IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Date of publication xxxx 00, 0000, date of current version xxxx 00, 0000.

Digital Object Identifier 10.1109/ACCESS.2018.Doi Number

Games for Teaching Mathematics in Nigeria: What Happens to Pupils' Engagement and Traditional Classroom Dynamics?

Opeyemi Dele-Ajayi[1] (Member, IEEE), Rebecca Strachan[1] (Member, IEEE), Alison Pickard[1], Jonathan Sanderson[1]

[1]Digital Learning Laboratory, Northumbria University, NE1 8ST, Ellison Place, Newcastle upon Tyne. United Kingdom.

Corresponding author: O. Dele-Ajayi (e-mail: o.dele-ajayi@northumbria.ac.uk).

ABSTRACT Mathematics education is under threat in Nigeria. Young people report it as boring and difficult; teachers say young people are not engaged, even when they are achieving academically. Meanwhile digital games are part of everyday childhood. They are now being used to benefit young people academically as they have been shown to help motivate reluctant learners. This action research case study aims to determine if a digital educational game can stimulate interest and engagement with mathematics. SpeedyRocket, a digital educational game was designed and used in the classroom in three schools in rural Ado-Ekiti, Nigeria to teach pupils about estimation, as part of the mathematics curriculum. Evaluation was carried out with the pupils through a combination of a pupils' mathematics attitude questionnaire, and classroom observation. The results demonstrate significant improvements in attitude to and engagement with mathematics across the target group, after two weeks of using SpeedyRocket. Learners became co-creators of their own knowledge, sharing ideas, forging new learning pathways, competing and cooperating with one another. Furthermore, the findings from this study provide insights into the changes that occur in the dynamics of the traditional classroom through the introduction of digital technology, especially in settings where it has not been previously used.

INDEX TERMS Active learning, digital game, education, game-based learning, mathematics, Nigeria, young people.

I. INTRODUCTION

Mathematics affects all aspects of human life. The social, economic, political, geographical, scientific and technological aspects of human beings are centred on numbers [1]. Regardless of the profession an individual is involved in or their career path, mathematics remains an essential tool that prepares the individual for effective work. According to reference Omameh [2] the knowledge of mathematics is not just for one's profession or national development, mathematics is intimately connected to our daily lives and life-long planning.

Whilst the study of mathematics can improve the imaginative and cognitive capabilities of the mind [3], its impact on national development is also significant. Several studies maintain that the progress of any nation depends on their technological and scientific advancements, which is contingent on an effective mathematics education system [4], [5], [6]. Research shows that developed countries have benefited widely from well-planned mathematics curriculum and educational systems as they have proven to be the bedrock for scientific, technological and economic development [7]. The Nigerian government is committed to developing its people in this respect and therefore has made mathematics a compulsory subject from primary school to secondary school [8]. In addition, any student who wishes to gain admission into any tertiary institution in Nigeria (colleges, polytechnics, universities) for study on any course must pass mathematics at a credit level. The Nigerian government continues to invest millions of dollars into the teaching and learning of mathematics. The rationale being that they understand that it is a major driver in the push for development.

Despite the seemingly obvious importance of mathematics education and the efforts successive governments have continued to put into improving mathematics performance across secondary institutions in Nigeria, no significant improvements have been recorded to date. Performances in the West African Senior School Certificate Examination (WASCCE) have been poor in recent years. Adedigba [9]

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2019.2912359, IEEE Access

reported that in 2015, only 28.59% made the minimum requirement of 5 credits including a credit pass in mathematics. In 2016, the results were slightly better - 38.50% but dropped back further in 2017 as only 26% made the minimum requirement. Given the awareness and resources the government is putting into mathematics education, these results are poor [10].

Whilst the government and academic institutions strive to find solutions to the continuing low level of performance in mathematics, several studies that detail potential causes have been published over the past twenty years. Asikhia [11] cited the work of Bakare [12], which categorized the causes of poor performance in mathematics into four main areas:

i. Causations resident in the society, such as instability of educational policy; under-funding of the educational sector; mismanagement, leadership; job security and satisfaction.
ii. Causations resident in the school, such as school location and physical buildings; mathematics curriculum, teachers' training and skills.
iii. Causations resident in the family, such as cognition stimulation/basic intuition during the early years; type of discipline at home; lack of role model and finance.
iv. Causations resident in the child, such as basic cognition skills, physical and health factors, psycho-emotional factors, lack of interest in school programme.

These four key areas: government/wider society, family, the student and the school/classroom also encompass the individual factors identified by other studies. This study focuses on the school/classroom challenge.

A. The challenge of the Nigerian classroom

As Bature *et al.* [13] maintains, the classroom climate as well as the mode of teaching impacts on the attitude of students towards a particular subject. According to Bierman [14] classroom climate is "the classroom environment, the social, emotional, intellectual and the physical aspect of the classroom". Research has shown that students experience the classroom as not just an intellectual space, but as a social and emotional environment, one that can enhance or hinder their learning experience [15], [16]. Thus, the climate of the mathematics classroom can have a significant influence on a child, not just emotionally and intellectually but can also either positively or negatively impact on their mathematics attitude [17].

The experience of mathematics in Nigerian classrooms therefore poses a challenge to young peoples' attitude to mathematics. The traditional classroom in Nigeria is passive, unengaging and boring. According to Bature *et al*. [13] most classroom activities are teacher-centered with students as mere listeners and recipients of knowledge playing a passive role in knowledge acquisition. This agrees with Okafor and Anaduaka [18] who maintains that most of the classroom dialogue comes from the teachers while the pupils listen or write what is on the chalkboard. Students also work individually to solve problems and submit their completed tasks to the teachers to be graded. These traditional teaching methods and strategies do not have a multi-sensory effect on pupils. Ajayi *et al*. [19] suggested that this style of teaching is one of the reasons students develop negative attitudes towards mathematics.

Classroom sizes also present a challenge to an enjoyable educational experience for young people and teachers in Nigeria. Due to over-population and inadequate number of teachers, many of the classes in Nigeria are overcrowded. This classroom structure often results in young peoples' loss of attention and disengagement during teaching. Ajayi *et al.* [19] suggests that when classroom sizes increase and become unmanageable, teachers find it impossible to give individual learners the attention they deserve. This leads to learners that are less motivated and disconnected and unengaged with their subject and learning. Ayeni [20] explored the relationship between effective classroom management and the learning outcomes of students. In that study, 75% of the sampled teachers listed congested classrooms as a major constraint to effective classroom management. In a similar study, Ajayi *et al.* [19] examined the impact of class size on students' classroom discipline, engagement and communication. The study revealed that class size had a significant influence on engagement. It also recommended a maximum of 40:1 student-teacher ratio for effective classroom discipline, engagement and communication. This recommendation is substantially higher than UNESCO's standard of a 25:1 student-teacher ratio [21].

Several potential solutions to improve the performance of students in mathematics have been suggested in the literature. Mbugua *et al.*[22] believes that adequate staffing, better teaching and learning resources and materials, as well as an improved curriculum would improve students' performance in mathematics. Two strategies suggested by Ojimba [23] include incorporating the concept of constructivism, and the use of computer-aided instructional material such as games. To address the issue of phobia of mathematics, which is one of the reasons for poor performance, Bornstein [24] suggested that a way to improve the attention of students in the classroom is to build their confidence in the subject. According to Okafor and Anaduaka [18] one way to build confidence is by encouraging discussion in the classroom. They challenge teachers to disrupt the typical classroom method in which teachers do most of the talking while the students take a more passive role and sit, write notes and practice whatever the teachers do. Allowing students to get more involved in their learning journey should engage them more and boost their confidence allowing them to explore and try things out by

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

themselves. One of the findings of Sule *et al.* [25] study of mathematics phobia among students in Nigeria is that students' interest is increased when physical and visual objects are used in teaching and learning mathematics concepts. Similarly, Etuk and Bello [3] opined that the usual memorization method of teaching mathematics is archaic and therefore not useful in the 21st century. They suggest that to increase the prospects of mathematics education, better teaching methods that are friendly and student-centred would help 'unveil the reality of mathematical concepts to the learners'. One of the ways abstract concepts in mathematics can be brought to life for the student is through the use of game-based environments in teaching.

