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TECHNOLOGY IN MATHEMATICS EDUCATION

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Abstract
The use of technology in education has grown rapidly in recent years, and the integration of technology in the teaching and learning of mathematics and other subjects has become a very critical issue. By technology in education, we mean the use of computers and other tools (for example, calculators, projectors, software, and the internet) inside and outside of class. In this paper, we report on and analyze the use of technology and the attitudes towards it of both students and instructors at Nuhu Bamalli. Thus, we examined whether students and instructors would like to use technology in the future and the reasons upon which this decision is based. The results indicated that, in general, both students and instructors have a positive attitude towards technology and support its integration into the course of mathematics.

Keywords: Mathematics education, Technology, Attitudes, Integration, Information Technology

Introduction
The integration of technology in the teaching and learning of mathematics is a critical issue in mathematics education and raises many questions. By technology in education, we mean the use of computers and other tools (for example, calculators, projectors, software, and the internet) inside and outside of class. Even though the technology that can enhance the teaching and learning of mathematics is not new, its implementation in some educational institutions in Kaduna State has been very slow. Before integrating technology further into the courses of mathematics, research must examine its current use. As Pierson (2001) states, there is a high degree of variability in educational beliefs, technological availability, and community expectations; technology integration should be locally defined, using available research models and national standards as a foundation. Thus, the present paper aims to analyze the use of technology and the attitudes towards it in mathematics education at Nuhu Bamalli Polytechnic, Zaria, Kaduna State. We also feel that it is important to examine both the students' and the instructors' attitudes. "It may be that as teachers we have unrealistic expectations and that there is a mismatch between what we expect as providers and how the students perceive the provisions" (Peat & Franklin, 2003, p. 913). Our results may benefit instructors of mathematics, in case they decide to use them to take appropriate action. In such a case, the benefit will impact their students' learning.

The paper reports on and analyzes questionnaires that were administered to students and instructors of all mathematics courses taught during the 2020 first semester at Nuhu Bamalli Polytechnic, Zaria, Kaduna State. The questionnaires investigated the extent to which technology is used in mathematics courses, the reasons behind its use or no use, difficulties, advantages, disadvantages, and reactions of both the instructors and the students toward the integration of technology in mathematics courses. In cases where technology has already been integrated into the mathematics course, we examined the type of technology that is used and how successful instructors and students think that this integration has been. Worldwide, technology has already been integrated to a great extent and in a variety of mathematics courses at different levels (from elementary to tertiary education and from basic to advanced courses). Many instructors from both technologically developed and underdeveloped countries have realized that "[technology] serves as an engine for changing the nature of the course from one where students passively receive information to one where students actively participate in their education" (Abudiab, 2001, p. 10). Why does this happen? "...Through interactive technology, students become active learners at their own pace,

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having control over their learning individuality or as members of a group. Due to the fact that the material is presented in a more interesting and challenging way, learners become motivated" (Ktoridou et al., 2002, p. 449), and the students' curiosity and fantasy are triggered. As a result, the learners feel more confident when they use interactive software since they have the opportunity to evaluate themselves (Ktoridou et al., 2002).

Technological tools that can enhance mathematics learning have been around for a while. Furthermore, "...the Standards [United States National Science Education Standards] emphasize that students should learn, a range of topics from all the major disciplines, emphasizing active learning and the use of tools, such as calculators and computers" (Penick, 2003, p. 15). One may wonder though, why, then, is the impact of technology in academia very slow in some schools? According to Spratt et al. (2000), "it is often difficult to convince instructors that investment of their time in learning to use new technologies effectively will provide long-term gains" (p. 459).

