Classroom practices in primary schools' mathematics teaching supported by the Interactive Mathematics Software for Rwanda

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ABSTRACT

Over recent decades, the integration of technological resources in education increased growingly. However, studies about the assessment of information and communications technology integration in primary school mathematics activities remained few. This research intended to comparatively examine the aspects of classroom practices observed during the implementation of the Interactive Mathematics (IM) Software in primary schools in Rwanda. Designed as quasi-experimental, it involved the experimental groups from Primary-2, Primary-3, Primary-4, and Primary-5 and analyzed aspects of school statuses, the school years, and the educational cycles. Data collected using Likert-scale measurements from 63 classroom observations were analyzed using Microsoft Excel and a two-sample t-test analysis was conducted to determine if the significance of mean differences. The findings revealed no significant difference between lower and upper primary based on a p-value of 0.829368908 (p-value>.05) and between the 2019 and 2020 teaching periods (considering the same teacher) based on the p-value=0.324542 (p-value>.05). However, the findings revealed that private and public schools' mean differences were significant based on the calculated p-value equal to 0.007144 (p-value<.01). The study made various recommendations towards using IM software to promote quality mathematics education in primary schools in Rwanda and pre-service teacher training to boost the initiation process of their technology-enhanced pedagogy knowledge to teach mathematics.

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1. INTRODUCTION

Over recent decades, educational technological resources increased growingly together with related policies to cope with 21st-century educational aspirations. Information and communications technology (ICT) was advertised as a powerful tool that can improve educational outcomes [1]. Therefore, education systems within different countries strived to integrate technology-based tools to improve learning [2]. Technology development in education implies new teaching methods and technologies that are expected to support effective learning [3]. With the current educational orientation focusing on developing 21st-century educational competencies, appropriate interactive technological tools should be used to support the teaching and learning processes to achieve quality education.

Different countries' development depends on many factors including ICT use [4]. In Rwanda, science, ICT, and mathematics are among the priority subjects to be focused on while striving for sustainable development [5]. Technology is considered one factor among others that are likely to promote rapid economic and industrial growth [5]. Different strategies and policies to improve quality education from primary and secondary education levels have been put in place. Those include the adoption of the Competence-Based Curriculum (CBC) together with ICT policy to support its implementation. This can be realized through the Education Sector Strategic Plan of 2018-2024 (ESSP) [5] and in the tool for monitoring the government performance of the second Economic Development and Poverty Reduction of 2013-2018 (EDPRS2) [6], which identify technology use among the priority areas for productivity, and youth education. Policies promoting ICT in education aim at creating smart education nationwide, ensuring ICT use in the effective implementation of learner-centered approaches and inquiry-based learning in classroom practices [7]. The implementation of these policies resulted in some initiatives like the One Laptop Per Child (OLPC) program which was implemented in Rwandan primary schools with the purpose to distribute learners' laptops as the main target of ICT policy to enhance quality education in Rwandan primary schools [8].

However, quality education achievement through ICT use in classroom practices faces different challenges. First of all, the rate of learners per teacher keeps increasing. Teachers have to deal with teaching in overcrowded classrooms with a double-shifting system of handling two different classes in one classroom alternating in mornings and afternoons [7]. In addition, the traditional teaching methods using blackboard, chalk, and talk, which still dominate mathematics classes are not effective for quality teaching and learning. While integrating ICT into education, the majority of students teachers and teachers in service teach without adequate training about the ICT tools use, which results in learners' poor learning outcomes [9]. Therefore, despite the provision of ICT tools and infrastructures to many schools, teaching continues to be traditional with an insufficiency of teaching resources like books [10].

While public and private schools in Rwanda implement the same curriculum, these challenges are more pronounced in public schools than in private ones. For example, many teachers in public schools in Rwanda, especially the most experienced ones, are from a French background and struggle to teach in English from Primary-4 since 2009 [11] though strategies like Mentorship Program had been put in place to address that issue. The Government of Rwanda invested much in integrating technology into primary schools and many schools have been provided with ICT tools and infrastructures [9]. However, there is no literature about the assessment of effect of technology integration in education on the learning outcomes and the classroom processes within primary schools, especially in mathematics. Therefore, based on all mentioned challenges to quality education, there is a need to question what happens in an ICT-enhanced classroom while considering also that the teachers' teaching skills with ICT tools are questionable too [7].

The present study follows an initial piloting phase of Interactive Mathematics (IM) software in classrooms as a result of collaboration between Rwanda Education Board (REB), University of Rwanda-College of Education (UR-CE) and Japan International Corporation Agency (JICA), where UR academics closely worked with selected sample schools. It sought to ascertain the aspects of classroom practices in IM-supported mathematics classes. Particularly, it intends to answer the question: what are the classroom practices differences observed in IM-supported classes based on school status, class levels, and school years? The findings will inform Rwanda Basic Education Board (REB) about the role of IM software to promoting quality mathematics classroom activities in primary schools in Rwanda.

