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Mathematical modeling approach in teaching Statistics and Probability

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Abstract

This study determined the effect of mathematical modeling approach in teaching Statistics and Probability in selected Grade 11 Senior High School-Academic Track students of Vinisitahan National High School, School Year 2024 – 2025. The topics covered in this study are random variables and probability distribution, normal probability distribution, sampling and sampling distributions of sample mean. The researcher employed experimental research wherein pre and post-test design was applied, using two (2) groups, the control and the experimental groups. In the control group, they received the traditional method of instruction, while in the experimental group, the researcher employed a mathematical modeling approach in the delivery of the lessons.

Test results were utilized as basis in providing judgement to the effect of the interventions provided. To test the hypothesis that there is a significant difference on the performance of the control and experimental groups in the pre and post-tests, a t-test for independent samples was utilized.

The main tool used by the researcher to gather the data is a teacher-made pre and post-test. After the experimentation process, developed lesson plans applying the mathematical modeling approach to address the least mastered competencies are presented. Results showed that the performance of the control and experimental groups vary significantly in the post-test using mathematical modeling approach.

Keywords: Mathematical Modeling Approach; Statistics and Probability; Experimental Research; Pre-test; Post-test; Lesson Plans

1. Introduction

Mathematical modeling is a process in which real-life situations and relations are expressed using Mathematics. In this method, the abstract idea of Mathematics became more realistic to the students by linking mathematical concepts to real-life scenarios. In educational settings, mathematical modeling has been considered a way of improving students' ability to solve problems in real life. In this approach, students are guided by linking mathematical concepts to reality and dealing with how to solve problems. It is also the process of using a model to solve any given math problem.

Moreover, mathematical modeling approach is one of the effective strategies in enhancing critical thinking and problem-solving skills in improving students' academic performance in Mathematics. Through this approach, students are able to utilize different models during the teaching and learning process and allow students to visualize the problems and understand mathematical contexts more deeply. Solving problems in each lesson is made relatable to the students with the use of models.

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1.1. Statement of the Problem

This study determined the effects of mathematical modeling approach in teaching Statistics and Probability. Specifically, it answered the following sub-problems:

- What is the performance of the control and experimental groups in the pre-test along:
  - illustrating a random variable (discrete and continuous);
  - distinguishing between a discrete and a continuous random variable;
  - finding the possible values of a random variable;
  - illustrating a probability distribution for a discrete random variable and its properties;
  - computing probabilities corresponding to a given random variable;
  - illustrating the mean and variance of a discrete random variable;
  - calculating the mean and the variance of a discrete random variable;
  - interpreting the mean and the variance of a discrete random variable;
  - solving problems involving mean and variance of probability distributions;
  - illustrating a normal random variable and its characteristics;
  - identifying regions under the normal curve corresponding to different standard normal values;
  - converting a normal random variable to a standard normal variable and vice versa;
  - computing probabilities and percentiles using the standard normal table;
  - illustrating random sampling;
  - distinguishing between parameter and statistic;
  - identifying sampling distributions of statistics (sample mean);
  - finding the mean and variance of the sampling distribution of the sample mean; and
  - defining the sampling distribution of the sample mean for normal population when the variance is:(a) known; (b) unknown?
- What is the performance of the control and experimental groups in the post-test in the above-mentioned skills?
- Is there a significant difference in the performance of the control and experimental groups in the pre-test and post-test?
- What are the least mastered skills of the experimental group in the post-test?
- What enhanced lesson plans applying mathematical modeling approach may be proposed to address the least mastered skills?

1.2. Assumption of the Study

This study was based on the following assumptions:

- The performance level of Grade 11 Academic Track students of Vinisitahan National High School is the same in the pre-test.
- The performance level of the control and experimental groups varies in the post-test using the mathematical modeling approach.
- There are identified least mastered skills after the conduct of the post-test of the experimental group.
- Enhanced lesson plans applying mathematical modeling approach can be developed to address the least mastered skills in statistics and probability.

1.2.1. Hypothesis

There is no significant difference in the performance of the control and experimental groups in the pre-test and post-test.

