International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 6, December 2025, pp. 4966~4977
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i6.30273

Practical instruction and mathematics academic achievement in selected Ugandan secondary schools

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Article Info

Article history:

Received Feb 13, 2024
Revised May 31, 2025
Accepted Jun 12, 2025

Keywords:

Academic achievement
Learners
Mathematics
Practical instruction
Secondary schools
Teachers

ABSTRACT

The challenges met in academic achievement of learners in mathematics at secondary school level are enormous. Taking a glance at the academic achievement of learners in mathematics in Uganda, poor academic achievement becomes more and more striking. It is a puzzle to understand the origin of the causes of this poor academic achievement despite the prominence and significance bestowed upon it by the Ugandan government and society at large. It is accepted that ways mathematics is taught have high impact on learners' achievements. Therefore, an investigation on the effect of practical instruction (PI) on learners' academic achievement in mathematics is timely. The study was carried out using a total of 383 senior three students from eight secondary schools both private and government aided schools. It involved a quantitative approach using mathematics achievement test (MAT). The results revealed that PI affects learners' academic achievement positively in mathematics. They showed that learners that were taught using PI improved in their academic achievement more than their counterparts in the posttest examination. Considering these findings, the study recommends proactive measures to ensure the widespread adoption of PI strategies in secondary school classrooms. This includes revising curriculum standards, providing teacher training programmers, and allocating resources to support the implementation of PI, thereby fostering learning outcomes in mathematics.

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1. INTRODUCTION

Mathematics as a discipline is one of the phenomena which mankind from ancient periods has been using either indirectly or directly. It is a subject of great concern in the whole world as it directs the learners' academic success [1], [2]. Mathematics plays an absolutely necessary role in peoples' lives around the whole world. It enhances various learners' skills including analytic and problem solving as well as promotion of aesthetic, functional, and logical skills [1], [3].

Mathematics serves as a powerful cognitive model, fostering courage in learners to logically observe, reflect, reason, and communicate ideas effectively when addressing problems. It is recognized as a vital intellectual discipline and essential tool in science, commerce, and technology [4]–[6]. Mathematics is the starting foundation of any productive academic scientific endeavor which every nation must develop in order to have a strong scientific and technological foundation for its youths and all other citizens.

The challenges being faced by societies in the 21st century require the education system that trains its learners the relevant skills which can empower them with critical thinking capabilities. The learners should be exposed to mathematical technology that requires hands-on-skills and teacher instructional approaches should be in support of this [7]. Therefore, for any nation to be able to compete globally, all its citizens must be taught highly with reasonable scientific and mathematical literacy.

It is well documented that lack of foundational mathematical skills can impede progress across various industries globally. Particularly in sub-Saharan Africa, including Uganda, the academic performance of learners in mathematics trails significantly behind that of counterparts in regions such as East Asia, exemplified by countries like Singapore, Japan, and China [8]. Scholars in the field, such as Wakhata *et al*. [9], have consistently advocated for a shift towards pedagogical methodologies that offer immersive learning experiences, engaging students physically, socially, and intellectually. Practical instruction (PI) stands out as one such approach with the potential to deliver such enriching experiences, emphasizing hands-on, problem-solving, reasoning activities, and more [10], [11].

PI teaching has a central meaningful role in the curriculum and is viewed/recognized as essential for mathematics learning. However, PI faces several challenges, including how to ensure that it is effective in helping children learn mathematics [12]. Teachers should understand that learning is a process that entails exploring, creating, reasoning, and applying suitable solutions to solve issues. It is also more effective when students are given tasks to complete rather than being asked to memorize facts [13]. A traditional classroom setting where the teacher gives a presentation followed by a lecture does not encourage student engagement or help them reach the necessary level of reasoning [11]. Engaging students in problem-solving tasks with real-objects during class can enhance their comprehension of the fundamental concepts and foster hands-on skills.

Realistically, it is vital in this highly-technological world to equip young students with confidence in mathematics. This can only be achieved through teaching mathematics practically that can be used to solve day to day activities [14]. This further builds their abilities to challenge an ever-increasingly highly global competitive societies [15]. Since most of the decisions that students make in life may eventually depend on how we choose to teach mathematics and science, educators who support students in gaining confidence in their mathematical and scientific abilities can benefit students' careers. In an increasingly competitive global environment that primarily relies on the sciences, technology, and mathematics, it is truly our responsibility as a community of educators to make a difference for our children's futures [16]. Should educational institutions (schools) prioritize the integration of mathematics and science, the results could have a lasting effect on students' lives, leading them to view mathematics as a valuable instrument for scientists.

