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Translation of PhET simulations in Ibibio language: A seamless and culturally responsive learning of mathematics in Akwa Ibom State

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Abstract: This paper discussed the translation processes of PhET interactive simulation into Ibibio langauge in the concept of special angles. The study uses the translated PhET applet to design a seamless and culturally responsive approach of learning the concepts of special angles, and to assess the academic achievement of students in special angles. The study was quasi-experimental, with three treatment groups, purposively sampled. The findings show that students taught the concept of special angles using PhET interactive simulations with culturally responsive approach obtained significantly higher academic achievement scores when compared to their counterpart taught the same concept using Interactive Lecturing Approach. Although the study yielded a high statistical power, there was no practical significant difference on students' academic achievements when taught special angles using PhET interactive simulations with culturally responsive approach, and when taught the same concept using PhET interactive simulation without culturally responsive approach. Gender exerted a non-significant influence on students' academic achievements among the groups. Hence, using PhET interactive simulations with mother tongue features, enhanced academic achievement of students, and contextual instructional delivery in Mathematics. Also, the study underpins situated understanding of Mathematical concepts, leading to optimal learning experiences. In the same vein, it fosters the enculturation of mathematical concepts, glocalization of ethnopedagogical techniques, and reverts the extinction of mother tongue in the Nigerian culture. It was recommended that virtual and culturally responsive strategies should be adopted by instructors to diversify instructional delivery in mathematics education.

Keywords: Culturally responsive learning, PhET simulations, virtual manipulatives

Abstrak: Makalah ini membahas proses penerjemahan simulasi interaktif PhET ke dalam bahasa Ibibio dalam konsep sudut istimewa. Studi ini menggunakan applet PhET yang telah diterjemahkan untuk merancang pendekatan pembelajaran konsep sudut istimewa yang lancar dan responsif secara budaya, serta untuk menilai prestasi akademik siswa dalam sudut istimewa. Studi ini bersifat kuasi-eksperimental, dengan tiga kelompok perlakuan, yang diambil sampelnya secara purposif. Temuan menunjukkan bahwa siswa yang diajarkan konsep sudut istimewa menggunakan simulasi interaktif PhET dengan pendekatan responsif secara budaya memperoleh skor prestasi akademik yang secara signifikan lebih tinggi dibandingkan dengan rekan mereka yang diajarkan konsep yang sama menggunakan Pendekatan Ceramah Interaktif. Meskipun studi ini menghasilkan kekuatan statistik yang tinggi, tidak ada perbedaan signifikan secara praktis pada prestasi akademik siswa ketika diajarkan sudut istimewa menggunakan simulasi interaktif PhET dengan pendekatan responsif secara budaya, dan ketika diajarkan konsep yang sama menggunakan simulasi interaktif PhET tanpa pendekatan responsif secara budaya. Gender tidak memberikan pengaruh yang signifikan terhadap prestasi akademik siswa di antara kelompok-kelompok tersebut. Oleh karena itu, penggunaan simulasi interaktif PhET dengan fitur bahasa ibu meningkatkan prestasi akademik siswa, dan penyampaian instruksi kontekstual dalam Matematika. Selain itu, penelitian ini mendukung pemahaman kontekstual tentang konsep Matematika, yang mengarah pada pengalaman belajar yang optimal. Sejalan dengan itu, penelitian ini mendorong enkulturasi konsep Matematika, glokalisasi teknik etnopedagogis, dan membalikkan kepunahan bahasa ibu dalam budaya Nigeria. Disarankan agar strategi virtual dan responsif secara budaya diadopsi oleh para pengajar untuk mendiversifikasi penyampaian pengajaran dalam pendidikan matematika.

Kata kunci: Pembelajaran yang responsif secara budaya, simulasi PhET, manipulatif virtual.

