ISSN 2229-5518

Problem-solving using interactive simulations on learners' conceptual understanding of dynamics in physics: a case of St. Marcellin's secondary school.

Chinyama Vincent, Jumbe jack

Abstract— This study combined problem-solving and interactive simulations to address issues of learners' conceptual learning and perception of physics. The results revealed statistically significant gains in conceptual understanding and performance in dynamics by the experimental group in comparison to the control group at alpha level of .05. Qualitative findings that emerged inductively revealed that the visual features of PhET and Algodoo simulations changed learners' individual perceptions about dynamics in physics. The qualitative phase involved focus group interviews with six learners. Results suggested that the visual features of interactive simulations in PSIS enhanced learners' conceptual understanding, which complemented the findings from the quantitative results. The findings suggested that the PSIS method may have implications as an effective teaching and learning method in enhancing learners' conceptualization of dynamics in physics.

Key words: Effectiveness, Problem-solving, conceptual understanding, interactive simulations, perception.

1 Introduction

This introductory chapter examines problems on conceptual learning in dynamics through conventional instructional methods and proposes Problem Solving using Interactive Simulations (PSIS) as a solution to address issues of conceptual learning. The changing world and societal realities, as well as the rapid technological transformations, are reshaping life and work-force skills that employees and citizens must have in order to succeed (Humber, Krantzberg, & Grover, 2015). The Zambia education curriculum framework (2013) highlights some of the key competencies that learners have to acquire as a result of good quality education such as critical thinking, analytic thinking, strategic and creative thinking; problem-solving; participation and teamwork among other competences. Acquisition of these skills and competences by learners' demands application of pedagogical strategies that support investigation and problem-solving on the part of the learners through "learning as connection" (Shumba & Kampamba, 2013). Numerous studies conducted in the recent past have proposed that constructivist learning methods support the acquisition of problem-solving skills that lead to functional conceptual understanding of the subject matter. This is because constructivist theory of learning suggests that learners are active constructors of knowledge as they experience learning. The theory suggests that humans construct knowledge and meaningful frameworks from their learning experiences (Piaget, 1980).

For example, a study by Fernandez, (2017) reported that high school grade 10 learners that experienced authentic inquiry-based instruction demonstrated significant gains in conceptual understanding and learner self-efficacy. Another study by Fan (2015) in the context of grade 10 students in China found that the inquiry-based learning with interactive simulations method enhanced learners' conceptual understanding of concepts on force and motion. In yet another study by Ali, Nur and Rubani (2008) in the context of university engineering students, found that problem-based learning helped learners to understand physics topics in more depth and became more systematic in solving problems. In addition, they discovered that basic knowledge and past experiences were needed in solving problems during problem-based learning in physics (Ali, Nur, & Rubani, 2008).

Accordingly, this study developed Problem Solving using Interactive Simulations (PSIS) method in the context of St. Marcellin's secondary school for scaffolding learning activities that were meant to improve learners' conceptual understanding and performance. ICT applications are used as virtual simulation media that visualize physical phenomena that allow learners to experience the universe during the learning process (Nasir & Palangka, 2018).

PSIS is a learner-centered method in which learners learn concepts of the subject matter by solving real and meaningful problems with the aid of computer interactive simulations. In PSIS the learning process begins with meaningful and imaginable problems or problematic situations to set the context of the learning process. Acquisition of new knowledge by learners occurs as the problem under investigation demanded. The role of the learners is to learn the new concepts necessary in order to address the problem under investigation. Consequently, the role of the teacher is to facilitate learning by scaffolding, guiding and monitoring the learning process. The teacher also helps learners to understand and define the problem clearly and to stress the importance of the problem under investigation.

