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Effects of Interactive Mathematics Software on Grade-5 Learners' Performance

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Abstract. In order to cope with globalisation and the growing world of work, educational systems are challenged to improve the quality of education. The use of technology in education attracts the focus of developing countries aiming at raising their educational status to fit the global scale. Therefore, Rwanda education system is promoting the use of ICT in primary and secondary education as an instructional tool. Interactive Mathematics (IM) software for Rwanda was developed to support the effective implementation of the Competence Based Curriculum (CBC) of mathematics in primary level. Designed as quasi-experimental using control and experimental groups, this study was conducted in urban public and private schools to investigate the effect of IM software on grade-5 learners' performance. Considering IM software as a new technology under piloting phase, this study was grounded in TPACK framework with theories of technology acceptance model. Data collected through pre-test and post-test in form of scores were analysed using SPSS 23.0 to compute the statistical effect of the teaching interventions. From results, IM software descriptively showed a greater performance than the traditional class, based on the effect size of significance and learning gains. Using repeated measures ANOVA through the general linear model, it was found that IM improved learners' performance more in public than private schools, although private schools showed a high-performance level at both pre-and post-test stages. Despite that, males' performance remained higher than females' although females descriptively improved in post-test. The study suggests conducting qualitative studies that would bring more information about the features of IM in quality mathematics education.

Keywords: Interactive Mathematics software; grade-5 learners; learners' performance; experimental group; control group

1. Introduction

The major goal of any education system is to enable learners to achieve learning outcomes in relation to national aspirations. The current globalisation vision stresses the development of 21st century competences through education. This pushes education systems worldwide to a race of providing quality and the right education to equip the youth with the necessary skills to fit in the evolving world of work. In fact it was argued that education should change as quickly as the technology does to enable young people embrace the rapidly changing environment (Khun-inkeeree, 2016). In education systems, the aspect of quality education is generally translated into learning outcomes which are drawn from national aspirations. According to Dev (2016), learning outcomes are generally reflected by learners' academic performance. For example, in India, learning outcomes have become a phenomenon of interest such that many scholars have been working hard to untangle factors that militate against good academic performance (Dev, 2016).

Since 2015, Rwanda education system adopted a competence based curriculum (CBC) and different teaching and learning resources have been developed to support the effective implementation of the CBC. Information and Communication Technology (ICT) tools were prioritised to address barriers related to CBC effective implementation including insufficiency of resources, poor pedagogy and mediocre performance. In fact, it was argued that availability of technological aid could improve the quality of mathematics learning, the learning environment and performance of both boys and girls (Khun-inkeeree, 2016). Therefore, the Interactive Mathematics (IM) Software was developed to support the teaching and learning of mathematics in primary or grade level schools.

Drawing on this background, this study explored the effect of Interactive Mathematics (IM) software on grade-5 learners' performance. The objectives that guided this study consisted of a) investigating the role of IM on learners' performance; b) comparing the role of IM in different performances of public and private school learners; c) comparing the difference in females' and males' performance in IM supported mathematics classes.

2. Review of Literature

Existing literature on changes brought by Information Communication Technology (ICT) in human life highlights the importance of technology in empowering young people with skills to embrace the rapidly changing environment (Khun-inkeeree, 2016). Therefore, education systems opted to use ICT to stay updated with the dynamic life constraints and studies were conducted to analyse the effect of technology integration in education. For example, in mathematics education, a study argued that the availability of technological aid could improve the quality of mathematics learning and performance of both boys and girls (Khun-inkeeree, 2016). Other studies found that the best mathematics performers in International Mathematics and Science Study (TIMSS) among the OECD countries like Japan and Singapore mostly use computers in their classrooms (Gronmo et al., 2016; House, 2007). Seemingly, most advanced education systems, especially in developed countries which adopted ICT in teaching and learning many years ago, succeeded in producing learners who excel in mathematics worldwide. In light of advanced countries in mathematics performance, the promotion of the use of computers in basic levels of education, like primary school is of paramount importance (Gronmo et al., 2016). Therefore the use of IM software to support the implementation of the CBC in mathematics education in Rwandan primary schools would likely contribute to creating a classroom learning environment that would improve quality teaching and learning.

The purpose of quality education (Alshammari et al., 2017) is to improve learners' achievement. Learners' academic performance is the ultimate expectation for all educational stakeholders in general and for themselves in particular, without excluding teachers, parents and school administration (Dev, 2016). In elementary school learners, academic performance predicts the future of the youth and the whole nation (Dev, 2016). The ranking of schools from schools of excellence to the rest of the schools is guided by many criteria, but emphasis is always put on learners' achievement or academic performance. For example, in Rwanda's education system, it is a habit to rank schools from the best to the worst by considering many criteria but, most importantly, by putting an emphasis on academic achievement or learners' performance. Therefore, all schools aspire to be excellent by allowing learners to improve their achievements. These include time for self-study, the increase in assignments or tests and the urge for teachers to provide feedback timely and to integrate ICT in teaching and learning activities.

In education systems, different factors influence the quality of education and learners' performance. These include the school statuses, gender issues, learners' educational level, qualification of teachers, the type of pedagogy and the availability of instructional material as well as the scope of the subject content. The type of school is a factor of the effective teaching and learning process and school academic performance based on the differences between public and private schools including class population and teachers' qualifications. Khun-inkeeree (2016) investigated on the performance between public and private elementary schools in Thailand. Using ANOVA, he compared the difference between two public schools and one private school, and found that private schools showed better performance compared to public schools. Therefore, strategies to empower public school learners so that they can perform in the same way as their colleagues who study in private schools are necessary if they are all expected to achieve the same learning outcomes. In Rwanda, learning environment in private primary schools presents more opportunities to promote learners' better performance than public schools. These include a limited number of learners per classroom making it easier for the teacher to take care of individual learners and to teach them well. Therefore, the use of IM in public primary schools teaching will promote the learning environment of overpopulated class resulting in learners' increase in performance. Many other factors, including lack of instructional materials, lack of qualified teachers, teachers' poor pedagogical content knowledge or technological pedagogical content knowledge (TPACK), influence the quality of education and academic performance of learners in general and particularly in a mathematics lesson.

Literature on gender differences in mathematics performance reported that boys and girls have different perceptions about their difference in performance (Dev, 2016; Uwineza et al., 2018). Girls attribute their mathematics learning and performance more to external factors and less to abilities, while boys' abilities' to learning and performing well in mathematics were credited more to internal factors like reasoning and effort or commitment and less to external factors (Dev, 2016). Accordingly, the way IM content is developed and presented together with other features which makes the teaching attractive and enjoyable to learners show the potentials of IM to likely fit both female and male learning styles. Drawing on Dev, (2016)'s findings, IM supported class can change the learning environment from traditional learning environment using chalk and talks to smart learning environment which is ICT enhanced. In addition, mathematics content in IM software is developed from semi-concrete level to abstract level allowing learners to develop critical thinking and reasoning while learning. Therefore, IM software seems to be an instructional tool that may address female and male differences in learning styles as explained by Dev (2016) and may bridge the potential gap in females' and males' performance. In addition, teachers should be empowered to develop the learners' understanding of mathematics without distinction between females and males (Habineza, 2018) using instructional resources including ICT resources.