Methodology

Our sample consisted of students and instructors from Nuhu Bamalli Polytechnic, Zaria, Kaduna State., which is a tertiary institution in Kaduna State. It has about 20000 students that represent different States. We have collected data by administering questionnaires to both students and instructors. The student questionnaires were administered to a sample of students from each mathematics subject that was taught during the First Semester of 2020, whereas the instructor questionnaires were administered to all instructors teaching mathematics during the semester. The students were asked to answer 30 closed questions and 6 open-ended questions, while the instructors answered 31 closed and 4 open-ended questions. The questionnaire referring to students consisted of three parts; namely, "General Information," "Personal Use of Technology," and lastly, the main part, the "Use of Technology in Mathematics Courses." In the case of instructors, the questionnaire consisted of five parts*;* "General Information," "Academic Use of Technology in Mathematics Courses, "Integration of Technology in Mathematics Courses," "Administrative Use of Technology *and* "Personal Use of Technology." The students' ages ranged from 17 to 36 years old with 21 as the average age (SI) = 6.10). The average age of the instructors was 36 years old (*SD* = 4.77) and they had on average 7 years of teaching experience. All the participating instructors were Master's degree holders, whilst 40% of them also had a Ph.D. For the student sample, we randomly selected several students from each class, the number being proportional to the class size. The fact that we did not distribute questionnaires to all the students in a class to ensure a better quality of responses; students felt more responsible since they were selected to participate and they were not influenced by others' responses as we asked them not to sit close to each other. A total of 196 students representing 10 different majors participated in our research. More specifically, 39% of them were majoring in Computer Science, and 27% were majoring in Business Administration. Regarding the instructors, our sample was the entire population of instructors who taught a mathematics course during the First semester of 2020. A total of seven different mathematics subjects were represented; more specifically, these courses were: Algebra, Finite Mathematics, Calculus I**,** Calculus II**,** Statistics, Differential Equations and Discrete Mathematics.

Results

Students' Attitudes Towards Mathematics and Technology

Any attempt to strengthen students' academic skills should first take into account their attitudes, preferences, and fears because these play a crucial role in their performance. Most of us are aware that science courses cause some degree of fear to many students. Our data indicated that only 22% of our students are not afraid of mathematics at all. Table 1 presents the relationship between students' attitudes towards mathematics and their performance in the course.

Table 1:Students Attitudes Towards Mathematics and Their Performance in the Course

Questions	Rank	Percentages (%)
How much do you like mathematics? Is mathematics a subject you are afraid of How good are your grades in mathematics?	Somewhat A bit Average	23
How much do you like mathematics? Is mathematics a subject you are afraid of? How good are your grades in mathematics?	Not at all A lot of Low	10
How much do you like mathematics? Is mathematics a subject you are afraid of? How good are your grades in mathematics?	Very much Not at all Very good	9
How much do you like mathematics? Is mathematics a subject you are afraid of? How good are your grades in mathematics?	Not at all A lot Very good	1
How much do you like mathematics? Is mathematics a subject you are afraid of? How good are your grades in mathematics?	Very much Not at all Low	0

The results in Table 1 indicate that there is a strong relationship between students' attitudes towards mathematics and their performance in the course. The biggest percentage of students (23%) like mathematics somewhat and are a bit afraid of the course, while their grades in the course are average. Other students (10%) do not like mathematics at all, are scared of the course a lot, and have low grades. As expected, a very small percentage of the students (1%) stated that they do not like mathematics at all, are scared of the course a lot, and their grades are very good. None of the participating students (0%) with low grades in the course stated that they like mathematics very much and are not afraid of the course at all. We should not distinguish students' lives from the classroom's environment, but instead try to relate them. In a century where computers take over many activities and are found in almost all homes (95% of the students who participated in our study have a computer at home), we expected to see that the majority of our students like to use computers.

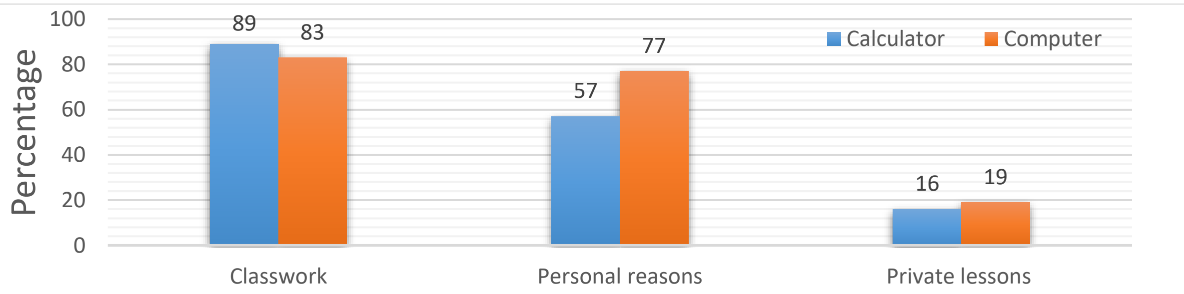

Figure 1: Students' preferences regarding the use of calculators and computers in mathematics