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INTRODUCTION

The digital transformation in science, technology, engineering, arts, and mathematics education (STEAM) has been considerably progressive in the area of Mathematics Education. The Smart learning environment provokes a rethink on the hindrances of traditional teaching and learning strategies in Mathematics. These are technology-enhanced learning tools that infused virtual learning strategies into classroom practices, while facilitating the teaching and learning of Mathematical concepts in this digital era (Sousa et al., 2022). Its seamless learning connotes a virtual environment which enable students to learn anytime, and anywhere because the learning materials are available twenty-four hours, day and night, and accessible from any location both in-class or out-of-class. Seamless technological tools have numerous advantages, including the benefit of saving time. It is a flexible and dynamic digital platform suitable for both blended and flipped learning techniques, since there is no need of any field trip to training which might cause barriers to teaching and learning. Students have the opportunity to learn at their own pace and become constructively minded and autonomous (Dita et al., 2023; El-Hussein, et al, 2022; Mustofa et al., 2024). In such processes, students can choose the content and become self-regulated learners by taking responsibility of knowledge creation and elaboration.

Seamless technological tools for learning purposes can enable the student to reuse the learning contents and experiences: the contents of the course can be reused in other courses partially or totally, as students are given the leverage to have access to updated information. This implies that learning is no longer halted when children leave the classroom, but rather continues and is interwoven with everyday activities, providing chances to enhance comprehension of topics, apply information in real-world situations, and widen children's perspectives. Seamless technological tools facilitate the learning of mathematics and other STEM education disciplines in two major dimensions, namely seamless adaptivity and seamless connectivity (Ahmad & Siller, 2024). Both characterizations are geared toward the opportunities to support learning across variety of contexts as offered by the advancement of technological tools. Seamless technological tools render assistance in the aspect of enabling continuity of the learning experience and maintaining the learning across diverse devices and setting, and helping the learners to carry on where they stopped, and re-establish activity from previous time. Complete sensory usage has been characterized to seamless technological learning platforms, all senses are actively involved; in other words, learning with seamless tools involves visual, auditory, olfactory, and kinesthetic (proprioceptive) engagement when possible and appropriate. Furthermore, seamless learning refers to a progression of learning across numerous settings using networked personal computer devices. Seamless teaching necessitates appropriate computer hardware, and schools should guarantee that all teachers have access to a personal computer/laptop for planning and delivering evidence-based teaching and learning opportunities. Smart phones and other online learning gadgets are resources that can promote a seamless learning environment.

Seamless learning environemt yields numerous positive impacts on the learners. Learners are developing manipulatative and transferable skills in learning of Mathematics when engaged in a seamless learning environment such as Physics Education Technology (PhET) interactive simulation applications. Its offers such a flexible and an inclusive learning environments (Diab, 2024; Manlapig, 2024). PhET interactive simulation is a platform that offers a robust dynamic learning environment with millions of simulations (sims) available for learning in STEM Education worldwide. Carl-Wieman, a Noble Laureate and founder, presented the PhET project in 2002 at the University of Colorado in the United States. PhET interactive simulation becomes adaptive to the learners' situated experience, and facilitates intrinsic and primary knowledge of the learners, while providing situations that enable the learning processes through the use of first language (L1) or mother tongue.

PhET simulations offer a seamless learning manipulative that could enrich the sociocultural learning context through the translation of numerous simulations to local languages in Africa, including indigenous Nigerian languages (Ibgo, Hausa, Yoruba, Ibibio and Efik). The translated simulations cut across all STEAM education related subject. A typical PhET translated sim in Mathematical concept can be downloaded and re-used without internet access via https://phet.colorado.edu. The design of PhET simulation by localizing its features is supporting culturally responsive learning of abstract concepts in mathematics. This ensures the sustainability of sociocultural and entho-based learning of mathematics, where first language (L1) or mother tongue are used as a supportive language of instruction in the mathematics classroom.

