EDUMASPUL
JURNAL PENDIDIKAN
Vol. 8 – No. 1, year (2024), page 718-729
| ISSN 2548-8201 (Print) | 2580-0469) (Online) |

# Effectiveness of IoT Integrated Problem Based Learning Model on Students Creative Thinking Skills Abilities

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| *Receive:17/01/2024* | *Accepted: 27/02/2024* | *Published: 01/03/2024* |
|---|---|---|

**Abstrak**

Penelitian ini bertujuan untuk mengetahui efektivitas model problem based learning terintegrasi Internet of Things (IoT) terhadap kemampuan berpikir kreatif siswa. Jenis penelitian ini adalah penelitian meta-analisis dengan mengevaluasi efek size model problem based learning berbasis IoT terhadap kemampuan berpikir kreatif siswa.Kata kunci pencarian data yaitu model problem based learning; model problem based learning berbasis IoT; dan Kemampuan berpikir kreatif siswa. Teknik pengumpulan data adalah melalui observasi langsung database jurnal dan dokumentasi. Kriteria eligibility yaitu penelitian berasal dari jurnal yang terindeks SINTA, Scopus dan Web of Science; Penelitian harus dipublikasi tahun 2020-2024; Penelitian diperoleh melalui database mendeley, google scholar, Researchgate; ERIC, dan ScienceDirect, penelitian terkait dengan efektivitas model problem based learning berbasis IoT terhadap kemampuan berpikir kreatif siswa serta penelitian memiliki data yang lengkap untuk menghitung nilai effect size. Analisis data adalah analisis kuantitatif dengan menghitung nilai effect size dengan aplikasi Microsoft Excel 2020. Hasil penelitian menyimpulkan dari 12 jurnal yang dianalisis penerapan model problem based learning berbasis Internet of Things (IoT) memberikan pengaruh yang signifikan terhadap kemampuan berpikir kreatif siswa dengan nilai rata-rata nilai effect size sebesar 0.942 Temuan ini memberikan informasi penting bagi guru penerapan model problem based learning memperikan pengaruh dengan kategori yang tinggi untuk meningkatkan kemampuan berpikir kreatif dalam proses pembelajaran.

**Kata Kunci**: *Problem based learning; Internet of Things (IoT); Berpikir Kreatif; Efek Size*

**Abstract**

*This study aims to determine the effectiveness of the Internet of Things (IoT) integrated problem-based learning model on students' creative thinking abilities. This type of research is a meta-analysis research by evaluating the effect of the size of IoT-based problem-based learning models on students' creative thinking skills. Data search keywords are problem-based learning models; IoT-based problem-based learning model; and Students' creative thinking skills. Data collection techniques are through direct observation of journal databases and documentation. The eligibility criterion is that research comes from journals indexed by SINTA, Scopus and Web of Science; Research must be published in 2020-2024; Research obtained through mendeley database, google scholar, Researchgate; ERIC, and ScienceDirect, research related to the effectiveness of IoT-based problem-based learning models on students' creative thinking skills and research has complete data to calculate the value of effect size. Data analysis is a quantitative analysis by calculating the effect size value with the Microsoft Excel 2020 application. The results of the study concluded from 12 journals analyzed the application of the Internet of Things (IoT)-based problem-based learning model had a significant influence on students' creative thinking ability with an average value of effect size of 0.942 This finding provides important information for teachers, the application of the problem-based learning model exerts a high category of influence to improve creative thinking skills in the learning process.*

***Keywords***: *Problem based learning; Internet of Things (IoT); Creative Thinking; Size Effect*

## Introduction

The ability to think creatively is an important ability that allows students to solve problems with an innovative and original approach (Dewi &; Mashami, 2019; Hu et al., 2016). Creative thinking involves the ability to generate new ideas, uniquely connect different concepts, and look at problems from unconventional angles (Zulkifli et al., 2022; Santosa et al., 2023). Students who have creative thinking skills tend to be able to face challenges more flexibly, find solutions that were not thought of before, and make valuable contributions in a variety of contexts, from the business world to the arts and sciences (Siswono, 2011). By practicing creative thinking skills, one can increase the power of innovation, increase creativity, and open up new opportunities to solve complex problems (Ikalindhari et al., 2020; Marcos et al., 2023).