2. LITERATURE REVIEW

Mathematics learning is considered as a social undertaking [12]. During mathematics activities, learners are provided with powerful math problems to solve through thinking, agreeing, and disagreeing. In addition, they are trained to check and clarify solutions to problems that are beneficial to their conceptual understanding and achievement [12]. During mathematics class activities, different factors may influence learners' achievement. Learners' attitudes toward mathematics problem-solving activities or other tasks, like patience, confidence, and willingness influence their mathematics achievement [13]. The willingness to invest in learning is called cognitive engagement [14]. Hence, learner engagement in mathematics is factor in their achievement. Positive and negative engagement dimensions influence learners' level of classroom activity and later on influence their academic achievement [13]. The promotion of classroom interaction during mathematics class may draw on strategies like using rich mathematics tasks with multiple solutions and technological tools. This likely promotes learners increased opportunities to explain and justify their reasoning which cannot be achieved with simple operations and single solution [12]. However, in lower primary, multiple-solution problems are presented with the concrete, abstract, and semi-concrete nature of math tasks [12]. Hence, ensuring the effectiveness of mathematics teaching and learning should result from engaging learners in concrete, semi-concrete, and abstract mathematics tasks with multiple solution activities.

While enhancing interactive conversation in the classroom, interactive ICTs can be good tools to provide learners with multiple solution activities. According to various studies [15], [16], interactive technologies share the same potential as any other ICT tool for quality classroom practices improvement. These include various impetus portrait and use like movement, image, and sound, while addressing the needs of diverse types of learning [16]. Depending on the subject, different types of interactive technologies can be used in classroom activities. Those include interactive whiteboards (IWBs), iPads, and PowerPoint presentations with or without learners' technological tools for their interaction, general data projectors, and interactive projectors [17]. Some interactive technologies are useful in gaining learners' attention and interest because they give them opportunities to share their ideas anonymously. They also require them to respond frequently to the material being presented.

In primary mathematics class, the IWB increases pupils' interest and facilitates their learning [18]. However, some literatures highlight different pedagogical and financial challenges of using IWBs in education [17], [19]. For example, the use of IWB requires the constant presence of electricity which otherwise interrupts the classroom activities processes [17]. In addition, one study explained that that IWB perpetuates the traditional role of the teacher as a "sage on the stage" while learners follow classroom activities passively [17]. However, for interactive projectors, the teacher-learner interactivity is improved with their free movement around the class although they can both strengthen the teacher-centered approach unexpectedly [17]. While using IWBs, teachers remain next to the board, standing in front of learners instead of moving around the classroom checking on learners' engagement and interactive learning [17]. Besides, there is no significant change in teachers' pedagogy by using IWBs as they are poorly aligned with the vision of learner-centered classroom instructions that most people claim to believe [19]. On the contrary, interactive projectors can allow movements around the class and increase the teacher-learner-content interactivity.

However, some research suggested that newer technologies under development can remove the concern about teachers being anchored in front of their classes and promote more interactivity in learner-centered teaching. For example, a larger iPad can enable full interactivity from any position in the classroom, not just limited to the teacher [19]. Jalinus and Alim [20] argued that teaching mathematics to elementary kids using interactive mathematics media is important since it enhances learners' creativity, learners,' enjoyment of the lesson through a fun environment, and enhanced independent learning [20]. The current educational era is promoting learner-centered teaching and learning approaches with more learners' engagement in activities. Therefore, less lecturing and more engaged learners' activity should be expected in-class activities to ensure quality classroom activities.

ICT not only facilitates teachers in their teaching but also contributes to learners' performance and everyday learning [8]. ICT has the potential to monitor learners' achievement through regular assessments, which can lead to making appropriate decisions and effective educational management. In addition, ICT can contribute to strengthening teachers' professional development, which will, in turn, improve the quality of education [7]. For example, spreadsheets, computer algebra systems, or graphical calculations can help learners to solve some mathematical problems [21]. Therefore, ICT use in mathematics subject could influence the classroom practices and improve quality mathematics delivery.