Okafor [18] recommends a strategy that encourages discussion, and diversifies the learning experience. In order to create an engaging experience for students, mathematics classrooms should introduce ways to make learning exciting and adventurous. A shift from the traditional method of teaching to those that engage better by appealing to more than one of the sensory organs [19] is recommended [18]. In contrast to the passive setup of classrooms in Nigeria where it is often frowned upon to speak, Okafor [18] also suggests that communication with peers and teamwork must be encouraged. Barriers to sharing and talking amongst the students and teachers should be removed. The learning experiences of students should also be varied especially as the attention span of young people can be very short [26].

B. *Benefits of technology-enhanced teaching*

Previous research has shown that one of the potential ways to diversify the learning experiences of young people in the classroom, and promote active learning is by using technology [27], [28]. Reference Boticki *et al.* [29] maintain that technology offers new ways to learn such as providing authentic learning environments that enhance the learning experiences of students. Research has also shown that learners' engagement improves when learning occurs through technology [30], [31]. Learning using technology enhances engagement by promoting instant access to information and proving hands-on learning [32]. Churchill and Wang [33] also argued that technology results in high motivational effects, serving as tools to reinforce students' learning process.

Immediate feedback is one of the particular benefits technology offers to the classroom [34]. This is of particular interest in the Nigerian classroom context where it is often difficult for teachers to provide adequate feedback to pupils on their performances due to the high classroom population. Immediate feedback is a key ingredient for self-regulated learning as it provides information about how well one is performing on a task [35]. It also provides information about goals and learning process, both of which are essential to self-efficacy, motivation, and improvement in cognitive and metacognitive performance [36].

Another benefit technology offers the learning experience in the classroom is the allowance it affords learners to make mistakes [37] without the concern of grievous repercussions. Due to the demand on the teacher in a traditional classroom and the number of students they have to attend to, it is often not possible to allow individuals to try as many times as they need to. The classroom is taught as a whole. The use of virtual reality and in particular simulated learning environments allows learners to make mistakes and learn in a non-public manner. This supports learning and re-learning as often as required by allowing the learner to make mistakes and perfect their learning according to their own individual needs.

Closely related to the allowance to make mistakes is the ownership of the learning process technology provides for students. The use of technology in the classroom promotes autonomous learning [38]. It permits students to own and control their individual learning and create their own learning paths. This also changes them from being passive participants to becoming active co-creators of their own learning process.

Technology can also support collaborative learning, allowing students to share and cooperate during the learning process [39]. This can be particularly useful for supporting peer feedback and increasing communication between peers to support shared understanding and meaningful discussions [29].

C. *Learning in game-based environments*

In the past few years, digital games have come to replace many traditional games and have established their impact on how leisure time is spent. This is largely due to the availability of new consoles, platforms and technologies for the delivery of games [40]. The increase in the number of games and the amount of time children (and adults) spend playing them has led to an increased interest by researchers into gaming.

Digital games are one of the many technologies educators are using in classrooms. While there are claims from some studies that digital educational games have improved learning and knowledge acquisition [41], [42], [43], results from the use of digital games for learning should be treated with caution [44]. There have been concerns about the lack of rigour and empirical studies that have investigated learning outcomes and digital educational games [45], [46]. However, the use of technology in the classroom should be focused on more than just educational attainment. What changes can be observed in the child's engagement and approach to learning, their motivation, and self-efficacy? It is these aspects that are central to address the current challenges observed in the Nigerian context.

Digital educational games can accommodate various learning styles and pace, which can result in increased motivation for students [47], [48]. Given the way many digital games are designed with several short-term goals and a long-term goal, players can make progress and have a sense of progression by achieving the short-term goals [47]. As Su and Cheng [48] argued, the feeling of competence derived from achieving the short-term goals may give the learner continued motivation on their learning journey.

One of the ways digital educational games are being used to enhance experience and motivate learners is by providing context and live examples of curriculum content in the classroom, often referred to as situated learning [49]. Clarke and Gribling [50] argues that this feature of situated learning promotes experiential learning and assists learners in understanding the application of the concepts they are studying. Hsu [49] also affirms that it improves on the traditional one-way teaching by getting students to actively engage in the learning environment themselves and changes the role of the teacher from instructor to facilitator. This aligns with the values of constructivism [51]. Constructivists believe that for learning to occur, context is very important. They stress that effective learning happens when the task and context are real and tangible to the learner. Digital educational games present a learning environment that engenders related context. Through the active engagement of the learner in the process, they are offered the opportunity to learn by going beyond already established formulas or solutions to develop their own solutions that work in different contexts and scenarios.

Digital educational games also provide a collaborative learning experience that promotes cooperation and engagement in the classroom. Cecez-Kecmanovic [52] suggest that more effective learning occurs during interpersonal interactions in a co-operative environment rather than a competitive one. Advocates of collaborative learning have further argued that it improves communication and dialogue between participants in the group, thereby making them more critical learners [53]. Working with others also exposes learners to a wider range of other learners' learning styles and perspectives enabling them to appreciate and engage in a greater variety of approaches to learning [54].

Despite the many possibilities offered by game-based learning, its potential has not been fully realised. This is due to a number of factors. One is that digital games do not have a positive image. For example, research has shown concerns about how games encourage antisocial characteristics [55], [56], reinforce gender biases [57], and can potentially lead to aggressive behaviours [58]. In addition to these concerns, there is a significant shortage of experimental empirical studies on what value digital games can offer to education and learning, especially in formal settings [59], [40]. This lack of evidence has meant that there is little concrete information to guide research and practice of game-based learning implementation including the effective engagement of stakeholders in the process. This has resulted in research about the value of game-based learning producing contradictory results [60], [61], [62].

A further challenge faced by digital educational games is how to design and implement them effectively within a classroom setting. Deeper investigation is needed particularly when used in a traditional classroom environment. As suggested by [63], research into game-based learning should focus not only on the features and content, but also specifically on the target audience and the learning outcomes: for whom it is being developed, and why is it being developed? To address these concerns, the authors initially worked with young people to identify a digital game engagement framework which identifies the most important set of factors that attract and engage young people in a digital game [64]. This provided a framework for designing an educational digital game to ensure it was entertaining as well as educational. The design also considered that the learning should align with the national primary mathematics curriculum and would be used in a traditional classroom setting in Nigeria.

The main aim of this study was to evaluate if *SpeedyRocket*, a game designed in accordance with this framework and educational requirements, could be used effectively to stimulate interest and engagement with mathematics in a Nigerian classroom. The research questions that guided this study are:

i. What is the effect of digital educational games on the attitude to mathematics of pupils in the classroom?
ii. What happens when digital educational games are introduced into the traditional Nigerian classroom?

II. RESEARCH METHODS AND SAMPLE

This study adopted an action research case study method where the authors engaged with children and teachers from a set of three primary schools in Nigeria to answer the main research aim and associated research questions. The implementation of *SpeedyRocket* for this case study used the ideal research site features described by [65] to select the schools. These features include sites where:

i. Entry is possible
ii. There is a rich mix of the processes and people
iii. There is a possibility of building strong relations with the participants
iv. Ethical and political considerations are not overwhelming.

