Students' Creative Thinking based on Loose Parts: A Case in Frugal context

Zahid Zufar At Thaariq[1], Fikri Aulia[1], Reno Nurdiyanto[1], Jasmine Nurul Izza[2], Devi Mariya Sulfa[2], Alby Aruna[1], Dhimas Adhitya Wijanarko[1]

[1] Educational Technology, Universitas Negeri Malang, Malang 65145, East Java, Indonesia
[2] Biology, Universitas Negeri Malang, Malang 65145, East Java, Indonesia
fikri.aulia.fip@um.ac.id

Abstract. Utilizing underutilized items is a crucial aspect of fostering environmental consciousness. This encompasses the utilization of miscellaneous components (loose parts) to create a frugal experience. The objective of this qualitative research is to investigate the perspectives expressed by junior high school students who participated in a case study. The case study provided a frugal framework for cultivating frugality. The findings revealed that despite the constraints of limited resources, the students were able to manifest their creative ideas through construction. This implies that creative ideas can be realized without the need for expensive and unaffordable resources. Consequently, educators can enhance the teaching and learning process by incorporating loose parts to contextualize students' frugal experiences.

Keywords: Creativity, Loose Parts, Frugal.

1 Introduction

Promoting creativity in education is aimed at addressing various concerns, such as effectively dealing with ambiguous problems, adapting to the rapidly changing world, and preparing for an uncertain future (1). Currently, the economic argument stands out as the most prominent justification for implementing policies that support creativity (2). The significance of creativity in the economy is increasingly recognized as essential (3) for enabling nations to achieve higher employment rates, economic success (4), and effectively navigate heightened competition. Consequently, it is imperative that creativity is not disregarded or suppressed within educational institutions (5), and its cultivation should not be left to chance or unfounded beliefs (6).

Creativity plays a crucial role in fostering innovative thinking across various domains, yet it often goes undervalued within formal educational settings. The process of generating solutions and constructing objects necessitates the application of creative thinking (7). Expressive creativity refers to the spontaneous creative abilities often observed in children, which are demonstrated through activities such as drawing and play. On the other hand, productive creativity is exemplified by scientists and artists, who possess the ability to create with a purpose rather than solely expressing themselves. For instance, the invention of an engine designed to enhance the fuel efficiency of farm

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tractors can be considered an example of productive creativity. Innovative creativity, on the other hand, involves the capacity to improve or reinvent an existing organism or object by utilizing conceptualization skills. A recent example of this is the movement to redefine government, where the existing governmental structure was reconceptualized. Lastly, emergenative creativity involves the creation of something entirely new, leading to the establishment of a new paradigm. The introduction of chemical fertilizers, insecticides, and hybrid seeds that played a crucial role in the Green Revolution serves as an example of emergenative creativity (8).

Fostering students' creativity entails establishing a conducive setting that promotes and sustains imaginative cognition, exploration, and experimentation. This approach transcends conventional disciplinary confines and advocates for an interdisciplinary perspective. Students are motivated to scrutinize assumptions, contest prevailing notions, and cultivate their distinctive problem-solving strategies (9). Incorporating creative thinking into the learning process is a responsibility that teachers should fulfill in order to foster the development of students' creative thinking abilities (10). This aligns with the viewpoints expressed by Wheeler, Bromfield, and Waite (11), who assert that it is the teacher's duty to create an optimal environment for students to acquire pertinent thinking skills. The significance of creative thinking skills for students is widely recognized (8).

The concept and relative significance of creative, open-ended play in the development of students has been widely acknowledged for a considerable period of time. The theory of loose parts, titled "How not to cheat children," was formulated by Simon Nicholson in 1971 (12). Loose parts are defined as materials that possess variability, allowing them to be utilized in multiple ways, thereby enabling children to engage in experimentation and invention through play. These materials can be either natural or synthetic. The theory itself emerged from two fundamental factors: the absence of evidence supporting the notion that creativity is an innate trait possessed by some individuals and not others, and the abundance of evidence demonstrating that all children possess a natural inclination to play and interact with their surroundings. Based on these observations, the theory of loose parts posits that "the level of inventiveness, creativity, and potential for discovery in any given environment is directly proportional to the quantity and diversity of variables present within it" (13). It is not only crucial to provide children with unstructured play opportunities, but also to furnish them with appropriate play materials that can enhance their play environment, thereby fostering creativity and growth. The theory of object affordance pertains to how various aspects of the environment can offer different possibilities for action or utilization (14).