1.3. Scope and Delimitation

This study focused on the K to 12 Most Essential Learning Competencies from week one (1) to week six (6) in Statistics and Probability. The other topics in Statistics and Probability from week seven (7) in K to 12 Most Essential Learning Competencies onwards and other subjects were not included in the study because they are not part of the focused skills in the present study. To determine the effects, this research used the pre-test and post-test as an instrument to measure the performance of the experimental and control groups.

2. Materials and Methods

2.1. Research Method

This study applied an experimental method wherein the experimental and control groups were utilized to determine the effectiveness of mathematical modeling approach in enhancing acquisition of knowledge of senior high school students academic track at Vinisitahan National High School for the school year 2024-2025 to improve their academic performance in Statistics and Probability.

2.2. Subjects of the Study

The subjects of the study were selected Grade 11 Senior High School – Academic Track (General Academic Strand and Humanities and Social Sciences) of Vinisitahan National High School, School Year 2024-2025. The subjects are divided into two groups. These groups were the control group and experimental group. Each of these groups has thirty-three (33) subjects with a total of sixty-six (66) Grade 11 students. Grades of students in the first semester were utilized to determine their mathematical ability. Each group was composed of an equal number of students- "above – average" students are those with grades from 93 to 100, "average" students attained the grades from 84-92, and "below – average" students achieved the grades from 75-83.

2.3. Research Instrument

The researcher used pre-test and post-test as the research instrument of this study in gathering data from the participants, which seeks to measure the performance level of the students. A table of specifications was also prepared to identify the weight and proper placement of the items. The said test was composed of fifty (50) items, twenty-five (25) items that involve random variables and probability distributions, ten (10) items for normal probability distribution, and fifteen (15) items on sampling and sampling distributions of the sample mean. This study also used lesson plans, which served as a guide for teaching both groups. Lessons were incorporated with various models as teaching materials in integrating the mathematical modeling approach.

2.4. Validation of the Research Instrument

The research instruments have undergone two phases of validation. These are the content validation and the dry run. The validation of the research instruments and lesson plans was conducted after the proposal had been approved. The researcher conducted careful preparations prior to the experimentation method to ensure the quality and accuracy of the research instruments and lesson plans. The validators were three (3) experienced educators—two (2) master teachers and one (1) department head of Mathematics.

3. Results and Discussion

3.1. The Performance of the Control and Experimental Groups in the Pre-Test

This study focused on the eighteen (18) competencies from week 1 to week 6 stated in the Most Essential Learning Competencies in Statistics and Probability. These competencies are the skills needed to enhance every learner, particularly in the senior high school curriculum. However, many students found it difficult because of the underlying factors, including gaps in foundational knowledge of the topics, academic pressure because of the cognitive overload, and the abstract nature of the concepts.

Table 1 The Performance of the Control Group in the Pre-Test

Skills	No. of Items	Total Score	Mean	PL (%)	Description
Illustrating a random variable	3	26	0.79	26	Low Mastery
Distinguishing between a discrete and a continuous random variable	2	32	0.97	49	Low Mastery
Finding possible values of a random variable	3	49	1.48	49	Low Mastery
Illustrating a probability distribution for a discrete random variable and its properties	2	13	0.39	20	No Mastery

Computing probabilities corresponding to a given random variable	2	23	0.70	35	Low Mastery
Illustrating the mean and variance of a discrete random variable	2	23	0.70	35	Low Mastery
Calculating the mean and the variance of a discrete random variable	4	39	1.18	30	Low Mastery
Interpreting the mean and the variance of a discrete random variable	3	34	1.03	34	Low Mastery
Solving problems involving mean and variance of probability distributions	4	35	1.06	27	Low Mastery
Illustrating a normal random variable and its characteristics	2	17	0.52	26	Low Mastery
Identifying regions under the normal curve corresponding to different standard normal values	3	34	1.03	34	Low Mastery
Converting a normal random variable to a standard normal variable and vice versa	2	15	0.45	23	No Mastery
Computing probabilities and percentiles using the standard normal table	3	25	0.76	25	Low Mastery
Illustrating random sampling	2	14	0.42	21	No Mastery
Distinguishing between parameter and statistic	3	33	1.00	33	Low Mastery
Identifying sampling distributions of statistics (sample mean)	3	20	0.61	20	No Mastery
Finding the mean and variance of the sampling distribution of the sample mean.	4	34	1.03	26	Low Mastery
Defining the sampling distribution of the sample mean for normal population when the variance is: (a) known; (b) unknown	3	17	0.52	17	No Mastery
OVERALL	**50**	**483**	**14.64**	**29.27**	**Low Mastery**