While studies by Fan, (2015); Gaigher et al., (2006); Omaga and Adeniran (2017); Argaw et al., and (2017); Omaga and Adeniran (2017) reported the positive impact of problem-solving on performance on one hand, on the other hand, Gormally, Brickman, Hallar & Armstrong (2009) reported that learners taught using problem-solving method experienced the complexity and frustrations faced by practicing scientists. In this particular study, it was reported that while learners attempted to solve problems, there appeared to be a lack of confidence in their answers, even among those who were able to provide correct responses. This explained the widespread reported student resistance to inquiry curricula because of the challenging process of solving problems on their own. This controversy renders the effectiveness of problem-solving on conceptual learning inconclusive even though there is a general consensus among many empirical researchers that problem-solving is more effective than conventional instruction on conceptual understanding. This study is therefore designed to contribute to this controversy by improving problem-solving method with the use of interactive simulations while anticipating that interactive simulations would easy the challenges experienced by learners.

2.0 Research Design and Methodology

This study depends on a common belief among many researchers that research questions and objectives are considered critical in determining the research design to be used. In accordance, this study's research questions and objectives that demanded objective explanatory answers influenced the research design to be adopted. Therefore, I chose mixed methods research design based on the critical realist paradigm, to integrate the two approaches into a more logical and consistent combination, and promote closer and more equal cooperation between qualitative and quantitative research, to increase the usefulness of both approaches (Pawson, 2014). This study believes ontologically that there is a real world that exists independently of our perceptions and constructions while embracing a form of epistemological constructivism that our understanding of this world is inevitably a construction from our own perspectives (Pawson, 2014). Objective reality exists and the role of the researcher is to look for it, to measure it and to test it. At the same time, the researcher should embrace the meanings that participants have constructed about the reality from their perspectives (Creswell, 2014). This study is both quantitative and qualitative in nature because the goal of critical realist research is to measure and verify underlying structures in reality (Bisman, 2010 cited in Shannon-Baker, 2016) and consequently seeks to understand individual perceptions in depth, to provide individual meanings in rich detail, and to interpret how each participant constructs their meanings and why.

2.1 Logical Design

An action research process was undertaken to investigate if a more interactive and engaging pedagogical method, such as Problem Solving using Interactive Simulations (PSIS), could empower learners to assume responsibility for their learning during problem solving and other social interactions. The study focused on 10th grade learners' conceptual understanding using PSIS in dynamics in physics. The main research question investigated was: what is the effectiveness of Problem Solving using Interactive Simulations (PSIS) on the learners' conceptual understanding of concepts and performance in dynamics? The other research question was; 2. What is the influence of PSIS method of instruction on the learners' perceptions of dynamics? A mixed methods research design was adopted to combine a quantitative phase with a qualitative phase because these questions demanded both quantitative and qualitative answers. The quantitative phase adopted a pretest-post-test control group quasi-experimental design. Two 10th grade intact classes of leaners were randomly assigned to experimental and control groups. Participants were randomly assigned to Problem Solving using Interactive Simulations (PSIS) (experimental group) and conventional instruction (control group) as learning methods. The quantitative phase answered the first research question; 1. What is the effectiveness of Problem Solving using Interactive Simulations (PSIS) on the learners' conceptual understanding of dynamics? The qualitative phase answered the research question; 2. What is the effectiveness of Problem Solving using Interactive Simulations (PSIS) on learners' performance in dynamics? 3. What is the influence of PSIS method of instruction on the learners' perceptions of dynamics?

2.2 Setting and participants

This study was conducted at St. Marcellin's secondary school in Kalulushi district on the Copperbelt province of Zambia during the regular academic calendar of the year 2019. Since this study was conducted during the normal academic calendar for the term, care was taken by the researcher to minimize any disruptions to the planned flow of activities during the term. Again, since this study focused on dynamics in physics, the participants were selected as those learners who were learning scientific concepts related to dynamics in physics at the point in time in which this study was conducted. Two grade 10 classes were randomly assigned to the experimental and control groups for this study. Grade 10A with 33 learners and grade 10B with 37 participated in the research. The study population for this research was N=103. Bearing in mind that randomization requirement cannot always be met in educational research, a heavy reliance on numbers may not be a sufficient representation (Delİce, 2010). For this reason, two intact classes were randomly assigned to the experimental and control groups for this study.