Loose part play is an engaging and effective educational tool that aligns with student's developmental needs, as it provides them with hands-on experiences during play (15). Loose parts play is a type of play that involves using open-ended materials that are moveable and nondictated, allowing children to use them in creative ways. Loose parts play has been found to have a positive impact on children's cognitive, social, and emotional development (16). In the context of education, loose parts play has been used to introduce children to concepts such as numbers (17), size (18), and local wisdom (19). Loose parts play has also been found to be effective in building collaborative competencies in primary school children (20). In a frugal context, loose parts play can be a cost-effective way to provide learning tools that can be found in the environment (19). Overall, loose parts play is a versatile and effective way to promote student's development and learning.

The utilization of loose parts has been examined in various research studies. For instance, Flannigan and Dietze's research (21) discovered that children did not exhibit explicit gender stereotyping or age-exclusionary behavior when engaging with loose parts. Additionally, Rahardjo's research (22) identified two main themes that emerged from the discussion, namely the role of loose parts in supporting creative freedom and problem-solving. Furthermore, Houser et al's research (23) contributed to a deeper understanding of the impact of integrating loose parts materials into outdoor play spaces on children's health, as well as the effects on educators' and parents' attitudes, beliefs, and understanding of physical literacy, active outdoor play, and risk-taking during play. As Farrugia (24) asserts, loose parts such as blocks, acorns, and pebbles can enhance children's experiences..

Based on the aforementioned explanation, the acquisition of learning Loose Parts yields various benefits. These advantages encompass the absence of differentiation in students' physical identification, as it can be cultivated by all groups. Additionally, learning Loose Parts fosters creative freedom, enhances problem-solving skills, promotes healthier habits, builds self-efficacy, and supports overall learning experiences. However, it is important to note that certain theoretical gaps exist regarding the absence of gender-stereotyped or age-exclusionary behaviors in the utilization of loose parts. Furthermore, there is a lack of empirical understanding regarding the comprehensive impact on children's health, educators' and parents' attitudes, beliefs, and comprehension of physical literacy, active outdoor play, and risk-taking during play. Additionally, there is a need for a concrete understanding of how loose parts effectively support children's play experiences. It is worth mentioning that loose parts have primarily been limited to early childhood, but Gascoyne (25) has revealed that they can be utilized or developed by individuals of all age groups, including secondary school students. Therefore, this research presents a novel approach to how secondary school students can generate their ideas based on loose parts, with an emphasis on the concept of frugality as the primary foundation.

2 Method

This study employed a qualitative approach in its research methodology. Qualitative research is often used to explore complex or sensitive topics, generate new theories or hypotheses, and provide rich descriptions of human behavior and interactions (26). We employed a case study methodology to accomplish this. Case studies are frequently employed as a means of inductively exploring phenomena that are not yet well understood, with the aim of generating new theories. Additionally, there have been suggestions to use case studies for deductive theory testing through analytical generalization (27). In this particular instance, we employ the framework of frugal experience as a predetermined scenario, utilizing the concepts generated by students in the creation of loose parts media.

In this particular study, a total of 20 students were included and organized into 6 distinct study groups. Each of these groups generated ideas pertaining to their respective loose parts. These ideas were subsequently analyzed using a descriptive approach that emphasized technical triangulation, which involved conducting interviews, making observations, and reviewing relevant documentation. This research methodology aligns with the assertion made by Tenny et al (28) that qualitative research typically aims to gather insights into participants' experiences, perceptions, and behaviors. Therefore, it is common for us to consider behavior as a component of research.

3 Result and Discussion

The field of educational technology focuses on the effective facilitation of student learning (29). Facilitating learning refers to the process of creating an environment and providing resources that support and assist learners in their educational journey. It emphasizes the learners' interests, abilities, and responsibilities in defining their own learning problems and controlling their internal mental processes (30). The act of facilitating learning encompasses more than the traditional methods of teaching conducted by the instructor. It involves the utilization of various teaching strategies and may also involve guiding the learner towards alternative sources of knowledge, such as the internet, e-learning resources, books, or journals, as well as connecting them with other individuals, such as colleagues, teachers, or students (31). In courses such as real analysis or algebraic structures, students are typically required to assimilate numerous formal definitions and theorem statements. These concepts are subsequently employed to validate or invalidate various statements presented in assignments and examinations. Our focus lies in examining the process by which students initially comprehend formal concepts (32).

The aforementioned discussion pertains to the work of Marzano and Kendall (33), and their initial taxonomy of learning, which focuses on the process of retrieval in the cognitive system. This process is an inherent neurological function that occurs unconsciously in all individuals. It differs from Bloom's (34) previous assertion that cognitive processes must always follow a sequential order, starting with remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). Bloom's perspective leans towards an external orientation, where the cognitive processes can be observed, heard, and felt externally. In contrast, Marzano and Kendall's viewpoint places emphasis on the highest level of cognition, known as metacognition.