For some studies, effective educational technology integration is directly associated with teaching and learning practices [22]. For other studies, success in technology-enhanced classroom practices results from the availability of ICT tools and facilities with the teacher's abilities to effectively deliver an ICT-supported teaching [4]. Gichuru and Ongus [22] assert that there exists a link between learners' academic achievement and the teachers' skills in effectively delivering an ICT-supported teaching [23]. This implies that teachers' competences level in teaching using technology may influence the quality of classroom practices. Technological pedagogical content knowledge (TPACK) model supports the growth of teaching competencies to effectively integrate ICT in the educational practices [24]. According to Antony *et al.* [25], the teacher's qualification and the teaching experience (with ICT) influence the teachers' TPACK level. Drawing on the TPACK theoretical framework, the effective teaching practices should demonstrate the effective connections among technological tools used, the content, and specific teaching approaches. In addition, the teachers' frequent use of ICT tools in teaching activities should improve their TPACK levels resulting in effective teaching and learning with ICT. The Interactive Mathematics (IM) software is a technological tool used in this study. It implies teachers' experiences in teaching practices with IM, their mastery of basic computer skills as well as technological pedagogical content knowledge to influence quality teaching and learning aspects in IM-supported class environment.

The Interactive Mathematics software is the educational software which is originally developed in Japan based on the experience, and know-how of Japanese mathematics education, which is utilized by both teachers for mathematics lessons and by learners for their learning of mathematics. IM is recognized as a unique software using animations, and sounds for explaining and learning mathematics effectively. The IM use requires the teacher to save it on a computer and to use a projector to display the IM content on a classroom screen. Compared to the IWBs and the interactive projectors, the IM need constant presence of electricity like the IWBs [17] but unlike the IWBs, the use of IM allows the teachers' free movement around the class using a wireless mouse. The IM software for Rwanda is a new ICT tool that has been in the official piloting phase since 2018 in primary schools. The pilot phase was planned for taking a period of three years which was however extended to 4 years due to lockdowns that resulted in the closing of school activities in 2020 following a covid-19 pandemic. Since its first implementation in Rwandan schools, it had not been empirically tested for its pedagogical potential. Therefore, there is a need to question the teaching and learning aspects that can be observed in IM-supported classroom activities.

3. RESEARCH METHOD

3.1. Research design

We designed our study as quasi-experimental involving the control and the experimental group as well as the classroom observation tool of data collection. It intended to examine the teaching and learning aspects in IM-supported classes of Primary #2, Primary #3, Primary #4, and Primary #5. It focused on the observation of teaching, and learning practices in the experimental group where the IM software supported the classroom activities. During the intervention, the IM software content was manipulated on a computer using a wireless mouse and projected on the classroom wall to be visible to all learners and to support mathematics teaching. The observation sheet stating items about the teaching, learning, and gender aspects that were expected to happen in class was developed in advance. Each item was planned to be evaluated with Likert scale measurement. One observation sheet was used for one 40 minutes lesson. While filling in the sheet, the observer used the item statements (for each variable) developed in advance and evaluated them as "Bad", "Fair", "Good", "Very Good" and "Excellent" depending on their manifestation in class. One lesson was observed generally by one or rarely by two observers. A reflection session between the observer and the mathematics teacher was always conducted at the end of each lesson. The teacher explained the teaching and learning activities and evaluated himself or herself with the purpose to improve in the next lessons. Based on the observation, and after the teacher's self reflection, the observer provided constructive feedback to the teacher. After each day, completed observation sheets were collected and classified for further data processing.

During the research activities the observer was the researcher herself or assistant researchers given that many lessons had to take place at the same time in different schools. Assistant researchers were SAKURA-SHA agents who were involved in IM piloting activities who participated in the teacher training sessions about IM and who contributed in the design of the observation sheet. During the observation activities, the researcher, assistant researchers as well as teachers established in advance a pedagogical community united by a common purpose [26] and collaborated mutually about methods and strategies to effectively deliver IM-supported teaching. They discussed the lesson plan and delivery through microteaching sessions undertaken during the IM training of teachers.

3.2. Instruments

This study used a classroom observation sheet developed in advance by the research team together with teachers to collect data. The items of the tool were developed to measure the teaching and learning aspects while IM-supported teaching of mathematics was taking place. On the teaching and learning aspects, one item was developed to measure curriculum compatibility with IM content while five items were developed to measure the teachers' methodology. On learning aspects, three items were developed to measure learners' engagements and one item to measure the aspect of gender differences of IM content. However, the teaching and learning aspects observed attracted the focus of this study.

The researcher, to maintain validity, independently revised the observation sheet. Items of the observation tool were evaluated using a Likert scale with five levels from bad, fair, good, very good, and excellently scored, respectively, from 1 to 5. The score 0 was not used because it was assumed that once there are teaching and learning activities, learning and teaching aspects are there but to different extents. Therefore, a score of 0 was believed to mean that the aspects were not there, while in any case, the aspects a likely there but at a different level. The observation method consisted of evaluating a particular item by ticking in front of it in the place provided as bad, fair, good, very good, or excellent. In addition, some comments or explanations were provided to clarify particular evaluation of an item and reduce some biased information from respondents. The heading of the observation sheet indicated the date, the lesson title, the teacher's name, the school name, and the school status, as well as the observer's name. This was used to classify these documents by respecting the school year of piloting phase (2019 or 2020), the school type (public or private) and the class level (P2, P3, P4 or P5) accordingly. The items were developed to evaluate each of the two main variables which were "the teaching aspects" and the learning aspects". The research observation tool used is presented in Table 1.

