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Assessing the Efficacy of Hands-On Games for Expanding Understanding of Probability Concepts in Mathematics Education

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Abstract

Gamification methodologies have gained profound and swift significance within the educational context over the past few years. In a subject like mathematics, conceptual understanding of the topics is decisive owing to their wide applicability to multiple areas. Therefore, hands-on approaches are extensively employed in teaching different mathematical notions so as to enhance and fortify students' problem-solving and computational skills. The current study also intends to explore one such area and assess the efficacy of incorporating hands-on games (using manipulatives) for expanding students' understanding of probability concepts in mathematics. A quantitative survey design was used, and the sample population was chosen from 6 schools (3 for males and 3 for females). The final sample was composed of 90 students who participated and filled out the questionnaires. For data analysis, SPSS statistics 23 was used, and frequency analysis was done to spot the most recurrent responses. The outcomes revealed that the theme of boosting student engagement/giving better learning outcomes got the highest positive responses (92.22%), followed by enhancement of strategic mathematical thinking (91.11%) and the rest. It was also noted that the majority of the respondents agreed with the given statements and showed high levels of satisfaction with learning through hands-on approaches. Hence, it can be concluded that owing to the greater appreciation for using gaming-integrated methods of teaching, the students can yield improved outcomes and develop skills that consequently result in a better attitude and more enthusiasm for mathematics.

Keywords: *Conceptual Understanding, Hands-On Approach, Mathematics.*

Introduction

Teachers and students alike recognize the significance of mathematics education. Math, on the other hand, is more than just memorizing a set of algorithms (Ernest, 2010). The study of mathematics can be applied to many different areas. As a result, the teaching of conceptual understanding of mathematics ought to be emphasized appropriately in mathematics education (De Lange, 1996). An efficient method for teaching a conceptual understanding of mathematics is to employ a hands-on approach.

Due to the fact that arithmetic and logical reasoning are the foundations of science and technology, mathematics has been regarded as a fundamental subject (Smith, 2002). As a result, educational authorities place an emphasis on students' ability to solve problems and use computational skills (Mabbott & Bisanz, 2008). Teacher-led instruction, which still dominates mathematics classrooms in most Middle East nations, is probably to blame for the existence of a significant number of students with low academic achievement

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(GebreYohannes et al., 2016). It is important to remember that students in every classroom have different abilities, which explains why they achieve different things (Felder & Brent, 2005). Sadly, in teacher-led instruction, every student must learn from the teacher in the same way and at the same pace (Hwang et al., 2012). Students who perform poorly are compelled, without sufficient time, to absorb information passively. According to Barr and Tagg (1995), there must be more opportunities for low-achieving students to learn mathematics at their own pace. One-to-one technology was suggested by researchers (Chan et al., 2006; Galligan et al., 2010; Harris & Al-Bataineh, 2015), which provides each student with a device that enables them to learn seamlessly at school and at home.

The nature of mathematics, comprehension, and pedagogical approaches are examined in the theories that support the teaching of conceptual understanding of mathematics (Radford, 2008). These theories are based on the presumption that understanding mathematics is essential: that a student is less valuable if they only have procedural knowledge of mathematics than if they have a conceptual understanding of mathematics (Sriraman & English, 2010). Additionally, a student's education is more comprehensive when they have a conceptual understanding of mathematics. Based on these theories and presumptions, teaching conceptual understanding through hands-on activities is recommended.

Literature Review

Investigating Mathematics

Before looking at how mathematics is taught, it's essential to know what mathematics is in and of itself. According to Bartell et al. (2013), the following provides a visual representation of mathematics for classroom instruction:

"Mathematics isn't a palm tree, with a single long straight trunk covered with scratchy formulas. It's a banyan tree, with many interconnected trunks and branches—a banyan tree that has grown to the size of a forest, inviting us to climb and explore."

There must be a shared understanding of what it means to teach mathematics before looking at teaching conceptual understanding through hands-on learning (Korn, 2014). As previously stated, mathematics is a significant component of the curriculum for students. In "Relational Understanding and Instrumental Understanding," Skemp (1976) explained that;

"There are two effectively different subjects taught under the same name, Mathematics."

Skemp (1976) believed that various educators were simply teaching mathematics to students of varying quality. The definition of understanding—in the context of mathematics—is the foundation of teaching mathematics.

Mathematical Meaning and Understanding

Mathematical understanding is founded on mathematical meaning. Baruah and Gogoi (2022) say that there are many levels of meaning in mathematics. When there is a purpose or application for mathematics, it has meaning in a child's mind. The understanding was defined by Skemp (1976), who distinguished between "instrumental understanding" and "relational understanding" and explained the implications of each. It is important to note that understanding mathematics requires reasoning (Ball and Bass, 2003). In conclusion, the importance of understanding mathematics in education cannot be overstated.