According to Thaariq (35), the upcoming years, specifically 2025 and beyond, will witness the emergence of numerous novel technologies, such as artificial intelligence, which will have a profound impact on various facets of human existence. Consequently, as highlighted by Rose and Nichol (36), the conventional skill set possessed by individuals will prove insufficient in adapting to the rapid advancements of this era. Therefore, it becomes imperative to introduce innovative approaches in educating students to adequately equip them for the future.

Frugal innovation in student success and development can involve developing affordable and effective solutions to address challenges faced by students. For example, one study developed a frugal classroom that boosted creativity and innovation in students (37). Another study explored the use of frugal science tools, such as the Foldscope microscope, to enhance out-of-school science education (38). Additionally, frugal engineering innovations have been used to empower rural and urban informal sector youth to address district problems (39). By leveraging lean principles and fundamentals, frugal product development processes can be structured and leveraged to attain significantly cheaper solutions on the market (40,41). Furthermore, progress indicators have been developed to assess student programming effort independently of the correctness of their code, which can foster the development of a growth mindset (42). Overall, frugal innovation can be a valuable approach to address challenges faced by students in a cost-effective and efficient manner.

In the context of this study, we allocated junior high school students to collaborate in groups and employ a cost-effective approach to create loose parts. Each group engaged in discussions to identify their most promising ideas. Ultimately, the students generated six concepts pertaining to loose parts.

Group 1 proposed the concept of "Hydraulic Hands", a prosthetic medium constructed from unused cardboard and equipped with straps. The primary objective of this innovation was to leverage hydraulic principles by utilizing a hose system to enable users to exert more precise and powerful control over the movements of the artificial hand. This idea amalgamates a straightforward concept with cutting-edge technology, wherein the water pressure within the hose is converted into motion within the lightweight yet durable cardboard prosthetic hand. By securely and comfortably fastening the prosthetic hand to their wrist using a strap, users can replicate the movements of their own hand through the application of hydraulic principles.

Group 2 proposed the concept of a "Solar System" model, utilizing cardboard and paper as the primary materials. The cardboard serves as the structural container, while the paper is transformed into pulp and molded to resemble the planets. The primary objective of this project is to visually and interactively demonstrate the process of planetary revolution around the sun. By employing a cardboard base as a container and shaping paper into malleable papier-mâché, Group 2 successfully constructed a three-dimensional representation of the Solar System. This model enables observers to comprehend the movement of the planets in relation to the sun. Each planet is represented by paper balls positioned at appropriate intervals within the cardboard container. By gradually rotating the container, observers can witness the planets' orbits around the central point, effectively illustrating their revolution against the sun. This interactive approach facilitates the comprehension of complex astronomical concepts that are often challenging to grasp through static imagery alone. Moreover, in addition to its educational value, this Solar System model can serve as a visually captivating attraction in educational environments such as classrooms or scientific exhibitions. The hands-on nature of Group 2's creation allows students and visitors to directly observe and experience the workings of the Solar System, thereby enhancing their understanding of astronomy and celestial mechanics.

Group 3 proposed the concept of a "Ship" as a means to illustrate Archimedes' law of buoyancy. The medium chosen for this demonstration consists of repurposed bottles and styrofoam for the ship structure, and cardboard for the sail. The primary objective was to create an interactive ship model that effectively visualizes the aforementioned law using readily available and cost-effective materials. By utilizing used bottles as the ship's hull, styrofoam as the buoyant component, and cardboard as the sail, Group 3 successfully developed a tool that presents the concept in an engaging and comprehensible manner. In this model, the empty bottle functions as the body of the ship, containing the styrofoam which is lighter than water. When the ship is immersed in water, Archimedes' law comes into play: the weight of the water displaced by the bottom of the ship (the styrofoam) generates a buoyant force that propels the ship upwards, causing it to appear as if it is floating on the water's surface. Additionally, the incorporation of cardboard sails allows for the manipulation of the ship's position and facilitates the exploration of how alterations in mass distribution impact the ship's buoyancy.

Group 4 proposed the concept of a "Book Cell", a creative and educational medium for visualizing and illustrating the structure and function of biological cells. This medium is constructed using moldable materials such as styrofoam and wax, allowing for the creation of a three-dimensional model that accurately represents the different components of a cell. The model incorporates various parts of the cell, including the cell membrane, nucleus, and mitochondria, with each component being represented by styrofoam shaped to match its specific size and form. To enhance visibility, night candles are utilized to provide lighting effects, enabling users to observe the inner structure of the cell more clearly. Additionally, the model can be designed to open like a book, enabling users to explore the layers of the cell and observe the interactions between its various components.