IEEE Access
Multidisciplinary ⁝ Rapid Review ⁝ Open Access Journal

The participants were 60 Primary Year 4 and Primary Year 5 (aged 8-11 years) students from the three primary schools, each located in Ado-Ekiti state, Southern Nigeria. The 60 students were randomly assigned to either Group A (study group) or Group B (control group) prior to the commencement of the study. In terms of a rich mix, the school populations were mixed with respect to gender and socio-economic backgrounds. Prior to going out to the schools, this research obtained ethical approval. The teachers were briefed one month prior to the research and information pamphlets were then provided to the parents through the pupils two weeks before the intervention. The next section provides more information about the design of the digital educational game and its implementation of within the classroom.

III. DESIGN AND IMPLEMENTATION OF *SPEEDYROCKET* IN THE CLASSROOM

A. ***Design of SpeedyRocket:*** SpeedyRocket was developed using JavaScript, HTML5 and CSS and could be supported by every browser that complies with the HTML5 standards. For the purpose of this study, the game was played on Google Chrome. The development of the game went through 14 iterations (all versions available online at www.ajayiopeyemi.com/research/speedyrocket) with testing and evaluation carried out at each stage. The 14th version was used for this research study. In playing the game, participants were expected to navigate their way in space to reach their destination using the arrow keys. Before the rocket can launch, participants have to calculate time and fuel values for the flight based on distance and rocket speed. Players collect as many coins as they can to unlock other rockets, whilst avoiding obstacles that can destroy rocket health. A 5% error is allowed for flight timings if values are higher or lower than expected values. For example if the expected flight time is 10 hours, then values between 9.5 – 10.5 are allowed.

Mathematical elements and formulae

The mathematical elements and formulae incorporated in the game were:
Time = Distance/ Speed
Fuel Needed = Time x Fuel Consumption Rate
Parameters of distance, speed and fuel consumption rate were supplied for each stage.

The authors undertook the design and development of SpeedyRocket. This was because of the requirements for the context of this study and the need to engage teachers in the process. SpeedyRocket was designed to fit with aspects of the mathematics curriculum. This was important, as its use/acceptance was dependent on teachers' acknowledging that it supports the classroom delivery of the mathematics curriculum. The learning outcomes of the game were drawn from the teachers' lesson notes. As the teachers informed the researcher, each mathematics period lasts for thirty minutes, which covers introduction, classwork, and corrections. This presents a strict constraint in terms of game time in the classroom.

The main factor considered was the type of game that would be developed. The researchers decided to make a 2D game as opposed to the currently more popular 3D games. While a 3D game would present more interesting and exciting graphics and possibly a more engaging experience to the players, there was a key consideration that made the researcher opt for a 2D game. A 3D game would require the end device to have high specifications that could run the game. At the time of the development, the researchers were not certain about the devices available for the game so planned to go with a design specification that could work on low-end devices.

One other major determinant of the game engine was the development approach adopted by the researchers. The development of *SpeedyRocket* researcher used the iterative design methodology. This method is well developed in game design [66], [67]. It is based on a cyclic process of prototyping, testing, analysing and refining a product or process. In iterative prototyping, each prototype is not discarded but used as the basis for the next iteration in the development [68]. This was considered the most appropriate methodology as it afforded the researcher the flexibility to design, build, test and modify simultaneously and within a short time.

The game engine was therefore limited to a 2D platform with readily available events and behaviours and one that supports iterative prototyping and deployments to test. The researchers considered the following game engines: Game Maker Studio [69], CoCo2D [70], GameSalad [71], Construct2D [72] and Stencyl [73]. Although these all support iterative prototyping, the researchers eliminated CoCo2D, Stencyl and GameSalad as they do not offer enough flexibility and extension to create new games.

Apart from the apparent shortcomings of these engines, Construct2D is free to use and offer a better level of flexibility with respect to create one's own events and behaviours. Another major advantage of Construct2D to the researchers is its plugin feature. Construct2D plugin is in JavaScript – which helps the developer extend or create entirely new events and behaviours using the JavaScript Software Development Kit (SDK) [74]. One of the other major advantages of Construct2D is that it supports an extensive variety of devices and platforms. This was quite important, as the choice/availability of devices was not certain during the initial development of the game.

The design requirements for the design and implementation of this digital educational game were carefully drawn from the engagement framework [75], [76] combined with the

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2019.2912359, IEEE Access

specific educational requirements of the environment in which it was being used. The engagement framework provides the set of factors (challenge, social interaction, feedback, rewards, clarity of goal, immersion, thematic appeal, visual appeal and creativity) that young people regard as important entertainment elements in a game.

It also aligned with the estimation elements of the Nigerian mathematics curriculum with a focus on calculating speed, distance, time and fuel consumption. This latter requirement of linking the game to the curriculum was important for ensuring the teachers could see the relevance of using the game in their classroom. In addition to the curriculum connectedness, SpeedyRocket also had requirements around *ease of use* and *enabling environment*- constructs drawn from the initial work using the Technology Acceptance Model (TAM) with the teachers [77].

The game has seven levels of play, of increasing complexity and challenge. The authors were aware that the computers in the participating schools either had low specifications or were not functional. The schools were also not able to confirm that electricity would be available to power the desktop computers, or that there would be internet access to run web applications. As a consequence, the research team decided to design SpeedyRocket to run on any device with a web browser, whether it has internet access or not. Construct2D engine with Angular JS framework was used to develop SpeedyRocket.

B. ***Implementation of SpeedyRocket:*** The implementation of SpeedyRocket lasted for 3 weeks with one week of preparation/follow-up and two weeks of implementation of SpeedyRocket in the classroom. It took place in the second term of the schools' 2016/2017 academic session during October 2016. All but one of the thirty pupils (one child was absent on one of the days) in the study group played SpeedyRocket for 160 minutes over two weeks - an average of 15 minutes per session. The control group had traditional mathematics lessons for 30 minutes every day while the study group had 15 minutes for traditional mathematics lessons and thereafter played the game for 15 minutes every day for the two weeks. While the teachers in the control classrooms kept to their usual practice and taught their lessons on the chalkboard, teachers in the study group taught in each period for 15 minutes and supervised the game-play sessions for the rest of the time.

IV. DATA COLLECTION

Two types of data were gathered through the course of the intervention. Two weeks before the intervention, the mathematics attitude questionnaire was distributed to the sixty pupils across the three schools to gather the baseline data. Using the same questionnaire, follow up data was collected from the pupils on the last day of the study. Video, photos and notes using a proforma were used to collect observation data from the classrooms during the game play. The following instruments were used for the data collection

1) Attitude to mathematics questionnaire

The questionnaire was developed using Keller's ARCS model of motivational design theories [78] as a basis with a modified Fennema Sherman attitude scale [79]. It comprised ten attitudinal questions and two demographic questions and was kept intentionally short to limit the demand on the classroom time and ensure the pupils did not lose concentration while completing the questionnaires. A team of primary school teachers from the Nigerian schools checked the questionnaire for appropriateness of language, style and layout for the target age group. The reliability of the scale was also estimated using the Cronbach's alpha measure. The score is higher than the recommended 0.7 [80] indicating that the scale is reliable.

The questionnaires were administered to the pupils before and after the two-week intervention. Within each of the three schools, the subjects were grouped into two classes: study and control. The questionnaire measured the pupils' attitude to mathematics using a 10-item scale. For the descriptive analysis, the responses were coded as strongly agree = 4, agree = 3, neither = 2, disagree = 1, and strongly disagree = 0.

2) Pupils' observation

Observation was used in this study to answer the 'what is going on here question'. Studies that have examined the use of technology in schools often rely on self-reported data from teachers or students, which can often be unreliable. Observation also offers researchers insight into the 'lived' experiences of the pupils in the classroom context, and can highlight areas that pupils may not necessarily want to talk about or self-report. This was particularly important as this study took place in classrooms where technology had not been used initially.

Observational data was collected in order to ensure that the experience of the pupils with *SpeedyRocket* could be explored and captured in situ and to support the self-reported data collected through the questionnaire. The observation process allows a better understanding of the context of the research and how it is influencing the classroom experiences and occurrences. This was "so that theories remain grounded in observations of the social world, rather than being generated in the abstract" [81]. Also, in the context of the pupils, there may have been elements they may have been unwilling or shy to talk about in an interview or focus group. Furthermore, "a major advantage of direct observation is that it provides here-and-now experience in depth" [82].

