DIGITAL SIMULATION: ENHANCING PERFORMANCE IN PROBABILITY THROUGH DYNAMIC VISUAL REPRESENTATION OF CONCEPTS

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ABSTRACT: *This study assessed the performance of Grade 10 students at Tantangan National High School using digital simulations to represent probability concepts visually. By integrating real-life scenarios, the researchers aimed to enhance students' understanding of uncertainty and likelihood. A mixed-methods approach was employed, combining descriptive questionnaires with pretest and post-test assessments aligned with the Philippine Department of Education standards. The results showed a 19.54% improvement in formative assessment scores for students who used digital simulations. Additionally, significant differences in post-test and gain scores were found between the control and experimental groups, demonstrating the positive impact of digital simulations. The study concludes that these tools can improve student performance and recommends their strategic use to optimize learning outcomes in probability concepts.*

Keywords: *Digital simulation, dynamic visual representation, mixed-methods*

1. INTRODUCTION

Traditional methods of teaching probability often rely on textbook examples and calculations, leading to a lack of understanding among students. As noted by Koparan and Rodriguez-Alveal [8], this issue remains unresolved. Digital simulations and dynamic visual representations are promising solutions to this problem. Simulation-based learning has been shown to enhance students' probability understanding and problem-solving abilities, as demonstrated by Koparan [6]. Numerous studies have demonstrated the benefits of digital simulation for various learning outcomes. A meta-analysis by Brito et al. [2] found that individuals who underwent simulation training exhibited greater self-efficacy and procedural knowledge than those in a control group. Digital simulations, notably in probability, are vital for hands-on learning, connecting theory to practical applications and promoting engagement and critical thinking. Department Of Science and Technology – Philippine Council for Industry, Energy, and Emerging Technology and Development (DOST-PCIEERD) and the Department of Education (DepEd) collaborated on a project to implement K in 12 programs that integrated digital technology. The Digital Simulations for Grades 7–10 Mathematics project, led by de las Peñas et al. [4], developed an application that allows students to explore probabilistic experiments and practice concepts related to uncertainty, likelihood, and experimental probability. The project aimed to design software that facilitates the construction and exploration of mental representations of concepts in mathematics. Pilot studies have demonstrated its potential to improve performance, facilitate conceptual development, and increase learner engagement. Simulation-based learning has been shown to enhance cognitive skills across various educational levels, as observed in probability simulators[7]. The study sought to fill this gap by investigating the efficacy of digital simulations in improving students' understanding of probability instruction to achieve optimal learning outcomes.

1.2. FRAMEWORK

The significance of developing conceptual models that connect theoretical mathematical ideas with practical applications is highlighted by the various models and modelling perspectives. This involves learning in which students purposefully construct, comprehend, modify, and apply models to various situations [1]. This perspective is grounded in the studies of psychologists and philosophers, such as Vygotsky, Piaget, Dienes, and American pragmatists Mead, Peirce, and Dewey. Model Eliciting Activities (MEAs) are used to prompt students to create conceptual models to solve practical problems [11]. Additionally, it highlights the efficiency and effectivity of practical models that connect abstract mathematical concepts to real-world situations, particularly in probability concepts, where problem scenarios, physical enactments, digital representations, and randomization and sampling processes must be linked.

2. MATERIAL AND METHODS

To grasp the objectives, the research in question was initiated with a quasi-experimental design [13]

Experimental Group	O_1	X	O_2

Control Group	O_1		O_2

Where O_1: pretest of the control and experimental groups

O_2: posttest of the control and experimental groups

X: is the tool/treatment (Digital Simulation)

during its initial phase and subsequently transitioning to incorporate a sequential explanatory design in its second phase. The dependent variable was assessed by manipulating the instrument to evaluate the effects of independent variables. Subsequently, the sequential explanatory design involved surveying to explore the experimental group's experiences, perceptions, and contextual factors that may be related to the observed effects of the tool [3].

