. (2020)	PBL	European Journal of Educational Research	S/Q3
	A10	The Impact of Problem-based learning with argument mapping and online laboratory on scientific argumentation skill	Jumadi et al. (2021)	PBL	International Journal of ecaluation and Research in Education	S/Q4

Treatment	Code	Title	Author Name and Publication Year	Variable	Journal	Index S*/WoS*
Learning Approach	A11	Exploring the Effectiveness of STEAM Design Processes on Middle School Students' Creativity	Ozkan & Umdu Topsakal (2020)	STEAM	International Journal of Technology and Design Education	S/Q1
	A12	Increasing Creative Thinking of Students by Learning Organization with STEAM Education	Ahmad et al. (2021)	STEAM	Jurnal Pendidikan IPA Indonesia	S/Q2
	A13	Effects of STEAMification Model in Flipped Classroom Learning Environment on Creative Thinking and Creative Innovation	Wannapiroon & Petsangsri (2020)	STEAM	TEM Journal	S/Q3
	A14	STEM-Inquiry Brainstorming: Critical and Creative Thinking Skills in Static Fluid Material	Saregar et al. (2020)	STEM	Periodico Tche Qumica	S/Q1
Techno-logy-based Learning Media	A15	Interactive Multimedia Thermodynamics to Improve Creative Thinking Skill of Physics Prospective Teachers	Hakim et al. (2017)	Techno-logy-based learning media	Jurnal Pendidikan Fisika Indonesia	WoS/ ESCI
	A16	Cultivating Creative Thinking in Engineering Student Teams: Can a Computer-mediated Virtual Laboratory Help?	Hirshfield & Koretsky (2021)	Techno-logy-based learning media	Journal of Computer Assissted Learning	S/Q1
	A17	GeoGebra: Towards Realizing 21st Century Learning in Mathematics Education	Kim & Md-Ali (2017)	Techno-logy-based learning media	Malaysian Journal of Learning and Instruction	S/Q1
	A18	Creative Self-efficacy of Children Aged 9-14 in a Science Center using a Situated Mobile Game	Atwood-Blaine et al. (2019)	Techno-logy-based learning media	Thinking Skills and Creativity	S/Q2
	A19	Android-Assisted Mobile Physics Learning through Batik Culture: Improving Students' Creative Thinking and Problem Solving	Shabrina & Kuswanto (2018)	Techno-logy-based learning media	International Journal of Instruction	S/Q2
	A20	Use Integrated Mobile Application with Realistic Mathematics Education: A Study to Develop Elementary Students' Creative Thining Ability	Rudyanto et al. (2019)	Techno-logy-based learning media	International Journal of Interactive Mobile Technologies	S/Q3

Treatment	Code	Title	Author Name and Publication Year	Variable	Journal	Index S*/WoS*
	A21	The Effect of Technology Integration in Education on Prospective Teachers' Critical and Creative Thinking, Multidimensional 21st Century Skills and Academic Achievements	Yılmaz (2021)	Techno-logy-based learning media	Participatory Educational Research	S/Q3

With:
*S: Scopus
*WoS: Web of Science

Statistical Analysis

Statistical analysis in meta-analysis is an effect size (Borenstein et al., 2017; Cleophas & Zwinderman, 2017; Cumming, 2012). In this study, the Hedges equation was used to calculate the effect size of Problem-based Learning, STEM, and Interactive Multimedia on students' creative thinking abilities. Comprehensive Meta Analysis software is used as software to help calculate the effect size of the 21 sample articles used.

To find out what learning treatment is the most effective to be applied as an effort to develop creative thinking skills, an interpretation of the Effect Size value is used. The Effect Size interpretation in this study uses the interpretation of Thalheimer & Cook (Suparman et al., 2021; Tamur et al., 2020; Thalheimer & Cook, 2002). The interpretation is shown in Table 2.

Table 2. Thalheimer & Cook's Effect Size Classification

Effect Size	Interpretation
$-0,15 \leq ES < 0,15$	Ignored
$0,15 \leq ES < 0,40$	Low
$0,45 \leq ES < 0,75$	Moderate
$0,75 \leq ES < 1,10$	High
$1,10 \leq ES < 1,45$	Very High
$1,45 \leq ES$	Excellent

RESULT AND DISCUSSION

Variables that are Often Related to the Keyword 'Creative Thinking' based on Bibliographic Mapping

After the selection was made by limiting the year of publication (2016-2021), articles (proceedings and books excluded), and final articles (not in press) on 13,593 articles from Scopus and Web of Science, bibliographic data were obtained from 1,663 articles from research done in various countries. The distribution of the article locations can be seen in Figure 3.

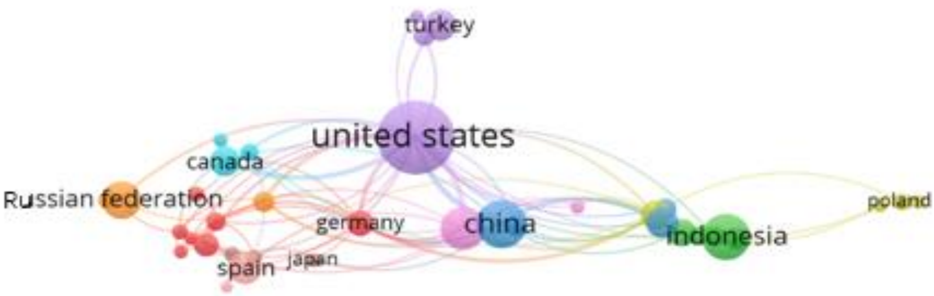

Figure 3. Distribution of Article Locations with 'Creative Thinking' Keyword in 2016-2021

The United States is still the country that publishes the most articles related to creative thinking followed by China and Indonesia. The next step is to do a bibliographic analysis to list keywords which are often related to creative thinking. Based on data from Vosviewer, there are 105 keywords appearing, at least, 10 times along with creative thinking. Table 3 presents data for the top 10 keywords that often appear along with data occurrences and total link strength, and the illustration of the relation between keywords from 1,663 creative thinking articles. It can be seen in Figure 4.