Conceptual Understanding of Mathematics

A student needs to be able to understand concepts in order to be successful in mathematics. According to Jones (2011), the concepts of relational understanding and

instrumental understanding are similar to concepts of procedural knowledge, which focuses on how to perform arithmetic (conceptual knowledge). A student has conceptual knowledge in mathematics when he or she "understands the meaning and underlying principles of mathematical concepts" (Frederick, M. F., & Kirsch, 2011).

Conceptual interconnected knowledge (Jones, 2011). According to Moyer and Milewicz (2002), "conceptual knowledge requires the learner to be active in thinking about relationships and making connections, as well as making adjustments to accommodate the new learning with previous mental structures." According to Jones (2011), procedural knowledge should be taught first, followed by conceptual knowledge, when teaching procedural knowledge. However, conceptual and procedural knowledge of mathematics is frequently linked strongly. It is essential to cultivate a student's conceptual understanding when teaching mathematics in a meaningful way.

There are a number of good reasons to teach an understanding of a concept, especially in mathematics, despite the opposing arguments. On the one hand, just learning the algorithm is a more straightforward, quicker way to get to the right answer and pays off immediately. Students who have a relational understanding of mathematics have an easier time remembering material and applying a principle in an unfamiliar setting (Skemp, 1976). Additionally, there are numerous advantages to specifically teaching conceptual understanding of mathematics. In Principles and Standards for School Mathematics, Carpenter et al. (2000) argued that in the twenty-first century, students need to have a conceptual understanding of mathematics in order to thrive and solve problems as adults in the changing environment. Additionally, students who have a conceptual understanding of mathematics are more likely to be independent and self-assured, as evidenced by their willingness to approach difficult problems openly and in new ways.

Theoretical/Conceptual Approach

The investigated theories serve to set the stage for various methods of teaching mathematics. The methods demonstrate how to achieve the objectives and interpret the theories. In particular, the following strategies will be investigated:

1. Constructivism

The term "a theory of learning that asserts that humans construct their own knowledge" refers to constructivism. In the classroom, teachers would instead facilitate knowledge rather than transmit it. Additionally, "a child, when faced with problematic arithmetic situations, can develop their own solution methods" is a presumption of constructivism (Jones, 2011). Thus, constructivism is an appropriate educational philosophy

2. Hands-on

Hands-on learning is a natural outgrowth of the constructivist philosophy of education in general and in mathematics education in particular. In fact, constructivism relies heavily on a hands-on approach. "Learning by doing, or learning in which students are actively engaged in an activity or process," is the definition of hands-on learning.

Curriculum and activities that involve students touching, moving, and experimenting with materials are referred to as hands-on. Children consider the properties and relationships of the objects they manipulate. Children form "theories" about how things work over time, which can be tested by further manipulation. As children work with hands-on materials, their work can be evaluated and recorded, and this data can be analyzed to determine the child's progress in learning (Korn, 2014).

Students benefit from interactive learning opportunities that involve all five senses through hands-on instruction. Additionally, students are engaged in these hands-on activities, which require them to personally interact with the material rather than simply

listen to a lecture. Students are frequently required to solve problems during hands-on learning. Utilizing manipulatives is one strategy for engaging students in hands-on learning. Students' conceptual understanding can be significantly improved with the use of manipulatives. Hands-on learning is a suitable pedagogical strategy for meeting the requirement of teaching mathematical concepts (Mosimege, 2018).

Purpose of the Study

In employing a hands-on approach to teach conceptual understanding, one useful tool is using manipulatives. The present study intends to assess the efficacy of incorporating hands-on games for the purpose of expanding students' understanding of probability concepts in mathematics. It is anticipated that the study will show that students who have traditionally been below average on mathematics scores will develop a better attitude and more enthusiasm for mathematics after having used manipulatives to explore some areas of mathematics. Manipulatives aid students in noting and communicating with others their understanding of mathematical thoughts and also in making mental processes and thoughts more refined.

Research Questions

Considering the purpose of the current study, it has been intended to answer the following research questions:

Q1. Are there any significant impacts of using hands-on games for expanding students' understanding of mathematical concepts?

Q2. Are there any differences in students' understanding of mathematical concepts among those who are taught with a traditional learning approach and those with a hands-on approach?

Significance of the Study

Conceptual understanding of mathematics lies at the core of mathematics, and using a hands-on approach to develop students' conceptual understanding naturally flows out of current educational trends and research. Based on the responses from the students surveyed, results will show that hands-on activities are a necessary part of bridging general mathematics, and also, students' confidence has been increased.