An academic achievement in mathematics means that the learner has mastered content, and dedicated to apply it in real life situation. It refers to a significant attainment of a milestone by the learners in the field of mathematics [17]. It is manifested on the grades learners obtain in say standardized tests [18].

It is a good idea that learning/teaching should be an active process [19]. Appropriate PI arouse and improve learners' attitude towards the subject matter and lead to concrete knowledge acquisition in abstract concepts which lead to better academic achievement. The caliber and kind of the learner's learning activities will mostly dictate the quality of the learner's learning performance, or what and how much is learnt [20]. PI work has a significant positive effect on learners' academic achievement [11]. It is also reported that practical work improves and makes what is explained in textbooks real [21].

Taking a glance at the academic achievement of learners in mathematics in Uganda, poor academic achievement becomes more and more striking [22]–[24]. Therefore, despite the importance and respect that society has given to this poor academic success as well as the different efforts made by the Ugandan government, it remains a mystery as to what the root causes of this achievement. As a result, the aforementioned issues have created an attempt to investigate the impact of PI on students' academic achievement in mathematics at O'Level secondary schools in both Kigezi and Ankole Regions in Uganda. This has been thought about due to the fact that some scholars link up mathematics academic achievement with the methods of instruction [25]. The present study aimed at investigating the effect of PI on learners' academic achievement in mathematics. It also aimed at testing the following research hypothesis: teaching mathematics using PI does not affect learners' academic achievement in mathematics. Guided by realistic mathematics education (RME) theory, the study adopted a quasi-experimental non-equivalent group design.

The study findings are expected to complement existing studies and provide knowledge on how to uplift academic achievement in mathematics and science in general. The Ministry of Education and Sports (MoES) in Uganda is expected to be stimulated to set up mathematics laboratories which are not common in very many parts of the country as this will foster the attitude of learners towards the subject. There will be an empirical basis for development and improvement of learners' academic achievement in mathematics, among which the data collected, will demonstrate how PI affects students' academic achievement. Furthermore, multiple education stakeholders, such as curriculum planners and designers, policy makers, school authorities, and mathematics teachers are all expected to be beneficiaries as the information is expected to enable them integrate practical of mathematics in secondary teaching to boost academic achievement.

2. ACADEMIC ACHIEVEMENT AND PRACRICAL INSTRUCTION

According to research on the subject, learners' academic achievement in mathematics depends on learners' surrounding environment, instructional practices, subject curriculum, attitude towards the subject, and behaviors as well as various variables which describe different variations in learners' academic achievement in mathematics [26]. There is a remarkable concern on how to motivate learners and improve their academic achievement in all disciplines of which mathematics is one [27]. Accordingly, secondary school teachers need to be well equipped and grounded enough in both learners' management and motivation skills since this can boost mathematics academic achievement. Relatedly it is revived that although learners in South Africa show attitude towards mathematics, the rate of failing the subject is still very high [28].

Different instructors use different types of PI in their teaching where by several purposes are achieved [29]. They further opine that, PI enables learners to attain basic learning skills like measuring and recording skills among many. However, Hodgen *et al*. [30] argues that these kinds of PI at times they are "ill-conceived, confused and unproductive." It is noted that some instructors often miss-match different types of practical and the purpose they serve and therefore this suggests that PI intending to develop just one objective cannot dare improve an academic achievement in any way [13], [29], [31].