The results in Figure 1 indicate that 73% of the students like to use computers a lot. Hand-held calculators are of course not new, but have been around for three decades (Flores, 2002). Students, however, are not so enthusiastic about their use and 56% of them answered that they like their use a bit. Likewise, students were not so excited about the course of mathematics, as 50% of them liked the course only a bit. We conclude that students have a more positive attitude toward the use of technology rather than towards mathematics. Therefore, the integration of technology with the course of mathematics might trigger an increase in the interest towards the course, and, thus, lead to a more positive attitude towards the subject. Cretchley and Galbraith (2002) stated that ″...students' attitudes toward using technology in the learning of mathematics correlate far more strongly with their computer attitudes than with their mathematics attitudes″ (p. 8). Gavosto and O'Donnell (2002) also concluded from their research "that students' motivation increases in mathematics and writing with technology tools" (p. 4). Thus, we need to be aware of the different methods that students conceptualise and digest the material of mathematics so that we can address these ways through different teaching techniques. The students' responses starting with the most favourite method were: 1. By examples demonstrated on board; (2) Practising by solving exercises on my own; (3) By examples, I study from the book(s); (4) Memorizing definitions, theorems, formulas; (5) Reading and understanding the theory. (6) Visualizing graphs, diagrams, and pictures. Some other responses that the students provided were: ″In-class good listening and learning "Asking/working with other people on the subject," " By questions in class," " Practising first, then, lecturer gives the correct answer," *and ″* Solving exercises. Ask the teacher even if correct."

Personal Use of Technology by Students

Avery high percentage of the students (88%) stated that they use technology for personal purposes, that is, non-academic purposes. with a high percentage (96%) of students having a calculator at home and the act of those are very good/good users of it. Further, 95% of the participating students have a computer at home, and 93% believe they are very good/good users of it. A high percentage of the students (81%) have Internet access from home. Moreover, 36% of the students who use technology for personal reasons use it for more than 10 hours per week. The students who do not use technology for personal purposes (12%) stated that this is due to their ignorance of what type of technology to use, and their belief that technology is not necessary.

Non-Academic uses of Technology by Instructors

All the instructors of mathematics also stated that they use technology for non-academic purposes. All of them have a graphic calculator and a computer at home, whereas 80% of them have Internet access from home and use technology for their administrative duties. The main administrative tasks that they use technology for are to write examinations (100%), type handouts (80%), report and/or calculate grades (80%), draw graphs and other information that is difficult to do by hand (80%), and type lecture notes (60%).

Types of Technology

Table 2 indicates the types of technology that are most widely used for non-academic purposes, and the percentages of students and instructors who use them.

Table 2: Types of Technology Used for Non-Academic Purposes

Types	Personal use (students) %	Administrative duties (instructors) %	Personal use (instructors) %
Word Processors	94	100	100
E-mail	89	100	80
World Wide Web	73	80	80
Calculator	70	80	100
Spreadsheets	66	40	60
Presentation Graphics	64	60	80
Mathematical Software	16	60	80

The data in Table 2 indicate that Word Processors, E-mail, World Wide Web, Calculator, Spreadsheets, and Presentation Graphics are more frequent preferences, in order of priority, regarding the types of technology that students use for personal reasons and instructors for administrative duties. Referring to mathematical software, it seems surprising that it is used mostly by instructors and only for personal reasons.

Use of Technology in Mathematics by Students

When the students were asked whether technology is used in their course of mathematics, only 56% of them answered positively. This is a low percentage, if one compares it with the percentage of the students who use technology for personal purposes (88%). Among the students who use technology for their mathematics courses, 93% use a calculator, 76% a computer, and 71% use both. Despite the high percentage of students who use a calculator and a computer in their mathematics courses, only 18% of them use mathematical software. More specifically, 74% of the students who use mathematical software use Maple. Regarding the type of technology that is used during class time either by the instructor or by the students, the students answered that a calculator, mathematical software, and a projector are the main types used. Figure 2 depicts information about the sources from where students get intermating.