Methodology

Research Design

The main objective of this study was to emphasize the efficacy of hands-on games for increasing the understanding of probability concepts in mathematics education. To approach this aim, a quantitative analysis based on the survey forms has been executed.

Sample Population

The sample population of the study involved 6 schools in Jeddah city. Three schools were for females and three for males. In order to take a fair sample of students that would equally represent both genders, 15 students from each school were recruited. Thus, the final sample was composed of 90 students who willingly participated in this study. The sample population consisted of forty-five male and forty-five female students, which were assigned to these classes based on their previous year's performance in mathematics class.

Data Collection

A questionnaire was used for the purpose of collecting the required data. Through the questionnaire, students in eighth-grade math classes were asked to answer the survey designed to provide information about manipulatives and class performance. They were

asked to indicate whether or not hands-on activities were helpful in their current math classes. Surveys were distributed among eighth-grade students that were later compiled and evaluated. In the event that activities previously planned could not be completed, some activities were eliminated, and some activities were to be rescheduled. Results of the survey were used to indicate the importance of manipulatives as related to their curriculum. Reports were generated based on the number of survey responses received and student grades for all students enrolled in the eighth grade at the sampled schools.

Designing of Questionnaire

To attain the purpose of the study, a survey-based questionnaire was designed. The questionnaire consists of two consecutive sections. The first section was based on gathering the demographic details of the respective participants. The other part comprised questions related to the hands-on approach to an understanding of the probability concepts in mathematics education. These statements were designed after conducting a hefty literature search to identify the most cited features of incorporating hands-on gaming approaches in the educational context and their potential impacts on learning. The questionnaire was composed of 30 statements that were divided across six underlying themes (encouragement for self-exploration, development of familiarity with the number systems and concepts, enhancement of strategic mathematical thinking, development of computational fluency, inducing self-paced learning and boosting student engagement, and giving better learning outcomes). The questionnaire also included statements comparing the difference between teaching via traditional methods and the hands-on game approach so as to identify if the students have actually perceived any differences in these two approaches to better validate the significance of gaming-incorporated teaching methodology. The questionnaire was designed on a 3-point Likert scale strategy where the respondents were given three options, i.e., "Agree," "Neutral", and "Disagree", to choose from.

In order to validate the questionnaire, the final questionnaire was sent to three senior educational professionals who had experience in the field to allow them to check the items for suitability and indicate any underlying deficiency that they perceived in the given form. After the seniors made minor changes in the content, the questionnaires were then processed for the research.

Data Analysis

The data has been examined by means of IBM SPSS Statistics 23. Descriptive statistics have been utilized for this research. In order to identify the most cited features of hands-on games in relation to their significance for developing an understanding of mathematical concepts, frequency analysis was done as it allows for spotting out the most recurrent and heavily relied patterns.

Ethical Considerations

From an ethical point of view, all potential ethical considerations were made before initiating the research. Each of the participants willingly partook in the survey and gave consent to publish the data except for the identity revelation owing to confidential issues. However, the consensus was given to make the demographic details accessible as they were part of the questionnaire and research design. Students were also not pre-shared any information as to what types of questions or mathematical problems they would be given in order to record their timely and unbiased responses.

Results and Discussion

Analysis of Survey Questionnaire

The questionnaire started with questions related to the demographic details to get familiar with sample characteristics. The demographic information of every individual participating in the study is provided in Table 1.

Table 1. Demographic characteristics of Respondents

Characteristics	No. of Respondents (n=40)	Average (%)
Gender		
Male	45	50
Female	45	50
Age		
12 to 13 years	17	18.88
13 to 14 years	64	71.11
<15 years	9	10
School		
Khalid Bin Al Waleed School	15	16.66
Salalah Al Sharqiya School	15	16.66
Al Shula School	15	16.66
Aisha Bint Abi Bakr School	15	16.66
Source of Wisdom School	15	16.66
Al-Morouj School	15	16.66

As per the data seen in Table 1, it was observed that owing to equal sampling from boys' and girls' schools, the gendered representation of the study population was equal (50% males and 50% females). In terms of age, the most cited age group was 13 to 14 years (71.11%). Lastly, the representation of students from each school was also identical (16.66% in each group).

In the second section, the researcher designed 30 statements in relation to the most cited features of hands-on games for increasing the understanding of probability concepts in mathematics education, and a 3-point Likert rating was given to opt for the appropriate response. Table 2 recapitulates the overall outcomes received for each of the 6 study themes on the basis of which the results will be designed.

