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Creativity Towards Design based Learning in Stem Education

Kreativitas Pada Pembelajaran Berbasis Desain Dalam Pendidikan Stem

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Abstract: Creativity has become a pivotal component in 21st-century skills, emphasized in global curricular research, particularly in Indonesia. This study aims to analyze and identify the perspectives of creativity among pre-service teachers when generating potential solutions in Design-Based Learning (DBL) activities. Fourteen female and two male pre-service teachers participated in three separate DBL activities. Data were collected through written and drawn submissions, semi-structured interviews, and field notes. A mixed-methods approach was employed, incorporating quantitative analysis of pre-service teachers' works to explore aspects of creativity, including fluency, flexibility, and originality. Descriptive analysis revealed that creativity and flexibility were rated highest, while originality scored the lowest. Content analysis further highlighted various factors influencing the uniqueness of pre-service teachers' ideas, such as exposure to different ideas, knowledge of DBL, and the prototyping process. The findings suggest that DBL can enhance creativity in STEM education, offering insights for educators and researchers to better understand and develop students' creative capacities.
Keyword: Design based learning, learning model, creativity, and STEM Education

Abstract: Kreativitas telah menjadi komponen penting dalam keterampilan abad ke-21 dan ditekankan dalam penelitian kurikulum secara global, terutama di Indonesia. Penelitian ini bertujuan untuk menganalisis dan mengidentifikasi perspektif kreativitas di kalangan guru prajabatan saat mereka menghasilkan solusi potensial dalam kegiatan Pembelajaran Berbasis Desain (DBL). Empat belas guru prajabatan perempuan dan dua laki-laki berpartisipasi dalam tiga kegiatan DBL yang terpisah. Data dikumpulkan melalui tulisan dan gambar peserta, wawancara semi-terstruktur, dan catatan lapangan. Pendekatan metode campuran digunakan dalam analisis data. Analisis kuantitatif difokuskan pada karya guru prajabatan untuk mengeksplorasi aspek kreativitas, termasuk kelancaran, fleksibilitas, dan orisinalitas. Analisis deskriptif menunjukkan bahwa kreativitas dan fleksibilitas mendapatkan skor tertinggi, sementara orisinalitas mendapat skor terendah. Analisis konten lebih lanjut menyoroti berbagai faktor yang mempengaruhi keunikan ide guru prajabatan, seperti keterpaparan pada berbagai ide, pengetahuan tentang DBL, dan proses prototipe ide. Temuan ini menunjukkan bahwa DBL dapat meningkatkan kreativitas dalam pendidikan STEM, memberikan wawasan bagi pendidik dan peneliti untuk lebih memahami dan mengembangkan kapasitas kreatif siswa.
Kata Kunci: Pembelajaran berbasis desain, model pembelajaran, kreativitas, dan Pendidikan STEM

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INTODUCTION

Many creative definitions were offered in the literature. The leader of the notions Guilford (1950) creativity has been characterized as one of the greatest attributes of creative individuals, often described as "the way to education and the solution of the most important human issues." Moreover, significant literature highlights that creativity is perceived as the capacity to generate high-quality, innovative products. (Kaufma and Sternberg, 2007).

Creativity has been characterized as one of the greatest attributes of creative individuals, often described as "the way to education and the solution of the most important human issues." Furthermore, creativity in today's educational environments is considered a crucial engine of civilizations, driving the development of innovative, high-quality products and solutions to complex problems (Hennessey and Amabile 2010). In the educational system of Indonesia, there is a strong emphasis on teaching students how to explore and approach real-world issues creatively. The focus is on preparing students to navigate a rapidly changing world, equipping them with the skills necessary for evolving professions and fostering the production of innovations, discoveries, and artistic achievements (Kress and Rule 2017). Creative training can significantly enhance students' creative thinking. Additionally, research has shown that younger children tend to exhibit higher levels of creativity compared to older children (Conradty and Bonger 2018).

LITERATURE REVIEW

1. STEM education and creativity

The curriculum in scientific education is regarded as a fundamental component of 21st-century skills and is emphasized in Indonesia and other countries. The literature consistently highlights the importance of fostering creative thinking in schools, recognizing it as essential for students' development in a rapidly changing world (Denson 2015). The STEM teaching approach, defined by the integration of two or more disciplines, has the potential to enhance teachers' abilities to address real-world problems. By combining different fields of study, STEM education equips teachers with the tools to foster critical thinking and problem-solving skills in their students (Sanders 2009).