According to Uworwabayeho (2009), formal mathematics education in Rwanda started with arithmetic and developed through many curriculum reforms. It had long time been facing challenges to quality delivery related to but not limited to pedagogy (Maniraho & Christiansen, 2015), gender differences in attitudes and perceptions (Habineza, 2018), teaching and learning resources (Nyirahabimana & Twagilimana, 2019) and mostly the lack of professional mathematics teachers (Uworwabayeho, 2009). For example, a study conducted by Maniraho and Christiansen, (2015) revealed primary teachers' poor pedagogical content knowledge in unpacking mathematical content. At the same time, Nyirahabimana and Twagilimana (2019)'s study findings from one public secondary school mentioned insufficiency or sometimes unavailability of textbooks to support teachers' commitment to influence learners' performance. In another study, Umuhoza and Uworwabayeho, (2021) identified insufficiency or total lack of instructional materials for teaching mathematics. According to Msafiri (2017), teachers and students need instructional materials to easily achieve instructional objectives, increase learners' motivation to learn and increase understanding in practical ways. Therefore, instructional materials are necessary for successfully teaching and learning any subject including mathematics. It is worth noting that in Rwanda, nearly all studies conducted in mathematics education focused only on secondary school level. However, it is necessary to shift the focus of research attention to the primary level too, to build quality content delivery from the early level of education. Addressing mathematics issues including those related to pedagogy and instructional resources from primary level would be a means to predicting the quality of mathematics and to indirectly addressing issues at upper educational levels. Therefore, in this study IM technological tool was used as an instructional material that may also help teachers' effective delivery of the content following IM content development which was tailored following CBC framework.

In 1986, Shulman introduced the Pedagogical Content Knowledge (PCK) theory explaining quality knowledge for successful teachers in their teaching careers. According to Sri and Mardhiyah (2019), PCK is a manifestation of content knowledge and pedagogical knowledge, which means that teaching (mathematics) is not only understanding it but also knowing how (and who) to teach it. It is the teacher's ability to manage students in the learning process. According to Akturk et al. (2019), technology integration in education has become a necessity. Therefore, building on Shulman's formulation of "pedagogical content knowledge" in 1986, Punya Mishra and Matthew J. Koehler introduced Technology Pedagogical Content Knowledge (TPACK) theory in 2006 and extended it to the phenomenon of teachers integrating technology into their pedagogy. TPACK is one of the teaching methods which is currently becoming progressively more successful in promoting the effective integration of technology in teaching and learning activities (Soler-Costa et al., 2021).

Many studies used the TPACK theoretical framework in teacher education studies (Beri & Sharma, 2021; Omoso & Odindo, 2020; Antony et al., 2019; Bos, 2011). Other few studies used the TPACK framework focusing on the teaching and learning processes, students' learning and self-efficacy and academic achievement (Akturk et al., 2019). Some of the findings highlight that integration of technology and pedagogical content knowledge (TPACK) is beneficial to the school, college and university teachers' professional development (Beri & Sharma, 2021), teachers' qualifications and teaching experience (Antony et al., 2019). On teaching and learning activities, studies found that the TPACK framework likely helps teachers to update their teaching knowledge, to teach effectively and to increase their teaching experience (Antony et al., 2019; Beri & Sharma, 2021) and promotes confidence among learners, encourage to learn (Beri & Sharma, 2021). According to Akturk et al. (2019), TPACK framed lessons has a positive impact on learning outcomes. As for Soler-Costa et al., (2021), TPACK framework is likely appropriate pedagogical approach for content delivery with appropriate ICT tool. In addition, Akturk et al., (2019)'s study found that teachers' TPACK level influence on academic achievement was likely higher than learners' emotional self-efficacy.

The advent of different educational technological tools implies selective attention with respect to their potential to influence quality teaching and learning. Therefore the teachers' attitudes and perceptions about the new technological tool plays a role in developing or adjusting their TPACK with that particular tool. According to Alomary and Woollard (2015), when presented with a new technology, individuals behave differently with respect to acceptance or denial of the tool which affects the end product. Different theories related to technology acceptance have been used over time to explain end users' perceptions and intentions to use technology within and across organisations (Alomary & Woollard, 2015). In 1989, Davis introduced Technology Acceptance Model (TAM) which was drawn from the theory of reasoned action (TRA) with the aim justifying and explaining technologies user population and behaviour (Lee et al., 2003). According to Momani (2020), the way technology users perceive it or judge it ease of use and quality to produce desired outcomes results in user satisfaction. TAM underwent several empirical studies with a focus on various variables and organizations and has proven to be a robust model for understanding end-user adoption of technology. Several reviews led this model to take different forms, including TAM, TAM2 and the Unified Theory of Acceptance and Use of Technology (UTAUT). The purpose was to harmonise variables, focuses and constructs and address some limitations to identifying end users' perception and attitudes towards the use of technology. In educational settings, nearly all the UTAUT constructs and variables tested proven to have a significant influence on how technology is perceived by users' (Momani, 2020). Among the findings, factors influencing students' technology acceptance and the role of technology in improving students' levels of English were highlighted. Among the technology acceptance model variables measured, the performance expectancy constructs attracted our study's attention. We argue that learners' performance in technology supported class results from teachers' acceptance and attitude to the technology considered which influences the teachers' TPACK level.

Considering the current implementation of CBC in the Rwandan education system, improving the quality of mathematics education using ICT as a tool for teaching and learning is a priority issue. According to Ndihokubwayo and Habiyaremye (2018), CBC requires teachers to teach many skills and teachers' traditional teaching methods are not suitable to assist learners developing desired competences from schools. A study conducted by Rutz et al. (2003) about the use of instructional technologies to improve the learning process for students in fundamental engineering science courses found improvement in students' performance, time on tasks and interest in instructional technology class compared to traditional methods. In addition, students developed satisfaction attitudes towards technology. Therefore, research and policies suggest teachers to embrace participatory and interactive methods that engage learners in the learning process. Interactive technologies are among the ICT tools which are the most widely used in education that can enhance communication and interaction in the classroom (Eastman et al., 2009). Interactive technologies used in education include interactive whiteboards (Papanastasiou, 2016), iPads and PowerPoint presentation with or without learners' technological tools for their interaction (Eastman et al., 2009). In line with the effective implementation of the CBC in mathematics in primary schools, Sakura-Sha, a Japanese private company, has developed the Interactive Mathematics (IM) software for Rwandan basic education learners.

IM software is an offline and easy-to-use software that is built to ensure the exploitation of mathematics in all its aspects, following the CBC for respective levels. The IM content software is offline, easy to use, user-friendly even for IT-illiterate people, and portable (simply after copying and pasting it, you start using it).