2.3 Instruments

Four separate instruments were used in the collection of data so as to adequately address the research questions posed. The instruments that were used in the quantitative part of the main study that included the Modified Inventory of Basic Conceptions in Mechanics (MIBCM) [originated from inventory of basic conceptions in mechanics, IBCM, by Halloun, (2006)] and mechanics achievement test (MAT), were refined based on the pilot study. Specifically, twenty-four multiple-choice questions were used from the MIBCM test and then a Mechanics achievement test was prepared according to the standard format of the examinations' council of Zambia. All instruments used in the quantitative part of the main study were subjected to spearman's split half reliability coefficient testing during the pilot study. The coefficient values above .70 assumed that the items of both instruments used in the main study were reliable and internally consistent.

The pretest was given to both the experimental and the control groups to ascertain equality of the two groups in terms of conceptual understanding of basic concepts in dynamics. The results were analyzed statistically using SPSS v25 to check if there was a statistically significant difference between the experimental and control groups before the intervention was implemented.

2.4 Procedure

EXPERIMENTAL GROUP

The experimental group was instructed using PSIS method. Algodoo and PhET simulations were introduced to the learners in the experimental group in order to familiarize them with the software. The researcher had already downloaded the simulation software and installed them in advance on computers that were to be used. The researcher demonstrated to the learners how to use the software to learn dynamics. Furthermore, the official websites (www.algodoo.com and https://phet.colorado.edu) for Algodoo and PhET simulations respectively were given to the learners in order for them to download on their own and to check for the latest information. This introduction lasted for about 30 minutes and learners liked the software since it was user friendly. For example, the researcher demonstrated to the learners that when they are investigating falling objects and they want to learn about different forces acting on objects with and without air resistance, they were to use Algodoo simulation.

The researcher demonstrated to the learners how to use algodoo to conceptualize falling objects, and asked learners to do the same as shown on figures 2.4.1 and 2.4.2.

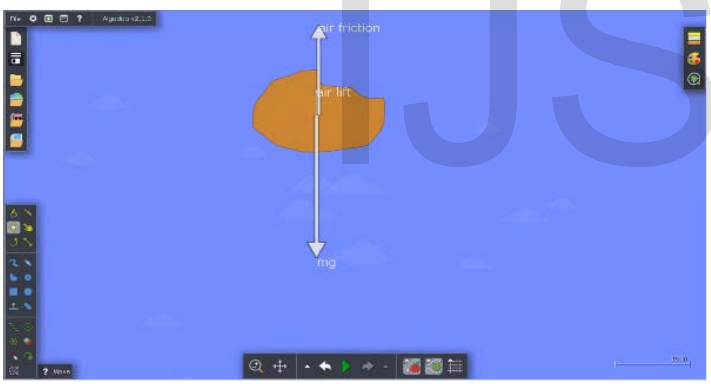

Figure 2.4.1 showing a falling object with relative forces/direction of weight and air friction.

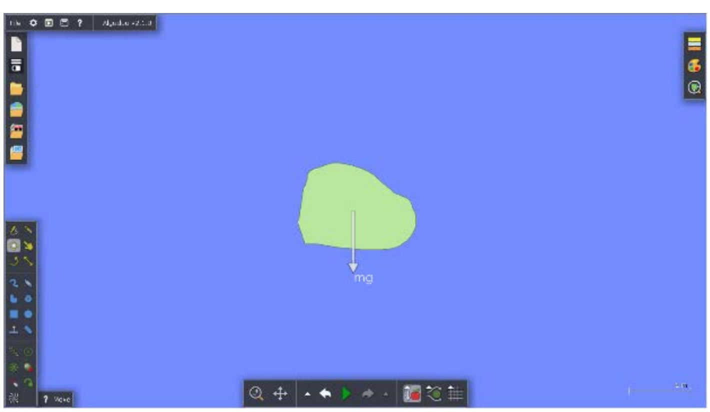

Figure 2.4.2 showing a falling object without air friction.

Figure 2.4.1 shows a screen shot of a falling object approaching terminal speed due to air friction. On the other hand, figure 2.4.2 shows a screen shot of a falling object falling with constant acceleration.