Table 1. Interactive mathematics lesson observation sheet

Variables	Items	Bad (1)	Fair (2)	Good (3)	Very good (4)	Excellent (5)
1. Teaching aspect						
Curriculum compatibility	IM is matching the contents of textbooks and the objectives of the syllabus					
Methodology	The teacher understands IM contents and effective operations for Learners					
	The time management is effective					
	The teacher passes a mouse to learners to let them operate IM					
	The teacher is motivates in his teaching using IM					
	The teaching methodology is effectively developed by IM compared to the last time					
2. Learners learning aspects						
Engagement	All learners are actively engaged in the task by IM lesson					
	All learners are concentrating on learning during a lesson with IM					
	All learners are motivated to learn					
3. Gender aspects						
Gender differences	IM content is not biased to one of the gender differences					

3.3. Sampling and population

This study was conducted in public schools and private schools during the teaching and learning activities that took place during school activities in 2019 and 2020. The total number of lessons conducted during this study was 108 from lower and upper primary during the 2019 and 2020 experimental periods. During 2019, P2 and P3 consisted of four classes in two public schools and two classes from a private school, and in 2020, P3, P4, and P5 consisted of nine classes in three public schools and three classes from one private school. Public schools presented more interest, and free consent to participate in the study and attracted the research attention due to different issues pertaining to quality teaching and learning they present, including big class sizes. Therefore, the number of public schools was higher than that of private schools. Theoretically, for every 40 minutes lesson (single period), the observation sheet should be filled in to provide data about the teaching and learning aspects of the IM-supported class activities. However, considering that IM-supported teaching was the first experience for teachers and learners, most lesson introductions were not recorded to allow teachers and learners to familiarize themselves freely with that first experience.

The classroom-recorded observation started after some IM-supported lessons had been observed without recording to serve as a building experience in IM-supported teaching and learning for teachers and learners. Therefore, from 108 lessons conducted, 63 observation sheets were used to evaluate the teaching and learning aspects of public and private schools during the 2019 and 2020 school years. In 2019, there were 29 observation sheets used which included 20 observation sheets from two public schools and nine observation sheets from one private school. During the 2020 school year, there were 34 observation sheets used to record observations from P3, P4, and P5, which included 25 from three public schools and nine from one private school out of the total number. The schools that participated in this study were non-randomly selected and assigned to an experimental group based on the availability of infrastructure facilitating the use of a computer and a projector. These schools consisted of public schools of Nine Years Basic Education (9YBE) and private schools, all from Kigali City.

3.4. Description of teaching intervention

During the IM-supported teaching period, the teacher delivered the lesson using IM software. There was no need to use other teaching aids as the software itself is set to clarify abstract mathematics concepts. In some schools, the IM-assisted lesson used to take place in the same classroom and learners did not move outside. In other schools, the IM-supported teaching in a particular smart classroom where learners had to move, accompanied by the teacher, from their classroom. That depended on the school organization. In the beginning, the teacher started by setting up the computer and the projector, and the wireless mouse.

After asking learners which lesson they were going to study, the teacher adjust the projection on the screen, opening the IM software and engaging the learners in the lesson. The teacher informed them that the learning of mathematics will be assisted by the IM-software for Rwanda and engaged the learners in the lesson. The introduction of the lesson was done by inviting learners to work on exercises written on the backboard and/or projected on the screen. The lesson development was assisted by the IM stages of understanding, quick exercises, and evaluation. All along the activities were interrupted by some workings of learners on the backboard or their draft papers. The teacher used to move around the class controlling the discipline or giving learners the wireless mouse for them to work with the IM. While the teacher was busy with the teaching activities powered by IM software content as an instructional tool to support quality teaching and learning. The researcher or the assistant researcher was standing behind the classroom recording the data about the teaching and learning aspects of IM-supported class activities using the observation sheet.

3.5. Data collection

After some teaching and learning activities assisted with IM software had taken place for every class, the teacher and the learners were considered familiar with smart teaching and learning, which was generally their first experience. Then, the recording of classroom observations using an observation sheet took place and was conducted by one observer. The observer used to sit behind the learners and follow the lesson while evaluating some aspects of teaching and learning activities using an observation sheet with Likert scale measures. For a poorly achieved teaching or learning aspect, the observer awarded one score by ticking in its corresponding Likert measure of level "bad." The process went in the same way for other items, and they were evaluated and awarded scores depending on how the observer evaluated a particular aspect. If, for example, during the teaching and learning activities, the teacher very often passed a mouse to learners to let them operate it, the observer evaluated this aspect as "excellent" (which corresponds to 5 scores during the analysis). However, in the opposite case, if the teacher did not give the wireless mouse to learners at all, the evaluation was "bad" (corresponding to one score in the analysis). The observation sheets were completed during IM-supported teachings conducted for 40 minutes per each lesson and six periods per week for lower and upper primary classes during three months of the first terms in 2019 and 2020.