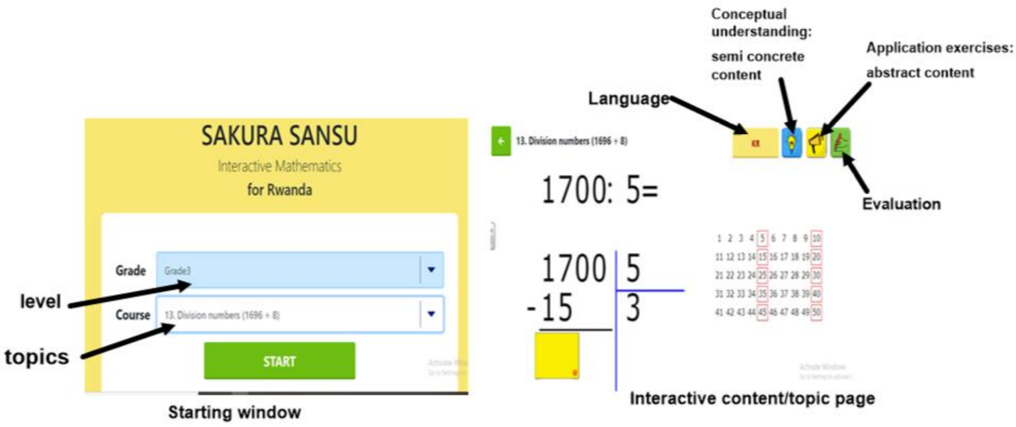

Figure 1. Interactive Mathematics content software outlook of the starting window and example of an interactive content

With Interactive Mathematics content software, mathematics objects are presented in semi- concrete combined with the abstract nature of mathematics, stimulating interactivity through colourful images, diagrams, movement text, and sound. There are also the speeds of activity as well as variation of mathematics activities at different levels of complication that can stimulate and sustain engagement and interactivity in IM content software supported class.

This study is grounded in the TPACK framework with theories of technology acceptance model with its performance expectancy construct. Considering IM software as a new technology in the piloting phase, teachers' attitude and perceptions about IM software ease of use and its quality in influencing quality teaching and learning will influence their TPACK level. This will result in learners' quality of learning and their performance. Therefore, learners' performance will be a result of teachers' TPACK level, which itself will be influenced by their attitudes and perception towards the IM software

3. Methodology

3.1. Research Design and Sampling Issues

This study was designed as quasi-experimental involving control and experimental groups. Schools that were involved in the study were selected depending on the availability of ICT infrastructures such as projection facilities, electricity and computers. The selection focused on public and private schools in an urban area, Kigali, Rwanda. The urban area attracted the focus of our study because of the likelihood of finding there are more private schools of primary level very close to one another and many public schools well equipped with ICT infrastructure compared to a rural area. In addition, the urban area presents more facilities to move from one school to another in a shorter time than in rural area. Therefore, after identifying public and private schools that are ICT equipped, we conveniently selected sample schools and focused on primary-5 learners to participate in this study. Sample schools were assigned to two research groups consisting of treatment and control groups. The teaching of mathematics in treatment group schools uses IM software as an instructional tool and is supported by a laptop, a wireless mouse and a projector. All learners were invited to follow the teaching on the projected content and a wireless mouse was used to facilitate the teacher's and learners' interactions with the content. The same content delivered in treatment group classes was delivered in control group classes but with different instructional tools. Before and after conducting research activities, a pre-test and a post-test were given to learners from control and experimental groups to compare their performance.

Table 1 summarizes the sample, research groups, and research activities.

Table 1: Sample and activities design

Sample groups	**Sample size**	**Research activities**		
	Learners	**Time 1**	**Time 2**	**Time 3**
Group 1: Experimental group [IM class]	92	Pre-test	IM assisted teaching	Post-test
Group 2: Control Group [Traditional class]	102	Pre-test	Chalk and talk teaching	Post-test

The population of this study consisted of primary-5 learners from public and private schools. The sample size consisted of 202 P5 learners including 83 from private schools and 119 from public schools. This study took place during the usual teaching and learning school activities. The scheme of work and the usual timetable were respected the way they were planned, and research activities were undertaken along with the first term (January–March) of the 2020 school year, depending on the topics. While lower grade (P1, P2, P3) learners study for six periods (one period is equivalent to 40 minutes), there are seven periods per week of learning in upper grade (P4, P5, P6). Thus, IM supported teaching activities in grade 5 which was the focus of our study, lasted 7 periods per week.

3.2. Research Tools and Data Collection

This study used quantitative research methods (Cresswell, 2014) whereby data were collected using pre-tests and post-tests. Japanese mathematics education experts in the Sakura-Sha project, together with mathematics teachers and the researchers worked together to design test questions guided by the Rwandan mathematics syllabus of P5 (REB, 2015). Eight questions in total were developed for each pre-test and post-test (see appendix 1). The tests focused on integers and consisted of the following lessons: finding the equivalent fraction, naming the shaded region or shading a region corresponding to a given fraction, comparing fractions, and changing the denominators of fractions to a given common denominator. Test items were similar in the pre-test and post-test with small differences but measuring the same construct. The purpose was to measure learners' understanding and consistency in their understanding. Test items were selected from those suggested in P5 syllabus and P5 learners' book with respect to related content and by respecting their formulation. All test items were routine problems requiring providing a direct answer or short problem-solving working. The answers and marks of the pre-test and post-test were given to learners two days after the post-test was done.

P5 teachers prepared the test items used in the pre-test and the post-test and the researcher based on the content to be delivered using IM and following their ordinary way of setting test items. The content taught in P5 focused on the unit of integers. The lessons delivered were the following: location of positive and negative numbers on a number line, comparison and ordering of integers, addition of integers, subtraction of integers and solving problems involving addition, and subtraction of integers. This content was the only P5 IM mathematics version available. During the teaching activities, the teachers and the learners were engaged with the soft content using the wireless mouse and manipulated the teaching material, working on examples, and learners' exercises projected on the classroom wall. IM supported teacher presentation was sometimes interrupted by switching on learners' individual or group workings followed by the teacher monitoring of learners' activities.

3.3. Research clearance and ethical consent

Before collecting data, the researcher was given ethical clearance to go into the field. In addition, data collection was simultaneously done during the REB-SAKURASHA IM pilot period. Therefore, REB itself prepared schools that participated in the IM piloting phase for hosting the piloting and research activities. The latter took place during the school normal activities and at the exact time fitting the one planned in the scheme of work of teachers. Henceforth, the research did not interrupt the normal school calendar. Instead, it supported/integrated itself into implementing the planned teaching. Before data collection and the implementation of teaching intervention, school head teachers signed consent forms and informed the teachers and learners about the research and project purpose. Teachers were trained and briefed on the traditional and IM teaching activity. The researcher discussed the units of content they were teaching and the concepts to be covered during the research activities.

3.4. Data Analysis

In this study, the researchers mainly used SPSS 23.0 to compute the statistical effect of the teaching interventions provided to analyse data. Class #1 (private and control) missed three learners (2 missed pre-test while one missed post-test), Class #2 (public and control) missed one learner that did not do the post-test, Class #3 (private and experimental) missed two learners (one missed pre-test while another missed a post-test), and Class #4 missed two learners who both did not attend post-test. Thus, 45 learners of Class #1, 57 of Class #2, 33 of Class #3, and 59 of Class #4 were taken for analysis.