Accordingly, the researcher demonstrated constant acceleration of a body pushed with a constant force on a surface without friction, as shown in figure 2.4.3;

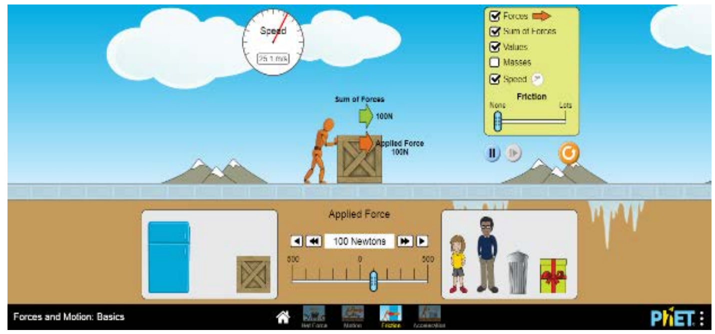

Figure 2.4.1, showing a body pushed along frictionless surface

Furthermore, the researcher demonstrated that for a body pushed on a surface with friction, the magnitude and direction of acceleration depends on the magnitude and direction of the sum of forces as shown in figure 2.4.4.

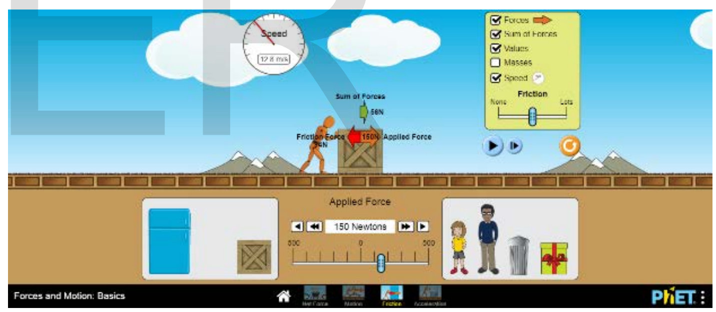

Figure 2.4.4, showing acceleration in the directionof the resultant force.

Learners were then encouraged to be creative as they interacted with the computer simulations during their problem-solving investigations.

Learners were then provided with worksheets to investigate concepts in dynamics by solving real and meaningful problems. Learners worked in groups of three during this investigation.

Problem-solving procedure

To be able to confront the problems identified, learners were engaged in problem-solving process using computer simulations in the following 6 steps;

1. Stimulation of prior knowledge and intuition by introduction of the learning outcomes and presentation of problems on worksheets by the teacher;

2. Problem analysis, brainstorming and prediction based on intuition and prior knowledge by learners collaborating in groups; the teacher who was also the researcher gave guidance

ISSN 2229-5518

during this stage especially in groups that experienced more difficulties.

3. Data organization, inquiry and research to formulate action plans to suggest possible ways of solving problems on worksheets by learners; learners were given textbooks where they did their research to understand the underlying concepts under investigation. At this stage, learners also used the simulations for visualizing the scenario of the problem under investigation.

4. Taking appropriate action in problem solving by learners collaborating in group work;

5. Confirmation of predictions, evaluation and reflections by learners engaging with interactive simulations to test their predictions and complete problems on worksheets;

6. Correlative and or derivative subsumption by learners reporting their claims with evidence and connecting phenomena to real life and by relating new knowledge to their pre-existing cognitive structures or by deriving new understanding from their prior knowledge thereby culminating into acceptable scientific conceptions was the final stage. Groups that completed their work were asked to present their findings to the rest of the class. Other groups were encouraged to support or challenge the findings of the presentation basing on what they found in their respective groups. The teacher who was also the researcher gave due credit to the effort put in by the learners and congratulated them for finding correct answers or by guiding the learners to find the correct answers. Most of the time, the researcher was referring to the interactive simulations in order to elaborate on the underlying core concepts in the problem under investigation.

The 6 steps blended different problem solving and inquiry practices such as problem analysis, proposing experimental process, testing hypotheses, observing experiments in real and virtual environments, discussing observations and findings, criticizing each other's procedures and findings, reflecting on their problem-solving procedure and carrying out self-evaluation.

This problem-solving process occurred in the laboratory setting prepared with eleven computers. The front of the laboratory had a demonstration table, a teacher's personal computer and a projector which beamed on the white board. Computers with Algodoo and PhET simulations installed on them were shared by three learners each for conducting the experiments to test their hypotheses in the virtual environment. Details of how each lesson was conducted were recorded in the lesson plans.