3.6. Data analysis

The data collected using Likert scale observation sheets were analyzed using an Excel sheet. Data entry was done class by class in two groups from sample schools. The purpose was to record the total frequency of evaluation on an item of a particular class level. We analyzed the data collected from P2, P3, P4, and P5 of private and public schools separately depending on the period of data collection, which were 2019 and 2020 years. Data analysis started by replacing the frequencies of evaluation with the sum of their respective scores. For example, if an item was evaluated as "very good" by two evaluators, the frequency of evaluation was two, and the corresponding sum of scores used in the analysis was 8 (i.e., 4+4). Therefore, means and standard deviations were calculated for each item of each class level for a particular school status and with respect to the period of data collection.

4. RESULTS AND DISCUSSION

4.1. Data presentation

Table 2 presents data collected in 2019 in P2 and P3 of private and public schools. In total, 29 observation sheets were completed and analyzed using an Excel sheet. The results show that the teaching aspects were better in P2 and P3 private schools than in public schools based on means and standard deviations. Likewise, the learning aspects were the best in private schools compared to public school ones. However, in P2, public school teachers demonstrated higher motivation in teaching (Mean=5; SD=0) than in private schools (Mean=4.06; SD=0.42). Therefore, according to the results, IM-supported teaching benefited the teaching and learning aspects more in private schools than in public schools.

Table 2. Means and standard deviation for data collected in 2019

Variables		Items	P2 Public		P2 Private		P3 Public		P3 Private	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Teacher's teaching aspect	Curriculum compatibility	IM is matching the contents of the textbook and the objectives of the syllabus	5	0	5	0	4.94	0.24	5	0
	Methodology	The teacher understands IM contents and effective operations for learners	3.5	0.71	4.5	0.71	3.39	0.92	4.86	0.38
		Time management is effective	4	1.41	5	0	3.06	1	4.86	0.38
		The teacher let the learners to operate IM	4	1.41	5	0	3.89	0.83	5	0
		The teacher is motivated in his teaching by IM	5	0	4.5	0.71	4.06	0.42	5	0
		The teaching methodology is effectively developed by IM compared to the last time	3.5	0.71	4.5	0.71	3.78	0.55	4.86	0.38
Learners' learning aspects	Engagement	All learners are actively engaged in the task by IM lesson	4.5	0.71	5	0	3.89	0.68	5	0
		All learners are concentrating on learning during a lesson with IM	2.5	0.71	5	0	3.83	0.51	4.86	0.38
		All learners are motivated to learn	4.5	0.71	5	0	3.89	0.58	5	0
Gender aspects	Gender differences	IM content is not biased to one of the gender differences	5	0	5	0	5	0	5	0

Table 3 presents data collected during 2020 research activities in P3, P4, and P5 from private and public schools. In total, 34 observation sheets were completed and analyzed using an Excel sheet. The results show that the aspects of observed classroom practices in public schools in P3 and P5 were better than in private while private schools showed better aspects of classroom practice in P4. However, the teaching aspects in private primary three were better than in public schools in terms of the teacher's mastery of the IM content and in letting learners manipulate the software using the wireless mouse. Therefore, there was no big difference in aspects of classroom practices in IM-supported classes between the participant schools during the 2020 research activities. This implies that, referring to 2019 (Table 2), and 2020 (Table 3), public schools improved the aspects of classroom practices by IM.

Table 3. Means and standard deviation for data collected in 2020

Variables		P3 Public		P3 Private		P4 Public		P4 Private		P5 public		P5 Private	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Teacher’s teaching aspect													
Curriculum compatibility	IM is matching the contents of the textbook and the objectives of the syllabus	5	0	5	0	5	0	5	0	5	0	5	0
Methodology	The teacher understands IM contents and effective operations for learners	4.3	1	4.7	0.6	3.5	0.8	5	0	4.7	0.5	3.7	1.2
	Time management is effective	4.5	1	3	0	3.6	0.8	4.3	1.2	4.3	0.7	4.3	0.6
	The teacher passes a mouse to Learners to let them operate it	3.8	0.5	4.7	0.6	4.1	0.5	5	0	4.4	0.7	3.3	0.6
	T is motivated in his teaching by IM	5	0	4.3	0.6	3.7	0.9	5	0	4.6	0.7	4	0
	The teaching methodology is effectively developed by IM compared to the last time	4.8	0.5	4	0	4.1	0.9	4.7	0.6	4.6	0.7	3.3	0.6
Learners learning aspects													
Engagement	All learners are actively engaged in the task by IM lesson	4.8	0.5	4.3	0.6	4.2	0.7	5	0	4.7	0.5	4	0
	All learners are concentrating on learning during a lesson with IM	4.8	0.5	4.7	0.6	4.2	0.6	5	0	4.7	0.5	4	0
	All learners are motivated to learn	4.8	0.5	4.7	0.6	4.3	0.7	5	0	4.7	0.5	4	0
Gender aspect													
Gender differences	IM content is not biased to one of the gender differences	5	0	5	0	5	0	5	0	5	0	5	0