The observation included the use of video, photos and notes from the classrooms. A camcorder on a tripod and a stills camera were used to record the gameplay in the classroom. This was supplemented with notes on interactions, communication and exchanges during the gameplay. These were analysed qualitatively. The observer was a member of the classroom settings for both the traditional classrooms and the *SpeedyRocket* classrooms where he observed the actions and reactions of the control and study groups over the two-week period.

V. DATA ANALYSIS AND RESULTS

The data from the attitude questionnaire was entered into SPSS and the Wilcoxon Signed-Rank test was carried out to test the hypothesis. The following presents details of this analysis and the subsequent results.

1) ***Demographics****: The demographics of the 60 research participants are provided in Table 1*

TABLE 1. DEMOGRAPHICS OF PARTICIPANTS

Age	Frequency (%)	Gender	Frequency (%)
Control Group			
8	27	Female	50
9	36	Male	50
10	20		
11	17		
Study Group			
8	23	Female	53
9	33	Male	47
10	40		
11	4		

2) Descriptive analysis:

The means of the attitude scale are shown in Table 2 and indicate that the attitude of the observed participants in the baseline data is quite low. This is particularly true for item 9 (This mathematics class was worth my time and effort) for the study group baseline, and item 10 (I would talk to my teachers about a career that uses mathematics) for the control group baseline. The two most positive responses for the control and study groups (item 3 and item 4 respectively) were neutral (item 3: M = 2.03; item 4: M = 2.53) showing a generally poor attitude to mathematics in the classroom by the participants.

TABLE 2. DESCRIPTIVE STATISTICS FOR CONTROL AND STUDY GROUPS

	Baseline Means		*Post Means*	
Item Description	study group	control group	study group	contr
1. Mathematics classes are not boring	1.97	1.53	3.00	1.
2. I look forward to my mathematics classes	1.93	1.63	3.30	1.
3. I am comfortable in my mathematics classes	2.07	2.03	2.97	1.
4. I love to attend mathematics classes	2.53	2.11	3.13	2.
5. I would like to have more mathematics classes	1.93	1.57	3.27	1.
6. I learn interesting things in mathematics classes	1.96	1.60	3.30	1.
7. I would like to know more about the topics we did in the mathematics classes	2.30	2.00	3.17	2.
8. I really enjoyed completing tasks in my mathematics classes	1.73	1.83	3.27	1.
9. This mathematics class was worth my time and effort	1.43	1.63	3.10	1.
10. I would talk to my teachers about a career that uses mathematics	1.97	1.43	3.30	1.

As shown by the post intervention means (Table 2), the responses of the study group to the attitude to mathematics questionnaires improved and were more positive than those of the control group. However, these numbers are not sufficient to determine if a significant change has occurred among the groups within the two weeks. It was therefore decided to use a more robust statistical test to examine the differences, improvement and how significant they were.

The Wilcoxon Signed-Rank test is a non-parametric test carried out to measure or compare differences between two sets of data from the same participants from one point to the other or after the participants have been subject to one or more conditions. It is an alternative to the dependent t-test, which is a parametric test and assumes an approximate normal distribution. In the case of this data, the normality assumption was violated, and so a Wilcoxon Signed-Rank test was an appropriate alternative to use. The researchers carried out separated non-parametric repeated measures on control and study groups rather than a single one because they were keen to examine the two groups separately. Moreover, the baseline results for both groups showed that they had slightly different scores. It was therefore appropriate to treat the analysis in such manner.

Following [83] and [84], an appropriate method of creating high, medium and low ranges from a likert-scale is to create composite scores and assign it to a variable. This can be done when the items of the scale are weighted equally – which is true in the case of this study. The composite score is a representative of the variable – attitude to classroom mathematics. The intention was to assess this as a variable and not assess the individual items on the scale as separate constructs. To get the composite attitude to mathematics score for the analysis, the likert values were weighted as below:

Strongly agree (2) Agree (1) Neither (0) Disagree (-1) Strongly Disagree (-2)

Therefore, a response of "*strongly agree"* to the 10 items will produce an attitude score of 20; "*neither*" would produce 0 while "*strongly disagree"* would produce -20.

The composite attitude to mathematics score was then divided into three – -20 to 6 (low), 7-14 (medium) and 15-20 (high), and these were coded into SPSSv22 as 1,2 and 3 respectively. The Wilcoxon Signed-Rank test for the control group was run and the results are presented in Table 3.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2019.2912359, IEEE Access

TABLE 3. RANK TABLE FOR CONTROL AND STUDY GROUP

	N	Mean Rank	Sum of Ranks
Control group			
Negative Ranks	2a	3.50	7.00
Positive Ranks	4b	3.50	14.00
Ties	24c		
Total	30		
Study group			
Negative Ranks	1a	15.00	15.00
Positive Ranks	19b	10.26	195.00
Ties	10c		
Total	30		

a. Post < Baseline
b. Post > Baseline
c. Post = Baseline

The control group's results shows that 2 participants had lower ranks after the two weeks than before the two weeks, 4 had positive improvements in their ranks and 24 saw no change in their ranks. For the study group, 1 had a lower rank after the 2 weeks, 19 had higher ranks compared to the baseline while there were 10 ties. These ranking results show a positive shift in the composite attitude scores of the study group compared to the those of the control group.

The test statistics Table 4 shows a significant ($p < 0.05$) positive change (as also shown by the rank table and post-means) in the attitude to mathematics ($Z = -3.464$; $p = 0.001$), while the results for the control group did not present any significant change ($p > 0.05$; $Z = -0.816$; $p = 0.414$). These statistical results show that the study group have a more positive attitude to mathematics following the intervention compared to the control group.

TABLE 4. TEST STATISTICS TABLE

Control group	
Z	-.816
Asymp. Sig. (2-tailed)	.414
Study group	
Z	-3.464
Asymp. Sig. (2-tailed)	.001

The following section presents the findings from observing the use of *SpeedyRocket* in the classroom.

3) *Observation of SpeedyRocket gameplay*

The quantitative results and analysis presented above demonstrate that young people who played digital educational games alongside their traditional mathematics lessons reported better attitude and enjoyment of the mathematics classroom. However, the quantitative results do not provide any information about the changes in the dynamics between teachers and pupils as well as other changes in the classroom experience of the pupils.

This section presents the key themes that emerged from the observations. Each theme presents the contrasts between the traditional classroom and the game classroom as well as the transformation that occurred with the digital educational game.

a) *Increased Motivation and Enjoyment*

One of the challenges teachers face in the classroom is that of motivating students [85]. This is particularly the case with Science, Technology, Engineering and Mathematics (STEM) [86]. Anecdotal evidence suggests that even high achieving students may not be motivated to learn mathematics, and do it only because they know they have to, and then they drop the subject as soon as they think it is no longer important. But mathematics skills are becoming more important in today's world and they are central to success in other science and engineering careers.

Figure 1a Pupils from 'school A' during one of the play sessions

The traditional classrooms in Nigeria, especially the upper primaries are often viewed as boring. Kindergarten classes (3-5 ages) are exciting as pupils' activities and tasks are more engaging and fun. However, the fun reduces from primary one (age 6) up until primary 5 (10) where 'serious academics' is the order of the day. Little or no fun, exploration or discovery is done in upper primary– this is the status quo in the classes. During the gameplay sessions, the first observation of the pupils who played *SpeedyRocket* was their increased motivation, enthusiasm and excitement with classroom mathematics. The current study cannot discriminate between the effect of the Speedy Rocket game and that of the tablet devices themselves. The traditional mathematics classroom presented mathematics as a theoretical and dull subject. The teachers and pupils both know this. Mathematics is not a subject many of the pupils

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2019.2912359, IEEE Access

looked forward to, so the excitement and enthusiasm that accompanied the mathematics period in the study group was obvious. With the control group, the usual reaction to the sound and announcement of the school bell for 'mathematics period' was the lack of enthusiasm and eagerness. There was also a visible difference in the amount of focus pupils in the study group had on classroom tasks. It appeared from the observations that the children demonstrated a deeper level of involvement in the tasks.