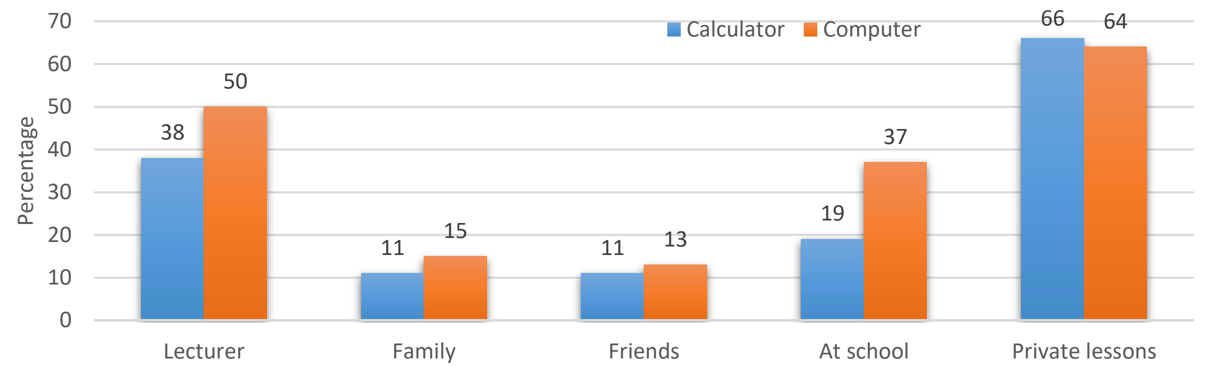

Figure 2: Students' response regarding the sources of information for learning how to use a calculator and a computer

The majority of our students have the ability and are willing to learn how to use a computer and a calculator by themselves (64% and 66%, respectively), while school instructors are the second source of information (50% for computers and 38% for calculators, respectively).

Table 3 presents the percentage to which technology is used in the course of mathematics either by the instructor or by the students.

Table 3 Extent to Which Technology is Used in Mathematics (Students' Responses)

Methods of use	Frequency	Percentages (%)
At home for homework and/or practice by students	Very Often/Often/Sometimes	74
Practice by students in computer labs	Rarely/Never	68
Demonstrations by the instructor in class	Very Often/Often/Sometimes	65
Demonstrations by the instructor in computer labs	Rarely/Never	67

The results in Table 3 indicate that instructors use technology mainly for demonstrations in class, whereas students use it mainly at home for homework and/or practice. Table 4 shows the preferences of the students who used technology in their mathematics classes.

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Table 4: Preferences of Students Who Use Technology in Mathematics

Preferences	Percentages (%)
Makes mathematics easier	73
Helps me verify my work	57
Makes mathematics more interesting	47
Makes mathematics more enjoyable	42
Makes me feel more confident	41
Improves understanding of material	39
Improves my mathematics grades	36
Improves my computer abilities	35

What the students, who used technology in their mathematics classes, like most about this new way of learning mathematics is that it makes the course easier (73%). However, it is agreed that. technology, in and of itself, cannot influence learning, no matter how powerful it might be′ (Valanides, 2003, p. 45). Consequently, the fact that students feel that the use of technology makes mathematics easier, improves their understanding of material, makes them feel more confident, and improves their grades in mathematics, is not due to the mere use of technology, but rather due to the *constructive* use of technology. Smith (2002) states that *"t*here is little evidence that one technology is 'better' than another. What matters is how the technology is used' *(p. 5).* If technology is integrated intelligently with curriculum and pedagogy, then it produces measurable learning gains (Smith, 2002).

It seems that students are aware of many obstacles in learning mathematics with technology. They feel that technology requires a lot of practice and takes a lot of time. Furthermore, they supported that there is not enough support by the instructor, while at the same time instructors use technology only for demonstration purposes depriving the students of the chance to practice with some hands-on exercises.

Ninety-one per cent of the students who use technology in their mathematics classes stated that they would like to continue doing so (Figure 4). From these students, 79% would like to continue using technology in the same way, the most frequent being the use of just the calculator (44%). However, the students who would like to continue using only the calculator might have been more willing to use other kinds of technology if the instructors had introduced them to other kinds beyond just a calculator. This conclusion seems to be valid as 95% of the students who do not use only a calculator are satisfied with the current use of technology and would like to continue in the same way.

Looking at the students who would like to continue using technology in their mathematics classes but in a different way, the change that they most often suggest is to use technology more often and in all mathematics classes. Some other suggestions include the use of more detailed and technical teaching of how to use technology, and more practice with it. In no case did students ask to use technology less. The result shows that a very small proportion of the students who currently use technology would not like to continue using it. They stated that they would like to practice by hand, solve problems on the board (that is, the traditional way of teaching and learning mathematics) and that it is impossible to practice in class as there are many students and not enough time. The result indicated that some of the students do not use technology in their mathematics classes. These students have provided useful insights concerning the reasons for not using technology. They stated that technology cannot be integrated with the course of mathematics, will make mathematics courses more difficult, is unnecessary for mathematics, and, finally, that instructors do not want to use it.