Table 1 implies that the results for the control group provide a baseline understanding of the group's initial knowledge and skills, having the low and no mastery category level of knowledge of the skills in Statistics and Probability. The result of the pre-test is proof that many of the students are still struggling with the above-mentioned skills. Also, it showed that before the actual implementation of the study, Grade 11 students in the control group had not enough understanding of the competencies in Statistics and Probability. Moreover, the researcher claimed, based on her teaching experience, that the students in Grade 11 always had low performance every school year in the pre-test in Statistics and Probability. In this result, it showed that students at Vinisitahan National High School really need major support in enhancing their problem-solving and critical thinking skills, particularly in Statistics and probability. Additionally, based on the data, the learners don't have strong foundational skills in the subject area.

According to Sinyosi, (2015)[1], in his study titled, he stated that one of the factors of low performance of senior high school students in Mathematics is that learners were poorly prepared in the lower grades for senior grades. In other words, learners lacked a proper foundation and background in mathematics. Learners were not well taught the basics of mathematics in previous grades. Hence, students will manifest low mastery or, worse, no mastery level of knowledge in Mathematics.

Obut et al., (2024)[2], stated that one of the challenges linked to students' struggles in learning Mathematics is ineffective teaching. Thus, students cannot understand mathematical concepts, as their conceptual understanding, problem-solving abilities, and overall engagement are hampered by rapid teaching speed. Based on the result of the pre-test and the claims of the different researchers, there is really a need for the teachers to develop strategies to address the needs of their students.

Table 2 The Performance of the Experimental Group in the Pre-Test

Skills	No. of Items	Total Score	Mean	PL (%)	Description
Illustrating a random variable	3	26	0.79	26	Low Mastery
Distinguishing between a discrete and a continuous random variable	2	26	0.79	40	Low Mastery
Finding possible values of a random variable	3	38	1.15	38	Low Mastery
Illustrating a probability distribution for a discrete random variable and its properties	2	17	0.52	26	Low Mastery
Computing probabilities corresponding to a given random variable	2	14	0.42	21	No Mastery
Illustrating the mean and variance of a discrete random variable	2	25	0.76	38	Low Mastery
Calculating the mean and the variance of a discrete random variable	4	54	1.64	41	Low Mastery
Interpreting the mean and the variance of a discrete random variable	3	31	0.94	31	Low Mastery
Solving problems involving mean and variance of probability distributions	4	33	1.00	25	Low Mastery
Illustrating a normal random variable and its characteristics	2	13	0.39	20	No Mastery
Identifying regions under the normal curve corresponding to different standard normal values	3	38	1.15	38	Low Mastery
Converting a normal random variable to a standard normal variable and vice versa	2	6	0.18	9	No Mastery
Computing probabilities and percentiles using the standard normal table	3	24	0.73	24	Low Mastery
Illustrating random sampling	2	12	0.36	18	No Mastery
Distinguishing between parameter and statistic	3	20	0.61	20	No Mastery
Identifying sampling distributions of statistics (sample mean)	3	25	0.76	25	Low Mastery
Finding the mean and variance of the sampling distribution of the sample mean.	4	45	1.36	34	Low Mastery
Defining the sampling distribution of the sample mean for normal population when the variance is: (a) known; (b) unknown	3	25	0.76	25	Low Mastery
OVERALL	**50**	**472**	**14.30**	**28.61**	**Low Mastery**

Table 2 means that Grade 11 students in the experimental group also manifested a low performance level in Statistics and Probability. This showed that another group of Grade 11 students is facing difficulties in Mathematics, which also need to be addressed accordingly. This group of students also does not have a strong foundation of the expected skills they were supposed to learn. Low performance in Mathematics requires an immediate response from educators to meet the needs of the students. Even the past year's group of Grade 11 students also obtained low performance in Statistics and Probability. There are so many factors that cause the students of Vinisitahan National High School to have acquired low results. That's why the present study aimed to determine if the mathematical modeling approach is an effective strategy in delivering the lesson in Statistics and Probability.