Firstly, researchers analysed groups of treatment and test and revealed percent mean score, standard deviation (Std. Dev), significance, the difference (p-value), effect size (f), and learning gains (g). The significance was taken at $p<.05$ (statistically significant), $p<.01$ (high statistically significant), or $p<.001$ (very high statistically significant). The effect size was calculated as f = (Post-test Mean – Pre-test Mean) / Average Std. Dev while learning gains were calculated as g = (Post-test Mean – Pre-test Mean) / (100% – Pre-test Mean). Then, histograms showing the number of learners in range scores were plotted and finally, the school and gender variables were analysed after the treatment effect. Considering that there were 8 participant learners who did not sit for both tests, data from 194 (92 in the experimental and 102 in the control groups) learners who sat for both pre-test and post-test were taken to the analysis phase to analyse the change in performance at individual level.

4. Results

4.1. Primary Five Learners' General Performance

Descriptive Statistics

Table 2. Descriptive and inferential statistics in testing (pre-and post-test)

Treatment	Test	Sample	Mean (%)	Std. Dev (%)	*p*-value	*f* (Test)	*g*
Traditional class	Pre-test	102	43.92	25.19	<.001	.52	.22
	Post-test		56.71	23.31			
IM class	Pre-test	92	39.56	19.77	<.001	1.32	.41
	Post-test		64.83	18.46			

Learners in both traditional and IM classes performed well. Results in Table 2 show that the traditional method improved learners' scores significantly from pre-test to post-test (p<.001, effect size (f) =.52). The learners gained .22 of learning (learning gain, g) from this method. Likewise, IM software improved learners' scores significantly from the pre-test to the post-test (p<.001, f =1.32). The learners gained .41 of learning (g). Therefore, the IM class descriptively showed a greater performance than the traditional class, based on the effect size of significance and learning gains.

Table 3. Descriptive and inferential statistics in teaching intervention (treatment)

Test	Treatment	Sample	Mean (%)	Std. Dev (%)	*p*-value	*f* (Treatment)
Pre-test	Traditional class	102	43.92	25.19	>.5	-.19
	IM class	92	39.56	19.77		
Post-test	Traditional class	102	56.71	23.31	<.01	.38
	IM class	92	64.83	18.46		

Table 3 demonstrates the descriptive difference observed in Table 1. Learners in both traditional and IM classes showed no statistically significant difference (p>.05, effect size (f) =-19) in the pre-test (before learning), while such significance was found to be highly significant (p<.01, f=.38) after learning (in post-test) in favour of IM software. Table 2 shows that learners in the traditional class got an average score of 56.71%, while those in the IM class got an average score of 64.83. This shows a statistical mean difference in performance between traditional and IM supported teaching.

Figures 2 and 3 present the number of learners in a specific range of scores. Figure 2 shows that the number of learners in the pre-test and post-test seem to be at the same level along with each score range.

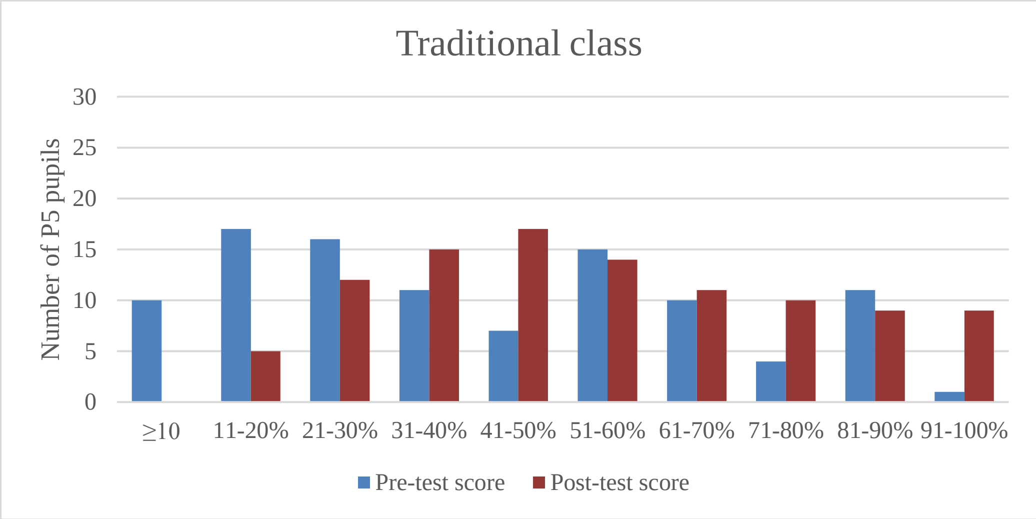

Figure 2. Histogram of traditional class

However, Figure 3 shows a different outlook. Many learners are below 50% scores in the pre-test, while many learners got above 50% on the post-test. Therefore, descriptive analysis shown by these two histograms shows that the IM class improved learning more than the traditional class did.

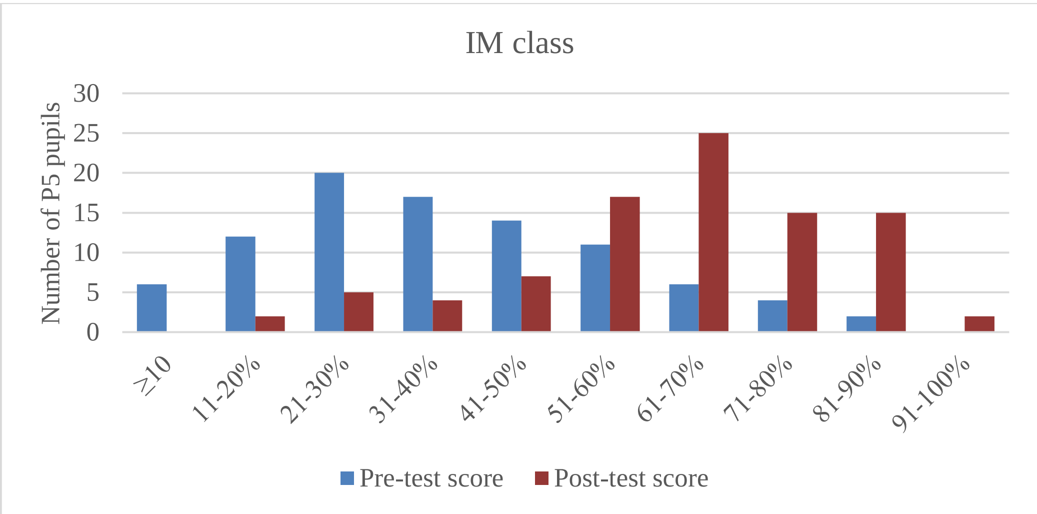

Figure 3. Histogram of IM class

4.2. Variables Analysis with Repeated Measures ANOVA in General Linear Models

After analysing the general characteristics of teaching intervention delivered, researchers opted to look into other different factors, such as the type of schools (public or private) involved and the gender (male or female) of learners involved in the treatment. Private schools (N=78) showed a higher level of performance both before and after learning than public schools (N=116), although public schools showed a slight improvement in post-test (see Figure 4).