It is interesting though that some of the students who do not currently use technology in mathematics would like to do so in the future. The most frequent explanation was that it would make mathematics more interesting (83%). Other reasons that guided them to this decision are presented in Table 5.

Table 5: Reasons Why Students Would Like to Use Technology in Mathematics

Reasons	Percentages (%)
Makes mathematics more interesting	83
Makes mathematics more enjoyable	65
Makes mathematics easier	63
Improves their understanding of material	63
Helps them verify their work	60
Makes them feel more confident	54
Makes them feel more creative	46
Improves their mathematics grades	44

The remaining 41% of the students who do not use technology in their mathematics classes have a negative attitude towards its integration into the course and are not willing to use it in the future. These students believe that technology takes a lot of time (42%), is unnecessary for mathematics courses (39%), makes mathematics more difficult (39%), and is difficult to understand (27%). All educators and facilitators who are seriously planning to effectively introduce technology in mathematics courses should seriously consider students' attitudes and beliefs.

On the other hand, among the students who use technology, only 6% stated that technology is unnecessary for mathematics, 8% that it makes mathematics more difficult, and 5% that it is difficult to understand. The results indicate that there is a striking inconsistency regarding the disadvantages of using technology between students who currently use technology in mathematics and those who do not The students' responses regarding the current and future use of technology in mathematics and their attitudes towards it are best summarized in Figure 4

Use of Technology in Mathematics and Students' Attitudes Towards it

It is worth mentioning that only 6% of the students who use technology would not like to continue using it, whereas 41% of the students who do not use technology would not like to continue doing so in the future. Thus, we -may reach the conclusion that there might have been fewer negative feelings towards the future use of technology if students were more familiar with it. The responsibility to introduce students to technology lies heavily on instructors. Flores (2002) agrees as well by stating that *"teachers are the catalysts for helping students use technology effectively to learn mathematics"* (p. 310).

Use of Technology in Mathematics Courses by Instructors

While all instructors use technology for personal reasons, only 40% use it in the mathematics courses they teach. All instructors who use technology in their mathematics classes use a calculator, 50% use a projector, while none of them use mathematical software, programming languages, Internet, e-mail or educational videotapes. Additionally, 50% use technology in the classroom very often and 50% often. All the instructors who use technology in mathematics would like to continue doing so. More precisely, 50% of them would like to continue using technology in the same way, while 50% in a different way, namely more frequent use of it. The findings of our research indicate that even though all instructors are informed, at least somewhat, on the use of technology as a physical tool in the classroom, they are reluctant to apply its use since 60% of them do not use it in their teaching. Similar results were obtained in another study (Ktoridou et al., 2002) that examined the use of technology in teaching English as a Foreign Language (EFL) in Cyprus. It was found that although instructors appear to know about the possible ways of integrating technology in EFL when it comes to applying this knowledge into practice, they avoid any application. The primary reason for not using technology in the classroom is lack of time (67%). Other reasons are that instructors feel that there is no need to use technology in mathematics (33%), are ignorant of available means (33%), and lack training (33%). In other words, instructors feel the need for more guidance, so that they will feel comfortable enough to introduce technology in their classes. Most importantly, they need more support, in terms of time, from the educational system. If these conditions were satisfied, then instructors would be willing to use technology in the future, as all of them indicated their willingness to do so. Similarly, instructors also strongly agree/agree that it is good to integrate technology with mathematics courses. The main reasons that they use to justify their opinions are presented in Table 6.