In the study of Mji & Makgato, (2006)[3], some of the factors of low performance of the Grade 11 students in mathematics are a) teaching strategies and b) content knowledge and understanding. It was stated that educators saw things differently, wherein they were sometimes focused only on how they would deliver their lesson without identifying the needs of their students. In addition, teachers need to integrate varieties of teaching approaches to meet the needs of the students.

According to Santos et al., (2015)[4] they claimed that mathematical modeling is more effective compared with the use of guided practice in teaching problem-solving topics in Mathematics; the use of mathematical modeling, compared with the use of guided practice, in teaching problem-solving is more effective in reducing the grade 9 high school students' math anxiety level specifically in terms of numerical anxiety, mathematics test anxiety, and its combination. They also stated that mathematical modeling activities move beyond traditional problem solving to encourage children to develop and explore significant, real-world mathematical ideas, making them see the relevance of mathematics in real-life contexts, thus allowing them to lessen their aversion to the said subject. In connection with this, the researcher is determined to employ a mathematical modeling approach in teaching Statistics and Probability.

3.2. The Performance of the Control and Experimental Groups in the Post-test

After the implementation, a post-test was administered to determine if there were improvements in the performance of the two groups using different approaches. The post-test was the same as the pre-test material.

Table 3 The Performance of the Control Group in the Post-Test

Skills	No. of Items	Total Score	Mean	PL (%)	Description
Illustrating a random variable	3	68	2.06	69	Near Mastery
Distinguishing between a discrete and a continuous random variable	2	44	1.33	67	Near Mastery
Finding possible values of a random variable	3	62	1.88	63	Near Mastery
Illustrating a probability distribution for a discrete random variable and its properties	2	46	1.39	70	Near Mastery
Computing probabilities corresponding to a given random variable	2	36	1.09	55	Near Mastery
Illustrating the mean and variance of a discrete random variable	2	41	1.24	62	Near Mastery
Calculating the mean and the variance of a discrete random variable	4	46	1.39	35	Low Mastery
Interpreting the mean and the variance of a discrete random variable	3	57	1.73	58	Near Mastery
Solving problems involving mean and variance of probability distributions	4	45	1.36	34	Low Mastery
Illustrating a normal random variable and its characteristics	2	42	1.27	64	Near Mastery
Identifying regions under the normal curve corresponding to different standard normal values	3	44	1.33	44	Low Mastery
converting a normal random variable to a standard normal variable and vice versa	2	36	1.09	55	Near Mastery
Computing probabilities and percentiles using the standard normal table	3	59	1.79	60	Near Mastery

Illustrating random sampling	2	49	1.48	74	Near Mastery
Distinguishing between parameter and statistic	3	46	1.39	46	Low Mastery
Identifying sampling distributions of statistics (sample mean)	3	55	1.67	56	Near Mastery
Finding the mean and variance of the sampling distribution of the sample mean.	4	71	2.15	54	Near Mastery
Defining the sampling distribution of the sample mean for normal population when the variance is: (a) known; (b) unknown	3	61	1.85	62	Near Mastery
OVERALL	**50**	**908**	**27.52**	**55.03**	**Near Mastery**

Table 3 implies that the use of traditional approach of teaching still positively impacted students' performance in teaching Mathematics, but then, there remains room for improvement in fostering deeper critical thinking and problem-solving skills. The researcher noted significant shifts in educational strategies over the years, using the traditional methods which no longer aligning the demand of producing 21st century learners. To truly enhance students' academic performance in Statistics and Probability, teachers must continually adapt their instructional strategies to incorporate varieties of models in the teaching and learning process to make more effective and engaging to the students.

In the study of Noreen, et.al., (2019)[5] it was stated that in traditional method of teaching the instructor is viewed as the pivot in the classroom, responsible for all actions and guaranteeing that all classroom message goes through him or the deductive strategy for instructing. Conventional technique is content focus. In this, instructor remains more dynamic, more subjective and less affective. Conventional techniques are concerned with the review of true information and mainly disregard higher levels of rational outcomes. Traditional teaching strategy works against the normal working of human mind. Students are involved in repetitive learning.

In the present study, the researcher also can attest that the use of traditional way of teaching has a great impact on the performance of her students in Mathematics. She observed that her students are just merely controlled of the process of paper and pen, chalkboard way of teaching. In result, students were just dependent on what the teacher discussed and shared with them. Also, limited engagement to think critically and creatively in solving problems which made math feel dull and irrelevant to practical applications in life.

