# The integration of hands-on games in the learning of probability: A case of Grade 12 learners in the Oshakati Cluster of Oshana Region

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***Abstract***
*This study sought to investigate the effects of integrating hands-on games in the learning and their effects on the performance of Grade 12 Mathematics extended learners in probability in Oshakati cluster schools, in Oshana region. The study tested the following hypothesis at the significant level α = 0.05:* ***$H_o$:*** *There is no significant difference in the Grade 12 Mathematics learners' mean scores on probability between those who were taught using hands-on games and those taught using the traditional method only ($\mu_1 = \mu_2$).* ***$H_1$****: There is a significant difference in Grade 12 Mathematics learners' mean scores on probability between those who were taught using hands-on games and those who were taught using the traditional method only ($\mu_1 \neq \mu_2$). A quantitative paradigm, quasi-experimental design was used to gather data from participants. A pre-test-post-test control design was used to assess the effects of hands-on games on the learning and performance of Grade 12 Mathematics extended learners in probability. A sample of 57 Mathematics extended learners was drawn and randomly assigned to the experimental or control group. Each group was pre-tested using the same test after which 8 days of intervention of teaching probability using games was administered to the groups. The control group was taught probability content through the integration of hands-on games while the control was taught the same content using the traditional approach. The same test with changed numbering on the test items was administered to both groups. The findings revealed that, the experimental group performed better in the post-test compared to the pre-test. The t-test performed at the 0.05 significant level indicated a significant difference in the performance of the experimental group. Results provided the evidence that, the integration of hands-on games in teaching and learning of probability facilitated learning and enhanced learners' performance. The study therefore recommends that hands-on games should be used in teaching mathematics as a means of facilitating learning and enhancing learners' performance in probability.*

**Keywords:** *probability, hands-on games, extended level mathematics, grade 12 learners, Oshana region*

## Background of the problem

Mathematics is one of the compulsory subjects in the Namibian school curriculum since 2012 (Ministry of Education, 2010a). In addition, mathematics is also one of the requirements for admission to science and science related fields at higher education institutions in Namibia (University of Namibia, 2013). Furthermore, the Ministry of Education's (2013, 2014) reports on the Grade 12 examination indicate that learners studying mathematics on extended level find it difficult to answer questions on probability in Paper 4. If unaddressed, this situation could compromise the performance of learners on the national examinations, hence the need for an intervention to address the teaching of probability using different approaches. This study was therefore carried out to determine the effects of integrating hands-on games in the learning of probability and their effects on the performance of Grade 12 mathematics extended level learners in the Oshana region on probability.

Therefore, this study was carried out on the assumption that giving learners opportunities to use hands-on games allows them to advance and explore their knowledge on probability and might improve their performance on probability. Various researchers (Dollard, 2011; Xiayan, 2015; Nicolson, 2005) argue that teaching probability to students is difficult due to its abstractness as well as teachers' insufficient theoretical knowledge and inexperience with probability. They emphasise that learners need proper instructions such as hands-on games that actively engage them if the learners are to learn the content; Use of hands-on games might enable then to build on their existing knowledge and foster understanding of probability.

**Research hypotheses**
In this study, the following hypothesises were tested at the significant level of $\alpha = 0.05$:

- $\mathbf{H_o}$: There is no significant difference in the Grade 12 mathematics learners' mean scores on probability between those taught using hands-on games and those taught using the traditional method ($\mu_1 = \mu_2$).
- $\mathbf{H_1}$: There is a significant difference in the Grade 12 mathematics learners' mean scores on probability between those taught using hands-on games and those taught using the traditional method ($\mu_1 \neq \mu_2$).

***Theoretical framework and literature review***
*Theoretical framework of the study*
According to Taylor (2011), probability is the branch of mathematics that describes randomness. The conflict between probability theory and learners' view of the world is due to learners' limited contact with randomness. Thus, learners need to be provided with instructions that promote the study of chance to provide them with experience on the random behaviour in the mathematics classroom.

Ojose (2008) notes that, learners' cognitive development in mathematics instruction is based on the application of Piaget's theory, and depends on hands-on experience and multiple ways of representing a mathematical solution. All these imply that hands-on game activities are of great importance in providing learners an avenue to make abstract ideas concrete, allowing learners to get their hands on mathematical ideas and concepts as useful tools for solving problems as indicated in Figure 1.