Most people believe that mathematics is important and helpful. Its applications in social, artistic, practical, and communicative domains are all beneficial [32]. In Uganda, the goal of almost the whole mathematics curriculum is to give students the skills and attitudes they need for life after school. It also seeks to cultivate a favorable mindset on the recognition of mathematics' value and significance to contemporary society. It is no secret that students in classes tend to be diverse individuals with a range of abilities, motivations, and backgrounds. This presents difficulties for the teacher and necessitates the use of a range of instructional strategies [33]. In order to maximize students' learning efficiency in our classrooms, it is necessary to adapt mathematics lessons into a concentrated setting with relevant activities. It is possible that the employment of diverse instructional techniques to improve the teaching of mathematics ideas in Ugandan secondary schools would be very beneficial in cases where the concepts are either difficult to teach using traditional methods of instruction or where student motivation is poor [34]. The idea of teaching mathematics practically is supported by many scholars. Errors and mistakes in mathematics calculations especially proofs can be best minimized through valid mathematical arguments and justification which can be achieved via good instructional approach [7]. This perhaps means that poor academic achievement of the learners in mathematics is greatly contributed to teachers' inability to conduct lessons practically [22], [23].

A review of the literature has also clarified the requirement for and definition of effective teaching. Good curriculum defines as well as determines an effective teaching and the effectiveness of teaching depends on the grounds of successful teaching practices which may be questionable. Therefore, learners should be exposed to practices that are hands-on for good mastery of the content which should be the focus of the mathematics teachers [19]. Teachers globally have been teaching mathematics for years and the performance has remained very low. It is not clear what underpins this achievement in mathematics [35].

The contribution of PI in mathematics is viewed as essential by many science educators and at the same time that, it is facing many challenges especially at implementation stages. PI involves learners' themselves making direct observations, manipulating learning materials and equipment. It all involves instructors creating enabling situations where learners experience things at first hand during the teaching/learning process [36]. PI further is discussed as a vital practice among the methods of instruction as it supports, motivates and hence enabling the learners understand much more about science. The instruction is essential both in outdoors and in the classroom setting [37]. The fundamental role of teaching mathematics at secondary school level is primarily to promote knowledge transmission and bring a positive outcome at the end of the cycle. Teacher-centered approaches have widely been used compared to learner-centered approaches. Determining the degree to which different teaching strategies promote learning growth of students in mathematics has been an ongoing challenge [38].

The scholastic standing of a student at any particular time has been defined as academic achievement. One way to understand this academic standing would be to look at the course grades [39]. The need to raise learners' academic achievement in mathematics is the main challenge facing Ugandan mathematics education at the moment. In addition, Uganda Certificate of Education (UCE) examinations' report in the year of 2019 and 2021 suggests for PI approaches to teachers of mathematics due to the nature of how candidates were giving solutions to the questions that required practical reasoning and problem-solving skills. Hence there is a need to critically expand knowledge on the side of teachers and address such issues since they academically challenge the learners in mathematics academia.

3. RESEARCH METHOD
3.1. Design and sampling procedures

This study used a quasi-experimental non-equivalent group design as its research design [40]. Both the pretest and posttest were utilized and administered at different time intervals. The study was designed to comprise two groups, control and experimental. The pretest mathematics achievement test (MAT) was administered to the learners to check whether the two groups were homogeneous and it acted as a statistical control. Each group was made up of four secondary schools, two private secondary schools and two government aided secondary schools. Initially, each group was given a pretest MAT and thereafter; the experimental group was treated and taken through teaching using PI for one month (4 weeks). The conventional methods of instruction were applied to the other group. After carrying out the teaching and learning process which took a period of 4 weeks, both groups were again given a posttest MAT under similar testing conditions. Table 1 shows the design used in the study.

Table 1. Study design

Grouping	Pretest	Treatment	Posttest
Control group	Pre_1	T_1	$Post_2$
Experimental group	Pre_3	T_2	$Post_4$

In Table 1, Pre_1 and Pre_3 represent the pretest MAT for both control and experimental groups, while $Post_2$ and $Post_4$ represent posttest MAT after treatment T_1 and T_2, respectively. In addition, T_1 represents the traditional approach present in control group, where as T_2 represents the PI approach implemented in the experimental group. The results that we obtained from pretest and posttest MAT were both analyzed to check the appropriate difference between the two groups.

The study employed a multi-stage cluster sampling procedure, incorporating a purposive sampling technique at one stage. From Kigezi and Ankole Regions in Uganda, which comprise sixteen districts, two were selected randomly. This approach ensured equal representation for all districts while maintaining the study's manageability. In the chosen districts, secondary schools that met specific criteria were identified for the study. These criteria included a minimum student enrollment of 300 and an operational history of at least ten years. The schools identified were both government-aided and private institutions. They were listed to form a sampling frame. From this frame, a random selection was made: two government-aided and two private secondary schools from each district in each region. This selection process ensured a fair representation of the different types of schools in the districts.