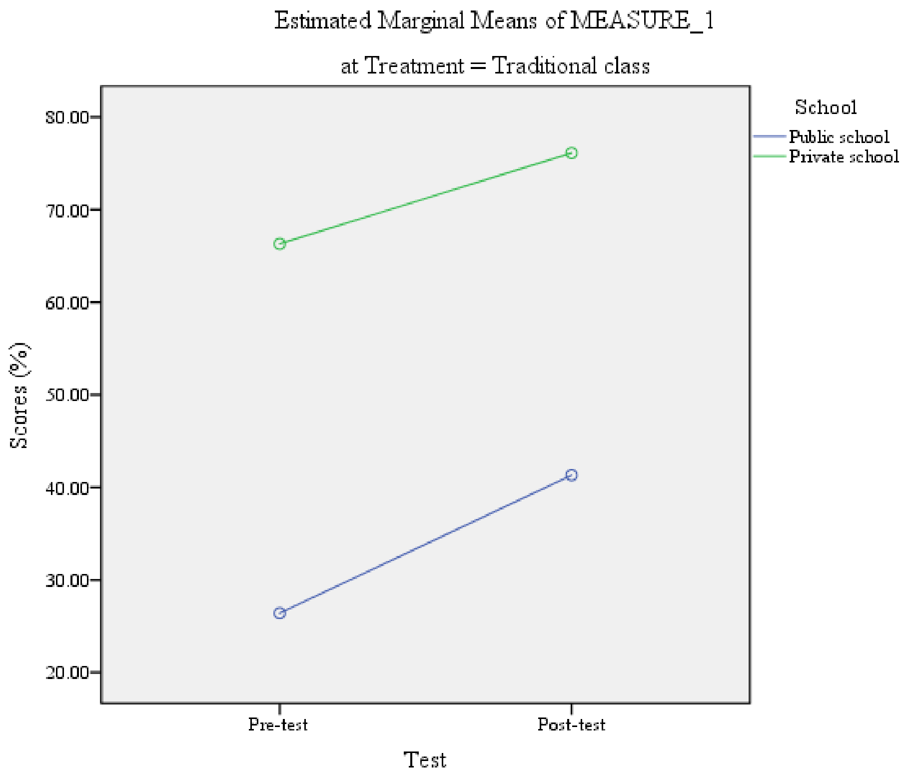

Figure 4. Interaction between Tests, treatment, and schools [Public and private schools performance] in a traditional class

In IM class, such a difference was not large as in traditional class. But still private was higher than public schools, and public schools showed an improvement from the intervention offered more than private (see Figure 5).

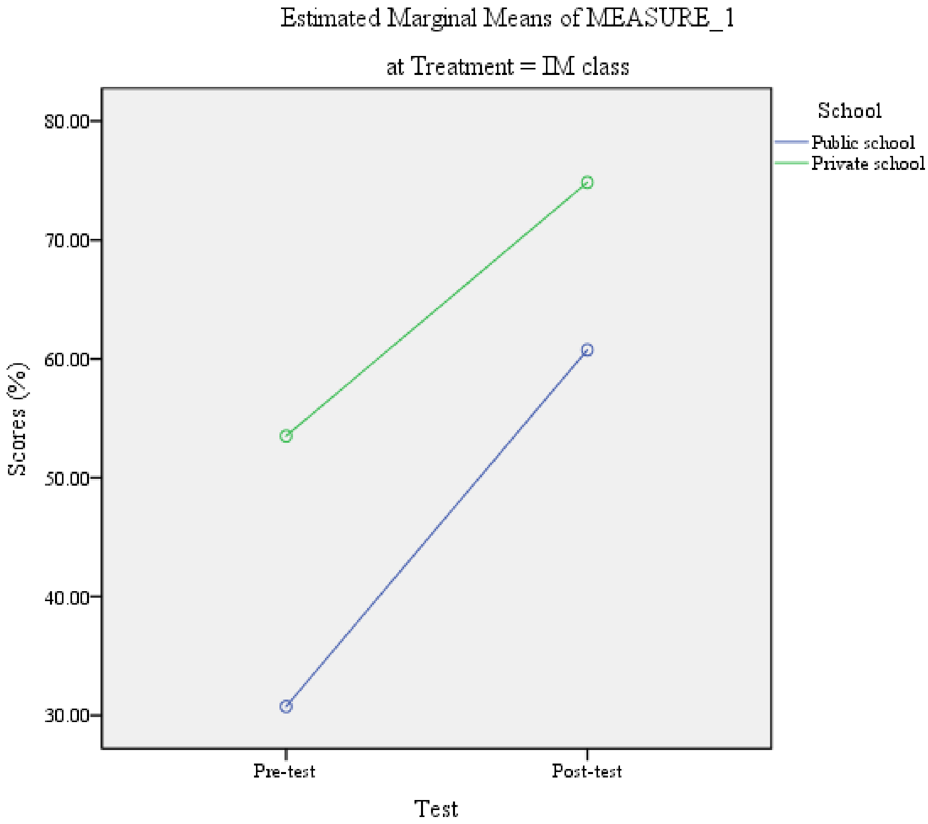

Figure 5. Interaction between Tests, treatment, and schools in IM class

Similarly, an investigation done on gender differences showed male learners (N=100) performing higher than their female counterparts (N=94). For instance, Figure 6 shows that male learners in traditional classes got higher pre and post-test scores. Interestingly, females showed a will to improve in the post-test, descriptively, of course.