Table 3. Occurrences and Total Link Strength of the Keywords

No	Keywords	Occurrences	Total Link Strength
1	Creativity	242	2347
2	Education	229	2270
3	Critical thinking	77	1006
4	Thinking	180	897
5	Divergent thinking	52	626
6	Problem-based learning	37	361
7	Convergent thinking	16	225
8	Design thinking	23	81
9	Technology	18	76
10	STEM dan STEAM	14	52

NB: sorted by total link strength

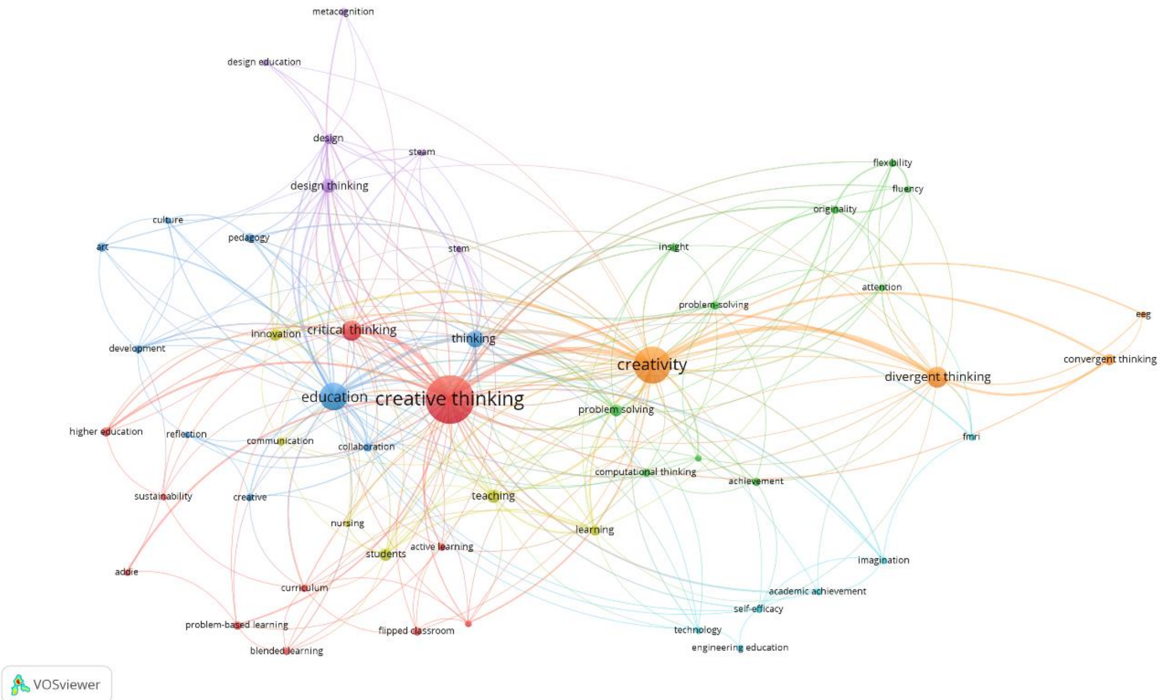

Figure 4. Variables that are Often Associated with Creative Thinking

Based on the results of bibliographic analysis, from the top 10 keywords, the variables which were taken comprise of learning models, learning approaches, and learning media (technology in learning). The selection process is presented in Figure 5.

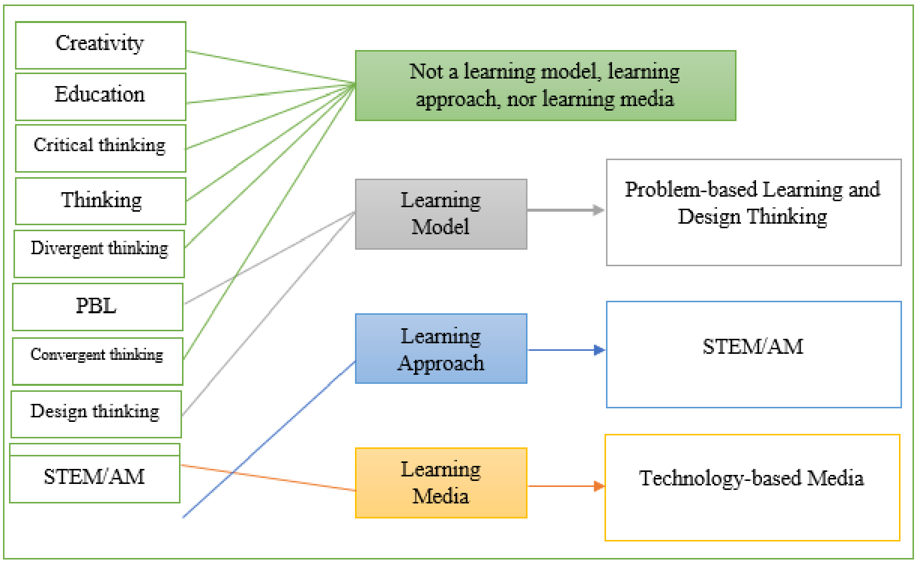

Figure 5. Manual Selection Process

Based on Figure 5, it can be seen the research related to learning models for creative thinking that are most popular are PBL and Design thinking, while the research on popular learning approaches for creative thinking is STEM and STEAM, and then for learning media on creative thinking, the popular research is technology-based learning media. The purpose of this grouping is to make data search more focused. Therefore, manual analysis was carried out to find the right research articles to be processed by meta-analysis. There were 21 articles which were eligible to enter the meta-analysis stage.