Group 5 proposed the concept of "Dinosaurs" as a means of educating individuals about the various ages of these prehistoric creatures. The medium chosen for this educational tool was a diorama constructed from recycled cardboard, which served as a container. Additionally, wax was utilized to create accurate replicas of dinosaurs. The primary objective of this project was to provide an informative and visually engaging experience for users, allowing them to explore the history of dinosaurs across different time periods. Each geological era was meticulously represented in the diorama, with attention to detail. The dinosaur replicas, crafted using wax, accurately depicted the shapes and characteristics of these creatures based on current scientific knowledge. Through its visually appealing presentation, this learning tool enables users to examine and compare the size, morphology, and lifestyles of dinosaurs throughout various epochs.

Group 6 proposed the concept of utilizing cardboard as the primary material for constructing a model car, supplemented by a toy engine to facilitate its movement. The objective of this project was to present the fundamental principles of force acting upon a vehicle through the development of an interactive model that effectively demonstrates physics concepts in a practical manner. By employing a cardboard framework as the foundation for the car's structure, and incorporating a toy engine to propel it, Group 6 devised a tool that enables users to directly observe the impact of force on the car's motion. Within this model, the application of force to the car is visually represented by the resultant movement generated by the toy engine. Users are afforded the opportunity to manipulate the car's direction and speed, thereby witnessing firsthand the influence of force on altering its motion. Furthermore, users are also able to discern the effects of friction and gravity within a tangible context.

Table 1. Overview of Student Ideas related to Loose Parts

Product Name	Concept	Objectives
Hydraulic Hands	By using cardboard and hydraulic principles, they were able to create a functional prosthetic hand that enables users to replicate the movements of their own hand, showcasing the potential of combining basic materials with cutting-edge concepts.	The main goal of this innovation was to use hydraulic principles and a hose system to give users better and more powerful control over the artificial hand's movements.
Solar Systems	Through the construction of a cardboard and paper-based model, they successfully demonstrated the movements of the planets around the sun, making complex astronomical concepts more comprehensible and engaging.	This project aims to visually and interactively show how planets revolve around the sun.
Ship	Repurposed bottles, styrofoam, and cardboard can be used to create an interactive ship model that effectively illustrates Archimedes' law, providing a tangible way for users to understand the principles of buoyancy.	The main goal was to design an interactive ship model that vividly represents the mentioned law using easily accessible and affordable materials.
Book Cell	By utilizing styrofoam and wax, they developed a three-dimensional model of a biological cell with illuminated components, allowing users to explore and understand the structure and function of cells more effectively.	To employ creative and educational methods to visually represent and depict the intricate structure and functionality of cells.
Dinosaurs	A diorama made from recycled cardboard and wax can be used to educate individuals about the history of dinosaurs, offering a visually engaging tool to explore the characteristics and evolution of these creatures.	This project aimed to offer users an informative and visually captivating experience, enabling them to delve into the history of dinosaurs throughout various time periods.
Cars	Constructing a model car from cardboard and incorporating a toy engine demonstrates fundamental physics principles like force, friction, and gravity in an interactive manner, helping users grasp these concepts through practical observation.	This project aimed to convey the basic principles of vehicle forces by creating an interactive model that practically illustrates physics concepts related to force.

In summary, all of these projects demonstrate the effectiveness of using frugal materials and loose parts to create interactive learning tools that enhance understanding and engagement in various subjects, from science and physics to biology and history. Loose parts materials are used by children in the formation of sociodramatic play, including episodes of trading, bartering, and advertising that support their shared understandings (20). The emphasis is on hands-on experiences that make complex concepts more accessible and enjoyable.

4 Conclusion

Based on the preceding explanation, the concept of loose parts and the frugal approach in creative learning can be observed. Each group has implemented the principle of loose parts, which involves the utilization of materials that can be rearranged and combined in various ways to facilitate a diverse and interactive learning experience. Specifically, materials such as cardboard, sterofoam, used bottles, and wax candles are regarded as flexible loose parts that can be employed to create different learning media.

Furthermore, the frugal approach is evident in the ideas presented by all the groups. Groups 1 to 6 have utilized readily available and affordable materials, such as used cardboard, sterofoam, used bottles, and wax candles. By employing simple and cost-effective materials, they have devised innovative and creative solutions for educational purposes. This frugal approach exemplifies how meaningful learning does not necessarily necessitate expensive resources, but can be achieved through resourcefulness and the utilization of available materials.

In summary, the ideas put forth by the groups exemplify the application of the loose parts principle and the frugal approach within an educational context. These concepts demonstrate that creative and interactive learning can be accomplished using simple materials that can be rearranged, enabling learners to delve into a deeper comprehension of scientific concepts without incurring significant expenses.

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