It is necessary to envisage that the availability, accessibility and usability of virtual resources for the purpose of mathematics instruction make learning situated and adapted to societal changes. It makes instructional delivery seamless and culturally relevant as local semiotics and languages can be integrated to the learners-centered strategy. These in turn corroborate the dialectic nature of activity system. These artifacts are in the form of instructional resources acting as the "more knowledgeable others" in the classroom and completes the cycle of Vygostkian zone of proximal development (ZDP). The use of digital tools including PhET Apps facilitate dynamic interactions as learners are involved in changing the artifacts, with corresponding internalization and externalization of ideas leading to expansive learning. Hence, abstraction in mathematics classroom is reduced through the use of mathematical symbols, pictorial diagrams, graphics, ethno-artifacts and local languages, which supports the notion of mediated semiotics associate with AT, and learners become much more engaging.

In this study, we adopt the design science research framework(DSRF) proposed by Peffers (Lepore, 2024; Johannesson & Perjons, 2021). This framework unlocks descriptive, prescriptive, and explanatory knowledge through the creation and localization of a virtual Mathematical artifact using PhET interactive simulations.

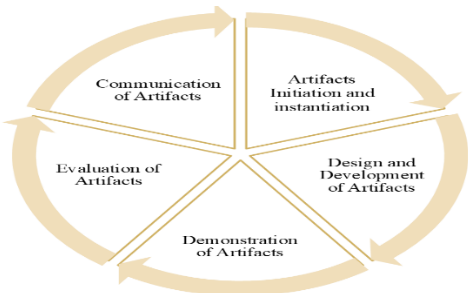

Fig. 1. Design science framework

In Figure 1, the design science framework consists of five activities processing steps with various sub-activities within each phase as stipulated (Venable et al., 2016). The initial phase of the DSRF is initiation and instantiation of artifact. In this case, the problem conceived is lack of innovative teaching tools that support culturally relevant knowledge for the "at risk learners". In this case, the subject Mathematics has been taught disconnectedly from the arts, creativity, instructional design components, and technological affordances which hinders learners' exploration and inquiry skills about Mathematics concept such as the geometry of special angles. The understanding of instructional design principles for effective and adaptive teaching becomes a necessity for the in-service teachers and instructors. Hence the enculturation of virtual learning applications such as PhET Interactive simulations through the use primary knowledge tool (i.e., first or indigenous language) is a way of diversifying instructional practices for the disadvantaged learners in the local area.

The second phase is design and development of artifact. In this context, the PhET interactive simulations has been designed as a virtual learning tool (both as an online web resource and a stand alone mobile learning app) accessible via the link https://phet.colorado.edu. The design has unique assistive technological features in the user interface. This application is dynamic, interactive and manipulatable that is suitable to augment instructional practices in STEM Education. The application has a downloadable option for each simulations (sims) for ease of usage in areas without internet coverage. The PhET interactive simulations has been designed with embedded specification for different languages including the formal language of instruction (English) in Nigeria, and other designated indigenous language such as Ibibio language for all the sims. It has a robust language translation utility package as embodied built-in option for "Trusted PhET Translator" within African continent and others across the globe. The programme retraining of professionals and Educational Enthusiast on proper guidelines for translation of PhET simulations to their respective local languages.