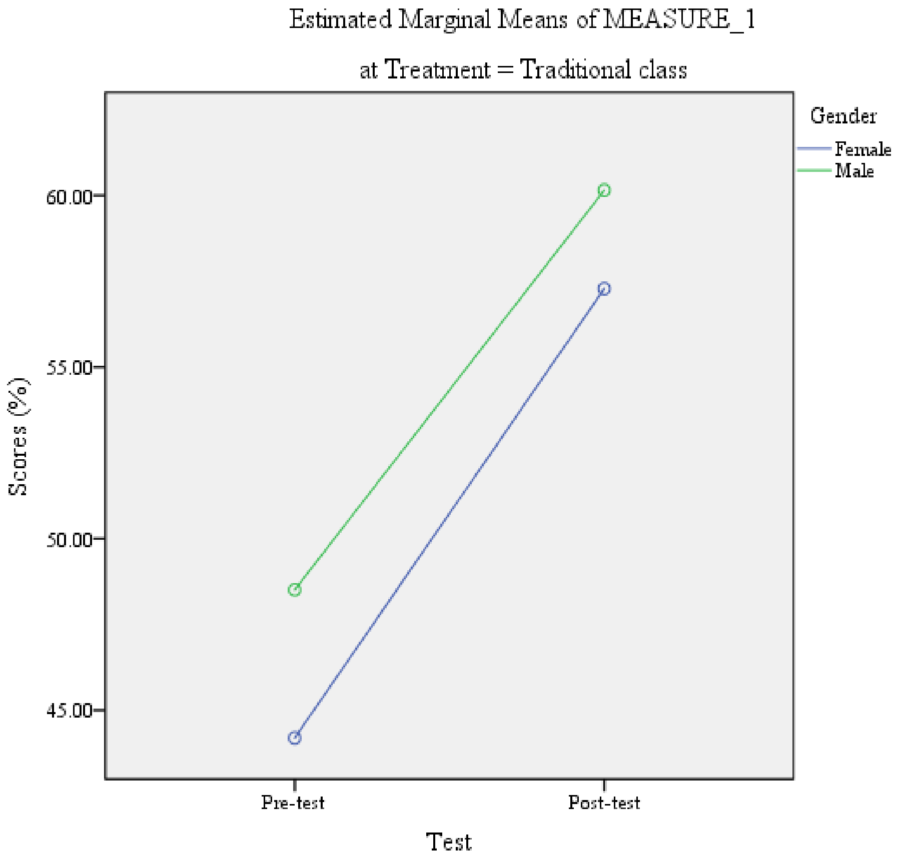

Figure 6. Interaction between Tests, treatment, and gender in the traditional class

Figure 7 shows that male learners in IM class got higher scores in both pre-and post-test, and females showed a will to improve in the post-test.

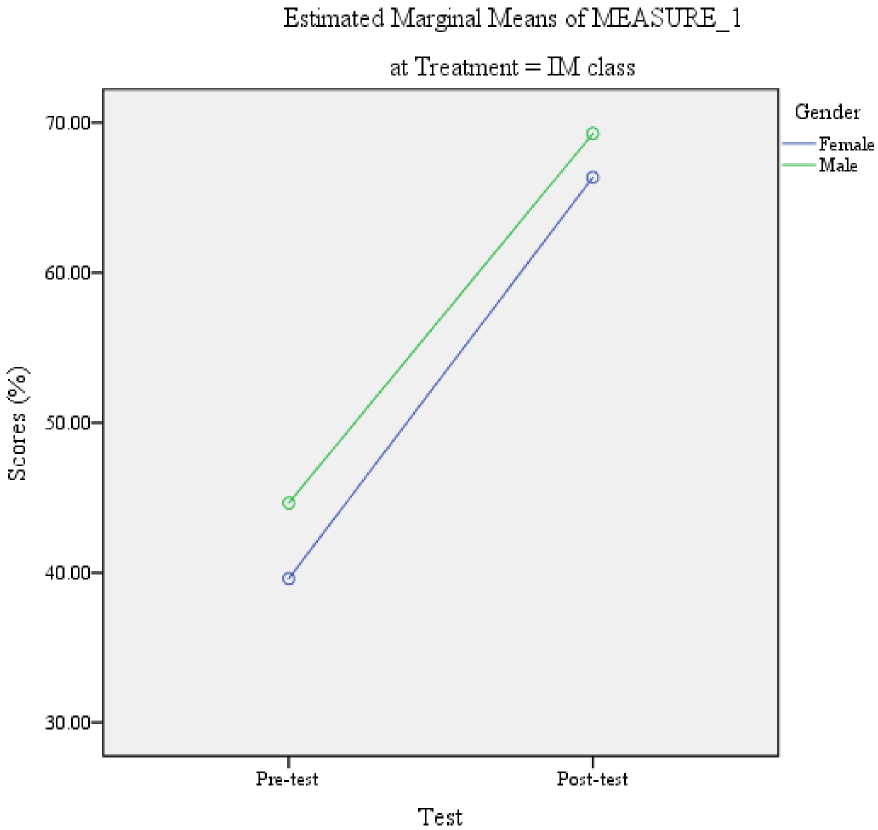

Figure 7. Interaction between Tests, treatment, and gender in IM class

From the above figures, one can descriptively depict information related to school and gender factors. Table 3 presents inferential statistics. Using repeated measures ANOVA through the general linear model in SPSS, there was a statistically significant difference ($p<.05$) between public and private schools in both pre-and post-test scores despite the treatment offered (traditional method or IM software). However, such difference was not realized throughout the test provided and treatment offered.

5. Discussion

5.1. Summary of results

From the analysis of learners' scores, at the beginning of the treatment, the pre-test administered to both traditional and IM class groups generated no statistically significant difference ($p>.05$). Learners' knowledge from the treatment and control groups was found equivalent. However, results from the post-test generated a significant difference ($p<.01$, $f=.38$) in learning outcomes between the treatment and control group in favour of IM software. This is consistent with Beri and Sharma, (2021)'s study findings about the role of ICT in improving conducive learning environment. Therefore, our study results showed that the teaching of mathematics with IM software as a teaching and learning technology support might promote a conducive learning environment and influence learners' academic achievement. Comparing performances, IM-assisted class learners performed better than learners who studied the same content in traditional class settings. In addition, statistical analysis found learners learning gain to be higher in IM-assisted mathematics classes than in traditional mathematics class teaching and learning. Although learners performed better in the post-test than in the pre-test for both traditional and IM assisted classes, more learners who scored above 50% were found in IM assisted classes than in traditional classes. Considering the school statuses, the study found that although private school performance was higher than public in traditional and IM assisted classes in pre-test and the post-test, the public school showed a greater improvement in the post-test than in private. By analysing learners' scores by gender, boys outperformed girls in both traditional and IM teaching. However, girls in IM-supported teaching manifested a greater improvement in performance than the boys' by comparing their pre-test and post-test scores.

5.2. The Role of Smart Teaching Using Interactive Mathematics Software on Learners' Performance

According to Orodho et al. (2016), administering a pre-test to the experimental group and control group is likely a means to measure the groups' equivalence of knowledge. From our study's findings, learners in both traditional and IM classes showed no statistically significant difference ($p>.05$, effect size (f) $=-19$) in the pre-test (before learning), while such significance was found to be highly significant ($p<.01$, $f=.38$) after learning (in post-test) in favour of IM software. Therefore, the pre-test results showed the equivalence of knowledge in the two groups, while the post-test results showed an improvement in learners' performance due to IM use in teaching and learning. Our study' results are in line with findings that hold the view that innovation through technology is one of the ways developing environments is necessary for effective learning (Delen & Bulut, 2011). This argument was based on the findings of OECD countries in international mathematics competitions, which ranked Japan and Singapore among the best mathematics performers resulting in their use of computer technologies in mathematics classrooms (Delen & Bulut, 2011). Therefore, using IM in teaching and learning mathematics at the primary level may be a good start on the journey of optimizing learning and improving the quality of mathematics education from early level of education. This confirms De Witte and Rogge, (2014)'s study results which found a correlation between access to technology and learner achievement. Considering differences in classroom environments, this study is in line with Rutz, et al. (2003)'s study which found that learners' performance improved in instructional technology methods more than in traditional teaching methods. In quest of reaching learners' different learning abilities, the use of IM may be a good means to help both slow learners and fast learners based on its potentials to attract learners' attention and to boost their learning interest. According to Jena (2013), a smart class learning setting is better for teaching both slow and fast learners than in traditional classes. In our study, this was confirmed by the results of IM class compared to control classes.