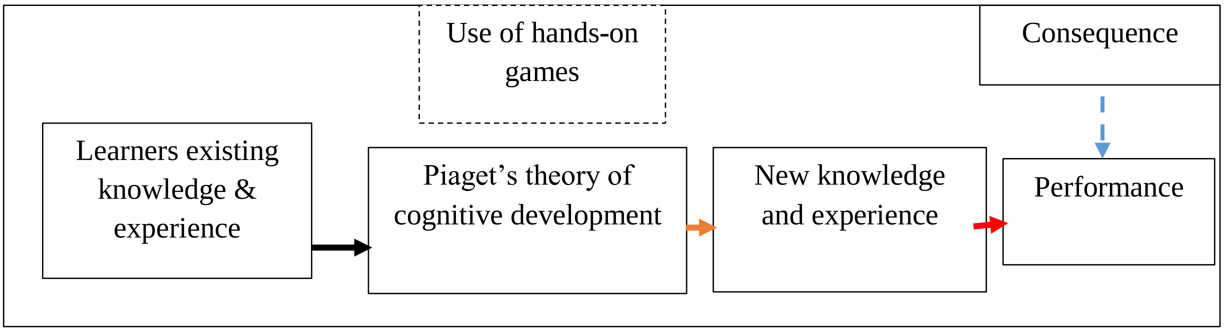



**Figure 1: Diagrammatic presentation of the theoretical framework of the study**
(Adopted from Ojose's application of Piaget's cognitive development theory in mathematics learning).

Furthermore, Ojose (2008) points out that, learners find it difficult to automatically link probability to its activities. It is therefore, important for teachers to provide various mathematical presentations that will help learners make connections and facilitate learning of probability, taking into consideration the uniqueness of learners. Knowledge of Piaget's stages can help teachers understand the cognitive development of learners as they plan cognitive stage-appropriate activities to keep learners active and fully engaged in learning. .

***Teaching and learning of probability***
Grinstead and Snell (2012) indicate that, probability theory began in the seventeenth century with French mathematicians based on games of chance. Probability continued to influence early research until it was a well-established branch of mathematics that has applications in every area of scholarly activity in daily experience. Dollard (2011) explains that high school probability where teachers are likely to use random chance devices like dice and spinners is described in terms of equally likely outcomes and defines probability as the ratio of desired outcome to total possibility outcome.

Nicolson (2005) and Taylor (2011) indicate that, the development of learners' mathematical reasoning through the study of probability is essential in daily life because probability offers the fundamental theory for the development of statistics and problem solving in science and mathematics related fields. Probability presents real-life mathematics and connects main areas of mathematics such as counting, statistics and geometry. Probability is also used in medicine such as in predicting the risk of new infections or new medical treatments (Grinstead, & Snell, 2012).

The understanding of probability is essential in understanding politics, weather reports, genetics, sports and insurance policies. Thus probability enhances learners' problem solving skills (Taylor, 2011). Taylor further emphasises that learning probability can contribute to learners' conceptual knowledge of working with data and chance which can help learners in making correct decisions as they go through life issues such as fairness, questioning and searching for relationships when solving real-world problems.

Studies by Nicolson (2005) and Taylor (2011) emphasise the importance of teaching and learning probability. They note that probability theory plays a major role in modern society both in the daily lives of the public at large and in the professionals' activities within society. Thus, probability theory calls upon many mathematical ideas and skills developed in other school subjects such as sets, mapping, numbers, counting, graphs and enables learners to work in different branches of mathematics, which are relevant to current life situations.

***History of manipulative or use of hands-on games***

Ruzic and O'Connell (2001) indicate that hands-on games as part of manipulative objects began in ancient times when people of different civilizations used physical objects to help them solve every day mathematical problems. South West Asians used counting boards (wooden or clay covered in thin layer of sand). In the late 1800's, mathematicians invented manipulative-manoeuvrable objects that were specifically designed to teach mathematical concepts. Around 1837, the German educator Friedrich Froebel designed and introduced the educational play material "Froebel Gifts or Frobelgaben" which included geometric building blocks. Manipulatives then became more popular and were considered essential in the teaching of mathematics; several educational researchers have shown the significant difference the manipulatives make once integrated in teaching of mathematical concepts in comparison to other methods since the 1900's (Ruzic & O'Connell, 2001).

***Use of hands-on games and activities in probability***

Taylor (2011) indicates that many high school learners find it difficult to understand probability. He also points out that inadequate pre-requisite mathematical skills and abstract reasoning as well as lack of instruction that enables learners to be actively engaged in learning contribute to difficulties in learning probability. He further notes that instruction that encourages learners to discover and construct their own understanding of probability concepts may result in understanding of probability.