The study's target population comprised all senior three students in the selected schools. However, the final sample consisted of 383 students who participated in the study. This sample included 228 female students (40.5%) and 155 male students (59.5%), ranging in age from 13 to 22 years. Additionally, the sample was almost evenly split between the two regions, with 198 students (51.7%) from the Kigezi Region (Kabale District) and 185 students (48.3%) from the Ankole Region (Ntungamo District). Even though we did not implement certain recommended procedures, such as power analysis or a two-stage adaptive design to ascertain the minimum sample size required to detect a specific effect with adequate power, as suggested by Vankelecom *et al.* [41], it is worth noting that the sample size for this study (n=383), comprising n_1=183 for the control group and n_2=200 for the experimental group, was deemed adequate. This aligns with a study by Mukuka *et al.* [42] in a similar context, where the sample size of 301 grade 11 students was also considered sufficient. Besides, the sampling procedure in our study, which involved the selection of intact classes with a fixed number of participants, did not allow for further manipulation, further justifying our sample size. While the multi-stage cluster sampling method allowed for a broad, representative sample, the use of purposive sampling at one stage enabled the inclusion of schools that met specific, relevant criteria for instance those schools that had existed for 10 years operating.

3.2. Data collection procedure

The collection and analysis of data took ethical considerations into account both before and after. Before the data collection exercise from the intended respondents, permission from the headteachers of selected schools and inspectors of schools was first asked by the corresponding author and granted. All the respondents first agreed and thereafter signed the consent forms. The study had ethical approval from the first author's institution prior to the aforementioned.

To avoid disorganizing the teaching and learning processes, arrangement was made prior with administration of the schools and agreed on appropriate dates and time to administer the MAT. The MAT was administered to senior three secondary school students. In part 1 of the questionnaire, they were asked to fill in their demographic information which included, gender, age, class level, and name of the school.

The teachers of mathematics who were purposively selected from respective schools assisted in administering and scoring this instrument. The participants were required to attempt all the MAT items and show all the working since the marking was not only looking at the final answer but generally the reasoning of the learner in trying to attempt the question. With the teachers' help, all participants would be sat at the same time to answer the test items which would take a period of about 1 hour and 30 minutes.

The twelve MAT questions were formulated by the first author basing on the topics according to how students have been performing in UCE reports [23], [24], [33], [34]. They were further validated using other three mathematics teachers, two mathematics education senior lecturers and one English teacher whose suggestions were incorporated in some statements for clarity. The nature of MAT items can be viewed in Appendix. Concerning the reliability of MAT, it was first piloted using 30 students from a school that was not part of the actual study but with similar characteristics as those sampled so as to avoid contamination of the results and the Cronbach's alpha reliability coefficient value was .884 indicating sufficient reliability of the items [43].

All the respondents participated in a pretest in April 2023 to establish the equivalence of the two groups (experimental and control) in terms of their mathematical achievement abilities before the intervention. This was followed by conducting a series of lessons on statistics and trigonometry. The experimental group was taught using the PI approach (hands-on using real objects), while control group was handled using the conventional methods and mainly via lecture together with chalk and talk. This intervention was done in May 2023. This kind of instruction took one month after which the same groups were given a posttest in June 2023 under similar testing conditions. Both the pretest and posttest were marked and scored out of 100% for each student participant. This helped to generate quantitative data that were after analyzed using the statistical package for the social sciences (SPSS) version 22.

3.3. Data analysis procedure

The MAT was scored and data generated quantitatively. SPSS version 22 was used in this data analysis. The significance level of 0.05 was used throughout this analysis. The learners' scores were checked for normality using histograms as part of the descriptive statistics using SPSS and they were approximately normally distributed. Additionally, the skewness and kurtosis values for MAT 1 and MAT 2 respectively were also based on in determining the normality since they all proved to be in the range, as shown in Table 2. The appropriate descriptive statistics (means and standard deviations) were used to describe mathematics achievement abilities of the learners. Therefore, appropriate parametric tests and in particular, the independent-samples t-test was used to determine whether using PI does not affect learners' academic achievement in mathematics. The assumptions required for the test above were put into consideration.

