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Scoping Literature Review: What Activities Can Help Students Discover Permutations?

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Abstract. Mathematical knowledge will be meaningful for students if it is discovered through mathematical rediscovery activities. This research aims to provide an overview of the activities carried out by researchers in teaching permutation topics as an insight for other researchers to try various activities that are relevant for teaching combinatorics topics in general. This research is a scoping literature review using the 8-stage framework of Xiao & Watson. The study was carried out on 6 relevant articles published in various reputable international journals without a specific time limit. Based on the results of the review, it was found that learning permutations using activities included the context of tower replicas, beaded bracelets, presentation order, bear dolls, and photography. The learning activities used generally consist of arranging physical objects. The author suggests using reorderable objects to teach the permutation topic. The context must be adapted to the knowledge and experience of the students.

Keywords: Combinatorics; Discover Permutation; Literature Review; Mathematics Learning; Students' Activity

Abstrak. Pengetahuan matematika akan bermakna bagi siswa jika ditemukan melalui aktivitas penemuan kembali matematika. Penelitian ini bertujuan untuk memberikan gambaran tentang aktivitas-aktivitas yang dilakukan oleh para peneliti dalam mengajarkan permutasi sebagai wawasan bagi para peneliti lain untuk mencoba berbagai aktivitas yang relevan untuk mengajarkan materi kombinatorik secara umum. Penelitian ini merupakan scoping literature review dengan menggunakan 8 tahap kerangka kerja Xiao & Watson. Tinjauan dilakukan terhadap 6 artikel yang relevan yang dipublikasikan pada berbagai jurnal internasional bereputasi tanpa batasa rentang waktu tertentu. Berdasarkan hasil tinjauan, ditemukan bahwa pembelajaran permutasi dengan menggunakan aktivitas antara lain menggunakan konteks replika menara, gelang manik-maik, urutan presentasi, boneka beruang, dan fotografi. Aktivitas-aktivitas yang digunakan umumnya berupa aktivitas menyusun objek-objek fisik. Penulis menyarankan penggunaan objek-objek yang dapat disusun ulang untuk mengajarkan permutasi. Konteks yang digunakan harus disesuaikan dengan pengetahuan dan pengalaman siswa atau mahasiswa.

Kata kunci: Aktivitas Siswa; Kombinatorika; *Literature Review*; Penemuan Konsep Permutasi; Pembelajaran Matematika

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INTRODUCTION

Combinatorial thinking refers to the ability to understand and solve problems that involve the permutation, combination, and arrangement of objects or elements in various possible ways (English, 2005). This skill involves the use of imagination, creative thinking, and logical analysis to systematically explore all the relationships between different elements and identify various combinations of given elements (Charalambides, 2002).

Combinatorial thinking has significant applications in various fields, including mathematics, computer science, science, business, and everyday life (Krekić-Pinter et al., 2015). In the field of mathematics, combinatorial thinking helps students solve problems involving permutations, combinations, and arrangements of objects. Apart from that, it also helps in understanding combinatorics, probability, statistics, and discrete mathematics (Batanero & Sanchez, 2005). Meanwhile, in everyday life, combinatorial thinking helps in managing time and sequence of activities, compiling new work alternatives with the same components, and making decisions from the various available options (Vinogradova, 2019)

Combinatorial thinking is a skill that can be honed and developed through practice and experience. Therefore, mastery of enumeration rules, such as the rule of product and permutation, has a significant influence on combinatorial thinking (Usry et al., 2016). By understanding and mastering the rules of multiplication and permutation, students can improve their combinatorial thinking abilities and thus be more confident in facing various mathematical problems and real-world situations that involve the combination and arrangement of elements (Matitaputty et al., 2022).

Learning enumeration rule concepts, including permutations, should not be limited to a mechanistic approach that only involves memorizing formulas and rules (Barnes, 2005). This approach tends to make learning less meaningful for students, so they have difficulty solving problems in the context of different situations (Liu & Schunn, 2017). To achieve a more profound understanding, a more holistic and contextual learning approach is recommended. Educators need to introduce mathematical concepts in a way that is relevant and connected to everyday life (Vinner, 2011). Apart from that, interactivity in learning also plays an important role (Voigt, 2013). Students can be invited to participate in activities that encourage students to discover, understand, and apply the concept of permutation (Antonides & Battista, 2022a). With a more contextual and interactive approach, students are expected to be able to discover mathematical concepts for themselves, develop deeper understanding, develop skills in solving mathematical problems, and create learning experiences that are more meaningful and relevant for them (Mumcu, 2018).