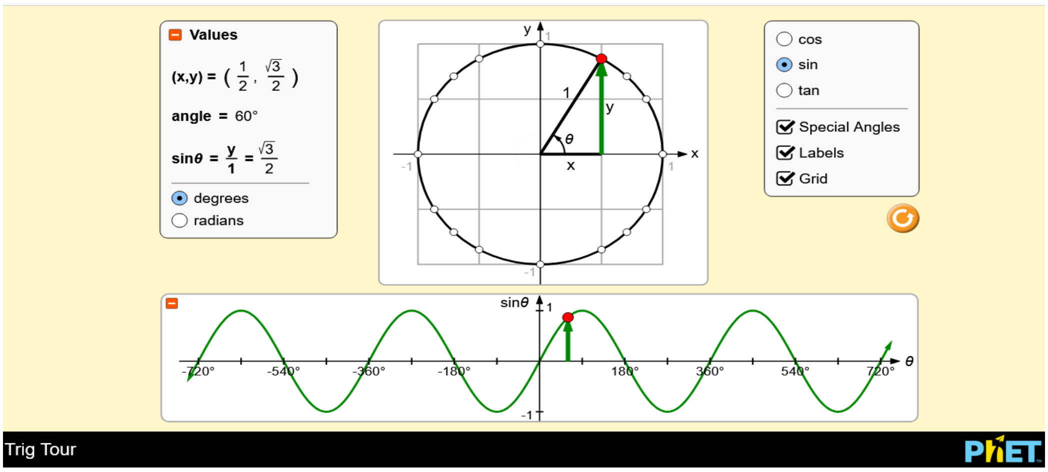

Fig. 2. Sample of PhET user interface of trignomotic functions in english

Figure 3 is the embedded user interface for a single PhET applet on trigonometric ratios of special angles in formal language of instruction (English language).

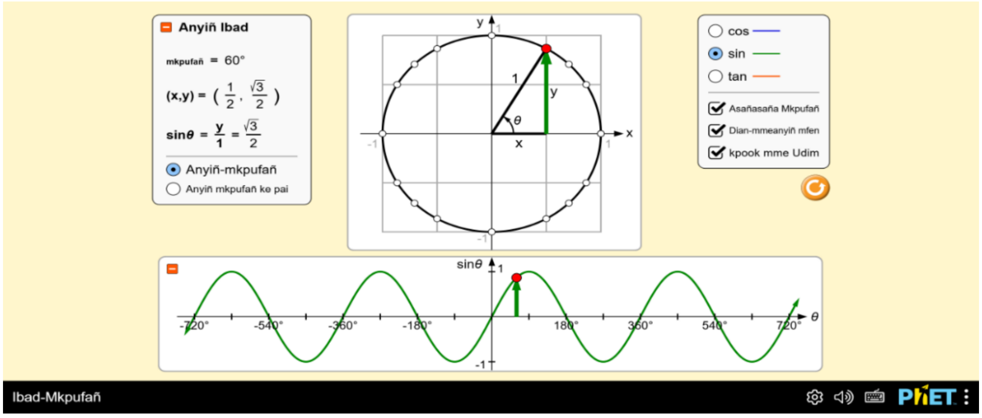

Fig. 3. Sample of PhET user interface of trignomotic functions in Ibibio

Similarly, Figure 3 is the user interface of the PhET manipulative in Ibibio language. The design of this applet follows the principles of multimedia instructional design to create an optimal learning environment. The next phase of design science framework is demonstration of artifact. In this phase, the virtual resource can be used to augment teaching and learning sessions of special angles in the classroom. There are teachers' instructional guidelines in the website to directs instructor on how to develop an interactive lesson delivery using the applet.

The fourth phase of this framework is artifacts evaluation. Its connotes the observation, assessment and measurement of the designed artifacts effectiveness and efficiency in support of optimal learning of mathematical concepts. This phase of the design science framework has two sub-activities; ex ante evaluation and ex post evaluation (Venable et al., 2016). In ex ante evaluation, the embodied and embedded features of this application software has been assessed. For instance, during translation processes, expert knowledge in both mathematical concepts and Ibibio language are assessed to validate the iterative processes. Appropriate feedback and contributions were incorporated into the design knowledge of the artifact. In the same vein, the ex post evaluation of this artifact is done to assess the final utility of the artifacts through descriptive and quasi-experimental design procedures as will be discussed in subsequent section of this paper. Communication of artifacts is used to redefine the artifact where necessary, while solving and reporting the inherent mathematical problems in special angles that led to the design of the artifact. In this stage, some intervening variables, such as gender, are taken into consideration as moderator variables that affect the outcome and achievement scores of the users or the learners. The cycle keeps looping continuously, as it demonstrates the designers and users' kernel knowledge about the concept of special angles in mathematics.