Table 2. Skewness and kurtosis values

Group, where the school belongs			Statistic	Std. Error
MAT 1	Control	Skewness	.699	.180
		Kurtosis	-.090	.357
	Experimental	Skewness	.111	.172
		Kurtosis	-.558	.342
MAT 2	Control	Skewness	.245	.180
		Kurtosis	-.925	.357
	Experimental	Skewness	-.257	.172
		Kurtosis	.380	.342

4. RESULTS AND DISCUSSION

The research results pertaining to the accomplishment tests administered to the experimental and control groups are presented in this section. Both groups were given pretest and posttest. The results recorded are from both tests using an independent samples t-test.

4.1. Pretest results

Descriptive statistics for the pretest were computed, as shown in Table 3, before conducting an independent samples t-test, as in Table 4. Regarding Table 3, separate results were obtained for the control and experimental groups. Table 3 reveals nearly identical mean pretest performances for both groups: control (M=23.0, SD=16.0) and experimental (M=22.9, SD=10.6).

The equivalence of mean scores, as shown in Table 3, was validated through an independent samples t-test, as in Table 4. Assuming unequal variances between groups, results indicated no significant difference in pretest performance between experimental and control groups [t (311.46)=0.114, p=.910].

Variances heterogeneity reflected in Levene's test results possibly resulted from non-normality detected through Kolmogorov-Smirnov and Shapiro-Wilk tests. However, despite this non-normality, an independent samples t-test was conducted, as data skewness and kurtosis values (Table 2) did not deviate much from normality both pre- and post-intervention. Notably, these values closely aligned with recommended norms [44]. Furthermore, the similarity in pretest performance between the two groups is supported by a very small and insignificant effect size (d=0.000034109). This implies that the mean scores for both control and experimental groups were practically identical, with an almost negligible difference.

Table 3. Descriptive statistics for both control and experimental groups in MAT 1

Group		N	Mean	Std. Deviation
MAT 1	Control	183	23.04	15.97
	Experimental	200	22.89	10.58

Table 4. Independent samples t-test for the pretest

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
MAT 1	Equal variances assumed	33.106	.000	.116	381	.908	.159	1.374	-2.542	2.859
	Equal variances not assumed			.114	311.464	.910	.159	1.398	-2.591	2.909

4.2. Posttest results

Descriptive statistics for the posttest were computed, as in Table 5 before conducting an independent samples t-test, as in Table 6. Concerning Table 5, separate results for the control and experimental groups were generated. Analysis of Table 5 does not reveal close identical mean posttest performances for both groups: control (M=40.2, SD=19.3) and experimental (M=66.0, SD=11.9). The mean score for the control group became low compared to the experimental group mean score. However, there was an improvement in the MAT posttest for the control group which was taught using traditional methods for 4 weeks after the pretest.

Table 5. Descriptive statistics for both control and experimental groups in MAT 2

Group		N	Mean	Std. Deviation
MAT 2	Control	183	40.19	19.252
	Experimental	200	66.00	11.868

The inequivalence of the mean scores, as shown in Table 5, was validated through an independent samples t-test, as in Table 6, which was conducted after intervention to compare MAT scores of the posttest for both groups. Assuming unequal variances between groups, results revealed a statistically significant difference in MAT posttest performance between control and experimental groups [t (297.66)=-15.62, p=0.00]. Variances heterogeneity reflected in Levene's test results, as shown in Table 6, possibly resulted from non-normality detected through Kolmogorov-Smirnov and Shapiro-Wilk tests. However, despite this non-normality, an independent samples t-test was conducted, as data skewness and kurtosis values (Table 2) did not deviate much from normality both pre- and post-intervention. Further, the magnitude of the differences in the means was not small (effect size, d=0.390) implying that the mean scores for both control and experimental groups were practically different.

Additionally, the results in Table 6 revealed that, the treatment given to experimental group influenced the academic achievement of the learners greatly. For the case of the control group, the difference between the pretest and posttest mean score is not much as evidenced in the case of experimental scores. Generally, students in experimental group statistically have higher academic achievement in their mean score in the posttest examination compared to the control group in the posttest examination. This indicates that students who were taken through teaching/learning process using PI performed better in doing the posttest compared to their counterparts who were taken through using traditional teaching approaches mainly using lecture and chalk and talk approaches without using any real material in the learning and teaching process.