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A contextual learning approach can be optimized by integrating mathematical concept rediscovery activities through relevant problem contexts. Involving students in exploration and solving real problems can improve their understanding of mathematical concepts (Nunokawa, 2005), including the concepts of enumeration and permutation rules. By providing interesting and contextual challenges, students have the opportunity to identify mathematical patterns and relationships themselves (Clarke & Roche, 2018). For example, they can solve permutation problems by designing scenarios that involve the arrangement of objects or people in everyday life situations. This rediscovery process not only increases their understanding but also motivates learning because students can see the direct relevance between mathematical concepts and the real world (Hajian, 2019).

In addition, involving group discussions or presentations of student findings can enrich the learning experience (Nkhoma et al., 2017). Interaction with classmates can help students gain new insights and see problems from different points of view (Hernandez-Martinez & Vos, 2018). It also encourages collaboration and critical thinking skills. By combining a contextual approach and rediscovering concepts through relevant problems, mathematics learning can become more dynamic and interesting and build more robust understanding in students.

The context used in designing mathematical concept rediscovery activities must be genuinely relevant to students' daily lives or easy for them to imagine (Clements et al., 2019). By relating math concepts to situations or problems that are familiar to students, they can see direct applications of what they learn in their daily lives. For example, when teaching permutations, an educator can design activities that involve real situations, such as arranging chairs in a room (Lewis & Carroll, 2016), dividing tasks in a team (Younas, 2018), or even making travel plans to visit several places (Gionis et al., 2014). In this way, mathematical concepts no longer feel like separate theories but as valuable tools in everyday problem-solving.

This research aims to provide an in-depth description of the activities used by researchers in teaching permutations. Thus, the results of this research can provide valuable insight for mathematics educators and researchers in designing more effective permutation learning strategies. It is also hoped that the findings from this study will encourage teachers and researchers to try and develop various activities that are relevant to the mathematics learning process in general.

METHOD

This research is a systematic literature review with a scoping literature review type. A scoping literature review was chosen with the aim of identifying research results, especially regarding permutation learning alternatives, as well as trying to formulate new alternatives as a future research agenda (Tricco et al., 2016). In addition, scoping literature reviews are more suitable for

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reviewing limited research results so that the scope of the research can be expanded to extract as much relevant literature as possible (Arksey & O'Malley, 2005), while the quality of the literature is not a noteworthy concern (Peters et al., 2015). However, this literature review uses a general framework consisting of 8 stages, namely formulating the research problem; developing and validating the review protocol; searching the literature; screening for inclusion; assessing quality; data extraction; analyzing and synthesizing data; and reporting the findings (Xiao & Watson, 2019).

Formulating the Research Problem

This research aims to identify alternative student activities in learning mathematics on permutation material so that the research question asked in this research is what activities can be carried out by teachers or researchers in teaching permutations? Apart from that, this research was also conducted to answer the question of what context can be used by teachers or researchers in teaching permutations?

Developing and Validating the Review Protocol

To answer the questions that have been formulated, this article only collects the results of research on learning permutation material with certain activities or learning trajectories. Learning that is merely mechanical or deductive is not collected.

Searching the Literature

The author collected literature for this research from relevant sources by utilizing the Scopus database and applying keyword combinations using Boolean operations. Keyword combinations used include (“learning” OR “learning activity” OR “learning trajectory” OR “discover” OR “enumerate” OR “student”) AND (“combinatoric” OR “permutation”).

This literature search process was carried out using the Publish or Perish application, which is known as an effective tool for extracting data from various academic sources. Using this application, authors can detail and manage search results efficiently, ensuring engagement with relevant and quality sources. Using this method allowed the author to collect 190 articles from the Scopus database that met the specified search criteria. This process reflects the care and rigorous methodology in collecting literature to ensure its relevance and quality.