The traditional approach of the teacher writing on the chalkboard, explaining examples and giving pupils their own tasks to do was the teaching style observed in the control classroom. Pupils remained visibly disconnected and mostly participated because they had to with the teachers continually asking the pupils to focus. However, the study group looked more like the lower primaries and kindergarten classrooms, with pupils smiling, engaging and interested in both the play and the tasks. For these pupils, the use of the game enhanced their learning experience, captured their attention and focus and provided an opportunity to enjoy the classroom mathematics. This increased their motivation making them more receptive and ready to learn.

The pupils were aware that the game formed just part of their usual mathematics period. They knew they were also doing tasks associated with the topic that was on the chalkboard, yet despite that, their interest in the mathematics topic grew as they played the game. They did the calculations on their worksheets with more enthusiasm, and this was noticeable as they knew they needed to use the results to 'power their rockets' in the game. The application of the calculations was immediately apparent and the incentive to perform the calculations was also evident to the pupils.

b) Change in young people's perception of failure

In the traditional classroom setting in the school, the mathematics period starts with the teachers presenting the topic with examples for about ten minutes. After this, he/she gives the class a set of exercises to do based on the examples. The teacher then collects the pupils' books, scores them and hands them back to the pupils. The correction of the tasks is performed on the chalkboard and students who missed some exercises write the corrections into their books. In Nigeria's primary education setting, the performance position of each pupil within the classroom is widely used. There is a general sense (from teachers, pupils and parents) that some pupils are brilliant and smart while others are not. This assessment is based on the daily and weekly performance in classroom exercises. The report sheet at the end of the school term, which is cumulative of classwork, tests and exams, shows the positions of the pupils from first to last position – with high-achieving students awarded prizes at an event attended by teachers, pupils and parents. This end of term activity is also modelled daily in the classroom. Pupils who are not considered 'brilliant' are often not expected to do well in mathematics. This attitude from teachers and other pupils in the classroom can often discourage these pupils from engaging in the classroom. From observing the traditional mathematics classroom, it was easy to identify the pupils that are classed as brilliant and the ones that are classed as not so smart.

The fear of saying something wrong, failing, and being classed as 'poorly performing' in the classroom isolates, stresses and disengages these students in the classroom. The practice in the classroom is that teachers share the scores of every pupil to the whole classroom. In becoming part of the classroom and in order to perform better, pupils can end up stressed and may even give up responding to questions or assume that they are not good at mathematics.

The stress from the fear of failure is often compounded by the insecurity pupils feel. Not all pupils get the chance to show they are good at something in the classroom as teaching is fully theoretical and performance-based.

Figure 1b Pupils from 'school A' during one of the play sessions

In the study group, pupils' confidence as well as comfort visibly increased. Engaging with the game appeared to result in a decrease of both anxiety and stress that often accompanied mathematics lessons. Learning while having fun, without the pressure of getting it at once or according to a standard method on the chalkboard brought calmness and relaxation to the learning experience. Pupils were also more tenacious and persistent in solving problems. It was interesting to observe that they felt they knew they could find the solutions to the mathematics tasks. Failure was no longer a permanent stop for them but was an invitation for them to try harder at their own pace without the pressure of being classed as poor performing or less intelligent than others. From the observation, players enjoyed the flexibility and

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2019.2912359, IEEE Access

freedom to try as many times as possible to succeed as they played.

This agrees with previous findings from game-based learning [87], that argues that one of its values is the chance it provides to players to fail in a safe environment where their decisions do not cause catastrophic implications. The stigma in the traditional classroom associated with being the person the whole class is waiting on to progress to the next task was missing during the game-based learning sessions. It was alright for the pupils to learn at their own pace, and try things out and experiment until they were satisfied with their results.

c) Personalised learning pathways

In contrast to some implementations of digital game-based learning in the classroom, this study did not use a leader board, or anything similar to record achievement during game play. Primarily, this was to avoid a competitive situation which might discourage pupils who may not progress through the game as quickly as others. It also allowed the research team to explore the actions and reactions of the pupils to the different game dynamics. Given that different engagement factors were built into *SpeedyRocket*, the researchers were keen to observe how the pupils interacted with the game with respect to the different factors.

Figure 1c Pupils from 'school B' during one of the play sessions

One of the interesting observations from the gameplay is the different ways pupils chose to structure their play and how that presents different definitions of success. To some, success in the game was the accumulation of coins, while to others it was progression from one planet (level) to another. While some students chose to earn more coins to buy a bigger rocket which could travel faster and help them make progress in the game, other pupils simply made more coins, and stayed on the same level. They appeared to be more fascinated by the rewards but less concerned about completing the levels. Another example is provided through the creativity feature embedded within *SpeedyRocket.* Whilst some pupils spent time designing their rockets, and naming them, other players skipped the process and just wanted to start the game and get on with it. The pupils interacted with the game in a variety of ways, reinforcing the findings from [88] on the spectrum of game engagement factors. Individual players find different combinations of engagement factors personally appealing.

d) Collaboration and cooperation in the classroom

As noted earlier, the traditional classroom, especially the older ages is mostly quiet apart from the teacher's voice explaining or passing instructions to the pupils. The class captain often keeps a list of 'noise-makers' who are punished by the teacher at some point during the day. The quietness is accompanied by a strong sense of competition as the pupils' performances are assessed by who gets the highest score in classroom tasks. However, this competition manifests in a negative fashion, discouraging teamwork or peer support.

In contrast to this dynamic, in the study group classroom, collaboration and teamwork were apparent. Pupils, knowing there was no noisemakers list being written had the freedom to be expressive. The usual 'calm down' and "face your work" in the traditional classroom was overturned. The expressions came in the form of cooperation but also competition.

It was interesting to observe some of the pupils who had completed some arithmetic calculations on their worksheets, or successfully navigated one of the planets, offering to help their colleagues through the same process. The pupils shared advice and tips on how to make progress in the game. This peer support did not remove competition as some players who offered to help and share tips on how to make progress in the game still celebrated their wins and advancements over the players they helped. Some of the pupils took up leadership positions in the classroom, sometimes jumping out of their desks to go across and help others to navigate a difficult path or do some arithmetic.

SpeedyRocket helped to break the barrier of communication in the classroom as pupils engaged and interacted with one another. This change was not acceptable to some of the teachers: it challenged the fundamental structure of classroom setup in the schools.

e) Power shift in the classroom

This is one of the most apparent changes the researchers observed between the control and study classrooms. It was also the second most challenging change (after interactivity) for the teachers to accept. In the traditional classroom, teachers are the 'sage on the stage'. They are considered to be the 'expert' and for the majority of the time, instructions

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

are handed down to the pupils. The teachers do most of the talking while the pupils respond once in a while to questions (from the teachers). The questions are also usually closed-ended, such as "do you understand?" or "is this right?". These questions often do not require any thinking from the pupils, who mostly chorus "yes" or "no" depending on what they think the teacher wants to hear.