The study was conducted at Tantangan National High School, and the research involved 60 students, 30 for the experimental and and 30 for the control group, sampled randomly from two random sections to represent each group. Surveys assessed their experiences and challenges with the tool, while pretest and post-test measured performance improvement in probability using digital simulation. Pretests and posttests were administered to measure improvements in participants' academic performance before and after using the tool. The assessment instrument in this study consisted of 15 items, each weighted at 4 points per item, designed to evaluate students' understanding of probability concepts. The pretest and posttest, each comprising fifteen (15) items, were administered as formative assessments to measure academic proficiency in probability, based on specific competencies outlined by the Department of Education (DepEd). To provide finer granularity in the assessment and allow for more precise differentiation of student performance, each item was weighted accordingly, resulting in a total possible score of 60 points per assessment. These assessments were conducted before and after the instructional intervention to evaluate the impact of the digital simulation on students' learning outcomes. The test was aligned with Bloom's Taxonomy, with items distributed across various cognitive levels and objectives tailored to the topic. The test underwent pilot testing and item analysis to ensure its ability to discriminate effectively between participants and to align with student abilities. The reliability of the pretest and posttest was evaluated using the Kuder-Richardson Formula 20 (KR-20), which yielded a coefficient of 0.8, indicating a high level of internal consistency. This demonstrated that the test reliably measured participants' academic performance in probability, contributing to the validity and robustness of the study's findings.

The study spanned five days following the Department of Education's mathematics curriculum guide in the final quarter. In this study, participants completed both pre-exposure and post-exposure surveys to assess their perceptions, experiences, challenges, and prior knowledge while using a digital simulation tool during a lesson on probability. The survey instrument employed a five-point Likert scale to evaluate participants' opinions and beliefs regarding the tool. The pre-exposure survey gauged the experimental group's prior knowledge of digital simulations, while the post-exposure survey gathered feedback on the tool's effectiveness, usability, and efficiency. Before instruction commenced, a pretest was administered to both the experimental and control groups to assess their initial understanding of probability concepts, while the pre-exposure survey was given exclusively to the experimental group to gauge their prior knowledge of digital simulation. After five days of instruction covering specific topics and learning objectives, the experimental group used the simulation tool, while the control group did not. A posttest was administered to both groups to assess progress in probability concepts, and a post-exposure survey was given to the experimental group to gather feedback on their perceptions and challenges encountered. Although the study's findings cannot be extended to conventional techniques, digital simulation can be applied to higher-probability concepts, opening possibilities for further research on using digital simulations to enhance learning in mathematics.

3. RESULTS AND DISCUSSION

Given that $n \leq 50$, we employed the Shapiro-Wilk test to assess the normality of the pretest score distributions for both the control and experimental groups. Table 1 below shows that pretest scores in the two groups did not show a significant departure from normality: control group ($W(30)=0.97,\ p=.59$), experimental group ($W(30)=0.96,\ p=.33$). Hence, we accept the H_0. It is assumed that the data in the two groups are normally distributed.

Table 1. Test of normality of observation in pretest scores

	Shapiro-Wilk		
Group	Statistic	df	p
Control Group (n=30)	.971	29	.59
Experimental Group (n=30)	.961	29	.33

Mean and percentage calculations were conducted to determine significant differences between the pretest, posttest, and gain scores of the experimental and control groups. Additionally, a correlational analysis was employed to examine the relationship between pretest and posttest scores before and after the experimental group's exposure to the intervention. Independent t-tests (with pooled variance) were performed following Levene's test to evaluate the homogeneity of variance assumptions for both groups' pretest and posttest scores. Levene's test results confirmed that the assumption of equal variances was satisfied, as all p-values exceeded 0.05. Paired t-tests were also conducted to compare differences within the same group.

Table 2. Comparison of pretest and posttest mean scores, gain scores, and percentages between experimental and control groups

Group	Scores	Mean	Percent (%)
Control Group(n=30)	Pretest	34.88	58.13
	Posttest	41.27	68.78
	Gain Score	6.39	10.65
Experimental Group(n=30)	Pretest	36.07	60.11
	Posttest	47.79	79.65
	Gain Scores	11.79	19.54

Table 2 presents a comparison of the pretest, posttest, and gain scores between the experimental and control groups. In the pretest, the experimental group achieved a mean score of 36.07, indicating that students answered 60.1% of the test correctly, while the control group had a mean score of 34.88, corresponding to 58.13% correct answers. These results suggest that both groups had limited prior knowledge of the probability lesson. For the posttest, the experimental group attained a mean score of 47.79 (79.65% correct answers), whereas the control group achieved a mean score of 41.27 (68.78% correct answers). These findings indicate that both groups surpassed the 50% passing rate on the 15-item formative assessment, demonstrating significant learning progress. However, the experimental group performed notably better, with a 10.87% higher score than the control group. Regarding the gain scores, the experimental group had an average gain of 11.71, meaning students improved by 19.54% on the test. In contrast, the control group had an average gain of 6.39, indicating a 10.65% improvement. These results imply that the experimental group outperformed the control group in terms of knowledge gains, as demonstrated by the correlation coefficient analysis. As explored by de las Peñas et al. [4], this study highlights the potential of this application in improving performance, facilitating the development of concepts, and increasing learner engagement.