Table 4 The Performance of the Experimental Group in the Post-Test

Skills	**No. of Items**	**Total Score**	**Mean**	**PL (%)**	**Description**
Illustrating a random variable	3	89	2.70	90	Near Full Mastery
Distinguishing between a discrete and a continuous random variable	2	58	1.76	88	Near Full Mastery
Finding possible values of a random variable	3	80	2.42	81	Mastery
Illustrating a probability distribution for a discrete random variable and its properties	2	58	1.76	88	Near Full Mastery
Computing probabilities corresponding to a given random variable	2	52	1.58	79	Mastery
Illustrating the mean and variance of a discrete random variable	2	58	1.76	88	Near Full Mastery
Calculating the mean and the variance of a discrete random variable	4	78	2.36	59	Near Mastery

Interpreting the mean and the variance of a discrete random variable	3	86	2.61	87	Near Full Mastery
Solving problems involving mean and variance of probability distributions	4	69	2.09	52	Near Mastery
Illustrating a normal random variable and its characteristics	2	51	1.55	78	Mastery
Identifying regions under the normal curve corresponding to different standard normal values	3	57	1.73	58	Near Mastery
Converting a normal random variable to a standard normal variable and vice versa	2	56	1.70	85	Near Full Mastery
Computing probabilities and percentiles using the standard normal table	3	75	2.27	76	Mastery
Illustrating random sampling	2	55	1.67	84	Near Full Mastery
Distinguishing between parameter and statistic	3	62	1.88	63	Near Mastery
Identifying sampling distributions of statistics (sample mean)	3	89	2.70	90	Near Full Mastery
Finding the mean and variance of the sampling distribution of the sample mean	4	97	2.94	74	Near Mastery
Defining the sampling distribution of the sample mean for normal population when the variance is: (a) known; (b) unknown	3	83	2.52	84	Near Full Mastery
OVERALL	**50**	**1253**	**37.97**	**75.94**	**Mastery**

Table 4 means that the results of the experimental group showed that there is a significant improvement in the students' performance using the mathematical modeling approach. Integrating mathematical modeling approach in teaching Statistics and Probability, the researcher attested that it is effective in enhancing her students' critical and problem-solving skills. Using models in each lesson made her lesson easy to understand by her students and they were able to find it relevant.

According to Egamov, et.al., (2024)[6] in their study entitled, Application of mathematical modeling in probability theory and mathematical statistics, they claimed that mathematical modeling is indispensable in this context because it not only enhances comprehension of complex concepts but also facilitates the application of these concepts in solving real-world problems. By integrating such models into educational frameworks, educators can simulate real-world scenarios that allow students to observe the practical implications of theoretical knowledge.

Mathematical modeling has been widely recognized as an effective teaching strategy that enhances students' understanding and application of mathematical concepts. According to Lesh and Doerr (2003)[7], mathematical modeling involves using mathematical structures and relationships to represent, analyze, and solve real-world problems. This approach promotes active learning, where students engage in problem-solving tasks that require critical thinking, logical reasoning, and communication skills.

Table 5 Test of Difference on the Performance of the Control and Experimental Groups in the Pre-Test

Group	**Mean**	**Mean Difference**	**Variance**	**t-value**		**Remark**
				Computed	Critical	
Control	14.64	0.34	11.68	0.38	±1.67	Not Significant
Experimental	14.30		15.22			

Table 5 shows the mean of the scores of the control group is 14.64 and 14.30 for the experimental group with 0.34 mean difference. The variance of the scores of the control group is 11.68 and for the experimental group is 15.22. Based on the data, the t-computed value is 0.38. This t-computed value is within the t-critical value of ±1.67 at 0.05 level of significance with 64 degrees of freedom. The null hypothesis is accepted that there is no significant difference on the performance of the control and experimental groups in the pre-test.

This implies that the control and experimental groups had comparable performance on the pre-test, validating that they possessed nearly equal levels of knowledge and skills prior to the intervention. This equivalence in performance is crucial for the experiment's validity, as it guarantees that any differences noted in the posttest can be linked to the teaching intervention used, rather than to prior differences in ability. Moreover, in this case the researcher could really determine the effectiveness of mathematical modeling approach as the intervention in teaching Statistics and Probability since the two groups has similar standing on their performance in the pre-test.