CONTROL GROUP

Learners in the control group were taught using conventional instruction method. However, having read extensively about active learning and its benefits on learning, I did not want my participants in the control group to miss such an opportunity for active learning. I therefore integrated active participation of learners in the conventional instruction method. I introduced the concepts by asking learners to explain them or say whatever they knew about those concepts. I then connected their definitions into equations by deriving them on the board in some form of mathematical structure, and then I demonstrated how to use the equations with an example problem. I give the class a similar exercise problem to try on their own to actively engage them in the problem-solving activity. I then marked the books to give feedback on the correctness of their solutions to the exercise problems. This was followed by a set of practice problems to be given as homework. The next lesson demanded solutions to the previous homework in which learners were expected to present to the class. The learners were assigned homework problems every time they learnt physics and asked them to present their solutions during the introduction of the next lesson. These activities were assumed to support learners' conceptual understanding and acquisition of problem-solving skills. This method was easy to implement and time saving because it allowed the teacher to cover more material within a short period of time in physics classrooms.

3.0 QUANTITATIVE DATA ANALYSIS, PRESENTATION AND INTERPRETATION OF FINDINGS

In the quantitative part of the study, the MIBCM test and Mechanics Achievement Test were used as data collection instruments. Scores of the tests were analyzed using SPSS v25. Independent t-test analysis and paired samples t-test were performed to look for any statistically significant differences between groups and within groups respectively. Table 3.0.1 gives a summary of the research questions, operational research questions, data collection sources and data analysis procedure;

Table 3.0.1 a summary of the research questions, operational research questions, data collection sources and data analysis procedure

Research questions	Operational research questions	Data sources	Data analysis
What is the effectiveness of PSIS on the learners' conceptual understanding of concepts in dynamics?	Which instructional method provides better conceptual understanding of concepts in dynamics between PSIS and conventional instruction?	Scores on MIBCM pretest and post-test	Independent samples t-test and paired samples t-test
What is the effectiveness of PSIS on learners' performance in dynamics?	Which instructional method results in better performance in dynamics between PSIS and conventional instruction?	Scores on achievement post-test	Independent samples t-test

3.1 Effectiveness of PSIS method on learners' conceptual understanding of dynamics

The first research question aimed at finding out whether or not there was a statistically significant difference between learners' conceptual understanding during the PSIS method and the conventional instruction method. Scores in the MIBCM test ranged from 0 to 100, with higher scores indicating better conceptual understanding. Findings are discussed below.

Hypothesis: H_{01}: There is no statistically significant difference in MIBCM pre-test and the MIBCM post-test between learners using the PSIS method and those using the conventional instruction method.

An independent samples t-test was used to analyze whether or not the two treatment groups had any statistically significant difference in the MIBCM pretest and post-test. Table 3.1.1 shows t-test analysis table of results obtained from pretests.

Table 3.1.1 MIBCM pretest score statistics

MIBCM Pretest statistics						
Treatment	**N**	**Mean**	**SD**	**df**	**t-value**	**p-value**
Experimental group	37	22.89	11.91	68	-1.041	.302
Control group	33	25.76	11.02			

In table 3.1.1, the mean score of control group learners in MIBCM pretest was 25.76% while the mean score of experimental group learners was 22.89%. The result showed that there was no statistically significant difference in conceptual understanding before the intervention between the two groups in the MIBCM pretest, t (68) = -1.041, p = .302. The interpretation of this statistic outcome was that the equality of the two groups in terms of conceptual understanding before the intervention was implemented was assumed.

The mean score of control group learners in MIBCM post-test was 39.39% while the mean score of experimental group learners was 59.92% as shown in table 3.1.2.

Table 3.1.2 MIBCM post-test score statistics

	MIBCM post-test statistics					
Treatment	**N**	**Mean**	**SD**	**df**	**t-value**	**p-value**
Experimental g Group	37	51.92	7.35	68	6.751	.000
Contro Group	33	39.39	8.17			

The independent samples t-test for the post-test showed that there was statistically significant difference in conceptual understanding between the control and experimental groups in the MIBCM post-test after the intervention, t (68) = 6.751, $p < .001$. In other words, the difference between the mean of the experimental group and the control group was big enough to be statistically significant. This means that the chance of type1 error (rejecting a correct H_0) is small enough to support the alternative hypothesis, H_1. Additionally, the greater the t-value, the greater the evidence against the null hypothesis, and therefore, the null hypothesis was rejected.