According to Yang (2015), when learners are presented with interesting teaching strategies, they develop positive attitudes toward mathematics, which is likely to contribute to quality learning resulting in good performance. These strategies may include the using technological tools, like IM used in our study, or applying mathematics learning models like the one used by Dafid Slamet et al., (2021)'s study. Factors of performance in mathematics include learners' ability to think critically and solve problems. Dafid Slamet et al.'s (2021) study found that junior high school learners' critical thinking abilities developed after using a mathematical learning model and that dissatisfactory performance results from learners' low critical thinking abilities. Effective teaching should not only promote critical thinking skills but also creative thinking skills. Purwoko et al., (2019) explained that a comprehensive implementation of PCK model can improve learners' creative thinking skills more optimally. Therefore, improved learners performance may be an indicator of their improved critical thinking abilities. Henceforth, considering that learners' performance improved thanks to IM use in mathematics class, IM software can be ranged among the strategies to promote learners' critical thinking skills. This is obvious based on IM settings and features of feedback whereby the right answer is accompanied by an audio and written positive reinforcement while a wrong answer is accompanied by a negative reinforcement. The latter triggers learners thinking critically to dig up to finding the right answer. We can infer that if IM is used repeatedly and effectively, teachers' TPACK knowledge would improve and learners may move from being critical thinkers to becoming creative thinkers (Purwoko et al., 2019).

Although some studies found that learners working with computer-assisted instructions are more likely to be low achievers compared to their classmates in traditional classes (Drigas & Papanastasiou, 2014), other studies highlighted the potential of ICT to make learning enjoyable and to help learners improve their performance. For example, Gachinu, (2014)'s study explains that when ICT components are applied in concretizing abstract mathematics concepts such as 3D geometry, it may serve as a means to improve performance or test scores. Likewise, the findings of our study revealed that learners' scores from the post-test improved after learning in IM supported class.

Drawing on our study results, the improvement of performance by IM can be interpreted as resulting in learners' and teachers' positive attitudes towards mathematics and IM software. Therefore, these results seem to be in line with the UTAUT model with its performance expectancy construct on the outcomes of technology use in educational settings (Momani, 2020). In addition, the results may have depended on the teachers' ability to effectively integrate IM in teaching and learning as recommended by the curriculum. Our findings confirmed that the effective use of IM in teaching and learning might result from teachers' perception and acceptance of that technology as stipulated by the UTAUT model based on the performance expectation. This results in the development or improvement of teachers' TPACK level, which leads to the effective use of technology as an instructional tool. During this study, teachers' TPACK level manifested during IM assisted lesson through experimentation period when teaching activities were integrated with ICT skills. From lesson planning stage to IM supported teaching activities, teachers' pedagogy was IM enhanced and the content was delivered using IM enhanced instructions. Teachers themselves were the ones to set the projector, the computer, wireless mouse and use them to teach or engage learners in using them to learn. IM content was organised into semi-concrete, quick exercises and evaluation levels. Teachers managed to take learners through all these levels using a wireless mouse. In addition to mathematics knowledge, teachers helped learners to develop, for the first time and for almost all learners, basic ICT skills including clicking, cautiously moving the mouse and the curser. During evaluation, questions were projected for learners to work on them, while the teacher was moving around to check learners' working. Using IM software, evaluation was given in plenary and a specific sound accompanied each right or wrong answer for reinforcement or correction. The software presented also checking options which were very interesting to learners. Teachers managed to use all these IM features to make the lesson understandable and enjoyable to learners. IM features including ease of use and its motivational features including different forms of sound, colours and movement influenced teachers' acceptance of the tool and their flexibility to integrate it in lessons. Therefore, drawing on TPACK theory and technology acceptance model, our study confirmed that technology use in mathematics class can promote effective learning (Delen & Bulut, 2011) and improve learners' performance.

5.3. The Role of Interactive Mathematics Software on Public and Private School Learners' Performance

From the analysis of the variables with repeated measures ANOVA in general linear models, private school (N=78) showed a higher level of performance both before and after learning than public schools (N=116). However, the public schools showed a slight improvement from the intervention offered more than private schools. Therefore, the use of IM in mathematics teaching influenced learners' performance more in public schools than in private schools. This led us to confirm our argument that the use of IM in public primary schools teaching promote the learning environment of overpopulated classes resulting in learners' increase in performance. On the one hand, our results align with Khun-Inkeere's (2016) study, which found a difference in private and public school performance in favour of private schools. This was confirmed by the results, which showed that private schools' performance was higher than public schools' one in both the pre-test and the post-test. This is obvious as private schools present a conducive learning environment due to factors including a manageable number of learners per teacher. In addition, private schools host learners from able families, mostly educated and having enough financial means and technological tools to help learners learn effectively both in class and outside class (Khun-Inkeeree, 2016). For example in Rwanda, it was reported that while one public school teacher struggles to teach an average of 62 learners, a teacher in a private school teaches only 35 learners (MINEDUC, 2018).

On the other hand, our findings show that public school learners' performance can improve by IM use in class. These findings are in line with Chenoby's (2014) study, which found the existence of a relationship between access to technology and learner achievement. Gachinu's (2014) study explains that when ICT components are applied in concretizing abstract mathematical concepts such as 3D geometry, it may serve as a means to improve performance or test scores and to address the teachers' and learners' challenges caused by exposure to ICT in class.

The use of IM influenced teachers' TPACK level in teaching mathematics, which also resulted in IM software ease of use and acceptable by teachers. The findings show public school performance increased in post-test more than private schools did. We can say that public school teachers perceived IM as easy to be used in teaching and manifested acceptance towards it. Therefore, this resulted in better teaching and learners’ performance. This can be understood using Akturk et al.'s (2019) study, which explained that TPACK framed lessons have a positive impact on learning outcomes. In addition, it was found that teachers’ TPACK levels influence academic achievement (Akturk et al., 2019), especially with appropriate ICT tools. Our study used IM software developed in accordance with the CBC framework, which is under its implementation. Therefore, IM is an appropriate ICT tool to teach mathematics in primary level. It can therefore influence learners’ performance as it influences the development or improvement of teachers’ TPACK levels. Besides, the way teachers perceived IM as easy to be used and their acceptance to use it while expecting performance, influenced their ability to integrate it in teaching and learning resulting into learners’ performance. Therefore, the use of IM in public schools in Rwanda can be a means to overcome hindrances to achieving quality education which includes poor teaching, crowded classrooms and teacher heavy load as mentioned by Nizeyimana et al., (2021). This would result in improving performance in public schools as it was realised from our study findings. If quality education is to be achieved in public schools of 9YBE and 12YBE statutes, which present many hindrances to quality education compared to private ones, the learning environment conducive to effective learning should be set out primarily. Therefore, IM software is an important ICT tool for primary level schools that should be considered when designing classroom environments for effective learning (Delen & Bulut, 2011) and that can contribute to the development of TPACK knowledge of primary level school teachers.