Table 6: Instructors' Responses Regarding the Reasons for Integrating Technology in Mathematics Courses

Reasons	Percentages (%)
Enhancement of visualization	100
Mathematics instructors must keep up with technology	80
Improvement of computer abilities	80
Development of creativity	60
More interesting mathematics lecturing	60
Easier mathematics lecturing	60
Development of self-confidence	60

One interesting result relates to the realization that only 16% of the students who use technology feel that it enhances their visualization, whereas, in the case of instructors, the corresponding percentage is 100%. This raises the question of learning gains as perceived by both instructors and students, versus students' actual learning gains, which is something that we would like to investigate in the future. As Henderson (2002) also wonders, *"*...are students' perceptions of the purpose of this type of activity [integrating computing work with standard lectures] markedly different from that of the teacher?" *(p.* 1). On the other hand, instructors view as a disadvantage the fact that the use of technology may lead students to be dependent on technology. They do not feel that the money spent on technology is an unnecessary additional economic expense nor do they agree that the use of technology may lead to worse students in mathematics. All instructors strongly agree/agree that the main difficulties of integrating technology in mathematics are lack of computer access as well as lack of time for appropriate preparation. All of them strongly disagree/disagree that technology is not helpful and the majority of them were neutral regarding the statements "Students are not interested," *and "*Mathematics lecturers, in general, are not willing to change the standard way of teaching mathematics courses."

Discussion

The study reveals that both students and instructors have a positive attitude toward the integration of technology in mathematics education. The positive attitude aligns with previous research that suggests technology can transform the learning experience (Abudiab, 2001) and enhance motivation (Ktoridou et al., 2002). The paper notes that while technology is prevalent in students' personal lives, its integration into mathematics courses lags behind. This is supported by findings that only 56% of students indicated technology use in their mathematics courses. The discrepancy between personal technology use and its integration in mathematics courses echoes the challenges in implementing technology in education highlighted by Spratt et al. (2000). The study highlights a strong relationship between students' attitudes toward mathematics and their performance in the course, underscoring the importance of addressing students' attitudes when enhancing mathematical skills. This finding is consistent with the idea that attitudes, preferences, and fears play a crucial role in students' academic performance (Valanides, 2003).

Students express a more positive attitude toward the use of technology than toward mathematics itself, with 73% liking to use computers. The idea that technology use can make mathematics more enjoyable and engaging, increasing motivation, is supported by the literature (Gavosto & O'Donnell, 2002). Instructors are reluctant to integrate technology into mathematics courses, with only 40% using technology. The reasons cited include a lack of time, lack of need, ignorance of available tools, and the need for more training. This hesitance among instructors echoes the need for support and guidance to help them feel comfortable using technology in the classroom, consistent with findings in other studies (Ktoridou et al., 2002). Instructors who support technology integration believe it enhances visualization, helps them keep up with technology, improves computer abilities, fosters creativity, and makes mathematics lectures more interesting. These reasons align with the benefits of technology integration in mathematics courses, such as enhancing visual representation and improving computer skills.

Instructors identify the lack of computer access and insufficient time for preparation as the main difficulties in integrating technology. This underscores the need for adequate resources and training to facilitate technology integration in mathematics courses, consistent with findings from other studies (Henderson, 2002). A significant portion of students who do not currently use technology in mathematics express a desire to use it in the future, particularly if it makes mathematics more interesting and enjoyable. This reflects the potential of technology to engage students and improve their attitudes toward mathematics. The study indicates a positive attitude toward technology integration in mathematics education among both students and instructors. However, several challenges, such as the reluctance of instructors and the need for more resources and training, must be addressed to effectively integrate technology into mathematics courses

Conclusions

The data indicate students have a very positive attitude towards technology. Only twenty percent of the students who participated in our research do not want to continue using technology or do not want to try using it in the future. The overwhelming majority of the students who do not want to use technology in the future are those who have not tried its use. Consequently, there could have been fewer negative reactions towards the use of technology in mathematics if students were more familiar with its use and had more support from instructors. There are reasons to believe that the introduction of technology in mathematics courses can create a more positive attitude towards mathematics and, therefore, improve students' performance. By an improved performance. We also conclude that mathematics instructors have a very positive attitude towards technology and in some cases even more positive than that of the students. Thus, all of them stated that they would continue using technology in their mathematics courses or would like to begin using it in the future. Future coordinated research efforts should investigate whether the same trends appear in other private and public tertiary institutions in Kaduna State as those identified in the present study with instructors in Mathematics and their students from Nuhu Bamalli Polytechnic. More research data are needed before answering important questions related to the use of technology in mathematics teaching and learning. We should continue investigating issues related to instructors' and students' attitudes towards technology integration in mathematics teaching and learning. Attitudes and learning outcomes are always interconnected and interrelated. Needless to say, what matters is not the type of technology used but rather *how* it is used to facilitate conceptual understanding and construction of mathematical knowledge for all types of learners in the classroom.

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