Meta-Analysis of the Effects of Learning Models on Creative Thinking Skills

Meta-analysis was carried out with the help of Comprehensive Meta-Analysis software version V3 by entering data in the form of mean, standard deviation, t value, and p-value. The data are then processed to see the effect size results. The effect size of the learning model on creative thinking skills is shown in Tables 4 and 5.

Table 4. Effect Size and Standard Error of Learning Model Study

Code	Publication Year	Country	Variable	Effect Size	Standar Error	ES Criteria
A01	2021	Japan	Design thinking	0.291	0.157	Low
A02	2021	Thailand	Design thinking	0.039	0.255	Ignored
A03	2020	Korea	Design thinking	0.430	0.314	Moderate
A04	2018	Malang, Indonesia	PBL	0.668	0.232	Moderate
A05	2019	Malang, Indonesia	PBL	1.890	0.313	Excellent
A06	2016	Semarang, Indonesia	PBL	3.765	0.396	Excellent
A07	2017	Semarang, Indonesia	PBL	0.993	0.244	High
A08	2020	Lampung, Indonesia	PBL	1.240	0.279	Very High
A09	2020	Semarang, Indonesia	PBL	2.264	0.328	Excellent
A10	2021	Yogyakarta, Indonesia	PBL	-0.487	0.192	Ignored

Table 5. The Research Results based on Estimation Model

Estimation Model	n	Z	p	Q	I-squared (p=0.05)	Effect Size
Fixed effects	10	8.728	0.000	154.464	94.173	0.675
Random effects	10	3.269	0.001	154.464	94.173	1.075

The data in Table 4 shows the effect size values of each study, and it is known that the largest effect size in the excellent category is indicated by the application of the PBL model with 3.765. In this part of the learning model, it is known that there are two models tested, namely design thinking and PBL. Each learning model was tested in different places, with different samples, and the results which were also very different. As in the article with the design thinking model, in the article with code A02, the effect size shows the ignored criteria, which means it cannot be used as a basis, but in the article with code A03, the effect size value is larger (0.430). This points out that the use of the design thinking model is very dependent on the state of the sample and the implementation strategy. Meanwhile, in the case of the PBL learning model, the samples were all from Indonesia albeit from different cities. However, it appears that, compared to design thinking, PBL has more influence on creative thinking skills. If the overall average is calculated, the average effect size of the design thinking model on creative thinking skills is 0.254 in the Moderate category, while the average effect size of the PBL model on creative thinking skills is 0.950 in the High category.

Based on the data in Table 5, it is known that based on the fixed effects estimation model, the overall effect size value (average) is 0.675 in the moderate category. After measuring the level of homogeneity of the article sample, the Q value is 154.464, which means it is higher than the χ^2table value which is 3.94 (df = 10; $\alpha = 0.95$). This means that the effect size distribution is heterogeneous. It is not surprising because the sample articles were taken from various countries with different number of research samples. Because the effect size is heterogeneous, we use the effect size from the random effects estimation model, which is 1.075 and is in the high category. The Z value in the random effects estimation model is known to be 3.269 and is declared significant due to the p value < 0.05. The I-squared value of 94.173 indicates that 94.173 % of the observed variance is due to differences in effect size, while about 5 % is caused by random error.

As previously noted that this study took samples from various countries so that the possibility of publication bias is unavoided. The funnel plot in Figure 6 shows the distribution of effect sizes.