The importance of the ability to think creatively is also seen in the context of technological development and rapid social change. In an era where change is becoming constant, individuals who are able to think creatively have a significant competitive advantage (Buchori & Cintang, 2018; Andrievskaya &; Vaulina, 2023; Nasution et al., 2023). Students can create new solutions to emerging challenges, change the way we interact with technology, and inspire positive change in society (Fradila et al., 2021;Ichsan et al., 2023; Rahman et al., 2023). In addition, the ability to think creatively also broadens mental horizons, allowing individuals to explore new ideas and dive into previously untapped areas (Wilis et al., 2023; Payadnya et al., 2023). Thus, the development of creative thinking skills is not only important for student growth, but also for collective progress in the face of future challenges.

But in fact, the creative thinking ability of students at school is still relatively low (Hidayati et al., 2023; Sigit et al., 2023; Nurtamam et al., 2023; Suryono et al., 2023). In learning activities, teachers still use conventional learning models so that students find it difficult to understand the subject matter ( Rahman et al. , 2023; Utomo et al., 2023; Elfira et al., 2023). Teachers do not direct learning that encourages students to have creative thinking skills (Suwendra, 2023; Luciana et al., 2023; Khoiri et al., 2023; Asmara et al., 2023). Furthermore, based on the results of PISA in 2018, Indonesian students' science literacy obtained a score of 397, ranking 71 out of 78 countries (Zulyusri et al., 2023; Oktarina et al., 2021; Santosa et al., 2023; Razak et al., 2021). Furthermore, teachers still lack the application of technology in learning, so students are less creative in learning (Princess et al., 2023). The low ability to think creatively of students needs to be overcome by applying the right learning model. One of the right learning models encourages students' creative thinking skills, namely problem-based learning.

Problem-based learning (PBL) is a learning model that changes the traditional educational paradigm by placing real and complex problems at the core of the learning experience (Qondias et al., 2022; Loyens et al., 2023). In contrast to conventional methods where material delivery dominates, PBL engages students in active inquiry and critical thinking from the outset. In this model, students are introduced to real-world problems that require them to dive into the subject matter, collaborate with peers, and apply their knowledge to propose solutions (Chaidam &; Poonputta, 2022)i. By immersing students in challenging scenarios, PBL not only deepens understanding of the subject matter but also develops important skills such as problem-solving, communication, and cooperation. Furthermore, the dynamic nature of problem-based learning encourages students to have control over their own learning journey, triggering curiosity, motivation, and a sense of responsibility

towards student education (Munawaroh, 2020; Suharyat et al., 2022).

In addition, PBL transcends disciplinary boundaries, providing a platform for cross-disciplinary exploration and integration of knowledge (Ernawati, Sudarmin, et al., 2022). Through a process of inquiry and resolution of complex problems, students draw connections between different subject areas, gaining a holistic understanding of the subject matter (Xu et al., 2023;Campo et al., 2023). This cross-disciplinary approach reflects the interconnectedness of real-world challenges, preparing students for the complexities of their future careers. In addition, PBL also encourages lifelong learning by instilling a growth mindset and adaptability in students. Through engaging in real-world problem-solving experiences, students develop the resilience and flexibility necessary to navigate an ever-changing world (Mulyanto et al., 2018). Ultimately, the problem-based learning model empowers students to become active, independent learners equipped with the skills, knowledge, and mindset necessary to succeed in the 21st century (Duda &; Susilo, 2019; Dakabesi et al., 2019).

The problem-based learning model can be connected to the Internet of Things. The Internet of Things (IoT) has opened up new opportunities in the world of education by integrating technology in the learning process (Thakur et al., 2023). With IoT, classrooms can be transformed into smart, connected environments, enabling teachers to monitor and manage learning more effectively. For example, connected sensors can be used to monitor temperature, humidity, or lighting in classrooms, ensuring comfortable conditions for students (Issa et al., 2023; (Al-Taai et al., 2023). In addition, IoT devices such as smart whiteboards or wearables can be used to create interactive and personalized learning experiences. By harnessing the potential of IoT (M. S. Rahman et al., 2023), learning can be more adaptive and personalized, allowing for a more differentiated approach and adapting to the individual needs of students (Kumar et al., 2023; Shelare et al., 2023).

Previous research on problem-based learning is effective in encouraging students' creative thinking skills in learning (Wijayanto et al., 2023; (Adiilah &; Haryanti, 2023; Khoiri et al., 2023). The research gap is that many studies on problem-based learning models have not found a measure of the impact of IoT-based problem-based learning models on students' creative thinking skills. Therefore, this study aims at the effectiveness of the Internet of Things (IoT) integrated problem-based learning model on students' creative thinking abilities.