According to Xiayan (2011), teachers need to use multimedia and provide rich real life situations and games to facilitate learners' understanding of probability. Xiayan notes that lack of learners' interest to learn probability is due to lack of understanding the historical background and practical application of probability. Hence introducing situations such as games in the mathematics classroom can arouse learners' interest in learning and thus deepen their understanding of probability.

Ojose (2008), Nicolson (2005) and Budimir (2016) emphasise that implementing random phenomenon, such as games of chance like tossing coins, rolling dice and drawing candy from a bag and spinning spinners., are good ways of acquiring understanding of mathematical principles in probability learning. This approach is important for learners to gain basic knowledge, develop logical thinking, and acquire skills of recognising, describing and solving real life problems by probability methods.

Several studies (Nicolson, 2005; Dunn, 2005) explain that dice are used to determine and understand the probability of simple events, assuming equally likely outcomes. Learners are allowed to roll dice several times, record the number of times each number (1 to 6) comes up and discuss the results. Tossing coins involves throwing a coin in the air; the coin will turn a number of times in the air and land randomly “heads or tails”. This is done to seek and find explanation and interpretation of equally likely outcomes. Drawing candy from the candy bag is used to demonstrate the chances of pulling out candy depending on number of their particular type in the bag compared to other candy types. These activities help learners to understand the probability of independent and dependent events.

Nicolson (2005) and Dunn (2005) further describe spinning spinners as a common tool for exploring and understanding classic probability. For each spinner, learners use a circle divided into six equal parts and a paper clip twirled around the point of a pencil. They repeatedly spin and shade the area where it stops. These enable learners to predict the next possible outcome. These hands-on games can be used to create random, equally likely outcomes for experiments in probability, thus help learners to understand probability and form the connection between mathematics and real life situations. These hands-on games are used to create random and equally likely outcomes for experiments in probability.

Xiayan (2011) indicates that underachievement in mathematics is an ongoing worldwide concern. He points out that learners begin elementary mathematics lacking motivation which continues into secondary school which yields poor performance. Part of the reason may be due to poor attitudes toward mathematics and poor teaching strategies in mathematics. Therefore, to remedy poor motivation and increase learner achievement, teachers need to be aware of and implement best teaching practices by incorporating games in mathematics instruction.

***The benefits of using manipulatives including hands-on games***

Naresh (2014) indicates that there are difficulties related to topics such as randomness, sample space, conditional and independent probability. Naresh further emphasised that mathematics curricula denote a set of ideas that learners are taught and expected to learn. Therefore, teachers need to develop a strong, coherent, and intuitive pedagogical knowledge as well as simulation tools that will enable them to teach successfully and make learners to understand probability concepts.

Nareh’s study used games such as the Game of Plinko (a game of chance) and the Game of Pachisi (originated in India and involves two dice and four players) that showed a statistically significant difference in the performance of the learners as compared to the ones that were taught with the traditional method. Hence, emphasising the importance of tools or game activities set in everyday context or cultural context as they help learners to establish connections between probability content, context, and culture. This creates an in depth exploration of probability concepts, allowing learners to discover the importance of studying mathematics and its application which enhances learners’ interest, learning and improve learners’ performance.

Boggan, Harper, & Whitmire (2010) indicate that even though the National Council of Teachers of Mathematics (NCTM) has encouraged schools to use manipulatives in mathematical instruction, teachers are reluctant to plan, construct and use them in their lessons. This is despite the fact that most valuable learning occurs when learners actively construct their own mathematical understanding which is often accomplished through the use of manipulatives. It is therefore important for learners to engage with a variety of material to manipulate and have opportunity to sort, classify, weigh, stack and explore if they are to construct mathematical knowledge.