4.2. Findings

Figure 1 presents clustered results from analysis of observation data by comparing levels, years and school statuses variables. The results showed that the aspect of teaching and learning by comparing school statuses, the same teacher in different teaching periods, and the lower and upper level were generally very good based on the means that are all greater than 4. More specifically, by considering school statuses, teaching and learning aspects in private schools were at higher level compared to public schools. This means that IM-supported teaching and learning aspects in private schools (Mean=4.61) were better than in public schools (Mean=4.32).

Comparing the same teacher who was observed in 2019 and in 2020 in P3, the clustered results show that the teaching and learning aspects improved in 2020 (Mean= 4.54) compared to the same constructs in 2019 (Mean=4.46). From the analysis of levels based on the different two school statuses (combined), the clustered results analysis shows that the aspect of classroom practices were better in upper primary (Mean=4.54) than in lower primary (Mean=4.43). However, the comparison of the difference between school statuses, the teaching period and the levels cannot alone lead to firm conclusions. A t-test analysis was found necessary to analyze the significance of the mean differences.

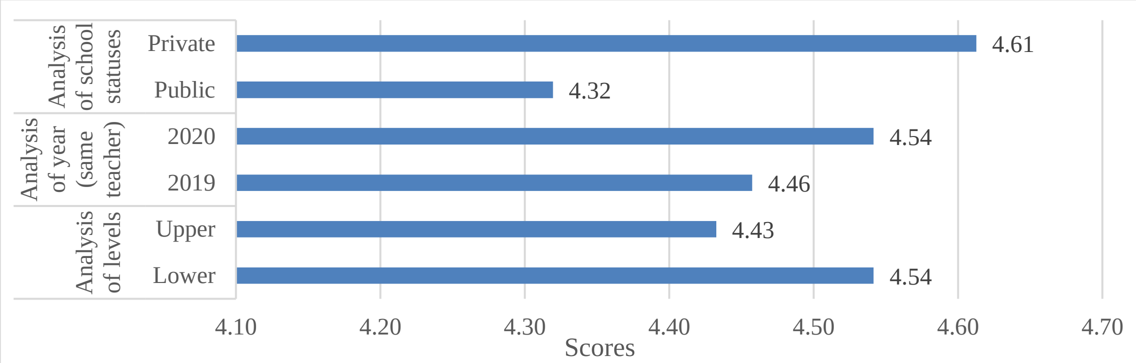

Figure 1. Clustered results from cycles, years and school statuses variables

The t-test analysis of school statuses, the years (for the same teacher), and the levels allowed drawing comparisons with precision on the significance of the differences. Table 4 shows the t-test of two-sample between lower and upper primary cycles of private and private schools combined. The results showed that the difference between lower and upper primary teaching and learning aspects was not significant based on the p-value=0.829368908 (p-value>.05). Therefore, the IM-supported teaching benefited the aspects of classroom activities in lower and upper primary schools in the same way (without differences).

Table 4. T-test of two-sample between lower and upper primary cycles

	Lower primary	Upper primary
Mean	4.541667	4.432576
Variance	0.250365	0.095663
Observations	20	20
Pooled variance	0.173014	
Hypothesized mean difference	0	
df	38	
t Stat	0.829369	
P(T<=t) one-tail	0.206038	
t Critical one-tail	1.685954	
P(T<=t) two-tail	0.412075	
t Critical two-tail	2.024394	

Table 5 shows the t-test of two-sample between 2019 and 2020 school years or the same teacher in two different teaching periods. The results showed that the difference between the 2019 and 2020 teaching period, considering the same teacher, was not significant based on the p-value=0.324542 (p-value>.05). Therefore, the IM-supported teaching benefited the teaching and learning aspects of 2019 and 2020 for the same teacher without a significant difference.

Table 6 shows the t-test of two-sample between public and private school variables. The findings showed a highly significant difference between the teaching and learning aspects of participant schools by considering the p-value=0.007144 (p-value<.01). Therefore, the IM-supported teaching benefited the teaching and learning aspects more in private schools than in public schools.