## Methods

This type of research is meta-analysis research, Meta-analysis is a research approach that analyzes previous research quantitatively to get a conclusion (Suparman et al., 2021; Wijnia et al., 2024; Ichsan et al., 2022; Tamur et al., 2020; Zhang & Ma, 2023). Data search keywords are problem-based learning models; IoT-based problem-based learning model; and Students' creative thinking skills. Data collection techniques are through direct observation of journal databases and documentation. The eligibility criterion is that research comes from journals indexed by SINTA, Scopus and Web of Science; Research must be published in 2020-2024; Research obtained through mendeley database, google scholar, Researchgate; ERIC, and ScienceDirect, research related to the effectiveness of IoT-based problem-based learning models on students' creative thinking skills and research has complete data to calculate the value of effect size. Data screening process through PRISMA 2020 (Figure 1.). Data analysis is a quantitative analysis by calculating the effect size value with the Microsoft Excel 2020 application. Furthermore, the criteria for effect size values can be seen in Table 1.

**Table 1.** Effect Size Value Criteria

| Effect Size | Criterion |
|---|---|
| 0.0≤ES≤ 0.2 | Low |
| 0.20≤ES≤ 0.8 | Medium |
| ES≥0.8 | High |

Source:(Cohen et al., 2007)

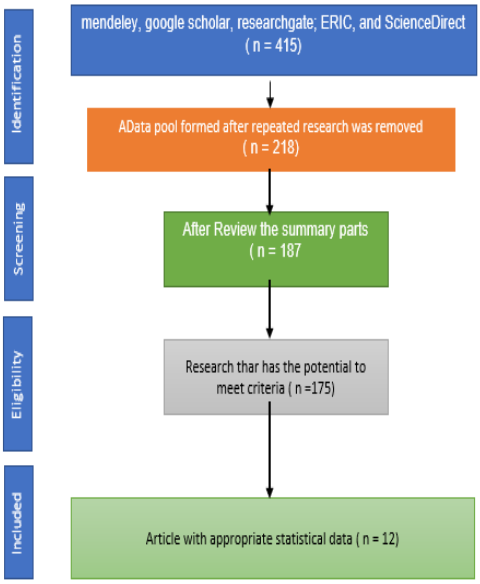


**Figure 1.** Data Selection Through PRISMA Method

## Result and Discussion

From the results of data search through the mendeley database, google scholar, Researchgate; ERIC, and ScienceDirect on the effectiveness of the Internet of Things (IoT) integrated problem-based learning model on students' creative thinking skills obtained 145 studies, but only 12 studies met the inclusion criteria that had been set. Data that has met the criteria for calculating the effect size value can be seen in Table 2.

Table 2. Value of Effect Size 12 Research

| Journal Code | Year | Bound Variables | Effect Size | Effect Size Criteria |
|---|---|---|---|---|
| P1 | 2023 | Creative Thinking | 1.26 | High |
| P2 | 2023 | Creative thinking | 0.92 | High |
| P3 | 2024 | Creative thinking | 0.62 | Medium |
| P4 | 2024 | Creative Thinking | 0.71 | Medium |
| P5 | 2021 | Creative Thinking | 1.82 | High |
| P6 | 2020 | Creative Thinking | 0.77 | Medium |
| P7 | 2021 | Creative Thinking | 0.41 | Medium |
| P8 | 2022 | Creative Thinking | 0.90 | High |
| P9 | 2023 | Creative Thinking | 1.11 | High |
| P10 | 2022 | Creative thinking | 0.87 | High |
| P11 | 2023 | Creative thinking | 0.66 | Medium |
| P12 | 201 | Creative Thinking | 1.16 | High |
| **Average effect size** | | | **0.942** | **High** |

Based on Table 2, the effect size value of the 12 studies analyzed was the highest at 1.26 and the lowest at 0.41.Furthermore, the average value of the overall effect size was 0.942 with high effect size criteria. The results of this study concluded that the Internet of Things (IoT) integrated problem-based learning model has a significant influence on students' creative thinking skills. This research is in line with Zulkarnaen et al., (2022) The application of the problem-based learning model can encourage students' creative thinking skills. In addition, research by (Maskur et al., 2020) The implementation of Internetnof things-based problem-based learning models can improve students' creative thinking skills in the learning process.