Table 3. Pearson correlation analysis between pretest scores(experimental) and pre-exposure in using Digital Simulation

N	df	Pearson (r)	r^2	p
30	28	.284	.081	.129

Table 3 shows that a Pearson correlation analysis indicated a non-significant, small negative relationship between pre-exposure survey scores and pretest scores in the experimental group, *r*(28)=.284, *p*=.129. Consequently, there was no discernible association between the pretest scores of the students and their preexposure in digital simulation.

Table 4. Pearson correlation between the posttest scores(experimental) and postexposure in using Digital Simulation

N	df	Pearson (r)	r^2	p
30	28	.198	.039	.295

Table 4 shows that a Pearson correlation analysis indicated a non-significant, small positive relationship between the post-exposure survey and post-test scores of the experimental group, *r*(28)=.198, p=.295. Consequently, this suggests that while there is a slight trend indicating that higher survey responses might be associated with better post-test performance, the relationship is weak and not statistically significant. Therefore, we cannot conclusively state that students' perceptions, as measured by the post-exposure survey, are strongly correlated with their academic performance in the post-test. This result indicates that other factors, beyond those captured by the survey, may be influencing students' posttest performance, and further investigation is needed to better understand the potential drivers of success in the experimental group.

Table 5. Summary of t-Test results for group differences in math pretest scores

Group	Mean	SD	t	p
Control Group(n=30)	34.88	5.40	-0.8	.419
Experimental Group(n=30)	36.07	5.96		

Table 5 shows the result of the independent t-test indicated that there is no significant difference between the pretest scores of control group (*M*=34.88, *SD*=5.40), and pretest scores of the experimental group (*M*=36.07, *SD*=5.96), *t*(28)=-0.8, *p*=.419. This indicates that the two groups were relatively equivalent prior to the conduct of the intervention. The null hypothesis, which stated that there was no significant difference between the pretest scores of the control and experimental groups, was retained.

Table 6. Summary of t-test results for group differences in mathematics post-test scores

Group	Mean	SD	t	p
Control Group(n=30)	41.27	5.59	-4.7	.000
Experimental Group(n=30)	47.49	5.21		

Table 6 shows the results of the independent t-test indicated a significant difference between posttest scores of the control group (*M*=41.27, *SD*=5.59) and experimental group (*M*=47.49, *SD*=5.21), *t*(28)=-4.7, p=.000. Given that the p-value is less than the standard significance level of α=.05, we reject the null hypothesis, which posited no significant difference between the posttest scores of the two groups. This finding suggests that the intervention applied to the experimental group had a positive effect on their performance compared to the control group.

Table 7. Summary of t-Test results in group differences in gain scores

Group	Mean	SD	t	p
Control Group(n=30)	6.39	7.38	-2.6	.011
Experimental Group(n=30)	11.79	8.44		

Table 7 shows the results of the independent t-test indicated a significant difference between the gain scores of the control group (*M*=6.39, *SD*=7.38) and experimental group (*M*=11.79, *SD*=8.44), *t*(28)=-2.6*, p*=.011. These results indicate that the experimental group, which received the intervention - digital simulation, exhibited significantly greater improvement in their gain scores compared to the control group. The low p-value=.011 suggests that the difference between the groups is statistically significant and unlikely to have occurred by chance. The assumptions of normality and homogeneity of variance were met, ensuring the reliability of the test. Thus, it can be inferred that students who utilized digital simulations significantly enhanced their learning, highlighting the value of such tools in improving educational outcomes and student engagement. Research conducted by Koparan and Kaleli Yılmaz [7] and Koparan [10] revealed that simulation-based learning enhances prospective teachers' critical thinking and problem-solving abilities in the context of probability education. Koparan and Taylan [9] used simulations to engage students in real-life mathematical experiences, fostering their ability to express mathematical concepts and employing higher cognitive skills. Similarly, a systematic review by Vlachopoulos and Makri [12] revealed that digital simulations can result in positive learning outcomes in cognitive, behavioural, affective, and multidimensional dimensions. The review emphasized the value of digital games in creating interactive and participatory learning experiences that enhance skill transfer and learner self-efficacy. Gegenfurtner *et al*. [5] also highlighted the significance of user control in digital simulations and emphasized the importance of designing simulations that allow learners to actively explore and operate the virtual environment. Overall, integrating digital simulations into learning enables students to explore probability ideas interactively, ultimately boosting their problem-solving and analytical thinking competencies.