These findings suggested that PSIS was more effective than conventional instruction method in facilitating conceptual learning.

As shown in Tables 3.1.1 and 3.1.2, the two methods of instruction (PSIS and conventional instruction) revealed mean increases from pretest to post-test. However, the largest difference between the pretest and post-test mean scores existed in the experimental group, with 29.03 points compared to the control group with 13.63 points. This reveals that learners learning using the PSIS method scored higher marks than those using the conventional instruction method. Furthermore, it was noticed that the measure of spread about the mean as measured by standard deviation in the experimental group was less than that in the control group. This suggested that the mean score of the experimental group was more representative of the learners' post-test scores than the mean score of the control group.

3.2 Effectiveness of PSIS method on learners' performance in dynamics

The second research question aimed at finding out whether or not there was a statistically significant difference in learners' performance in the achievement post-test between the experimental and control groups. Performance scores ranged from 0 to 100, with higher scores indicating better performance. Findings and their interpretation are discussed below.

Hypothesis: H_{02}: The difference in the mean performance score of learners learning by PSIS and those learning by conventional instruction method is not big enough to be statistically significant.

The mean score of control group learners in the achievement post-test was 39.91% while the mean score of experimental group learners was 51.19%. The independent samples t-test for the post-test showed that there was statistically significant difference in performance between the control and experimental groups in the achievement post-test, t (68) = 4.48, $p < .001$. This means that the difference between the mean scores of the experimental group and the control group was big enough to be statistically significant at α = .05. Therefore, the null hypothesis was rejected. Table 3.2.1 gives summary statistics of the achievement test analysis.

Table 3.2.1 achievement test score means and SD according to the two treatments

		Achievement post-test scores			
Treatment	**N**	**Mean**	**SD**	**t-value**	**p-value**
Experimental group	37	51.19	10.83	4.48	.000
Control group	33	39.91	10.14		

4.0 Qualitative Data Analysis, Presentation and Interpretation of Findings

4.1 Purpose of qualitative phase of this study

The purpose of this part was to explore the influence of PSIS method of instruction on the learners' perceptions of dynamics in physics. This qualitative phase used interviews and group conversation recordings as a source of data. Strauss' grounded-theory design was adopted to guide the collecting and coding of interview data so as to identify emerging categories and generate grounded theory (Charmaz, 2006). The purpose was to present a rigorous method of qualitative research that would enable a systematic collection of data, coding, categorizing, thematizing of data for the purpose of generating grounded theory in an inductive analysis of data (Creswell, 2014).

4.2 Participants in the focus group discussion

Six learners were invited to participate in the focus group interview. Six learners made a reasonable qualitative sample size, because they brought out almost all-important perceptions on dynamics representing the entire class. Using descriptive statistics, two interviewees were selected from the participants with scores in MIBCM post-test that fell in the first quartile of the distribution, two interviewees from the second quartile and two from the third quartile. Names of all participants were changed in order to maintain highest standards of ethics.

4.3 Grounded Theory - The theory of simulated-visualization of phenomena to enhance learners' conceptual understanding

Based on the participants' remarks and the researcher's observations and memos, data was coded, categorized, themes made and eventually grounded theory emerged inductively. From the analysis, it was discovered that the perception of learners towards physics changed with time. In other words, from the point of view of the learners, learning dynamics with computer simulations was very interesting and understandable to the learners because of its visual features. The theoretical statement that was generated as a result of connecting the relationships among the categories culminated into – The *theory of simulated-visualization of phenomena* to enhance learners' conceptual understanding.