Table 5. T-test of two-sample between 2019 and 2020 school years

	2019	2020
Mean	4.45754	4.541667
Variance	0.42245	0.250365
Observations	20	20
Pooled variance	0.33641	
Hypothesized mean difference	0	
Df	38	
t-stat	-0.45867	
P(T<=t) one-tail	0.32454	
t Critical one-tail	1.68595	
P(T<=t) two-tail	0.64908	
t Critical two-tail	2.02439	

Table 6. T-test of two-sample between public and private school variables

	Public	Private
Mean	4.319613	4.612698
Variance	0.168436	0.092093
Observations	20	20
Pooled variance	0.130264	
Hypothesized mean difference	0	
Df	38	
t-stat	-2.56792	
P(T<=t) one-tail	0.007144	
t Critical one-tail	1.685954	
P(T<=t) two-tail	0.014287	
t Critical two-tail	2.024394	

4.3. Discussion

In this study, we made observations to assess whether P2 through P5 benefitted from the IM-supported teaching and learning aspects in mathematics class. We looked at three aspects, namely: school statuses, the school years during which IM was used and the educational cycles. The study showed in general that, IM made visible changes in classroom activities conducted in public and private school during the two years of experimentation and in all class levels. Teachers were impressed with teaching using a computer and a projector and the distance between the teacher and the learner was reduced. While using IM software, the teachers were very close to learners as they were able to teach from anywhere in class using a wireless mouse while the whole content was displayed in front of learners. The comparison of differences in school statuses, school years and educational cycles can be discussed.

4.3.1. Comparative differences in teaching and learning aspects observed in IM-supported teaching among school statuses

The results about the differences in teaching and learning aspects observed in sample schools showed that the aspect of classroom practices in private school were at higher level compared to public schools. This means that IM-supported teaching and learning aspects in private schools (Mean=4.61) were better than in public schools (Mean=4.32). The results from the two-Sample t-Test of public and private school variables show a highly significant difference between the teaching and learning aspects between public and private schools based on the p-value=0.007144 (p-value<.01). Therefore, the IM-supported teaching benefited the teaching and learning aspects more in private schools than in public schools.

Public and private schools in Rwanda manifest differences in learning environments depending on the learner-teacher ratio, teachers' qualification and learners' socio-economic backgrounds. For example, while the ratio of learners by qualified teacher was the ratio of learners to the teacher was 58:1 in public schools, it was 35:1 in private schools [5]. In public schools, teachers have to deal with the teaching in overcrowded classrooms with a double shift system of handling two different classes in one classroom alternating in mornings and afternoons [5]. While, private schools in Rwanda show better performance than public schools [27]; these last face hindrances to the achievement of quality of education especially those of 9YBE and 12YBE statuses including poor teaching, limited financial and human resources and teachers' heavy workload [28].

Private schools on the other hand are characterized by learning environments that are more conducive to learning than public and which attract learners from wealthy and educated families [27]. Therefore, private school learners are likely more beneficial to IM-supported teaching based on the ratio of learners per teacher and the teachers' qualifications. However, public schools may benefit from using IM in their teaching and learning as it was found that ICT supported teaching helps in school management and administration [29]. IM may therefore be one way to address some limitations faced by public schools like individualization in overcrowded class while striving for achieving quality education.

4.3.2. Comparative differences in teaching and learning aspects observed in IM-supported teaching in lower and upper cycles

From the analysis of cycles from both schools statuses, the clustered results analysis show that the observed aspects of classroom practices were better in upper primary (Mean=4.54) than in lower primary (Mean=4.43). However, the two-sample t-test between public and private school variables combined show that the difference between lower and upper primary teaching and learning aspects was not significant based on the p-value=0.829368908 (p-value>.05). Therefore, the IM-supported teaching benefited the classroom practices in lower and upper primary schools in the same way (without differences). These results showed how much IM is friendly to learners regardless of their levels of education.

A study asserted that learners in primary schools enjoy interacting with ICT tools, which contribute to their performance [30]. The finding agree with Jalinus and Alim [20] arguments that teaching mathematics to elementary kids using interactive mathematics media is important since it enhances learners' creativity, and enjoyment of the lesson through a fun environment, and enhanced independent learning. The results agree with Azid *et al.* [31] who stated that ICT integration in teaching mathematics of primary school did not only increase learners' mathematical achievement but also motivated learners to complete their classroom tasks. Therefore, the results showed that IM suits the teaching and learning of primary educational level and promotes effective learning. It was found that the improvement of learning instructions and learners' conceptual understanding may depend on factors including the learning environment settings [15]. In this study, the classroom setting was IM-enhanced. Therefore, IM manifested its potentials to make the learning environment suitable to sustain the learning focus, to stimulate learners' interest and to boost their performance in both lower and upper levels of primary education.