Harris and Bruin (2018) and Henriksen (2014) have another theoretical research which says that STEM's interdisciplinary nature enables students to apply knowledge from various disciplines to develop new products, integrating science, mathematics, engineering, and technology. As such, STEM training is one of the most effective methods for fostering creative development. In STEM education, Nemiro et al. (2017) works together with 25 primary school children emphasized that new methods or techniques of evaluating or examining creativity in STEM education are needed Biçer et al. (2017). This study evaluated students' opinions on the requirements for creativity and computational design within STEM education, specifically utilizing engineering design procedures. By examining these perspectives, the study aims to understand how effectively these elements support creative development and problem-solving skills.

2. Creativity in STEM education through design based learning

In STEM instruction designed to address real-life challenges, Design-Based Learning (DBL) relies on the integration of engineering principles with classroom applications. This approach ensures that students can connect theoretical knowledge with practical, real-world scenarios, enhancing their ability to tackle complex problems effectively (Felix 2010). The DBL (Design-Based Learning) approach can pose challenges for students in building a comprehensive knowledge base. It often requires integrating students into the design process, which can be difficult but is essential for enhancing their understanding and knowledge development (Altan, 2017).

Design Engineering is a technique extensively documented in various models within the subject literature. The initial phase of the design process begins with problem identification (Brunsell 2012). The problem in design typically starts with a real-life scenario. During this phase, engineers identify the problem, specifying the qualities or properties that should be incorporated into successful designs, as well as the difficulties or barriers that might impede effective design. They also establish constraints to guide the resolution of these challenges (Hynes et al. 2011).

Only if the problem is properly stated can a successful solution be discovered. Students also endure the same technique with well defined issues as engineers. After the problem has been resolved, students might take time to thoroughly understand the challenge and define design standards and limits to avoid good student design (Brunsell 2012). The second phase of the design process which demands most creative thought is the creation of viable solutions (Valjak 2017). Students should offer as many recommendations for solving the problem based on the criteria and restrictions (Brunsell 2012). Third, the biggest way forward is to choose. In this example, students discuss how each solution fulfills the requirements of the issue (Hynes et al. 2011). Lee et al (2011) suggested examining other approaches and how a designer or problem solver might tackle comparable challenges.

This observation integrates both these design and creative phases with the development of different concepts and the optimum decision. Participants must create and test their solutions based on problem based in a prototype which is the final resolution report or model. At the end, students exchange ideas and results for feedback with other students, such engineers (Mentzer 2011).

Several engineering studies have emphasized the relevance of the arts of creativity (Kowaltowski et al. 2010) as well as other research projects in the fields of creativity (Syukri et al. 2017). Keana (2016) presented STEM as a technique for increasing creativity.

The poorly defined design problems and product-oriented design learning processes match the nature of creativity. The Siew (2017) study revealed that the STEM Engineering Process can be used to encourage creativity, problem resolution and thought among rural high school students. This technique is used to promote creativity. In another study, results showed that a creative product is dependent on the expertise of STEM preservice teachers (Mayasari et al. 2016). In each idea, Mayasari et al. (2016), discovered that after 15 design classes correspondingly, the flexibility, fluency, originality and the elaboration of participants' products increased. In another study, the output of the students was evaluated using the principles of fluency, flexibility, originality and elaboration based on creative thinking evaluations (Chasanah et al. 2017). The survey indicated that the notion that students obtain the greatest rating for their goods was elaboration.

Syukri et al. (2017) showed that DBL activities display creativity ideas in the prototype of their solutions for preservice teachers and the original technical prototypes of the students have got the lowest scores in the concepts of creativity. The effects of investigative questioning methods on creativity in DBL have been explored by Hathcock et al. (2015). In both experimental and control groups, they have carried out design oriented tasks. However, they also utilized research-based interrogation methods in the experimental

RESEARCH METHOD

This study employed a mixed-methods approach, combining both qualitative and quantitative techniques within a case study design. Case studies are a research method used to conduct an in-depth investigation into a particular program, event, activity, process, or individual. They are especially useful when addressing questions of 5W1H where the researcher has limited control over occurrences and focuses on current phenomena in real-life settings. The case study method can be categorized into four different designs: single-case, multiple-case, and multi-embedded designs.

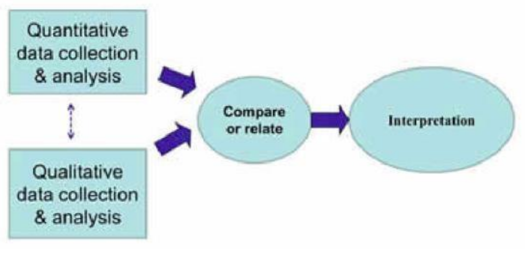

Figure 1. Research Methodology

The study focused on examining the various components of creativity present in student-generated ideas aimed at developing feasible Design-Based Learning (DBL) solutions. The analytical unit for this investigation was the student groups, each of which was tasked with generating solutions to specific design challenges. These groups were assessed on how their solutions incorporated key creative elements, such as fluency, flexibility, originality, and elaboration.