The theory of simulated-visualization of phenomena to enhance learners' conceptual understanding is an emergent perception within the process of problem-solving using interactive simulations by learners. The process requires active engagement of learners in exploring phenomena surrounding the problem under investigation using computer-simulated environments. Most importantly, learners perceive concepts in the topic of dynamics in physics as easy to understand with the visual-aid of interactive simulations. Learners also perceived themselves as more capable problem-solvers as they actively engaged in research and phenomena exploration of the problem under investigation using interactive simulations. Furthermore, learners were eager to take responsibility for their own learning provided they had resources for research and interactive simulations for their phenomena exploration of the problems.

5.0 Discussion of major findings of the Main Study

5.1 Major Findings

Form the quantitative phase of the study, the mean score of control group learners in MIBCM pretest was 25.76% while the mean score of experimental group learners was 22.89%. The pretest mean scores between the experimental group and the control group was not statistically significant at a level of .05. This revealed that the two groups were at the same level of conceptualization in basic mechanics before the treatment was implemented

For the posttest, the mean score of control group learners in the achievement posttest was 39.91% while the mean score of experimental group learners was 51.19%. The independent samples t-test for the post-test showed that there was statistically significant difference in performance between the control and experimental groups in the achievement post-test, $t(68) = 4.48$, $p < .001$.

Fig 5.1.1; showing relative mean scores and standard deviation for the pretest

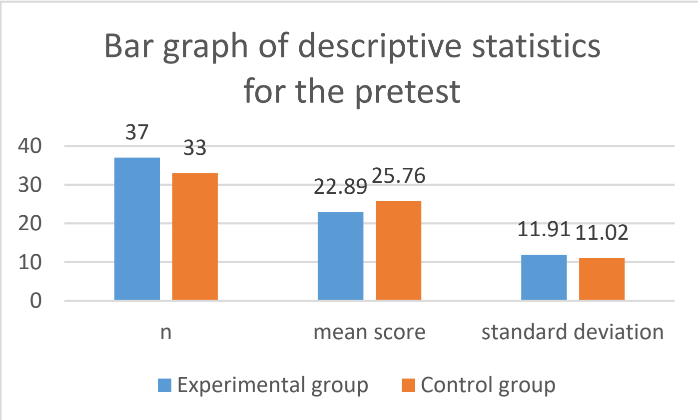

Figure 5.1.1, showing summary of pretest mean scores and standard deviation.

Figure 5.1.1 shows a bar graph showing descriptive statistics for the pretest. The mean scores show that the control group scored more marks than the experimental group. The standard deviation for the control group was relatively smaller indicating that the mean for the control group was more representative than that of the experimental group.

Figure 5.1.2 shows a bar graph for descriptive statistics for the posttest.

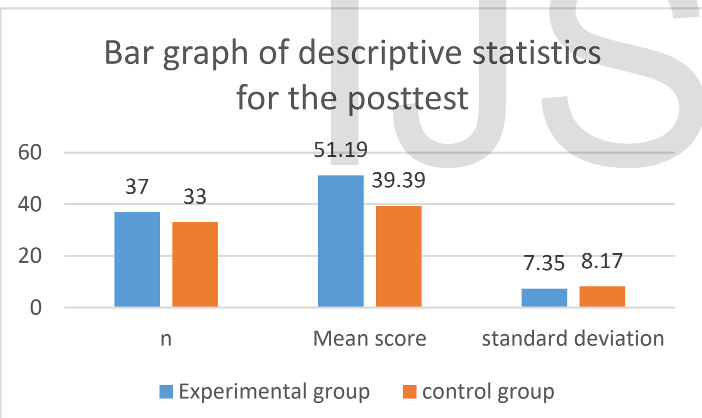

Figure 5.1.2, showing summary of posttest mean scores and standard deviation.

The statistics in figure 5.1.2 show that the mean score for the experimental group was higher than that for the control group. The standard deviation for the experimental group was less than that for the control group. This indicates that the mean score for the experimental group was more representative of the population mean.

5.2 Discussion of Findings

Based on the findings of this study, the average pretest scores of both the control and the experimental groups indicated that the groups' basic understanding of dynamics was quite the same. However, after 4-weeks of treatment, it was found that the experimental group enjoyed higher achievement in basic understanding of dynamics than the control group and the difference was statistically significant at a level of .05. From this result, I argue that PSIS method is more effective in enhancing learners' conceptual understanding in dynamics than conventional instruction methods at St. Marcellin's secondary school.