In retrospect to conventional instructional practices in Nigeria, the full range of senses might not be explicitly put to use, where most of the learners remain non-engaged by watching or mere listening to lectures. Thus, our traditional teaching methods hinder situated and personalized learning, and may slow the development of problem solving or higher-order intellectual skills among learners. These conventional instructional practices have been considered to be a major source of dysfunctional educational system when compared to utilization of digital tools. The present reality portrays the fact that digital and seamless technological tools could diversify and augment the conventional instructional practices. This could be achievable if teachers opt to integrate local and digital artifacts in their instructional deliveries. Thus, exploring the leverages offered by seamless learning tools such as Localized PhET simulation applications could enhance students' mathematical concepts, inculcation of dynamic engagement and improvement of academic achievement in Mathematics. Based on these antecedents, the present study focused on measuring students' academic achievement of mathematical concepts when taught using PhET interactive simulations (virtual learning approach) and localized PhET manipulative approach termed as a seamless and culturally Responsive learning (SCRL). This study examines the impact of PhET interactive simulations with a culturally responsive approach on students' academic achievements based on gender differences.

METHOD

This research adopts a quasi-experimental design with pre-test post test non-equivalent control groups. The research was conducted in Uyo Metropolis in Akwa Ibom state in Efficient secondary school as a protoptye to test the effect of the newly translated PhET interactive simulations applet in Ibibio language. The population of the study consists of all Senior Secondary one (SSI) students in all coeducational secondary schools in Uyo Metropolis, Uyo Local Government Area in Akwa Ibom State. Numerically, the total population of the study consisted of four thousand nine hundred and sixteen (4916) of senior secondary one (SSI) students with two thousand and twenty one (2021) males and two thousand eight hundred and ninety five (2895) female students of 2023/2024 academic session in Akwa Ibom State as reported in by State Secondary Education Board (SSEB). A sample of one hundred and sixty eight (148) with (62 males and 86 females) was selected purposively from two intact classes. The study has experimental group 1(treatment group taught special angles using PhET Interactive Simulation with culturally responsive approach PhET-CRA) and experimental group 2 (treatment group taught special angles using PhET Interactive Simulation without Culturally Responsive Approach (PhET-nonCRA).

The instrument of used for the study was mathematics achievement test (MAT) on Special angles. The researchers developed 20 multiple-choice items on the MAT, which functioned as the primary instrument for the study. To ensure the internal consistency of the instrument, the instrument was trial-tested on a sample of thirty (30) students. Kuder-Richardson 20 was used, which yields a reliability index (KR-20 = 0.85). The researchers developed two lesson notes for the treatment groups using the PhET teacher resources https://phet.colorado.edu/en/simulations/trig-tour/teaching-resources.

Regular mathematics teachers at the selected schools served as research assistants for the study. The researchers offered them a week of training on the application and instruction of the mathematical concept of special angles utilizing PhET Interactive Simulations. Lesson plans and notes were supplied to the mathematics instructors in both groups as a resource. Prior to commencing the treatment, the SS 1 students completed a pretest. The therapy duration was four weeks. After the fifth week, the posttest was administered.