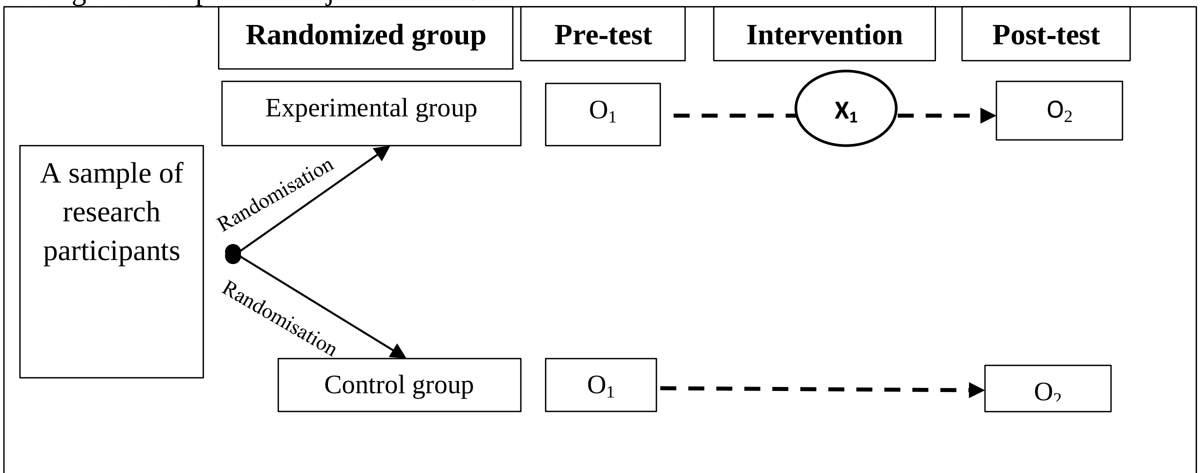
Research from both learning and classroom studies indicate that if manipulatives such as hands-on games are carefully designed, selected, planned and fit the mathematical ability of the learners and used at the appropriate level the manipulatives can help to teach mathematics and can positively affect learners’ learning at all levels of ability (Arnold, 2015; Ruzic & O’Connell, 2001). This implies that mathematics teachers need to carefully plan their lessons and use hands-on games appropriately in order to enhance their learners’ knowledge and understanding of mathematical concepts.

Using various hands-on games provides an exciting classroom environment, promotes learner positive attitudes toward mathematics learning and greatly reduce anxiety (Ruzic & O’Connell, 2001). Arnold (2015) and Ruzic &

O'Connell (2001) emphasise that apart from enhancing mathematical learning, learners are also given a chance to reflect on their past experience. Further, emphasise that hands-on games can be successfully used in introducing mathematics lessons, practice or remediate mathematical concepts in mathematics instruction. This will only be possible if the games are appropriate for the learners and have been chosen to meet specific goals in order to increase learners' mathematical thinking and understanding instead of learners simply moving the manipulative objects around.

**Methodology**

This study used a quasi-experimental design to collect the data from the learners. A sample of 57 extended mathematics learners was drawn and randomly assigned to the experimental and the control groups. The experimental group consisted of 27 learners and the control group had 30 learners. Figure 2 presents a diagrammatical presentation of the sample and sampling procedure used.




*In this case: $O_1$ represents the pre-test, $X_1$ represents the intervention (integration of hands-on games) and $O_2$ represents the post-test.*

**Figure 2 A diagrammatical presentation of the sample and sampling procedure**

A pre-test was administered to the two groups before the intervention. During the four weekends (8 days) of intervention on probability the experimental group were taught probability using the traditional method integrated with the hands-on games. The traditional method only was used to teach the control group probability. After the intervention, the two groups were post-tested using the same test with altered numbering of the test items. The t-test was used to find out whether significant differences existed between experimental and control groups, at $\alpha = 0.05$ (5%) level.

**Findings**

The results reported herein were an attempt to find out whether the experimental group's performance was better than that of the control group that was taught probability using the tradition approach only. Accordingly, a number of hypotheses were tested as indicated in this section.

***T-test for the pre-test for the experimental and control group***

To find whether the two groups were the same before the intervention, a pre-test was administered to both groups. The following hypothesis was tested:

- **$H_0$:** There is no significant difference in the pre-test mean scores of the control and the experimental groups.
- **$H_1$**: There is a significant difference in the pre-test mean scores of the control and the experimental groups.

The results of the t-test for the above hypothesis are given in Table 1.

**Table 1: Experimental and control groups' pre-test results**

| Statistical value | Experimental group (N = 27) | Control group (N = 30) |
|---|---|---|
| Mean | 7.85 | 8.20 |
| Standard Deviation (SD) | 1.99 | 2.04 |
| Variance | 4.0 | 4.2 |
| $t_{critical}$ ($\alpha = 0.05$, df = 55) | 2.021 | |
| t-calculated | -0.6532 | |

The t-test on the probability pre-test scores for independent groups with degrees of freedom (df) = 55, using the two tailed test, the critical t-test value ($t_{critical}$) at $\alpha = 0.05$ level of significance was 2.021. The $t_{calculated}$ absolute value $|-0.6532|$ is less than the $t_{critical} = 2.021$.

The pre-test mean score of the experimental group of 7.85 was close to 8.20 of the control group (see Table 1). Accordingly, the null hypothesis is accepted showing that the two groups were similar at the beginning of the intervention.

***T-test for the pre-test and post-test for the control group***

These tests attempted to test the hypothesis:

- **$H_o$:** There is no significant difference in the pre-test and post-test mean scores of the control group.
- **$H_1$**: There is a significant difference in the pre-test and post-test mean scores of the control group.