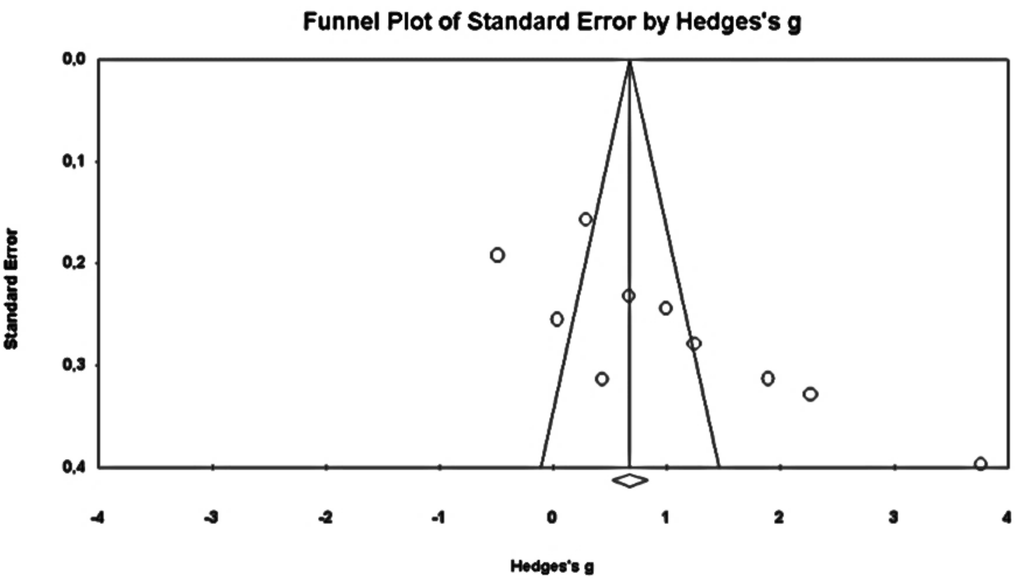

Figure 6. Funnel Plot

Based on the funnel plot in Figure 6, it can be seen that the distribution of effect sizes is uneven. Therefore, it is possible that these results are publication bias. To determine the resistance of the data to publication bias, it is calculated by using the Rosenthal's fail-safe N (FSN) statistic. Based on the FSN value calculated by CMA software, it is known that the Rosenthal safe N value is 244.00. Based on formula Mullen et al. (2001), the resistance of the data to research bias can be calculated by: 244.00/(5*10+10)= 4.1; where 4.1 > 1, the data used is resistant to publication bias, so there is no need for data to be discarded or recalculated.

Meta-Analysis of the Effects Learning Approaches on Creative Thinking Skills

A total of 4 articles with the application of the STEM/AM learning approach were involved in this statistical analysis. The effect size of the learning approach on creative thinking skills is shown in Table 6 and 7.

Table 6. Effect Size and Standard Error of Learning Approach Study

Code	Publication Year	Country	Variable	Effect Size	Standar Error	ES Criteria
A11	2020	Turkey	STEAM	0.236	0.231	Low
A12	2021	Jakarta, Indonesia	STEAM	3.335	0.418	Excellent
A13	2020	Thailand	STEAM	1.304	0.281	Very high
A14	2020	Lampung, Indonesia	STEM	1.773	0.286	Excellent

Table 7. The research results based on estimation model

Estimation model	N	Z	p	Q	I-squared (p=0.05)	Effect Size
Fixed effects	4	8.780	0.000	47.531	93.686	1.250
Random effects	4	2.793	0.005	47.531	93.686	1.627

Table 6 shows the effect size of each research result, and it is known that the largest effect size in the excellent category is shown by the application of the STEM Approach with 1.773. This learning approach is applied in different places, with different samples, and produces different effects. As in the article with code A11, it produces an effect size with low criteria, but in articles with code A14, the effect size value is much larger, reaching 1.773. This depicts that the effectiveness of the STEM approach will vary relying on the circumstances of the sample, the learning environment, and the implementation strategy.

Based on the data in Table 7, it is known that based on the fixed effects estimation model, the overall effect size value (average) is 1.250 in the very high category. After measuring the level of homogeneity of the article sample, the Q value is 47.531, which means it is higher than χ^2 table which is 0.7107 (df = 4; α = 0.95). This means that the effect size distribution is heterogeneous. Thus, we use the effect size from the random effects estimation model, which is 1.627 in the excellent category. The Z value in the random effects estimation model is known to be 2.793 and is declared significant because the p value < 0.05. The I-squared value of 93.686 indicates that 93.686 % of the observed variance is due to differences in effect size, while about 6 % is caused by random error.

As previously noted, this study took samples from various countries so that the possibility of publication bias cannot be avoided. The funnel plot in Figure 7 shows the distribution of the effect size.

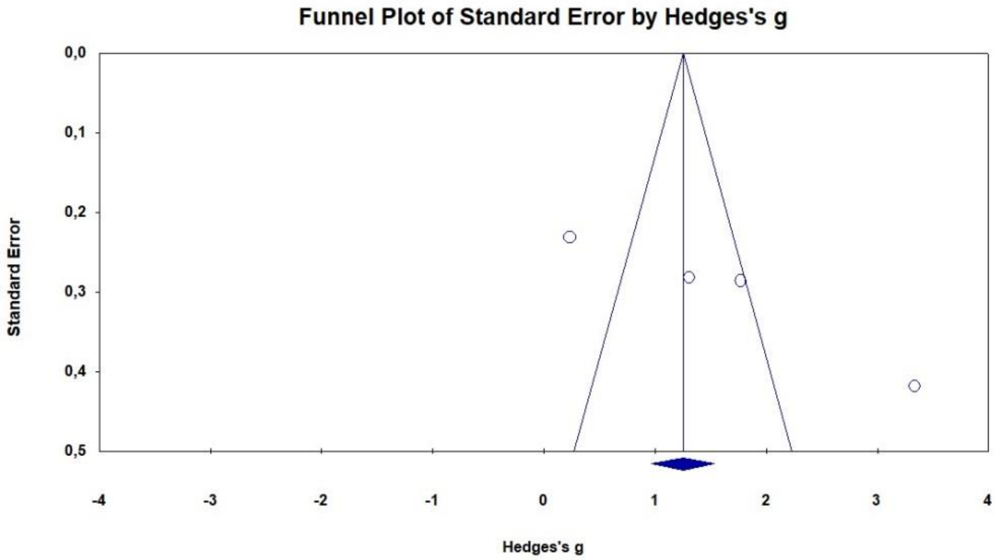

Figure 7. Funnel Plot

Based on the funnel plot in Figure 7, it can be seen that the distribution of effect sizes is uneven. Therefore, it is possible that these results are publication bias. To determine the resistance of the data to publication bias, it is calculated using the Rosenthal's fail-safe N (FSN) statistic. Based on the FSN value calculated by CMA software, it is known that the Rosenthal safe N value is 99.00 (Mullen et al. 2001). Then: 99.00/(5*4+10)= 3.3; where 3.3 > 1 then the data used is resistant to publication bias, so there is no need for data to be discarded or recalculated.