Table 2. Results of frequency Analysis for Questionnaires' Responses

Themes	Frequency of Responses (%)			Std.
	Agree	Neutral	Disagree	Dev.
Encouragement for self-exploration	84.44	7.77	7.77	.58155
Development of familiarity with the number systems and concepts	87.77	10	2.22	.41220
Enhancement of strategic mathematical thinking	91.11	5.55	3.33	.41941
Development of computational fluency	62.22	26.66	11.11	.69094
Induce self-paced learning	87.77	2.22	10	.61403
Boost student engagement/give better learning outcomes	92.22	3.33	4.44	.44540

It was observed that the majority of the respondents agreed with the given statements and were well aware of the information about the hands-on approach in mathematics education.

Based on survey results, it was investigated that students expressed their appreciation for manipulative activities and the opportunity to better understand some probability concepts in mathematics education.

While the hands-on activity provided an example of teaching conceptual understanding that educators can actually implement in the classroom, various studies offered various insights into the teaching of conceptual understanding via a hands-on approach. Gurbuz et al. (2010) provided an inside look at teaching conceptual understanding of mathematics in an actual classroom setting by examining the use of a hands-on approach in students' probability learning.

The value of manipulatives is demonstrated by the Ozgun-Koca and Edwards (2011) study comparing the use of physical and virtual manipulatives. Despite the fact that "some people believe that manipulatives are just for younger children or for slow learners," as was mentioned earlier, manipulatives are frequently at the center of a hands-on approach. As previously stated, hands-on learning is defined as "learning by doing, or learning in which students are actively engaged in an activity or process" (Tawil, 2018). Additionally, virtual manipulatives may still be included in hands-on activities.

Not only can virtual manipulatives be used in hands-on activities, but they also fit in well with the push to use technology in the classroom. Even though this movement and push are growing at an ever-increasing rate, it's possible that some schools lack the technological tools needed to incorporate virtual manipulatives into the mathematics classroom. In addition, it is necessary to determine the accessibility of virtual manipulatives and whether or not there are a large number of qualities that can be used by educators. The current educational trend of increasing the use of technology in the classroom is reflected in the discussion of physical and virtual manipulatives. A hands-on approach to teaching conceptual understanding of mathematics is bolstered by the use of manipulatives (Darling-Hammond et al., 2015).

Furthermore, Bartell et al. (2013) study utilized pre-service teachers. Despite the push for teaching conceptual understanding, current educators require the necessary training and physical reference tools in order to accurately assess students' levels of conceptual understanding. Bartell et al. (2013) provided a valuable perspective on the issue of evaluating a student's conceptual understanding, which may serve as a foundation for additional research, such as on educators' training in conceptual understanding evaluation.

Hands-on activities allow students to interact with mathematics concepts at a deeper level, not just provide superficial knowledge of how to find the correct answer. Instead, they foster students' conceptual understanding of topics like diagonals in a polygon (Johnson et al., 2016). As a result, educators can improve students' conceptual understanding through hands-on activities.

The research and objectives for employing a hands-on approach to teaching mathematical, conceptual understanding must be implemented in the typical classroom. Additionally, further research on this particular intersection of educational approach and goal is required in order to support the claim that hands-on learning enhances conceptual comprehension. However, even the existing research that recommends using a hands-on approach to teach conceptual understanding of mathematics has a number of repercussions for teachers and students alike.

Teachers and students alike benefit from a hands-on approach to teaching conceptual understanding of mathematics because it encourages differentiated instruction. Hands-on strategies can give you a lot of options for grouping people together, which goes well with differentiation. According to Marks, J. L., Purdy, C. R., Kinney, L. B., and Hiatt (2018), educators will need to tailor activities to students' instructional levels because students learn "as individuals" or at varying rates. However, students also learn in a community setting (Askew, 2012). Hands-on activities are a viable option for

encouraging the development of conceptual understanding in a classroom that embraces differentiated instruction due to the various interconnections between them.

Conclusion

An effective method for teaching mathematical concepts is through hands-on instruction. Using a hands-on approach to develop students' conceptual understanding naturally follows current educational trends and research. A conceptual understanding of mathematics is at the heart of the subject. Additionally, hands-on activities and conceptual understanding foster a more comprehensive education. A hands-on approach to teaching conceptual understanding of mathematics is extremely beneficial.

Even though the results are not displayed in the grades of the students, manipulative use is an important part of teaching probability concepts. When students enjoy math, it is much easier to keep them interested, and this research has found that manipulatives have done just that for these students. The research and data that were gathered were in line with the expected outcomes. Even though the number of students in the sample was sufficient, a larger number of students would be more accurate in capturing the effects of manipulative use.

The research will not change anything, regardless of how strongly or abundantly it demonstrates the value of a particular approach or a particular aspect of mathematics that should be taught. Interconnecting that they also see the value to educators, parents, students, schools, community leaders, school administrators, educational organizations, and others: specifically, that they place a high value on employing a hands-on approach to teaching mathematical concepts.

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