Dataset obtained were used for further analysis to answer the research questions, and hypotheses tested at 0.05 level of significance. The research questions are as follows; what is the effect size on academic achievement scores of students when taught special angles using PhET Simulation with Culturally Responsive Learning Approach (PhET-CRLA) and PhET Simulation without Culturally Responsive Learning Approach (PhET-nonCRLA)? what is the effect size on academic achievement scores of students by gender when taught special angles using PhET Simulation with Culturally Responsive Learning Approach (PhET-CRLA) and PhET Simulation without Culturally Responsive Learning Approach (PhET-nonCRLA)? These are led by the corresponding research hypptheses; there is no significant differences in the mean achievement scores between students taught spe- cial angles using PhET Simulation with Culturally Responsive Learning Approach (PhET-CRLA) and PhET Simulation without Culturally Responsive Learning Approach (PhET-nonCRLA). There is no significant difference on academic achievement scores of students by gender when taught special angles using PhET Simulation with Culturally Responsive Learning Approach (PhET-CRLA) and PhET Interactive Simulation without Culturally Responsive Learning Approach (PhET-nonCRLA). There is no significant interaction effects of PhET Simulation with Culturally Responsive Learning Approach (PhET-CRLA) and PhET Simulation without Culturally Responsive Learning Approach (PhET-nonCRLA) on achievement scores of students in special angles. The dataset was suitable for paramtric test and analysis, as the equality of variance (Levene-test), and normality test (Kolmogorov-Smirnov), shown no significance differences in both treatment groups ($p>.05$).

RESULTS AND DISCUSSION

In table 1, the result show significant difference on students mean achievement scores in the concepts of special angles when taught using the three different instructional strategies [$F(2,141) = 11.72$, $p = 0.00$] with a large effect size ($\eta^2 = 0.142$). Also, the instructional strategies accounted for a total variance of 66.67% on students scores, while the remaining percentage (44.4%) was attributed to confounding factors inherent in the experiment but not considered in the study. Therefore, hypothesis one (1) was rejected, while statistical and practical significant differences were upheld.

Table 1. ANCOVA analysis of treatment groups

Source	Sum of Sq.	df	Mean sum of Square	F	Sig.	Partial eta Squared (η^2)
Corrected model	1657918	6	2763.20	46.88	0.000	0.66
Intercept	6865.87	1	6865.87	116.50	0.000	0.452
Pre-test	7092.93	1	7092.93	120.35	0.000	0.460
Strategies	1380.95	2	690.47	11.72	0.000	0.142
Gender	142.70	1	142.69	2.42	0.122	0.017
Strategies * Gender	527.81	2	263.90	4.48	0.013	0.06
Error	8310.01	141	58.94			
Total	978500.00	148				
Corrected total	24889.19	147				

R squared = 0.67

Similarly, Table 1 shown that gender has no statistically significant effect on students' achievement scores between the treatment groups [$F(2, 141) = 2.421$, $p = 0.122$] with a very small effect size (η^2 = 0.017). Hence, hypothesis two (2) was retained. In the same vein, there was a statistically significant interaction effect between gender and instructional strategies on students' achievement scores in the concepts of special angles [F(1,141) = 4.478, p = 0.013], and no practical significance was observed as the model assumes a very small effect size (η^2 = 0.06). Subsequently, multiple comparisons (Post-Hoc); Least Significant difference (LSD) is used to report the differences in achievement scores and practical relevance of each instructional strategy between the treatment groups.

Table 2. Post-hoc: pairwise comparisons of achievement scores between groups

Strategy (A)	Strategy (B)	Difference (A-B)	Std. Error	Sig ^{b}	d	95% C.I LB	95% C.I UB
PhET-CRLA	PhET-nCRLA	1.93	1.66	0.25	.007	-1.34	5.21
	ILA	8.05*	1.69	0.00	1.99	4.72	11.39
PhET-nCRLA	ILA	6.12*	1.83	0.001	1.50	2.50	9.74

* The mean is statistically significant at 0.05 level and practically significant.

^{b} Adjusted for multiple comparisons: Least Square Difference (equivalent to no adjustments).

PhET-CRLA:PhET-Culturally Responsive Learning Approach.

PhET-nCRLA: PhET-nonCulturally Responsive Approach.

ILA: Interactive Lecturing Method.