**Table 2: The control group's pre-test and post-test results (N = 30)**

| Control group | Pre-test | Post-test |
|---|---|---|
| Mean | 8.2 | 13.1 |
| Standard Deviation (SD) | 2.04 | 3.64 |
| Variance | 4.16 | 13.2 |
| t- calculated ($\alpha = 0.05$, f = 29) | 6.209 | |
| t- critical | 2.045 | |

Table 2 shows that at $\alpha = 0.05$ and degree of freedom (df) = 29, the t calculated = 6.209 and using the level of significance for two tailed test, the t-test value $t_{critical}$ is 2.045. The $t_{calculated}$ is greater than the $t_{critical}$ which shows that there is a significant difference between the control group's pre-test and post-test scores. The results seem to suggest that the control did improve from the instruction that they received during the period of the study.

***T-test for the pre-test and post-test for the experimental group***

The following hypothesis was tested in order to find out whether the experimental group's scores on the pre- and post-tests were different:

- **$H_o$:** There is no significant difference in the pre-test and post-test mean scores of the experimental group.
- **$H_1$**: There is a significant difference in the pre-test and post-test mean scores of the experimental group.

**Table 3: The experimental group's pre-test and post-test scores (N = 27)**

| Experimental group | Pre-test | Post-test |
|---|---|---|
| Mean | 7.85 | 17.1 |
| Standard Deviation (SD) | 1.99 | 4.62 |
| Variance | 4.0 | 21.53 |
| t-critical ($\alpha = 0.05$, df) = 26) | 2.056 | |
| t-calculated | 10.036 | |

With the degree of freedom (df) = 26 and $\alpha$ = 0.05 the critical value of the $t_{critical}$ is 2.056. Table 3 shows the t-test result of 10.036. The $t_{calculated}$ is greater than $t_{critical}$, therefore, the $H_o$ is rejected and conclude that there is a significant difference in the experimental group's pre-test and post-test mean scores.

***T-test for the experimental and control groups' post-test scores(N = 57)***

This section tests the following hypothesis:

- **$H_o$:** There is no significant difference in the post-test mean scores of the control and the experimental group.
- **$H_1$**: There is a significant difference in the post-test mean scores of the control and the experimental group.

**Table 4: Comparison of the post-test results of the experimental and control groups**

| Statistical value | Experimental group N = 27) | Control group (N = 30) |
|---|---|---|
| Mean | 17.1 | 13.1 |
| Standard Deviation (SD) | 4.62 | 3.64 |
| Variance | 21.53 | 13.2 |
| t-critical ($\alpha$ = 0.05 with df = 55) | 2.021 | |
| t-calculated | 3.745 | |

Table 4 shows that the calculated t-test value was 3.745 which is greater that $t_{critical}$ = 2.021 at $\alpha$ = 0.05 with df = 55. Therefore, the $H_o$ is rejected and the researcher concluded that there is a significant difference in the post-test mean scores of the experimental and the control groups on the probability topic. It can be seen from the results that the experimental group benefited from the hands-on games and performed relatively better than the control group.

**Conclusion**

Based on these findings of the study we conclude that the integration of hands-on games in teaching probability in mathematics improved the performance of the extended level mathematics learners' performance in the Oshakati Cluster schools, Oshana Educational region. These findings provide strong evidence of the effectiveness of the use of hands-on games (or manipulatives) in improving learners' learning and performance. The use of hands-on games in probability has the potential to provide teachers with an effective method of facilitating teaching and learning of mathematics concepts.

**Recommendations**

Based on the findings, the following recommendations are made:

1. Mathematics teachers should integrate hands-on games in their lessons on probability in order to improve their learners' understanding of mathematics concepts and performance. The traditional approaches alone are not enough to enhance learners' grasp of the mathematics content especially probability.
2. Schools should purchase a variety of manipulatives such as marbles, dice and play cards for effective teaching of probability that teachers and learners can use in mathematics lessons to enhance learners understanding of probability and allow learners to link mathematics context in real life situations.
3. Mathematics teachers should also use different teaching approaches in teaching different mathematics topics. Teachers should be creative to develop attractive and educative hands-on games based on specific topic sand competencies to facilitate learning and understanding of mathematical concepts.
4. Teachers' workshops on the integration of hands-on games in teaching mathematics should also be encouraged. Workshops can activate teachers' interests in the use of hands-on games, and enable teachers to incorporate hands-on games comfortably in their lessons, which will in turn foster learning and enhance learners' performance.

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