Screening for Inclusion

The literature collected is not limited by the year of publication. By collecting literature without limiting the year of publication, authors can obtain more literature. After that, the author selected the collected literature by eliminating 3 duplicate articles and 176 articles not included in the field

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of mathematics education, leaving 11 articles remaining. Elimination of duplicate articles aims to ensure that each reference included in this research is a unique source and does not overlap (Okoli & Schabram, 2010).

Assessing Quality

Of the remaining 11 articles, the author only found 2 articles that explicitly included permutation learning activities using relevant contexts. Realizing the importance of gaining more comprehensive insights, the authors decided to proceed with the snowballing method to ensure the inclusion of other literature that might be relevant and enrich the analysis. By snowballing, authors can identify and access references from selected articles, looking for related literature that may not have been detected in the initial stages of the search (Hiebl, 2023). As a result, the snowballing process succeeded in producing 4 additional articles that were relevant to the permutation learning context. Thus, the total number of articles reviewed became 6 articles after combining the findings from snowballing with previously selected literature. The series of article search processes is presented in Figure 1.

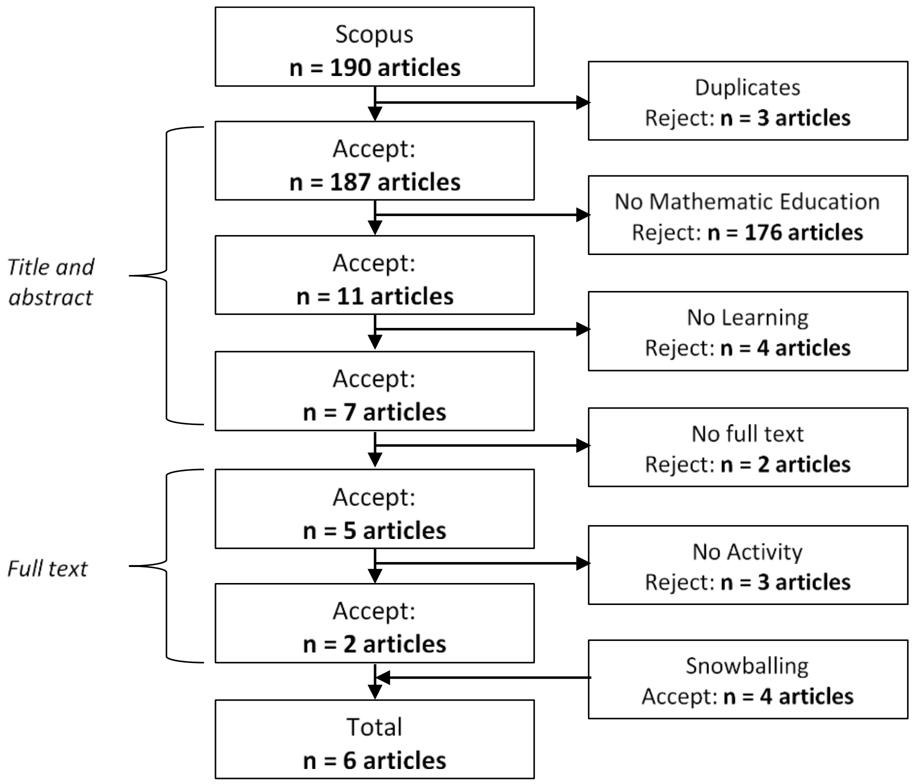

Figure 1. Flow Chart Illustrating the Systematic Search Process, Resulting in 6 Articles

Extracting Data

In this stage, the author abstracts various essential elements from the selected articles. This abstraction process involves identifying and extracting critical information related to the context

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used, the activities organized, the rationale for using the context, the subjects used, and the research methods applied in each article. By abstracting these elements, authors can develop a comprehensive understanding of the approach and findings of each article (Tricco et al., 2016).

Analyzing and Synthesizing Data

From the results of data extraction, the researcher conducted an in-depth discussion about the context used, the activities carried out, and the rationale. The context used means an informal situation that is understood by students regarding permutation material, while the activities carried out refer to the learning steps involved in permutation learning. Meanwhile, the rationale for using context refers to the argument or explanation of why the context was chosen to support permutation learning.

Reporting the Findings

The research report is aimed at providing a research agenda on the development and use of meaningful and relevant learning activities for teaching permutations.