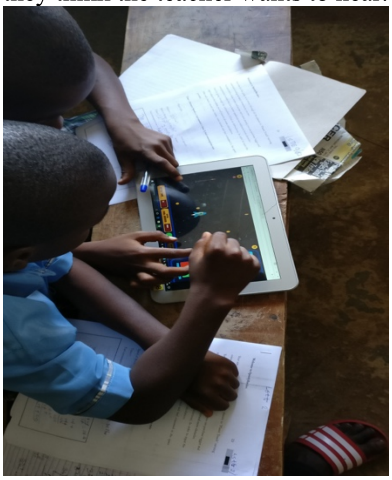

Figure 1d Pupils from 'school C' during one of the play sessions

The pupils are mainly recipients and consumers of information and therefore take a submissive role in the classroom. Due to this perspective and image of the teachers as 'experts', pupils do not question styles, methods or anything that the teachers write on the board. These things are considered to be sacrosanct and final. This power position of teachers means that pupils are largely excluded from the process of knowledge creation in the regular traditional classroom.

This dynamic changed in the study classroom. Apart from the improvement in the enthusiasm of the pupils, as the pupils began to feel more empowered, they felt more in control of their actions. It increased the interest, participation and involvement of pupils in the classroom compared to the traditional control classroom. Pupils took a greater responsibility for their learning and teachers played a supervisory role as opposed to the driver role. As mentioned earlier, this was strange to the teachers, who are used to doing most of the talking while students looked on. These teachers now had to look on as pupils played the game and found ways to complete the tasks by themselves. The teachers were not completely left out of the process, but they moved on from being the 'sage on the stage' to being a 'guide on the side'.

VI. Discussion

Firstly, the findings from this study show compelling evidence that digital educational games can improve the attitude to and engagement with mathematics of young people in the classroom. This supports other evidence from literature [34], [37] that suggest that the use of technology can enhance the motivation and attitude of students in the classroom. The components of the ARCS model were significantly improved in particular. as shown in the results of the post questionnaires. Particular items like "looking forward to my mathematics classes", and "learning interesting things in mathematics classes" were evidenced through the improved scores of the results of the post questionnaires with the study group. The use of SpeedyRocket demonstrates how digital games can be used to effectively transform the Nigerian classroom climate from what Bature *et al.* [13] described as "unengaging, boring and teacher-centered", to a fun, student-centered and engaging space for students to effectively participate and learn.

In addition to providing a more engaging classroom experience, findings from this study suggests that digital educational games can potentially bridge the gap between practical knowledge and theoretical understanding by presenting the educational concepts and their application in a more relatable way to students. This agrees with other research that suggests that digital game-based learning engenders experiential and practical learning [50], [51]. This is advantageous in two dimensions – firstly, it helps to address the challenge of impractical and rote teaching of mathematics identified by Etuk and Bello [3]. This challenge is particularly common in countries like Nigeria where practical science knowledge is not readily available and the economic environment limits the access of pupils to practical lessons. By providing a platform for students to experience and contextualise their learning experience, the use of digital game-based learning could offer this practical experience to learners.

Secondly, digital educational games have the capacity to create interests in subjects and careers that are experiencing shortages – especially STEM careers. Item 10 – "I would talk to my teachers about a career that uses mathematics", showed a significant improvement post the use of *SpeedyRocket* in the classroom. Digital educational games can therefore generate interest in not just classroom mathematics but also in related careers by providing practical and contextual examples of the application of the subjects and lessons they learn in school to the real world [50].

As previous studies suggest, one of the ways to diversify the learning experience of pupils is to encourage collaboration and teamwork [18], [53]. This was observed during the game-play sessions that took place as part of this study. Collaboration and cooperation provided a more engaging environment for the young people to learn together in the classroom. Likewise, friendly competition made the classroom atmosphere more exciting and interactive as students shared and learnt together. An interesting discovery was the confidence that the learning process produced with the pupils who are usually quiet and less responsive in the

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

traditional classroom. This research illustrates that collaboration, cooperation and teamwork can be put to use in getting learners to interact better in the classroom, thereby addressing the monologue challenge the Nigerian classroom faces [18], [19] and technology can support this collaboration.

The specific contribution of this research is the understanding and insight it provides into the changes in the classroom dynamics when the digital educational game was introduced. Most research into digital educational games has been carried out in classrooms in developed countries where the culture is different to that in Nigeria. As Perrotta *et. al.* [64] suggests game-based learning research needs to be carried out in respect to the context of study. As such the results of the impact of digital educational games cannot be generalised especially when the peculiarities of the specific educational context are considered. This research opens up a window of understanding by providing a rich qualitative account of the changes that occurred in a classroom through the introduction of a digital educational game, with the most important change perhaps being the shift in the power balance in the classroom. The use of SpeedyRocket in the traditional classroom 'gave voice to the pupils', and although it did not silence the teachers, it was not the most comfortable situation for them.

In addressing the main research aim, this research also found out that it is not enough to design an engaging game. It is equally as important to carefully consider the status quo of the educational context and how the innovation is likely to affect the current dynamics. Much more than that, it is important to prepare the stakeholders for the changes that will likely occur.

These findings suggest profound implications for using digital games and also digital technology generally in education in Nigeria. Amidst several calls to adopt innovative tools and integrate them to solve existing problems in the classroom [28], [29], [49], it is important that this is not a rushed activity as this could risk creating more problems. It should be well planned and structured. The findings of this research align with earlier literature [3], [13], [18] suggest that mathematics in itself may not be the challenge, but the challenge is how the subject is delivered and the inherent structure of classroom practice in Nigeria, agreeing with existing literature [3], [13], [18].

It implies that for young people to be better engaged in the classroom, barriers to communication, sharing, cooperation and collaboration need to be broken down [30], [54]. While digital educational games are great tools to enable this to happen, teachers do not necessarily have to use games to change the dynamics. However, there is a need for them to first acknowledge that the dynamics in the classroom need to change to facilitate a more student-centered, participatory and active learning approach, and for them to understand how they can contribute to that change. Many of the previous research studies as to why technology adoption and integration is slow in Nigeria have focused on factors such as unavailability of devices, infrastructure development and government policies. However, this research highlights the overarching significance of potential disruption to the status quo to the dynamics of the traditional classroom.

VII. FUTURE RECOMMENDATION AND LIMITATIONS

This study adopted a rigorous approach to the research, but the authors still recognise there are limitations to the study in terms of context and learning gain. The study was set in three primary schools in one state in Nigeria. It would be useful to look at a wider or different sample of young people to determine whether these would yield similar findings. In particular the authors would be keen to explore the following:

- Undertaking further interventions with groups of young people in similar and different contexts and locations
- Exploring the impact of individual differences such as age, gender, and technology proficiency on the results.
- Exploring whether an external control group (to the population under study) could be used to control the Hawthorns effect [89].

Also, this particular study did not evaluate the learning effectiveness of the game, as this was not the focus of the study. However, given that ultimately the goal of a classroom teacher would be to see if the tool they adopted does support the learning of their pupils, a future study could include an evaluation of the learning effectiveness of the digital educational game.

Finally, this study collected and measured attitude and engagement immediately prior to and posts the use of the game in the classroom. However, these concepts are much more complex and should be approached more critically. A longitudinal approach in which data is collected several times during and for a more considerable time after the intervention would provide an analysis of the effect the digital game is having on the young people over the longer term.

VIII. CONCLUSION

The use of digital educational games can help improve the engagement and attitude of pupils to mathematics in the classroom. Games can provide a useful tool to disrupt the classroom to bring about a more active learning experience, as observed in this study taking place in traditional classrooms in Nigeria where rote teaching and learning is common.

This research was conducted to examine what happens when a digital educational game enters a classroom – one in which such tools have never been used. The statistical analysis of the results shows that there was an improvement in the reported attitude of the pupils who played the digital game compared to the attitude of those who did not play. The classroom observation also shows that the use of *SpeedyRocket* improved classroom engagement and interaction and provided a more individualised learning experience for the pupils. Most importantly, this study supports the notion that digital educational games are found to be useful tools in breaking down barriers between learners and changing the classroom dynamics by helping young people to be active and collaborative participants in their learning and teaching of mathematics. The findings of this study provide valuable insights into the advantages of technology-enhanced learning for teachers, policy makers as well as learning technologists.