Meta-Analysis of the Effects Learning Media on Creative Thinking Skills

Different effect size results are shown by the application of learning media. The effect size of the learning media on creative thinking skills is shown in Tables 8 and 9.

Tabel 8. Effect Size and Standard Error of Learning Media Study

Code	Publication Year	Country	Variable	Effect Size	Standar Error	ES Criteria
A15	2017	Bandung, Indonesia	Technology-based media	3.590	0.387	Excellent
A16	2021	Oregon, United States	Technology-based media	1.17	0.274	Very high
A17	2017	Malaysia	Technology-based media	3.555	0.385	Excellent
A18	2019	Cedar Falls, United States	Technology-based media	0.481	0.233	Moderate
A19	2018	Yogyakarta, Indonesia	Technology-based media	0.968	0.269	High
A20	2019	Yogyakarta, Indonesia	Technology-based media	0.955	0.261	High
A21	2021	Turkey	Technology-based media	0.611	0.291	Moderate

Tabel 9. The Research Results based on Estimation Model

Estimation model	n	Z	p	Q	I-squared (p=0.05)	Effect Size
Fixed effects	7	11.475	0.000	90.691	93.384	1.242
Random effects	7	3.698	0.000	90.691	93.384	1.575

Table 8 shows the effect size of each research result, and it is known that the largest effect size in the excellent category is indicated by articles with code A15 with 3.590. Based on the data in Table 9, it is known that based on the fixed effects estimation model, the overall effect size value (average) is 1.242 with the very high category. After measuring the level of homogeneity of the article sample, the Q value is 90.691, which means it is higher than χ^2 table value which is 2.1673 (df = 7; α = 0.95). This means that the effect size distribution is heterogeneous. Because the effect size is heterogeneous, we use the effect size from the random effects estimation model, which is 1.575 in the excellent category. The Z value in the random effects estimation model is known to be 3.698 and is declared significant because the p value < 0.05. The I-squared value of 93.384 indicates that 93.384 % of the observed variance is due to differences in effect size, while about 6 % is caused by random error. Because this study takes samples from various countries so that the possibility of publication bias cannot be avoided, the funnel plot in Figure 8 shows the distribution of effect sizes.

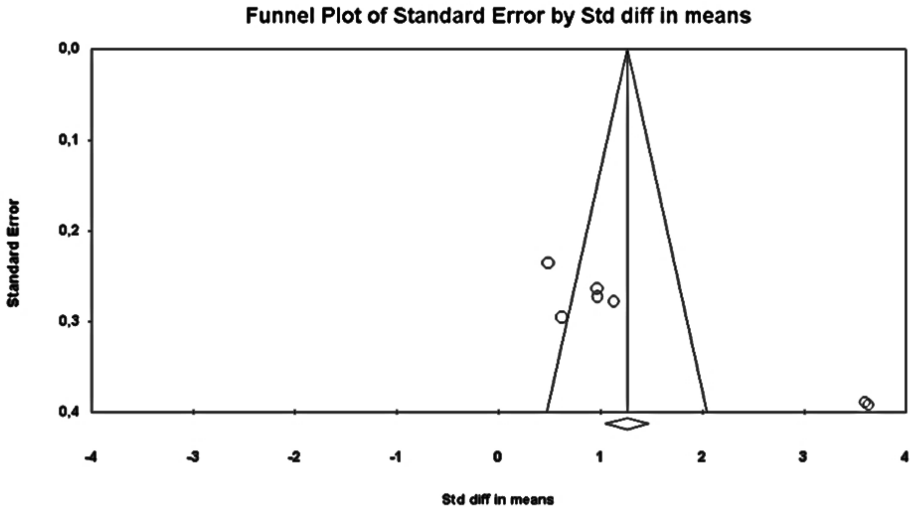

Figure 8. Funnel Plot

Based on the funnel plot in Figure 8, it can be seen that the distribution of effect sizes is uneven. Therefore, it is possible that these results are publication bias. To determine the resistance of the data to publication bias, it is calculated by using the Rosenthal's fail-safe N (FSN) statistic. Based on the FSN value calculated by CMA software, it is known that the Rosenthal safe N value is 298.00. Then: 298.00/(5*7+10)= 6.6; where 6.6 > 1 then the data used is resistant to publication bias (Mullen et al. 2001). Thus, there is no need for data to be discarded or recalculated.

Which Treatment is More Effective?

Based on the results of statistical tests of the three types of treatment, we can compare what treatment is the most effective for improving students' creative thinking skills. This comparison can be seen in Figure 9. Based on Figure 9, it can be seen that the learning approach has a greater effectiveness value than the learning media and learning models. Furthermore, based on Table 4, Table 6, and Table 8, we can clearly see which variables have the greatest effectiveness on creative thinking skills as shown in Figure 10.