Table 2 shown no practical and significant differences in achievement scores of students taught special angles using PhET-CRA and their counterpart taught special angles using PhET-nonCRA, as the effect size was very small (d = 0.007, 95% CI[−1.344, 5.208]). Similarly, the achievement scores of students taught special angles using PhET interactive simulation with culturally responsive approach PhET-CRA) is higher than those of their counterpart taught special angles using Interactive Lecturing Approach (ILA) with a the effect size being very large (d = 1.993, 95% CI[4.717, 11.387]). Also, table 2 show that students taught special angles using PhET Interactive Simulation without Culturally Responsive Approach (PhET-nonCRA) achieved higher scores than those taught using Interactive Lecturing Approach (ILA) with a very large effect size (d = 1.500, 95% CI[2.497, 9.743]).

The study has shown that students taught the concept of special angles using PhET interactive simulations without culturally responsive approach (PhET-nonCRA) achieved significantly better than their peers that were taught the same concepts using interactive lecturing approach (ILA). The differences in mean achievement scores between the two treatment groups were of practical importance, and PhET interactive simulation successfully enhanced students' achievement in the concept of special angles. These findings underscore the functions of technology-enhanced learning through its leverages such as dynamic, flexible and adaptive learning features embedded in the PhET application software. The manipulative ability of the applications, might facilitate students' deeper understanding and cognitive apprenticeship of the learners in the concepts of special angles. It corroborates a study which reported that technology enhances the learning in Mathematics, and the use of dynamic geometry applications facilitates learning of some dreaded and difficult concepts in mathematics (Arifuddin et al., 2025). Also, a similar study which investigated the effectiveness of mobile app simulation technique in some engineering courses reported that the application-based simulation showed ease and convenience of use, resulting in a positive effect in learning of mathematics (Tang et al., 2025).

This empirical findings is supported by Pérez Echeverría et al. (2025) and Damopolii and Kurniadi (2019, that digital manipulatives facilitates learning outcomes. In the use of SymboLab manipulative, Akpan et al. (2023) reported a significant positive effect of technology enhanced learning (TEL) to tools to be of positive improvement on students' academic achievement in Mathematics. In Akpan et al (2023), similar virtual manipulative has been found to be more impactful to the learners than concrete manipulatives. An experimental study on the effects of content and language integrated learning (CLIL) approach in mathematics has shown that students taught mathematical concepts using the CLIL approach performed better than students taught using the non-CLIL approach (Ruiz-Cecilia et al., 2023). In the same vein, PhET interactive simulations have been demonstrated as an effective virtual manipulative tool in teaching of Mathematics (Keldgord & Ching, 2022), as they hinted that students taught quadratic graphs using the PhET applets performed significantly higher than those taught the same concept using concrete manipulatives.

Gender difference has been found to be insignificant in this study, and it has been attributed to the inclusive nature of the learning applications. Moreover, female and male students have the cognitive capabilities to function effectively in Mathematics classroom. This has been supported by a study on gender related issues in Mathematics, and they opined that technology makes the teaching of mathematics to be flexible without any form of gender disparities (Yuberta et al., 2024). Also, gender was considered as an intervening variable without any substantial effects on performance among students taught quadratic graph using PhET manipulatives. In a similar study on the localization of PhET interactive instructions in indigenous Nigerian language, Akpan et al. (2024) pointed out that these virtual applets enhanced students' mathematical engagement and improved their academic achievements in Mathematics. In this regards, gender defferentials is insignificant when the instructional approach is dynamically interactive, flexible and digitized. Recent innovative research on Culturo-Techno-Contextual Approach (CTCA) has emerged as a promising strategy, particularly for African students, which showed a significant improvement in critical thinking for the CTCA group without significant gender differences (Adam, et al, 2025).