This finding agrees with PhET research-based claims that PhET sims are more effective for conceptual understanding of phenomena (https://phet.colorado.edu/en/research, 2019). The findings also agree with other researchers' findings such as Fan (2015); Çelik, (2015); Euler & Gregorcic, (2017) and da Silva et al., (2014) that interactive simulations play a major role in learners' conceptual understanding and achievement in physics. It could therefore, be said that numerous research papers support the use of interactive simulations' role in enhancing learners' conceptual understanding of physics phenomena and hence improved performance.

The qualitative phase of this study revealed the possible explanation for the improved conceptual understanding of the treatment group compared to the control group. It emerged that interactive simulations enhanced learners' conceptual understanding largely because of the visual features that enable learners to see key aspects of phenomena that could not otherwise be seen in a conventional laboratory. Learners also attributed improved conceptual understanding to the motivation that comes along with the use of computer technology in representing reality in the virtual environment. Learners were able to connect the phenomena they learned in class to what they experience in real-life through imagination by creating mental models that represented reality hence leading to conceptual understanding.

Another possible explanation was that PhET and Algodoo simulations played a role as scaffolds in the learning process which helped learners to reach their zone of proximal development (Vygotsky, 1978). In addition, learners were able to collaborate with each other in groups of three in order to analyze the problems that were presented to them to reach a shared understanding. The qualitative phase of this study brought out the insights of the role that collaborative problem-solving plays in reaching a shared understanding. The memos that I wrote concerning collaborative problem-solving were that I observed learners arguing, brainstorming, clarifying threshold concepts to one another and challenging each other's alternative conceptions. More knowledgeable learners were observed to scaffold their peers to reach their ZPD.

Furthermore, learners attributed problem-solving as one of the major motivations that provided the context for them to explore concepts that surrounded the problems that they were investigating. In other words, problem-solving motivated learners to research and come to a deeper understanding of concepts that represented reality. One of the learners remarked that they needed more worksheets that had challenging problems in order for them to use the computers to explore the concepts contained in the problem. This was quite important because learners were able to see the value of what they learned in class in solving real-world problems.

Grounded theory has been widely used by many researchers such as Chong & Yeo, (2017) to seek explanations for social phenomenon in real-life. This study therefore, used grounded theory in the qualitative phase to generate explanations for the findings of the quantitative phase. These explanations were deep rooted in the data and emerged from the data from the perspective of the participants who experienced learning first-hand. Grounded theory also is applicable to practical problems in which established theories do not exist. This discussion has clarified possible explanations that made PSIS more effective in enhancing learners' conceptual understanding of concepts in physics.

5.3 Recommendations

1. Teachers of Physics should integrate technological tools in their classrooms to teach abstract concepts effectively and systematically.
2. The use of these alternative teaching methods and supportive tools should be encouraged. In this way, teachers can make their physics teaching more effective so that students may be provided with a better understanding and hence improved performance.
3. Learners in schools should use these free interactive simulations to visualize real-life concepts in virtual environment and relate the concepts to reality. This could improve their conceptual understanding and achievement in assessments.

5.4 Recommendations for further research

In accordance with the findings of this study, the following are the recommendations for further research;

1. This study used only two interactive simulations namely, Algodoo and PhET (forces and motion basics) to teach dynamics. Therefore, there is need for more research to use other PhET simulations and Algodoo to teach other topics in physics.
2. This research was conducted in the context of grade 10 senior secondary school learners. Further research is needed to investigate whether these simulations could also be used to teach primary school science or even junior secondary school science.

5.5 Conclusion

Problem-Solving using interactive simulations (PSIS) method is more effective than conventional instruction method in facilitating conceptual learning of dynamics in physics because the difference in performance between learners in the treatment group and those in the control group was statistically significant. Furthermore, perception of learners towards dynamics changed over time due to the visual features of interactive simulations which led to the grounded theory- *The theory of simulated-visualization of phenomena to enhance learners' conceptual understanding.*

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Corresponding Author: Chinyama Vincent.

Co-Author: Jumbe Jack