Table 6 Test of Difference on the Performance of the Control and Experimental Groups in the Post-Test

Group	**Mean**	**Mean Difference**	**Variance**	**t-value**		**Remark**
				Computed	Critical	
Control	27.52	-10.45	11.07	-14.11	±1.67	Significant
Experimental	37.97		7.03			

The calculated mean score of the control group is 27.52 while the experimental group has 37.97 providing -10.45 mean difference. The computed variance from the control group is 11.07 while the experimental group obtained 7.03. The t-computed value from the data is -14.11, this value is beyond the t-critical value of ±1.67 at 0.05 level of significance with 64 degrees of freedom, the null hypothesis is rejected. This means that there is a significant difference in the performance of the control and experimental group in the post-test.

This finding suggests that the mathematical modeling method used with the experimental group may be regarded as more effective in improving students' academic achievement in Statistics and Probability. It also indicates that implementing this approach more widely might result in better academic results for various student groups.

Table 7 Least Mastered Skill of the Experimental Group in the Post-test

Skill	**Mean**	**Performance Level (%)**	**Description**
Calculating the mean and the variance of a discrete random variable	2.36	59	Near Mastery
Solving problems involving mean and variance of probability distributions	2.09	52	Near Mastery
Identifying regions under the normal curve corresponding to different standard normal values	1.73	58	Near Mastery
Distinguishing between parameter and statistic	1.88	63	Near Mastery
Finding the mean and variance of the sampling distribution of the sample mean.	2.94	74	Near Mastery

Out of the eighteen (18) tested competencies five (5) of them obtained a performance level which is lower than the standard which is 75 percent. These competencies are as follows: *finding the mean and variance of the sampling distribution of the sample mean* with mean score of 2.94 and performance level of 74 percent; *distinguishing between parameter and statistic* with mean score of 1.88 and performance level of 63 percent; *calculating the mean and the variance of a discrete random variable* with mean score of 2.36 and performance level of 59 percent; *identifying regions under the normal curve corresponding to different standard normal values* with mean score of 1.73 and performance level of 58 percent; *solving problems involving mean and variance of probability distributions* with mean score of 2.09 and performance level of 52 percent. These performance levels are all interpreted as *near mastery*.

3.3. Enhanced Lesson Plans Applying Mathematical Modeling Approach to Address the Least Mastered Skills

Out of the eighteen (18) competencies, there were five (5) identified least mastered skills. With this, the researcher was ought to developed enhanced lesson plans integrating the mathematical modeling approach to address these least mastered skills. In the first and second least mastered competencies which are *calculating the mean and the variance of a discrete random variable and solving problems involving mean and variance of probability distributions*, respectively, the researcher developed two (2) lesson plans which she merged the two competencies; on the first lesson plan it focus on the process of calculating the mean of a discrete random variable and solving problems involving mean of probability distributions. The enhancement made by the researcher is that on the activity titled Meanwhile she added the steps in solving the mean and additional task as well as students are provided of the material which include the illustrated model prepared by the teacher. On the second developed lesson plan, the researcher focused on calculating the variance and solving problems involving variance of probability distribution. She prepared all the answer sheets in application and evaluation wherein the models are illustrated which will gauge the students in solving the variance since the topic is a step-by-step process.

On the third least mastered competency which is *identifying the regions under the normal curve corresponding to different standard normal values*, the writer developed lesson plan which main objective is to find the area of the region under the normal curve integrating the mathematical modeling approach. Its enhanced part compared to the lesson plan during the experimentation is that it only focuses on the skill in finding the area of the normal curve. She does not include the skill in computing probabilities and percentiles using the standard normal table.

Along *distinguishing between parameter and statistic* which is the fourth least mastered competency, the researcher developed lesson plan. She enhanced the lesson plan by integrating a model of Venn diagram illustrating the similarity and differences of parameter and statistic which will gauge the students in answering the given problems. Moreover, on the fifth least mastered competency which is *finding the mean and variance of the sampling distribution of the sample mean*, the researcher prepared the answer sheets for the application and evaluation illustrating the model which include the step-by-step process in solving the mean of the sampling distribution.