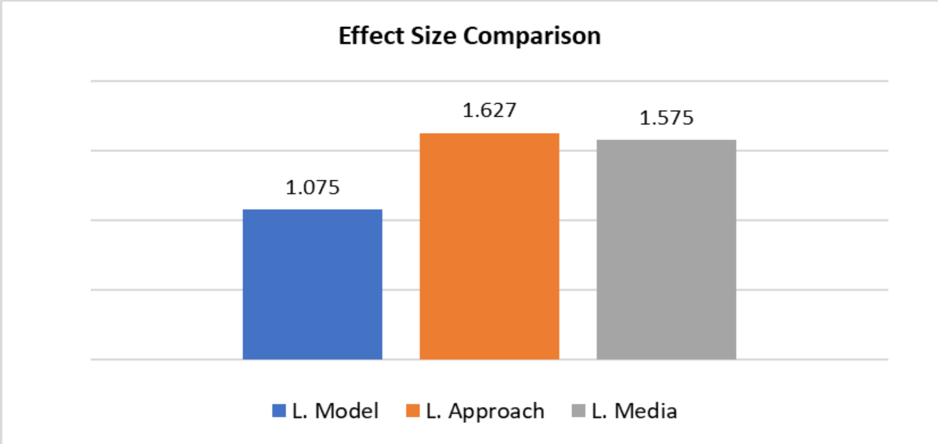

Figure 9. The Comparison of Effect Size Values

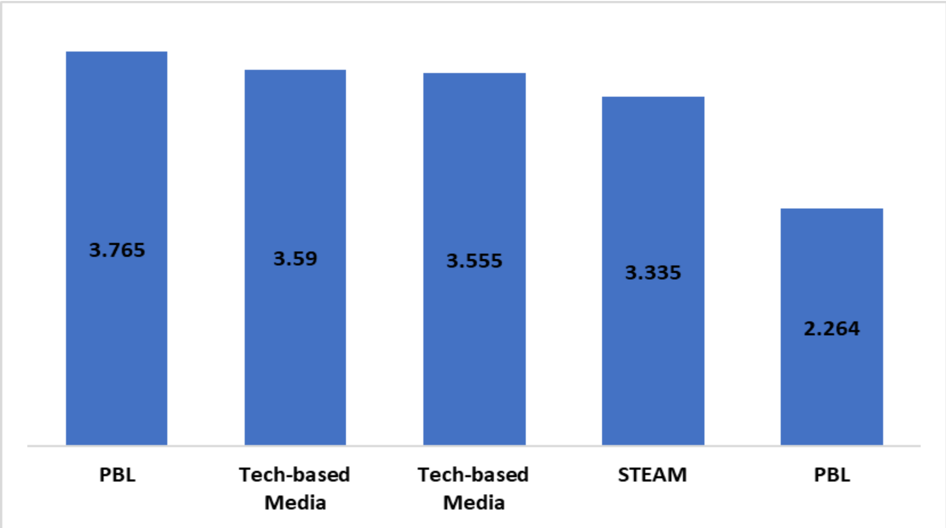

Figure 10. Top 5 Highest Effect Size Value

Although overall the learning approach has a larger average effect size, if we look at each variable, PBL shows the most impressive effect size results, reaching 3.765 (see Table 4) in the excellent category. Several previous studies have revealed that PBL is effective in improving several learning skills, such as problem solving skills (Juandi & Tamur, 2021) and enhance higher order thinking skills (Suparman et al., 2021). The second and third variables with the highest effect size values were the application of technology-based media, followed by the application of the STEAM approach and lastly, PBL once again recorded an excellent effect size value (2.264), strengthening the fact that PBL does have a strong effect in training creative thinking skills.

Based on previous research, meta-analysis proved to be able to provide accurate results supported by strong statistical data in making conclusions from several studies. As in the meta-analysis conducted by Ritchie & Tucker-Drob (2018), this study succeeded in proving that education with a longer duration (additional duration) has a better effect than education with a shorter duration (such as accelerated programs); And the meta-analysis conducted by Adesope et al. (2017) succeeded in proving that claims regarding exams which can hinder learning are false. Furthermore, this study provides a detailed description of information related to the effectiveness of learning treatments which are suitable for practicing creative thinking skills.Thus, for further research, the researcher suggests using one of the research variables mentioned in this study to be applied in learning to train students' creative thinking skills.

CONCLUSION

Research has been done to determine which learning treatment is the most effective to train students' creative thinking skills. Through bibliographic analysis, it is known that the most popular learning treatments studied along with creative thinking skills are design thinking learning models, problem based learning, STEM/AM approaches, and technology-based learning media. Based on the results of the meta-analysis, it is known that the learning approach has the greatest effectiveness value, which is 1.627, followed by learning media at 1.242, and the learning model to 0.675. However, if the value of the greatest effectiveness based on research is sorted, the PBL model occupies the first place, which is 3.765. The results also show that differences in learning treatment have a significant impact on creative thinking skills. Based on the results of the average effectiveness, the learning model is categorized as having a moderate effect in training creative thinking skills. Learning media is categorized as having a very high effect on the ability to think creatively. Then the learning approach has an excellent effect when it is used to train creative thinking skills. This study also reveals that even using the same learning treatment, the results will be different if applied to different places and samples. Especially for science and mathematics teachers, we suggest to consider the using of PBL (learning model), STEM/AM (learning approach), and technology-based learning media to train creative thinking skills.

REFERENCES

Adesope, O. O., Trevisan, D. A., & Sundararajan, N. (2017). Rethinking the use of tests: A meta-analysis of practice testing. *Review of Educational Research*, *87*(3), 659–701. https://doi.org/10.3102/0034654316689306

Ahmad, D. N., Astriani, M. M., Alfahnum, M., & Setyowati, L. (2021). Increasing creative thinking of students by learning organization with steam education. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 103–110. https://doi.org/10.15294/jpii.v10i1.27146

Akpur, U. (2020). Critical, reflective, creative thinking and their reflections on academic achievement. *Thinking Skills and Creativity*, *37*, 100683. https://doi.org/10.1016/j.tsc.2020.100683

Al-Momani, N. (2019). The effect of using 3d-virtual worlds and real worlds on creative thinking. *Opcion*, *35*, 1295–1309.