REFERENCES

[1] A. E. Maliki, A. N. Ngban, and J. E. Ibu, "Analysis of Students' Performance in Junior Secondary School Mathematics Examination in Bayelsa State of Nigeria," *Stud. Home Community Sci.*, vol. 3, no. 2, pp. 131–134, Dec. 2009.

[2] M. Omameh, "Survey of students' poor performance in mathematics," 2011.

[3] E. D. Etuk and D. O. Bello, "CHALLENGES AND PROSPECTS OF MATHEMATICS EDUCATION IN NIGERIA," *J. Assert.*, vol. 2276, p. 9684, 2016.

[4] K. Gravemeijer, M. Stephan, C. Julie, F.-L. Lin, and M. Ohtani, "What Mathematics Education May Prepare Students for the Society of the Future?," *Int. J. Sci. Math. Educ.*, vol. 15, no. 1, pp. 105–123, 2017.

[5] J. Suratno, "The Development of Students Worksheet Using Geogebra Assisted Problem-Based Learning and its Effect on Ability of Methematical Discovery of Junior High Students," *Implement. Educ. Methematics Sci. Proceeding 3thInternational Coference Res. Yogyakarta*, 2016.

[6] A. K. Tsafe, "Contributions of mathematics education to economic development and sustainability in Nigeria," 2014.

[7] P. O. Daso, "Mathematics Education for Sustainable Development: Implications for Scientific and Technological Literacy," *Acad. Res. Int.*, vol. 4, no. 5, p. 557, 2013.

[8] F. R. of Nigeria, *Nigeria National Policy on Education*. 2004.

[9] A. Adedigba, "WAEC performance drops nationwide, 26% candidates score five credits including Maths, English - Premium Times Nigeria," 2017. [Online]. Available: https://www.premiumtimesng.com/news/headlines/250226-waec-performance-drops-nationwide-26-candidates-score-five-credits-including-maths-english.html. [Accessed: 19-Nov-2018].

[10] T. U. Sa'ad, A. Adamu, and A. M. Sadiq, "The causes of poor performance in mathematics among public senior secondary school students in Azare Metropolis of Bauchi State, Nigeria," *IOSR-Journal Res. Method Educ.*, vol. 4, pp. 32–40, 2014.

[11] O. A. Asikhia, "Students and teachers' perception of the causes of poor academic performance in Ogun State secondary schools [Nigeria]: Implications for counseling for national development," *Eur. J. Soc. Sci.*, vol. 13, no. 2, pp. 229–242, 2010.

[12] C. G. M. Bakare, "Mass Failure in Public Examinations: Some Psychological Perspectives: Monograph," *Dep. Guid. Couns. Univ. Ibadan, Ibadan*, 1994.

[13] I. J. Bature, B. Atweh, and D. Treagust, "Inclusivity: An Effective Tool for Achieving Quality Mathematics Classroom Instruction in Nigerian Secondary Schools.," *Univers. J. Educ. Res.*, vol. 4, no. 1, pp. 173–180, 2016.

[14] K. L. Bierman, "The promise and potential of studying the 'invisible hand' of teacher influence on peer relations and student outcomes: A commentary," *J. Appl. Dev. Psychol.*, vol. 32, no. 5, pp. 297–303, 2011.

[15] K. Schenke, E. Ruzek, A. C. Lam, S. A. Karabenick, and J. S. Eccles, "Heterogeneity of student perceptions of the classroom climate: a latent profile approach," *Learn. Environ. Res.*, vol. 20, no. 3, pp. 289–306, 2017.

[16] S. Scrimin, U. Moscardino, G. Altoè, and L. Mason, "Attentional Bias for Academic Stressors and Classroom Climate Predict Adolescents' Grades and Socioemotional Functioning," *J. Res. Adolesc.*, vol. 28, no. 1, pp. 245–258, 2018.

[17] D. E. Adimora, E. N. Nwokenna, J. C. Omeje, and U. N. Eze, "Influence of Socio-Economic Status and Classroom Climate on Mathematics Anxiety of Primary School Pupils," *Procedia-Social Behav. Sci.*, vol. 205, pp. 693–701, 2015.

[18] C. F. Okafor and U. S. Anaduaka, "Nigerian school children and mathematics phobia: How the mathematics teacher can help," *Am. J. Educ. Res.*, vol. 1, no. 7, pp. 247–251, 2013.

[19] O. Ajayi, C. Audu, and E. Ajayi, "Influence of Class Size on Students' Classroom Discipline, Engagement and Communication: A Case Study of Senior Secondary Schools in Ekiti State, Nigeria," 2017.

[20] A. J. Ayeni, "Teachers' Classroom management and Quality Assurance of Students' Learning Outcome in Secondary Schools in Ondo State, Nigeria," *J. Soc. Adm. Sci.*, vol. 4, no. 2, pp. 166–180, 2017.

[21] UNESCO, "THE WORLD NEEDS ALMOST 69 MILLION NEW TEACHERS TO REACH THE 2030 EDUCATION GOALS," *UNESCO Institute for Statistics*, 2016. [Online]. Available: http://unesdoc.unesco.org/images/0024/002461/246124e.pdf. [Accessed: 07-Oct-2018].

[22] Z. K. Mbugua, K. Kibet, G. M. Muthaa, and G. R. Nkonke, "Factors contributing to students' poor performance in mathematics at Kenya certificate of secondary education in Kenya: A case of Baringo county, Kenya," 2012.

[23] D. O.-M. J. of S. Sciences and undefined 2012, "Strategies for teaching and sustaining mathematics as an indispensable tool for technological development in Nigeria," *erint.savap.org.pk*.

[24] D. Bornstein, "A Better Way to Teach Math," 2011. .

[25] B. Sule, M. M. Hussaini, U. S. Bashir, and A. Garba, "Mathematics Phobia among Senior Secondary School Students: Implication for Manpower Development in Science Education in Nigeria."

[26] D. Tolks *et al.*, "An introduction to the inverted/flipped classroom model in education and advanced training in medicine and in the healthcare professions," *GMS J. Med. Educ.*, vol. 33, no. 3, 2016.

[27] A. C. Butler, E. J. Marsh, J. P. Slavinsky, and R. G. Baraniuk, "Integrating cognitive science and technology improves learning in a STEM classroom," *Educ. Psychol. Rev.*, vol. 26, no. 2, pp. 331–340, 2014.

[28] G.-J. Hwang, C.-L. Lai, and S.-Y. Wang, "Seamless flipped learning: a mobile technology-enhanced flipped classroom with effective learning strategies," *J. Comput. Educ.*, vol. 2, no. 4, pp. 449–473, 2015.

[29] I. Boticki, J. Baksa, P. Seow, and C.-K. Looi, "Usage of a mobile social learning platform with virtual badges in a primary school," *Comput. Educ.*, vol. 86, pp. 120–136, 2015.

[30] J. Lu, S. Meng, and V. Tam, "Learning Chinese characters via mobile technology in a primary school classroom," *EMI. Educ. Media Int.*, vol. 51, no. 3, pp. 166–184, 2014.

[31] T. Rashid and H. M. Asghar, "Technology use, self-directed learning, student engagement and academic performance: Examining the interrelations," *Comput. Human Behav.*, vol. 63, pp. 604–612, 2016.

[32] P.-H. Cheng, Y.-T. C. Yang, S.-H. G. Chang, and F.-R. R. Kuo, "5E mobile inquiry learning approach for enhancing learning motivation and scientific inquiry ability of university students," *IEEE Trans. Educ.*, vol. 59, no. 2, pp. 147–153, 2016.

[33] D. Churchill and T. Wang, "Teacher's use of iPads in higher education," *EMI. Educ. Media Int.*, vol. 51, no. 3, pp. 214–225, 2014.