4. Conclusion

The following conclusions were drawn:

The performance level of the control group in the pre-test was considered low mastery along with illustrating a random variable; distinguishing between a discrete and a continuous random variable; finding possible values of a random variable; computing probabilities corresponding to a given random variable; illustrating the mean and variance of a discrete random variable; calculating the mean and the variance of a discrete random variable; interpreting the mean and the variance of a discrete random variable; solving problems involving mean and variance of probability distributions; illustrating a normal random variable and its characteristics; identifying regions under the normal curve corresponding to different standard normal values; computing probabilities and percentiles using the standard normal table; distinguishing between parameter and statistic; and finding the mean and variance of the sampling distribution of the sample mean.

However, the performance level of the group, along with illustrating a probability distribution for a discrete random variable and its properties; converting a normal random variable to a standard normal variable and vice versa; illustrating random sampling; identifying sampling distributions of statistics (sample mean); and defining the sampling distribution of the sample mean for normal population when the variance is (a) known and (b) unknown, was described as under no mastery.

The performance of the experimental group in the pre-test was classified as low mastery across various skills. These included: illustrating a random variable; distinguishing between a discrete and a continuous random variable; finding possible values of a random variable; illustrating a probability distribution for a discrete random variable and its properties; illustrating the mean and variance of a discrete random variable; calculating the mean and variance of a discrete random variable; interpreting the mean and variance of a discrete random variable; solving problems involving the mean and variance of probability distributions; identifying regions under the normal curve corresponding to different standard normal values; computing probabilities and percentiles using the standard normal table; identifying sampling distributions of statistics (sample mean); finding the mean and variance of the sampling distribution of the sample mean; and defining the sampling distribution of the sample mean for a normal population when the variance is (a) known and (b) unknown.

Meanwhile, the performance level of the group was considered under no mastery in computing probabilities corresponding to a given random variable. It also includes *illustrating a normal random variable and its characteristics, converting a normal random variable to a standard normal variable and vice versa, illustrating random sampling, and distinguishing between parameter and statistic.* These results indicate a significant need for targeted intervention and instructional support in these specific areas to improve conceptual understanding and skill proficiency.

In the post-test, the control group demonstrated near mastery in illustrating a random variable, distinguishing between discrete and continuous random variables, finding possible values, computing probabilities, interpreting mean and variance, converting normal random variables to standard normal variables, computing probabilities and percentiles, illustrating random sampling, identifying sampling distributions, finding mean and variance, and defining sampling distribution for normal population. *Low mastery* was observed in calculating mean and variance, solving probability distribution problems, and distinguishing between parameter and statistic.

The experimental group demonstrated mastery in illustrating a random variable and distinguishing between discrete and continuous random variables. It also includes interpreting mean and variance, converting normal to standard normal variables, and identifying sampling distributions. They also defined sampling distributions for normal population variance, which includes (a) known and (b) unknown, which was interpreted as *near full mastery*.

In addition, the performance level of the group along with finding possible values of a random variable; computing probabilities and percentiles using the standard normal table; computing probabilities corresponding to a given random variable; and illustrating a normal random variable and its characteristics was considered with *mastery*. Moreover, on calculating the mean and the variance of a discrete random variable; solving problems involving the mean and variance of probability distributions; identifying regions under the normal curve corresponding to different standard normal values; distinguishing between parameter and statistic; and finding the mean and variance of the sampling distribution of the sample mean, the performance level of the group was interpreted as *near mastery*.

There is no significant difference in the performance of the control and experimental groups along the different skills tested in the pre-test, but the results vary significantly in the post-test.

The least mastered skills of the experimental group in the post-test were calculating the mean and the variance of a discrete random variable; solving problems involving the mean and variance of probability distributions; identifying regions under the normal curve corresponding to different standard normal values; distinguishing between parameter and statistic; and finding the mean and variance of the sampling distribution of the sample mean. The performance along these skills was described as near mastery.

The researcher developed lesson plans applying the mathematical modeling approach to address the least mastered skills.

Compliance with ethical standards

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I declare that I have no conflicts of interest related to this research. I have no personal or financial relationships that could influence my work.

Statement of ethical approval

The present study does not contain any studies performed on animals/humans subject by any the author.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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