Aldalalah, O. M. A. (2020). The effectiveness of infographic via interactive smart board on enhancing creative thinking: A cognitive load perspective. *International Journal of Instruction*, *14*(1), 345–364. https://doi.org/10.29333/IJI.2021.14120A

Atwood-Blaine, D., Rule, A. C., & Walker, J. (2019). Creative self-efficacy of children aged 9-14 in a science center using a situated Mobile game. *Thinking Skills and Creativity*, *33*, 100580. https://doi.org/10.1016/j.tsc.2019.100580

Batlolona, J. (2019). Creative thinking skills students in physics on solid material elasticity. *Journal of Turkish Science Education*, *16*(1), 48–61. https://doi.org/10.12973/tused.10265 a

Batlolona, J. R., Diantoro, M., Wartono, & Latifah, E. (2019). Creative thinking skills students in physics on solid material elasticity. *Journal of Turkish Science Education*, *16*(1), 48–61. https://doi.org/10.12973/tused.10265a

Beghetto, R. A. (2019). Large-scale assessments, personalized learning, and creativity: Paradoxes and possibilities. *ECNU Review of Education*, *2*(3), 311–327. https://doi.org/10.1177/2096531119878963

Borenstein, M., Higgins, J. P. T., Hedges, L. V., & Rothstein, H. R. (2017). Basics of meta-analysis: I2 is not an absolute measure of heterogeneity. *Research Synthesis Methods*, *8*(1), 5–18. https://doi.org/10.1002/jrsm.1230

Cleophas, T. J., & Zwinderman, A. H. (2017). *Modern meta-analysis review and update of methodologies*. Springer International Publishing.

Cumming, G. (2012). *Understanding the new statistics effect sizes, confidence, intervals, and meta-analysis*. Routledge.

Gardiner, P. (2020). Learning to think together: Creativity, interdisciplinary collaboration and epistemic control. *Thinking Skills and Creativity*, *38*, 100749.

Gingl, Z., & Mingesz, R. (2019). Comment on "resistance of a digital voltmeter: Teaching creative thinking through an inquiry-based lab." *Physics Education*, *54*(5), 056502. https://doi.org/10.1088/1361-6552/ab2bdd

Hakim, A., Liliasari, L., Setiawan, A., & Saptawati, G. A. P. (2017). Interactive multimedia thermodynamics to improve creative thinking skill of physics prospective teachers. *Jurnal Pendidikan Fisika Indonesia*, *13*(1), 33–40. https://doi.org/10.15294/jpfi.v13i1.8447

Hirshfield, L. J., & Koretsky, M. D. (2021). Cultivating creative thinking in engineering student teams: Can a computer-mediated virtual laboratory help? *Journal of Computer Assisted Learning*, *37*(2), 587–601. https://doi.org/10.1111/jcal.12509

Jiménez, E. P., López-Catalán, L., López-Catalán, B., & Domínguez-Fernández, G. (2021). Sustainable development goals and education: A bibliometric mapping analysis. *Sustainability*, *13*(4), 1–20. https://doi.org/10.3390/su13042126

Juandi, D., & Tamur, M. (2021). The impact of problem-based learning toward enhancing mathematical thinking: A meta-analysis study. *Journal of Engineering Science and Technology*, *16*(4), 3548–3561.

Jumadi, J., Perdana, R., Riwayani, & Rosana, D. (2021). The impact of problem-based learning with argument mapping and online laboratory on scientific argumentation skill. *International Journal of Evaluation and Research in Education*, *10*(1), 16–23. https://doi.org/10.11591/ijere.v10i1.20593

Kardoyo, Nurkhin, A., Muhsin, & Pramusinto, H. (2020). Problem-based learning strategy: Its impact on students' critical and creative thinking skills. *European Journal of Educational Research*, *9*(3), 1141–1150. https://doi.org/10.12973/EU-JER.9.3.1141

Kijima, R., Yang-yoshihara, M., & Maekawa, M. S. (2021). Using design thinking to cultivate the next generation of female STEAM thinkers. *International Journal of STEM Education*, *8*(1), 1–15.

Kim, K. M., & Md-Ali, R. (2017). Geogebra: Towards realizing 21st century learning in mathematics education. *Malaysian Journal of Learning and Instruction, Special Issue*, 93–115. https://doi.org/10.32890/mjli.2017.7799

Lucas, B., & Spencer, E. (2017). *Teaching creative thinking: Developing learners who generate ideas and can think critically*. Crown House Publishing Limited.

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

Mathiesen, A. S., Rothmann, M. J., Zoffmann, V., Jakobsen, J. C., Gluud, C., Lindschou, J., Due-Christensen, M., Rasmussen, B., Marqvorsen, E., & Thomsen, T. (2021). Self-determination theory interventions versus usual care in people with diabetes: A protocol for a systematic review with meta-analysis and trial sequential analysis. *Systematic Reviews*, *10*(1), 1–13. https://doi.org/10.1186/s13643-020-01566-5

Mullen, B., Muellerleile, P., & Bryant, B. (2001). Cumulative meta-analysis: A consideration of indicators of sufficiency and stability. *Personality and Social Psychology Bulletin*, *27*(11), 1450–1462. https://doi.org/10.1177/01461672012711006

Nuswowati, M., Susilaningsih, E., Ramlawati, & Kadarwati, S. (2017). Implementation of problem-based learning with green chemistry vision to improve creative thinking skill and students' creative actions. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 221–228. https://doi.org/10.15294/jpii.v6i2.9467

Nuswowati, Murbangun, & Taufiq, M. (2015). Developing creative thinking skills and creative attitude through problem based green vision chemistry environment learning. *Jurnal Pendidikan IPA Indonesia*, *4*(2), 170–176. https://doi.org/10.15294/jpii.v4i2.4187

OECD. (2021). PISA 2021 creative thinking framework (third draft). *Oecd*, *53*(9), 1689–1699.