Comparatively, this study upheld that students taught the concept of special angles using PhET Interactive simulations with culturally responsive approach (PHET-CRA) achieved significantly higher than their peers taught the same concepts using Interactive Lecturing Approach (ILA). This underpins the fact that students were more engaged manipulatively and adaptively during the teaching and learning sessions because of the use of mother tongue. The use of mother tongue has been envisaged as a culturally responsive instructional strategy, advantageous to the disadvantaged learners in the rural settings. An integrated language and culturally responsive pedagogy has been reported to be an effective strategy in teaching of Mathematics, because of its adaptability, and inclusivity (Cobian et al., 2024). In a similar study Sunzuma and Umbara (2025) reported that ethno-pedagogical technique exerted discernible positive impacts on students' mathematical awareness and problem-solving skills, and fosters scientific glocalization and cross-cultural developmental careers among historically excluded groups (Iffah et al., 2025). This is supported by Dosinaeng, et al (2025) as they reiterated the efficacy of Culturally Responsive Approach (CRA) in teaching algebra with emphasis that CRA ensures equitability and social cohesiveness between the classroom and social practices. A localized instructional strategy becomes more glocalized when integrated with digital tool, and Bertrand. et al. (2024) implemented similar strategy using augmented reality (AR) and virtual reality (VR) tools in Mathematics Education through culturally responsive pedagogies. They used a game-design-like coding software and Cospaces Edu application and cultural aritfacts to teach within storytelling context, and observed that students were motivated to learn. On the investigation of the impacts of culturally relevant engineering design (CRED) on students' perception and engagement in k-12 STEM classroom (Adetunji, 2025). There was a significant positive correlation between students' perceptions of culturally relevant engineering design and their engagement in STEM learning activities. Students who perceive culturally relevant engineering design positively demonstrate higher levels of engagement in STEM learning.

This study is limited in transferability to other subjects in science and mathematics education because only a specific topic being the geometry of special angles were considered. The adoption of quasi- experimental procedure rather than a complete randomization process in sampling, may hinder the generalization of findings to the entire population of students in Akwa Ibom state. The study was carried out using purposive sampling with the conditions that the selected school has technology enhanced learning tools, hence the findings may not be transferable to schools outside the local government areas of interest, and in this case, Uyo Local Government Area. In this study, other psychometric variables such as engagement, motivation, interest and attitude toward the use of the PhET simulations were not considered, and many confounding variables could affect the findings of this results. Hence, further research on the effects of PhET simulations should be conducted in other STEM Education-related topics to measure such psychometric constructs.

CONCLUSION

The use of PhET interactive simulations with culturally responsive approach improved students' academic achievements in the concept of special angles, and facilitated inclusivity in the subject matter. This was seen in the mean achievement scores of students when taught the concept of special angles using PhET interactive simulations with culturally responsive approach, which were higher than their counterparts when taught using interactive lecturing approach. The achievement scores of male and female learners who received mathematics education through the three instructional methods showed no significant differences. This indicates that learners of both sexes in the three treatment groups saw equivalent benefits. This research significantly advances Mathematics Education by being the inaugural study to investigate virtual tools translated into the indigenous language (Ibibio) and their impact on students' academic performance regarding the concept of special angles in Uyo Metropolis, Akwa Ibom State, Nigeria. The study demonstrated to the Mathematics Education specialists that a flexible and virtual learning application software can be translated to local language to facilitate academic achievements in the concept of special angles. All in all, the study portrays the potential of integrating digital and ethno-virtual pedaogogy in Mathematics Education. This is achievable through the utilization of innovative pedagogical approaches and technology tools such as localized PHET simulation applets. Mathematics Educators can create engaging, culturally relevant learning experiences to foster deeper experiential learning in Mathematics among students. Instructional designer and mathematics teachers should demonstrate competence in the use of digital learning tools with culturally relevant components to augment their instructional practices in Mathematics. The government and relevant Education bodies should organize seminars and workshops for mathematics teachers on using PhET interactive manipulative for teaching and learning of mathematical concepts. School principals should ensure the availability, accessibility and usability of technology enhanced learning tools, resources and materials to boosts learners' achievements and engagements during the teaching and learning of mathematics in secondary schools.

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