RESULTS AND DISCUSSION

Published research articles are spread across various journals. These studies use various contexts, activities, subjects and research methods. However, in general, there are several rationales for the use of context and activities. A summary of several studies is presented in Table 1.

Table 1 Overview of Articles in Which Physical Activities Were Used for Teaching Permutations

Articles	Context	Activity	Rationale	Subjects Involved	Research Design
(Antonides, & Battista, 2022b)	Towers Replica	Constructin towers using multi-coloured linking cubes	Physical objects	two preservice middle school teachers	one-on-one constructivist teaching experiments
(Chotikarn, et al., 2021)	Cube Net	Painting a cube in different colors on each side	Concrete media	29 students of Khon Kaen University Demonstration School	case study
	Beads Bracelets	Arranging different beads to make bracelets	Concrete media	29 students of Khon Kaen University Demonstration School	case study
(Kimani, et al., 2013)	Presentation Order	Using Unifix cubes to model the order of presentations by 3 students	Physical model	sixth-grade students	(not mentioned)
(van Bommel & Palmér, 2021)	Bear Dolls	Arranging the position of different colors of bears	Virtual objects	5 classes with a total of 61 children	educational design research

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Articles	Context	Activity	Rationale	Subjects Involved	Research Design
(Palmér & van Bommel, 2022)	Drawing Bears	Drawing bears, creating pictographic and iconic representations	Physical activity	more than 40 Swedish preschool classes	educational design research
(Szydlik, 2000)	Photographs	Arranging four people in a straight line for a photograph	Physical demonstration	(not mentioned)	(not mentioned)

What Context is Used in Permutation Learning?

Several studies explore how to teach permutation material by utilizing concrete and virtual objects as learning contexts. Antonides and Battista (2022b) examine permutations through the application of the concept in the context of tower replicas. They looked for ways to make permutation learning more concrete and interact with the real world through vertical building structures. While Chotikarn et al. (2021) researched permutations using cube nets as a basic concept. By presenting permutation material through cube objects, they attempt to give students a deeper understanding of the possible relationships and arrangements.

Other research focuses on presentation layout in the context of permutations. They may have utilized concrete or virtual objects to visualize how various elements can be rearranged or positioned, enriching students' understanding of permutations Kimani et al. (2013). van Bommel and Palmér (2021) also investigated teaching permutations by using teddy bears as a learning medium to introduce the concept of permutations creatively and interestingly for students. Meanwhile, Palmér and van Bommel (2022) taught permutations by depicting a concrete object, namely a bear.

In addition, Szydlik (2000) has used concrete objects, namely photography, to demonstrate the principles of permutation in a visual context. Overall, these studies create innovative approaches to teaching permutation material by utilizing various concrete and virtual objects as contexts for teaching permutation material. Each study shows an attempt to make permutation learning more real and understandable by utilizing concrete elements in a creative context.

All studies explored how to teach permutations by integrating objects, such as replica towers, cube nets, teddy bears, and pictures of bears. Involving objects related to everyday life or imaginatively makes mathematics learning more exciting and more accessible for students to understand (Atallah, 2003). It is hoped that this creative approach can increase students' interest and understanding of permutation material. By using concrete or virtual objects, these studies create a more interactive and authentic learning experience. This approach can help students to be more actively involved in understanding and applying the concept of permutations. Through

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similarities, these studies imply that the use of concrete and virtual objects can be an effective strategy for teaching permuted material innovatively and engagingly.

What Activities Are Used in Permutation Learning?

Researchers have designed various creative activities in their research to support understanding of the concepts they research. Antonides and Battista (2022b) propose the activity of building tower replicas using small, colorful cubes that can be connected, giving an actual dimension to the concept of permutation. In contrast, Chotikarn et al. (2021) focus on the activity of coloring cubes with different colors on each side and arranging different beads to make bracelets, giving an artistic touch to permutation learning. Kimani et al. (2013) used Unifix cubes to model presentation sequences by three students, integrating permutations in a structured context.

Van Bommel and Palmér (2021) involve students in positioning colorful bears, while Palmér and van Bommel (2022) present bear drawing activities, creating pictorial and iconic representations. Finally, Szydlik (2000) conducted an activity of arranging four people in a straight line for a photograph, providing a visual dimension to the understanding of permutations. Overall, these activities create an interactive and creative learning experience, facilitating an understanding of the concept of permutation through a practical and artistic approach.