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

Park, E. J., & Kim, M. J. (2021). Visual communication for students' creative thinking in the design studio: Translating filmic spaces into spatial design. *Buildings*, *11*(3), 1–19. https://doi.org/10.3390/buildings11030091

Parno, Supriana, E., Yuliati, L., Widarti, A. N., Ali, M., & Azizah, U. (2019). The influence of STEM-based 7E learning cycle on students critical and creative thinking skills in physics. *International Journal of Recent Technology and Engineering*, *8*(2 Special Issue 9), 761–769. https://doi.org/10.35940/ijrte.B1158.0982S919

Ritchie, S. J., & Tucker-Drob, E. M. (2018). How much does education improve intelligence? A meta-analysis. *Psychological Science*, *29*(8), 1358–1369. https://doi.org/10.1177/0956797618774253

Rudyanto, H. E., Ghufron, A., & Hartono. (2019). Use of integrated mobile application with realistic mathematics education: A study to develop elementary students' creative thinking ability. *International Journal of Interactive Mobile Technologies*, *13*(10), 19–27. https://doi.org/10.3991/ijim.v13i10.11598

Rusimamto, P. W., Munoto, Samani, M., Buditjahjanto, I. G., Ekohariadi, Nurlaela, L., & Nuh, M. (2021). Assessment of electrical engineering students' creative thinking skills in PLC programming. *World Transactions on Engineering and Technology Education*, *19*(3), 287–292.

Saregar, A., Latifah, S., Hudha, M. N., Susanti, F., & Susilowati, N. E. (2020). Stem-inquiry brainstorming: Critical and creative thinking skills in static fluid material. *Periodico Tche Quimica*, *17*(36), 491–505.

Shabrina, & Kuswanto, H. (2018). Android-assisted mobile physics learning through indonesian batik culture: Improving students' creative thinking and problem solving. *International Journal of Instruction*, *11*(4), 287–302. https://doi.org/10.12973/iji.2018.11419a

Srikongchan, W., Kaewkuekool, S., & Mejaleurn, S. (2021). Backward instructional design based learning activities to developing students' creative thinking with lateral thinking technique. *International Journal of Instruction*, *14*(2), 233–252. https://doi.org/10.29333/iji.2021.14214a

Sun, M., Wang, M., & Wegerif, R. (2020). Effects of divergent thinking training on students' scientific creativity: The impact of individual creative potential and domain knowledge. *Thinking Skills and Creativity*, *37*(September 2019), 1–10. https://doi.org/10.1016/j.tsc.2020.100682

Suparman, S., Juandi, D., & Tamur, M. (2021). Does problem-based learning enhance students' higher order thinking skills in mathematics learning? A systematic review and meta-analysis. *The 2021 4th International Conference on Big Data and Education*, 44–51.

Suryandari, K. C., Sajidan, S., Rahardjo, S. B., Prasetyo, Z. K., & Fatimah, S. (2018). Project-based science learning and pre-service teachers' science literacy skill and creative thinking. *Cakrawala Pendidikan*, *37*(3), 345–355.

Suyidno, N., Yuanita, L., Prahani, K. B., & Jatmiko, B. (2017). Effectiveness of creative responsibility based teaching model on basic learning physics to increase student's scientific creativity and responsibility. *Journal Baltic Science Education*, *17*(1), 136–151.

Tabieh, A. A. S., Al-Hileh, M. M., Abu Afifa, H. M. J., & Abuzagha, H. Y. (2020). The effect of using digital storytelling on developing active listening and creative thinking skills. *European Journal of Educational Research*, *10*(1), 13–21. https://doi.org/10.12973/EU-JER.10.1.13

Tamur, M., Juandi, D., & Kusumah, Y. S. (2020). The effectiveness of the application of mathematical software in indonesia; A meta-analysis study. *International Journal of Instruction*, *13*(4), 867–884. https://doi.org/10.29333/iji.2020.13453a

Thalheimer, W., & Cook, S. (2002). How to calculate effect sizes from published research. *Work-Learning Research*, *1*(9), 1–9.

Wannapiroon, N., & Petsangsri, S. (2020). Effects of STEAMification model in flipped classroom learning environment on creative thinking and creative innovation. *TEM Journal*, *9*(4), 1647–1655. https://doi.org/10.18421/TEM94-42

Wartono, W., Diantoro, M., & Bartlolona, J. R. (2018). Influence of problem based learning model on student creative thinking on elasticity topics a material. *Jurnal Pendidikan Fisika Indonesia*, *14*(1), 32–39. https://doi.org/10.15294/jpfi.v14i1.10654

Wicaksono, I., Wasis, & Madlazim. (2017). The effectiveness of virtual science teaching model (VS-TM) to improve student's scientific creativity and concept mastery on senior high school physics subject. *Journal of Baltic Science Education*, *16*(4), 549–561.

Yang, H., Kim, M. Y., & Kang, S. J. (2020). The effects of design thinking in high school chemistry classes. *Journal of the Korean Chemical Society*, *64*(3), 159–174. https://doi.org/10.5012/jkcs.2020.64.3.159

Yılmaz, A. (2021). The effect of technology integration in education on prospective teachers' critical and creative thinking, multidimensional 21st century skills and academic achievements. *Participatory Educational Research*, *8*(2), 163–199. https://doi.org/10.17275/per.21.35.8.2