To conduct this evaluation, the researchers analyzed the solutions produced by each group through a detailed examination of their creative attributes. This involved assessing how many distinct and diverse solutions each group generated (fluency), the variety of approaches and adaptability in their solutions (flexibility), the uniqueness and novelty of their ideas compared to those of other groups (originality), and the depth and detail of the solutions presented (elaboration). By focusing on these creativity components, the study aimed to understand not only the effectiveness of the solutions in addressing the design challenges but also the overall creative processes employed by the students.

The use of student groups as the analytical unit allowed for a comprehensive evaluation of collaborative creative efforts and provided insights into how group dynamics and collective problem-solving approaches influence creativity. This approach helped identify strengths and areas for improvement in the DBL process, offering valuable feedback on how to enhance creative thinking and solution development in educational settings.

1. Research Sample

Sixteen randomly selected pre-service teachers from Universitas Esa Unggul in Indonesia participated in this study. The participants were academically successful, with GPAs ranging from 3.0 to 3.8 out of 4. The participants came from families with a medium socioeconomic status and at least one parent had completed secondary education.

In this study, the students were organized into four groups, each consisting of four individuals. The groups were assigned names group 1,2,3 and 4 based on pre-determined criteria set by the instructors. The researchers provided extensive information to facilitate this process.

2. Instruments and Procedure

As part of a major project funded by the University, statistics were collected to support STEM education for instructors. The initiative aimed to enhance concepts and proficiency in science, technology, engineering, and mathematics among pre-service teachers. Data for this survey were gathered from 16 students participating in three DBL activities.

These three exercises were designed for pre-service teachers majoring in elementary school education, considering the engineering design process and its implementation in the classroom through design-based training by Brunsell (2012). Design challenges were initially identified using the technique, considering the needs and constraints associated with them. The real-world context, various approaches, and multiple fields related to these problems were addressed. Following this, instructions for implementing and training in the DBL process were developed. Three experts evaluated the exercises: two assessed their alignment with DBL principles, while the third focused on the potential for fostering creative thinking and innovation. The experts affirmed that all three exercises were suitable for real-life application of the DBL process. However, they also contributed to improving the quality of the activities. Typographical errors noted by the experts were corrected. Additionally, a significant comment on the first exercise was the need to use language that encourages creative thinking without directing students toward a specific approach.

The researchers observed pre-service teachers not only as they created designs but also as they acquired the knowledge and skills necessary to address design challenges in STEM fields. The students utilized their existing knowledge in science, technology, and mathematics to tackle these challenges. The DBL activities used were: (1) Assisting people with visual disabilities in traffic, (2) Preventing dehydration in cats and dogs, and (3) Creating a habitat for birds.

3. Data Sources

In the second stage of Design-Based Learning (DBL), the analysis of pre-service teachers' writings and drawings provided quantitative data that contributed to the development of practical solutions. This quantitative information was crucial in assessing how effectively participants could generate viable solutions to the design challenges presented. Additionally, the researchers' field notes and the data collected from semi-structured interviews were used to evaluate the qualitative aspects of the data. These qualitative sources offered insights into the depth, relevance, and innovation of the solutions proposed by the pre-service teachers. The field notes captured observational details and contextual factors that influenced the creative process, while the semi-structured interviews provided a platform for participants to elaborate on their problem-solving approaches and reflect on their experiences. By combining both quantitative and qualitative data, the study was able to provide a comprehensive evaluation of the effectiveness of the DBL approach and its impact on the participants' ability to develop feasible and creative solutions. This multi-faceted analysis not only enhanced the understanding of the participants' creative capabilities but also contributed to refining the DBL methodology to better support future educational endeavors.

a. Writings and drawings of the preservice teachers

The investigators asked the groups to document, sketch, or explain any feasible approach to addressing the design challenge. Pre-service teachers were encouraged to communicate their ideas as effectively as possible. Some provided only written responses, while others included brief annotations to describe their choices.

As part of the quantitative data collection, the researchers used both written responses and drawings from the pre-service teachers. In exploring potential solutions, the researchers asked pre-service teachers to work quietly and independently. They were instructed to record their thoughts on possible solutions before discussing them with their peers. This approach aimed to prevent the imposition of individual ideas on the group and avoid disrupting the creative process. Each group's solutions were then compiled by the lecturer, listing all the ideas contributed by each member individually.

b. Semi structured interviews

As part of the data collection method, the researchers used semi-structured interviews to clarify responses and obtain detailed information on the subject (Given, 2008). To ensure the relevance of the interviews, the researchers considered the objectives, context of the activities, and age of the participants, and formulated three key questions.