4. CONCLUSION

Based on the study's results and findings, the use of digital simulation as a dynamic visual representation proved to be highly effective in enhancing student learning of probability concepts. The integration of this tool significantly improved student performance, indicating its potential to enrich the understanding of complex mathematical ideas. Moreover, the findings suggest that digital simulations serve as powerful educational aids, leading to improved learning outcomes and greater student success in mastering probability concepts.

5. RECOMMENDATIONS

Given the favourable outcomes observed, educators should incorporate digital simulations into their curricula as an auxiliary resource for teaching probability. The dynamic visual representations provided by these simulations can enhance students' ability to conceptualize complex ideas, thereby fostering deeper understanding and improved academic performance. Future research should investigate the long-term impacts of digital simulations on learning outcomes across various mathematical domains to better assess their effectiveness. Furthermore, professional development initiatives for teachers ought to include comprehensive training on the effective integration of such technologies, ensuring that the pedagogical advantages identified in this study are fully realized.

6. REFERENCES

[1] Bergman, A. J. (2017). Using a Models and Modeling Perspective (MMP) to Frame and Combine Research, Practice and Teachers' Professional Development. *CERME 10*, 3801-3808.

[2] Brito, L. P., Almeida, L. S., & Osorio, A. J. (2021). Seeing in Believing: Impact of Digital Simulation Pedagogical Use in Spatial Geometry Classes. *International Jouranl of Technology in Teaching and Learning*, 17(2), 109-123.

[3] Creswell, J. W. (2009). *3rd Edtion Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Nebraska City: Sage Publications Inc.

[4] de las Peñas, M. N., Versoza, D. B., Aberin, M. Q., Garces, L. M., Francisco, F. F., Bautista, E. P., . . . Tabares, W. C. (2019). Digital Simulations for Grade 7 to 10 Mathematics. *Philippine Journal of Science*, 148(4), 735-749.

[5] Gegenfurtner, A., Quesada-Pallares, C., & Knogler, M. (2014). Digital simulation-based training: A metaanalysis. *British Journal of Educational Technology*, 45(6), 1097-1114.

[6] Koparan, T. (2022). "How Does Simulation Contribute to Prospective Mathematics Tecahers' Learning Experiences and Results?". *Education Sciences 12*, 624.

[7] Koparan, T., & Kaleli Yilmaz, G. (2015). The effect of simulation-based learning on prospective teachers' inference skills in teaching probability . *Universal Journal of Educational Research*, 3(11), 775-786.

[8] Koparan, T., & Rodriguez-Alveal, F. (2022). Probabilistic Thinking in Prospective Teacher from the use of TinkerPlots fro Simulation: Hat Problem. *Journal of Pedagogical Research*, 1-16.

[9] Koparan, T., & Taylan Koparan, E. (2019). Empirical Approaches to Probability Problems: An Action Research. *Europian Journal of Education Studies*, 5(10), 100-117.

[10] Koporan, T. (2016). Using simulation as a problem solving method in dice problems. *British Journal of Education, Society & Behavioural Science*, 18(1), 1-16.

[11] Lesh, R., & Doerr, H. M. (2003). *Beyond Constructivism: Models and Modeling Perspectives on Mathematics Problem Solving, Learning, and Teaching.* Lawrence Erlbaum Associates Publishers.

[12] Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: a systematic literature review. *Int J Educa Technol High Educ 14*, 2

[13] Cook, T.D., Campbell, D. T., & Peracchio, L. (2008). Quai-experimentation. In S.F. Chipman (Ed.), The Encyclopedia of Psychology, Volume 6. Wiley