Table 6. Independent samples t-test for the posttest

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
MAT 2	Equal variances assumed	59.478	.000	-15.933	381	.000	-25.804	1.619	-28.988	-22.620
	Equal variances not assumed			-15.618	297.662	.000	-25.804	1.652	-29.055	-22.552

4.3. Discussion

The discussion is based on independent samples t-test performed on 383 students who participated in answering the MAT. An independent samples t-test was calculated (Table 6) to determine whether teaching using PI does not affect learners' academic achievement in mathematics and it found a statistically significant difference between the mean scores of the two independent groups. The results show that the learners' academic achievement improved greatly especially with the experimental group following the intervention. This corroborates with de Boer *et al.* [45], who suggested that when an intervention in educational setting is carried out correctly, the change on academic learners' performance can be imputed to the key attributes of the intervention. Therefore, the academic implication here is that, teaching mathematics using PI improves academic achievement since their attitude will have been aroused.

The current study showed that even those in control group improved in the posttest because possibly after the pretest, there were some keen students who made some revision and thus improving the general mean score in the posttest. The general improvement of the learners in the control group is attributed to other factors including discussion [30]. These scholars continue to argue that, it is anticipated after the pretest, these learners kept interacting through discussions which uplifted their academic achievement in the posttest, thus an increase in the MAT mean score in the posttest from 23.04 to 40.19, as in Tables 3 and 5. Therefore, discussion approach can be referred to as, a key and important element in teaching/learning of mathematics. Keenly, there was an observation where those who had performed badly in the first test maintained their performance and even some declined completely something that never happened with the experimental group. This therefore confirms that the intervention helped in uplifting the academic achievement of the learners. Teachers need adequate knowledge of how they can deliver the content in a clear and an understandable way by use of real-objects which can sustain learners' understanding [46].

The findings reveal that the null hypothesis is rejected. There is a mean difference between the groups who were taught with PI compared to learners taught by traditional approaches. Other scholars suggest the process of developing concepts and ideas in Physics that should be related to the real world and mathematics is not exceptional [11]. The use of PI approach helps the learners improve learners' understanding of mathematical concepts that are abstract in nature. This makes learning more meaningful as it was observed in the scores of the posttest in the experimental group. The practical approach is deemed to help learners understand concepts and use them in solving mathematical problems at a higher level [47].

The education quality that instructors (teachers) give to their learners highly depends on what they do in the classrooms while teaching mathematics. Thus, preparing to have better citizens who are problem solvers needs practicability teaching approaches [15]. This argument is in line with the obtained results, since it is clear that where PI was used, the academic achievement of learners improved greatly. Therefore, by using PI, learners become more active during and even after the process of teaching and learning, the teacher only acts as a facilitator for them [15], [48]. This has an implication that, the significant difference between the control and the experimental groups was contributed by the intervention given in practical form.

These findings support the studies by Das [49] and Le [50], which state that academic achievement can be improved by practical approach (realistic approach). Other scholars also emphasize that students taught by practical approaches learn to be more active. Furthermore, all of the aforementioned research discovered that when given realistic instruction utilizing practical skills, students can enhance their grasp of mathematical ideas either individually or in groups [19], [51]. Zakaria and Syamaun [48] conducted a study on students engaged in a rehabilitation program, and the study's conclusion indicated that academic achievement is higher for students who received practical skill instruction. It is also appropriate to teach mathematics practically to students at higher levels, such as university students. Research indicates that utilizing PI when teaching mathematics at a university can enhance students' comprehension of mathematical ideas, and at the end, this study indicates that students' academic achievement rose [52]. This implies that before learners join higher institutions, they should be well grounded practically in mathematics as this keeps their academic achievement progressing. The study shows how crucial mathematics is to comprehending and interpreting the connections between ideas in scientific language, particularly in the physical sciences. The degree to which science and mathematics are integrated in this context determines how successful students are since it inspires and involves them in meaningful learning.