According to Akturk et al. (2019), TPACK is appropriate for educational settings of the 21st century for learners and teachers of grade and secondary to support the development of basic skills, interests, and confidence in learners learning, which are necessary for lifelong learning. IM software manifested the potentials to develop teachers’ TPACK knowledge necessary to influence learners’ performance. In addition, teachers’ perception of IM ease of use and its potential to influence performance affect public school teachers’ TPACK levels. This was evidenced by the improvement of learners’ performance in the post-test by IM.

5.4. The Role of Interactive Mathematics Software on Male and Female Learners' Performance

Mathematics education in Rwanda has long been characterized by gender disparities in enrolment and in performance mostly in favour of males. From the findings, the use of IM in teaching improved female and male learners’ performance. Although males’ performance remained higher than females’, the latter showed a will to descriptively improve in post-test. Studies on gender and performance highlighted many hindrances to girls’ performance in mathematics. These include low confidence in learning mathematics (Uwineza et al., 2018) and external factors to learning, including the learning environment (Dev, 2016).

Based on the findings, IM use in mathematics class manifested potential to create a learning environment suitable to improve both females' and males' performance

(Khun-Inkeere (2016). Therefore, this study agrees with Dev's (2016) study, which found that girls learning and performance depend more on external factors and less on learning abilities, while boys depend on internal factors. Therefore, the use of IM in teaching mathematics created a suitable learning environment for all learners which, however, benefited female's learning and improved their performance. It was found that ICT adoption in conservative environments where females and males learn separately improved the performance of female learners more than male learners (Basri et al., 2018). However, our study was conducted in mixed gender learning environments whereby one classroom hosts females and males who learn together. Therefore, our results are not in line with Basri et al., (2018)'s findings as we conducted our study in mixed gender classroom and that IM benefited both males and females in the same way. Rwanda education system focuses on education for all (EFA) which promote equality, equity and inclusive education. Therefore, public schools (of 9YBE and 12YBE statutes) learning environments in Rwanda are all non-conservatives and promote equal, equitable and inclusive learning for all learners. However, some secondary private schools' learning environments are still conservatives. The focus of our study was in primary school level of public and private schools whose learning environments were non-conservative. Therefore, IM improved male and female learners' performance in non-conservative learning environments. As it is pointed out by Uwineza et al. (2018), teachers play an important role in widening the gap between male and female learners' performance. A study about teachers' TPACK level in teaching biology and chemistry found no difference between male and female teachers' TPACK level (Akturk et al., 2019). Therefore, these findings together with this study findings are supportive to the fact that the integration of technology in class activities can benefit both female and male learners. In addition, as mentioned by Akturk et al.'s, (2019) study that found no difference in males and females TPACK level, IM influences male and female teachers' TPACK knowledge in the same way. It follows that IM use in mathematics class can contribute to promoting gender equity and equality in class based on our findings. It can therefore be used to support teachers' to promote learners' gender balance in the learning of mathematics.

6. Conclusion

In quest of improving quality implementation of the CBC and addressing issues hindering the achievement of quality education in Rwanda, IM software was developed to support the effective teaching and learning of mathematics at the primary level. This study focused on the effect of IM supported teaching on grade-5 learners' performance. From our findings, IM software used as instructional tool manifested the potential to design the classroom environment for effective teaching and learning and to improve learners' performance. Therefore, IM software would be more beneficial to public schools in Rwanda to address issues related to quality education delivery in overpopulated classes. However, this would depend on teachers' perception and acceptance of IM software ease of use with reference to teachers' and learners' performance expectations. Teachers should be able to make a good judgment about IM use in mathematics lessons so that they can effectively and meaningfully use it in pedagogy. This is in line with the Ministry of education's policy that stresses the role of the teacher in the appropriate pedagogical use of ICT in class to transform teaching and learning and improve the quality of learning outcomes.

It is worth noting that this study faced different constraints. Some participant teachers and learners were having very low basic ICT skills at the time of experimentation. Therefore, they were assisted in some ICT activities like clicking and projecting content, which was sometimes interrupting the smooth and effective teaching flow. Since this study was purely quantitative involving learners, a similar study focusing on the qualitative aspect of IM in mathematics class and/or teachers' lived experience in using IM software would bring more information about the features of IM in quality mathematics teaching and learning.

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Declaration
Author contribution:
Innocente Uwineza: Conceptualisation, Writing- Original Draft, Methodology, Formal Analysis, Editing and Visualization;

Prof. Alphonse Uworwabayeho (Ph.D.): Review & Editing, Validation and Supervision;

Kenya Yokoyama: Methodology, Software Developer and Trainer

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Public Interest Statement
This article presents a comparative analysis of learners' performance in traditional teaching and technology-enhanced teaching in mathematics classes. It focused on primary-5 learners' performance using Interactive Mathematics (IM) software as an instructional tool. IM as a new technological tool under its piloting phase was developed to support the effective implementation of the Competence Based Curriculum (CBC) in mathematics at the primary school level in the Rwandan education system. Considering that the quality of mathematics education faces hindrances especially in public schools, this study explored the comparative effects of IM software in public and private schools with a glimpse into gender issues. It then explained the importance of IM in addressing quality mathematics education issues at primary school level in Rwanda.

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Appendix 1. The test provided to grade-5 learners

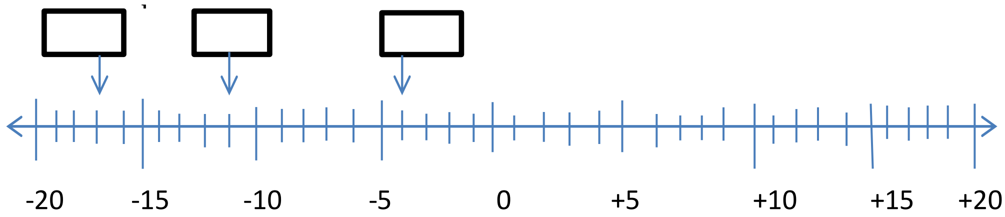
Test for P5

Pupils' name:…………………………………………………………………

Pupil's number:…………..…. Gender: Female: ☐

Male : ☐

1. Fill in the box below with



2. Match the right and the left by drawing the line

Negative numbers . .+20, +11,+8, +15

Zero . .+17, -9, +25, -31

Positive numbers . .-8, -17, -25, -14

Integers. .0

2. Fill in the box with "less" or "greater".

+14 is ☐ than -18

-15 is ☐ than -5

4. Fill in the box with the sign (< or >)

-11 ☐ +9

-12 ☐ -23

3. Write the numbers from smaller to greater in ascending order.

-12, +15, -6, +9, -18

Answer: ____ ____ ____ ____ ____

4. Write the numbers from greater to smaller in descending order.

-12, +15, -16, 0, +9

Answer: ____ ____ ____ ____ ____

5. Calculate the following:

(-6) + (+3) = (+5) – (-5) =

(-2) – (-6) = (-3) + (-7) =

6. Fill in the box below with number

(-13) + ☐ = 0

☐ +(+18)=0

7. Fill in the box below with number

The inverse of +5 is ☐

The inverse of -8 is ☐