Problem Based Learning (PBL) has been known as a learning model that encourages students to be active in identifying, analyzing, and solving problems, while the Internet of Things (IoT) has brought significant transformations in various aspects of life, including education (Simanjuntak et al., 2021). The combination of PBL and IoT promises a dynamic and up-to-date learning approach, which can enrich students' creative thinking skills. First of all, the integration

between PBL and IoT offers the opportunity for a deep learning experience that is directly related to the real world (Kardoyo et al., 2019). By leveraging IoT, students can engage in projects that allow them to design, program, and implement solutions to real-world problems that utilize IoT technology. This not only increases their understanding of technological concepts, but also gives them the opportunity to think creatively in solving complex challenges.

In addition, the integration of IoT in PBL can stimulate students' creative thinking abilities through the exploration of innovative technologies and interaction with data generated by IoT devices (Fradila et al., 2021; Ichsan et al., 2022). Students can learn to understand how data is collected, analyzed, and used to make intelligent decisions. In this process, they can develop the ability to see patterns, make assumptions, and create new solutions that integrate IoT technology (Mustofa &; Hidayah, 2020).

Furthermore, this learning model can increase student involvement in the learning process. With relevant and interesting projects supported by IoT technology, students tend to be more motivated to learn and engage in learning activities. This can create an environment where creativity is encouraged, where students feel comfortable experimenting and trying new ideas without fear of failure. In addition, IoT integration in PBL can facilitate collaboration between students and between teachers and students (Anazifa, 2017). Projects involving the use of IoT technology often require effective teamwork, where students need to work together to design, test, and implement solutions (Sani et al.,, 2019). Through this collaboration, students can learn to listen and appreciate the perspectives of others, as well as develop communication and teamwork skills that are critical in addressing problems (Ulger, 2018; Suharyat , et al., 2022; Rahman &; Ristiana, 2020).

Not only that, with the appropriate evaluation, it can be measured how effective the IoT integrated PBL model is in improving students' creative thinking skills. The use of tests, project assignments, and class observations can provide valuable insight into student progress in terms of creativity (Surya et al., 2017; Mbay et al., 2017). In addition, feedback from students and teachers is also important to evaluate the success of this learning model in achieving the desired learning goals. Using this data, we can refine and refine learning models to be more effective in facilitating students' creative thinking skills (Utomo et al., 2023).

The next step is to analyze the effectiveness of the Internet of Things (IoT) integrated problem-based learning model on students' creative thinking ability based on the level of education which can be seen in Table 3.

**Table 3.** Size effect based on education level

| Education Trail | Effect Size | Average Effect Size | Criterion |
|---|---|---|---|
| Elementary School | 1.26 | 0.87 | High |
| | 0.92 | | |
| | 0.62 | | |
| | 0.71 | | |
| Junior School | 1.82 | 0.97 | High |
| | 0.77 | | |
| | 0.41 | | |
| | 0.90 | | |
| High School | 1.11 | 0.95 | High |
| | 0.87 | | |
| | 0.66 | | |
| | 1.16 | | |

Table 3, the average value of the effect size at the elementary education level is 0.87, the effect size of the junior high school education level is 0.97 and the high school education level is 0.95. These results imply that the Internet of Things (IoT) integrated problem-based learning model is effective for fostering students' creative thinking skills based on education level. the use of PBL models integrated with IoT can also develop students' critical and analytical thinking skills

(Mursid et al., 2022). In the process of solving problems driven by IoT technology, students need to perform in-depth analysis of the collected data, identify patterns, and come up with relevant conclusions. This helps strengthen students' creative thinking skills, as they are faced with challenges that require students to think beyond conventional constraints and find innovative solutions (Ali et al., 2020).

The implementation of an IoT integrated PBL model can create a collaborative and inclusive learning environment. With technology-based projects that encourage teamwork and the exchange of ideas, students have the opportunity to share students' knowledge, experiences, and perspectives (Ernawati et al., 2022). This not only enriches their learning experience, but also fosters the values of cooperation, communication, and empathy that are essential for future success. Thus, research on the effectiveness of IoT-integrated PBL models at the educational level has the potential to produce valuable findings in supporting the development of more relevant curricula and preparing students to face the challenges of the globalization era (Cui, 2020).

## Conclusion

From this study, it can be concluded that concluding from 12 journals analyzed, the application of Internet of Things (IoT)-based problem-based learning models has a significant influence on students' creative thinking skills with an average value of effect size of 0.942 This finding provides important information for teachers, the application of problem-based learning models exerts a high category of influence to improve creative thinking skills in the process Learning. PBL and IoT can facilitate learning that is more contextual, relevant, and challenging for students. Through IoT-based projects, students are exposed to real situations that require creative and innovative problem solving.

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