5. CONCLUSION

The study investigated PI effect on students' academic achievement in mathematics. Significant improvements compared to traditional teaching methods were observed. The implication is that mathematics teachers should incorporate practical approaches, moving beyond traditional chalk-and-talk methods. The rejection of the null hypothesis suggests that PI positively influences academic achievement. Acknowledging change as inherent, the study encourages teachers to evolve in their teaching methods and content to support professional growth. PI teaching plays a crucial role in the mathematics curriculum, acknowledged as essential for effective learning. However, challenges exist in ensuring its effectiveness. Academic research on teaching and assessing practical work is needed; emphasizing that learning involves investigation, reasoning, and problem-solving. Active student engagement, hands-on activities, and real-world problem-solving enhance understanding and build confidence in mathematics, especially in our highly technological world. The study's limitation is that one of focusing only on senior three students. This suggests future research should encompass multiple levels for broader generalization. Recommendations include teaching using real-objects to liven up lessons and promoting a shift towards learner-centered mathematics instruction to make a positive impact on students' future success in a competitive global environment.

ACKNOWLEDGEMENTS

The authors thank all the learners who participated in doing mathematics achievement test and many thanks go to their teachers who assisted in administering and marking the test. Further appreciation goes to Dr. Thumah Mapulanga and Dr. Mukuka Angel who contributed during various stages of the study.

FUNDING INFORMATION

This research was supported by the African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science based at the University of Rwanda-College of Education (Grant number: ACE II(P151847)). The authors are therefore thankful for such great contribution towards this study.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
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I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflict of interest is declared by authors.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

Prior to participating in this study, all respondents were provided with detailed information regarding the research purpose, methodology and benefits. Ethical clearance and research permits were obtained from the University of Rwanda's Directorate of Research and Innovation and the Ugandan Inspectors of schools under consideration.

DATA AVAILABILITY

Upon reasonable request, the data that support the findings of this study are available from the corresponding author [FM].

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APPENDIX

Mathematics achievement questionnaire (MAT)
Part 1: Demographic information
Fill in the blanks

1. Name of your school ______________________________
2. Class you are in ______________________________
3. Email: (optional) ______________________________
4. Your name (optional) ______________________________
5. How old are you? ______________________________

Please, tick (√) where appropriate

6. Gender

Male		Female	

Instruction. For each item, please answer accordingly and show all your working. There is no any penalty for your failure to provide an answer to a certain question though you are encouraged to try on each.

Part 2: Achievement test questions on statistics

1. In a homework marked out of 20, a group of pupils obtained the following marks: 15, 20, 18, 17, 8, 18, 16, 20, 18, 17, 12 and 19. Find the mode and median marks.
2. The mean of 4 numbers is 8. If three of the numbers are 4, 5 and 10, find the fourth number.
3. The table below shows marks obtained by 34 students in a mathematics test. Calculate the mean mark.

Marks	No. of students
20-29	3
30-39	5
40-49	8
50-59	8
60-69	10

4. The data given below represents the ages in years of 30 senior four students of a certain school:

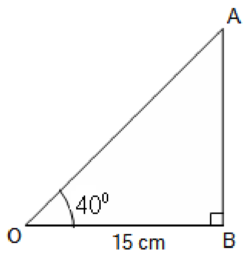
Age class	15-17	19-20	21-23	24-26
No. of students	7	11	9	3

Use the table above to draw a histogram and state the modal class.

5. Find the lower and upper quartiles of the following set of numbers: 3, 12, 4, 6, 8, 5, 4.
6. A car traveled at a speed of 80 km/hr for 30 minutes, 70 km/hr for 40 minutes and 90 km/hr for 20 minutes. What was the average speed for the whole journey?

Part 3: Achievement test questions on trigonometry

1. Given that $\sin a = \frac{3}{5}$ and a is obtuse. Without using mathematical tables or a calculator, find the values of $\cos a$ and $tan\ a$.
2. The angle of depression of the sun's rays to a man's head is 14^0. If the man whose height is $1.7\ m$ standing upright on horizontal ground, find the length of his shadow.
3. Find the length AB in the triangle OAB.



4. Calculate the acute angle between the diagonals of a rectangle that measures 20 cm by 14 cm.
5. A boy, 120 cm tall, is standing 50 m from a flag post on a level ground. He finds that the angle of elevation to the top of the flag post is 150. Calculate the height of the flag post.
6. Use a mathematical table to find the tangent of 12.8^0.

Thank you, dear students, for answering this questionnaire!

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