4.3.3. Comparative differences of teaching and learning aspects in IM-supported teaching between the two school years teaching periods by the same teacher

From the results, the comparison of teaching and learning aspects manifested in IM classes of P3 taught by the same teacher during 2019 and 2020 school years, the clustered results show that the teaching and learning aspects improved in 2020 (Mean=4.54) compared to the same constructs in 2019 (Mean=4.46) as it appears in Table 2 and Table 3. From the t-test results from two samples between the 2019 and 2020 school years or the same teacher in two different teaching periods, the results show that the difference between the 2019 and 2020 teaching period, considering the same teacher, was not significant based on the P-value=0.324542 (p-value>.05). Therefore, the IM-supported teaching benefited the teaching and learning aspects of 2019 and 2020 for the same teacher without a significant difference.

Therefore, the improvement in teachers' technological pedagogical content knowledge (TPACK) by IM was not significantly different although the difference in means was remarkable. According to some studies, the teachers' TPACK level may be affected by qualifications and teaching experience [25]. Therefore, the teaching experience with IM software should not be significantly remarkable after one year and considering that the first experience in 2019 took place in the first term only while the remaining terms were taught in traditional methods. According to previous study [24], the teachers' TPACK eases effective teaching and learning and assists prospective teachers to use ICT efficiently. This is beneficial to learning as learners enjoy learning and get interested in learning thanks to teachers improved TPACK.

Ukobizaba *et al.* [32] argued that learners like and get interested in learning mathematics when they are taught by a friendly teacher; a teacher who shows interest in learners while answering to their needs. One study pointed out that the teacher's and learner's quality mutual interaction with the content fosters quality learning [33]. For other studies, the teachers' improved TPACK skills stimulate an entertaining class capable of raising learners' interest, stimulating their input, keeping their attention, and obtaining useful feedback [23], [30]. Therefore, to cope with the 21st-century educational aspirations and competencies, IM software can be a technological tool suitable to be continuously used by teachers to develop their TPACK level and boost quality teaching and learning, improve learners' performance and, enhance their skills as they interact with that technological tools [21]. In addition, IM software as an ICT tool can be integrated into primary mathematics teaching to become an influential pedagogical tool [29].

Considering the three aspects of this research focus, our study supports Sezer [34] recommendations about the teacher training on technology-supported teaching, by focusing on the latest technological tools and contemporary teaching methods. Therefore, our findings revealed that IM can help to develop the 21st-century desired competences for both teachers and learners. Furthermore, based on the findings, we are of the same view that the whole school approach should be considered while prioritizing the development of educational ICT tools [35]. On the one hand, school administration should cater to necessary infrastructures to sustain the use of ICT use in classroom activities. Besides, teachers should be trained to be able to shift from using the chalk-and-talk teaching method to effectively implementing ICT-enhanced methods necessary to effectively implement learner-centered teaching approach [15]. Therefore, while striving for quality education, IM software may be a good example of ICT tool that can raise the quality of mathematics being taught in lower basic educational levels. This is because IM holds the potentials to help learners to enjoy the lesson, and the adaptive to the age of learners who are still at the concrete operational phase of learning mathematics [20], [36].

5. CONCLUSION

This study aimed to document several aspects of classroom practices in Rwandan primary school mathematics instruction aided by IM in the academic years 2019 and 2020. The results showed that IM enhanced the lower and upper primary teaching methods in public and primary schools as well as throughout various school years. When considering both school cycles and school year variables, the statistical comparative analysis of differences showed no influence ($p>0.05$). When the school status variable was analyzed however, a statistical effect favoring private schools was shown ($p<0.05$). Based on the results, IM could be a potential strategy to enhance the standard of teaching methods and tackle certain constraints encountered by public schools in managing overcrowding in classrooms, all while aiming for high-quality education.

For the first time, educators and students saw instruction facilitated by IM software as a teaching tool. Additionally, this study added to the body of knowledge regarding the observation of educators and students using technology to assist classroom activities. It was discovered that there were several obstacles to the successful growth of IM-enhanced teaching and learning practices. These included the limited creation of IM content, technical problems with IM, and low fundamental ICT proficiency among teachers and students. Therefore, educational establishments, such as the Rwanda Education Board and the University of Rwanda

College of Education, ought to prioritize the enhancement of ICT competencies among student-teachers and teachers-in-service. Furthermore, this study proposes additional, more comprehensive research that is based on the TPACK theoretical framework and concentrates on pre- service and in-service training on the use of educational technology. Additionally, carrying out more research on the application of IM in the classroom should enhance the body of knowledge regarding IM's potential to improve primary mathematics instruction.

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