In general, these studies focus on how to teach permutation material by involving the activity of arranging concrete and virtual objects. All of these activities create concrete or visual situations that help students understand the concept of permutations. By involving students in these activities, these studies effectively create a more exciting and applicable learning experience in order to help students discover and understand the concept of permutations.

Learning to rediscover the concept of permutations through the activity of arranging concrete or virtual objects has many advantages. First, the activity of arranging concrete or virtual objects provides an opportunity for students to visualize and experience the concept of permutations directly (Olympiou et al., 2013). By involving the visual sense, students can understand the concept in more depth. Second, physical involvement in arranging objects allows students to relate mathematical concepts to real experiences (Carbonneau et al., 2013). This activity can improve memory and retention of information because learning becomes more meaningful and linked to concrete experiences.

Third, learning activities involve collaboration between students and communication in explaining their processes. This activity not only enriches the social experience but also allows students to learn from each other and support each other in understanding mathematical concepts (Kalina & Powell, 2009). Thus, learning to rediscover the concept of permutation through the

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activity of arranging concrete or virtual objects not only increases understanding of the concept but also enriches students' overall learning experience.

Variations in Subjects and Research Designs Used

From the various studies that have been conducted, the researchers involved unique subjects and research designs to help students understand the concept of permutations while exploring how students understand the concept of permutations through a series of activities. Antonides and Battista (2022b) chose to involve two middle school-level intern teachers in a one-on-one constructivist teaching experiment. In this research, the focus is to understand how constructivist teaching can support students' understanding of the concept of permutations. Chotikarn et al. (2021), on the other hand, chose a case study approach involving 29 students from Khon Kaen University Demonstration School. In this context, the research aims to analyze the effectiveness of permutation teaching on a larger group of students and assess how the concept can be integrated into the school curriculum. At the same time, Kimani et al. (2013) took a more specific approach by involving sixth-grade students, although further details about the research design were not stated. These researches indicate variation in the educational level of subjects involved in permutation research.

Van Bommel and Palmér (2021) used an educational design research approach and involved five classes with a total of 61 children. Meanwhile, Palmér and van Bommel (2022) expanded the scope of their research to involve more than 40 preschool classes in Sweden, adopting a similar educational research design approach. These two studies create a solid foundation for understanding how the concept of permutation can be taught and applied at various stages of education. However, Szydlik (2000) does not provide details about the subjects involved or the research design used. Nevertheless, this research collection provides rich and varied insights into how the concept of permutations can be taught and understood by different groups of students through different research approaches.

Thus, these studies reflect variations in involving subjects from different educational levels and employing research designs appropriate to their research objectives, such as constructivist teaching experiments, case studies, and educational research designs. These variations reflect research efforts to explore the concept of permutation holistically and comprehensively. By involving subjects from different levels of education, this research provides more prosperous and more general insight into how the concept of permutation can be taught and understood by different groups of students.

Each study may have specific objectives that guide the selection of subjects and research approach. For example, research that focuses more on permutation teaching at the secondary school

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level could select subjects from among preservice teachers to observe the impact of direct teaching on the learning process. Some researchers may choose specific research methods that are considered more appropriate for their goals and research questions. For example, a constructivist teaching experiment involving two preservice teachers (Antonides & Battista, 2022b) may require a different approach compared to a university-level case study (Chotikarn et al., 2021). The availability of research subjects can also influence the selection of the subject's educational level. For example, research involving more than 40 preschool classes in Sweden (Palmér & van Bommel, 2022) may have been driven by the availability of participants at that level.

CONCLUSION

Several studies related to learning permutation materials emphasize the use of physical activities involving concrete or virtual objects, such as tower replicas, beaded bracelets, presentation sequences, teddy bears, and photography. Learning activities are designed with the aim that students can solve problems by rearranging objects, discover and understand the concept of permutation, and create a more direct and meaningful learning experience. This research shows that the use of concrete or virtual objects that can be rearranged is an effective approach to teaching the concept of permutation. However, it is important to consider that the choice of context and activities must be adjusted to the student's level of knowledge and experience so that learning becomes more relevant and can be better understood. Thus, this approach makes a positive contribution to understanding the concept of permutation through an interactive and creative learning experience.

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