These questions were then reviewed by two experts to evaluate their adequacy concerning the study's focus, activity context, and participant age range. Once validated, the final questions included: "What obstacles did you encounter while working on the design challenges?", "What factors do you believe contributed to these difficulties?", and "What insights or skills did you gain from this experience?" The interviews were conducted in the classroom, each lasting approximately 20 minutes.

4. Data Analysis

The data for this study were sourced from field notes, semi-structured interviews with students, and participants' essays. The analysis was conducted in two distinct phases: descriptive analysis and content analysis.

In the first phase, descriptive analysis focused on evaluating the participants' sketches and drawings using specific criteria. Fluency was assessed by counting the number of unique solutions each participant generated, with one point awarded per distinct solution. Flexibility was measured by the variety and adaptability of the solutions, giving one point to solutions that were significantly different from previous ones. Originality was determined by comparing solutions across groups, awarding one point for each unique solution. Elaboration was judged based on the depth and detail provided, with one point given for solutions well-supported by relevant literature.

In the second phase, content analysis was used to delve deeper into the results from the descriptive analysis, integrating insights from field notes and semi-structured interviews. The interviews were analyzed using a deductive approach, where the researchers developed a coding framework and labeled the codes accordingly. The analysis focused on three main areas: the challenges participants faced, the reasons for these challenges, and the impact of the experience on their creative processes. Each code was linked to design principles based on the creative insights gathered from the interviews and field notes. This comprehensive analysis provided a detailed understanding of the participants' creative processes and assessed the effectiveness of the Design-Based Learning (DBL) activities, offering valuable insights into how creative solutions were developed and applied.

RESULTS AND DISCUSSION

This study explored the development of feasible Design-Based Learning (DBL) solutions through creativity among pre-service teachers. The findings were organized based on research questions and creative concepts in the participants' responses. The analysis showed that fluency, the ability to generate many ideas, was the most frequently observed aspect, followed by elaboration, flexibility, and originality.

Although fluency was prevalent, it was not deemed sufficient for assessing overall creativity, which also encompasses adaptation, originality, and elaboration, as suggested by Guilford (1950).

The researchers found that participants struggled with generating original solutions and demonstrating flexibility, which were influenced by the emphasis on generating a high volume of responses in the initial activities. This issue aligns with Syukri et al. (2017), who noted that originality often lags behind fluency and flexibility in creative tasks. The limited originality may also stem from the small classroom environment, where proximity and interaction between students could have led to idea overlap and reduced creative thinking. To mitigate this, it is recommended that DBL activities be conducted in more dispersed settings to minimize the impact of peer ideas on individual creativity.

Further analysis revealed that participants, who were selected for their high academic standing, were generally competent in designing solutions but faced challenges due to a lack of experience with DBL activities. The semi-structured interviews highlighted that the participants perceived the development of solutions and prototypes as significant obstacles, a reflection of their general education experience which emphasized correct answers over creative solutions. This lack of exposure to creative problem-solving in traditional classrooms may have hindered their ability to produce diverse and innovative solutions. The study concludes that focusing solely on finding the "right" answer limits originality and creativity. Educators are encouraged to integrate lessons that foster both accurate and innovative responses to enhance creativity.

Future research should ensure that training environments support creative thinking by allowing students to work independently before joining groups and clearly define communication norms during activities. Additionally, researchers should explore methods to boost originality and comprehensive idea development in DBL processes, as prior studies have shown that sustained design instruction can enhance creativity (Syukri et al., 2017; Harris and Bruin, 2018). Longitudinal studies could further validate the effectiveness of DBL in fostering creative thinking within STEM education.

CONCLUSION

This article highlights that creativity and flexibility were reported at high levels among the pre-service teachers, yet originality was notably lower. This discrepancy indicates that while participants were adept at generating a wide range of ideas and adapting their solutions, they struggled more with producing truly unique and novel concepts. The further analysis uncovered several factors influencing the uniqueness of their ideas. Key among these were the participants' exposure to a variety of ideas, their familiarity with design-based learning (DBL) principles, and their engagement with the prototyping process. Exposure to diverse ideas and experiences can broaden the scope of creative thinking, while a deep understanding of DBL can provide structured approaches to problem-solving and innovation. Additionally, the prototyping process plays a crucial role in refining and implementing creative concepts, potentially impacting the originality of the final solutions. The study suggests that an increased application of DBL in educational settings could significantly enhance educators' and researchers' ability to understand and nurture students' creative strengths and limitations. By integrating DBL more extensively into the curriculum, educators can better support students in developing their creative abilities and overcoming challenges related to originality. This approach can offer valuable insights into how different aspects of DBL contribute to the creative process, ultimately leading to more effective strategies for fostering innovation within STEM education. The findings underscore the importance of continuous improvement and adaptation of teaching methods to better address the diverse needs of students and enhance their overall creative potential.

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