[34] M. L. Shirley and K. E. Irving, "Connected classroom technology facilitates multiple components of formative assessment practice," *J. Sci. Educ. Technol.*, vol. 24, no. 1, pp. 56–68, 2015.
[35] B. J. Zimmerman and A. S. Labuhn, "Self-regulation of learning: Process approaches to personal development.," 2012.
[36] D. H. Schunk, "Self-efficacy for reading and writing: Influence of modeling, goal setting, and self-evaluation," *Read. &Writing Q.*, vol. 19, no. 2, pp. 159–172, 2003.
[37] A. Saba, "Benefits of technology integration in education," 2009.
[38] L. Pombo, M. M. Marques, V. Carlos, C. Guerra, M. Lucas, and M. J. Loureiro, "Augmented Reality and mobile learning in a smart urban park: pupils' perceptions of the EduPARK game," in *Conference on Smart Learning Ecosystems and Regional Development*, 2017, pp. 90–100.
[39] E. Akpabio and I. B. Ogiriki, "Teachers use of Information and Communication Technology (ICT) in Teaching English language in Senior Secondary Schools in Akwa Ibom State," 2017.
[40] T. M. Connolly, E. A. Boyle, E. MacArthur, T. Hainey, and J. M. Boyle, "A systematic literature review of empirical evidence on computer games and serious games," *Comput. Educ.*, vol. 59, no. 2, pp. 661–686, 2012.
[41] V. Garneli, M. Giannakos, and K. Chorianopoulos, "Serious games as a malleable learning medium: The effects of narrative, gameplay, and making on students' performance and attitudes," *Br. J. Educ. Technol.*, vol. 48, no. 3, pp. 842–859, 2017.
[42] J. Hamari, "Transforming homo economicus into homo ludens: A field experiment on gamification in a utilitarian peer-to-peer trading service," *Electron. Commer. Res. Appl.*, vol. 12, no. 4, pp. 236–245, 2013.
[43] V. Riemer and C. Schrader, "Learning with quizzes, simulations, and adventures: Students' attitudes, perceptions and intentions to learn with different types of serious games," *Comput. Educ.*, vol. 88, pp. 160–168, 2015.
[44] E. Southgate, J. Budd, and S. Smith, "Press Play for Learning: A Framework to Guide Serious Computer Game Use in the Classroom.," *Aust. J. Teach. Educ.*, vol. 42, no. 7, pp. 1–13, 2017.
[45] E. A. Boyle *et al.*, "An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games," *Comput. Educ.*, vol. 94, pp. 178–192, 2016.
[46] C. Girard, J. Ecalle, and A. Magnan, "Serious games as new educational tools: how effective are they? A meta-analysis of recent studies," *J. Comput. Assist. Learn.*, vol. 29, no. 3, pp. 207–219, 2013.
[47] L. De-Marcos, A. Domínguez, J. Saenz-de-Navarrete, and C. Pagés, "An empirical study comparing gamification and social networking on e-learning," *Comput. Educ.*, vol. 75, pp. 82–91, 2014.
[48] C. Su and C. Cheng, "A mobile gamification learning system for improving the learning motivation and achievements," *J. Comput. Assist. Learn.*, vol. 31, no. 3, pp. 268–286, 2015.
[49] T.-C. Hsu, "Learning English with augmented reality: Do learning styles matter?," *Comput. Educ.*, vol. 106, pp. 137–149, 2017.
[50] L. Clarke and M. Gribling, "Obstacles to diversity in construction: The example of Heathrow Terminal 5," *Constr. Manag. Econ.*, vol. 26, no. October, pp. 1055–1065, 2008.
[51] D. Perkins, "The many faces of constructivism.," *Educ. Leadersh.*, vol. 57, no. 3, pp. 6–11, 1999.
[52] D. Cecez-Kecmanovic and C. Webb, "Towards a communicative model of collaborative web-mediated learning," *Australas. J. Educ. Technol.*, vol. 16, no. 1, 2000.
[53] S. Lane, "Promoting Collaborative Learning among Students," *Am. J. Educ. Res.*, pp. 602–607, 2016.
[54] R. M. Palloff and K. Pratt, *The virtual student: A profile and guide to working with online learners*. John Wiley & Sons, 2003.
[55] P. M. Greenfield, *Mind and media: The effects of television, video games, and computers*. Psychology Press, 2014.
[56] S. L. Calvert *et al.*, "The American Psychological Association Task Force assessment of violent video games: Science in the service of public interest.," *Am. Psychol.*, vol. 72, no. 2, p. 126, 2017.
[57] E. S. Pietri *et al.*, "Using video to increase gender bias literacy toward women in science," *Psychol. Women Q.*, vol. 41, no. 2, pp. 175–196, 2017.
[58] A. Gabbiadini, P. Riva, L. Andrighetto, C. Volpato, and B. J. Bushman, "Acting like a tough guy: Violent-sexist video games, identification with game characters, masculine beliefs, & empathy for female violence victims," *PLoS One*, vol. 11, no. 4, p. e0152121, 2016.
[59] S. Moser, "Linking virtual and real-life environments: Scrutinizing ubiquitous learning scenarios," in *Digital Tools for Seamless Learning*, IGI Global, 2017, pp. 214–239.
[60] H. Chung-Yuan, T. Meng-Jung, C. Yu-Hsuan, and J.-C. Liang, "Surveying In-Service Teachers' Beliefs about Game-Based Learning and Perceptions of Technological Pedagogical and Content Knowledge of Games," *J. Educ. Technol. Soc.*, vol. 20, no. 1, p. 134, 2017.
[61] M.-J. Tsai and H.-T. Pai, "Exploring students' cognitive process in game-based learning environment by eye tracking," in *Proceedings of the International Conference on e-Learning, e-Business, Enterprise Information Systems, and e-Government (EEE)*, 2012, p. 1.
[62] F. Crocco, K. Offenholley, and C. Hernandez, "A proof-of-concept study of game-based learning in higher education," *Simul. Gaming*, vol. 47, no. 4, pp. 403–422, 2016.
[63] C. Perrotta, G. Featherstone, H. Aston, and E. Houghton, "Game-based learning: Latest evidence and future directions," *Slough NFER*, 2013.
[64] O. Dele-Ajayi, J. Sanderson, R. Strachan, and A. Pickard, "Learning mathematics through serious games: An engagement framework," in *Proceedings - Frontiers in Education Conference, FIE*, 2016, vol. 2016–Novem.
[65] G. Rossman and S. Rallis, *Learning in the field: An introduction to qualitative research*. 2011.
[66] K. Gugerell and C. Zuidema, "Gaming for the energy transition. Experimenting and learning in co-designing a serious game prototype," *J. Clean. Prod.*, vol. 169, pp. 105–116, 2017.
[67] E. Adams, *Fundamentals of game design*. Pearson Education, 2014.
[68] G. Kumar and P. K. Bhatia, "Comparative analysis of software engineering models from traditional to modern methodologies," in *2014 Fourth International Conference on Advanced Computing & Communication Technologies*, 2014, pp. 189–196.
[69] YoYoGames, "Game Maker Studio." [Online]. Available: https://www.yoyogames.com/gamemaker. [Accessed: 02-Apr-2019].
[70] Cocos2d, "Cocos2d-x - World's #1 Open-Source Game Development Platform." [Online]. Available: https://cocos2d-x.org/.
[71] GameSalad, "GameSalad – Empowering Game Creators." .
[72] Scirra, "Create Games with Construct 2." .
[73] Stencyl, "Stencyl: Make iPhone, iPad, Android & Flash Games without code." .
[74] Scirra, "Construct 2 Javascript SDK documentation - Construct 2 Manual." [Online]. Available: https://www.scirra.com/manual/15/sdk.
[75] O. Dele-Ajayi, "SpeedyRocket - A Digital Educational Mathematics Game," *2016*. [Online]. Available: http://www.ajayiopeyemi.com/research/speedyrocket/. [Accessed: 01-May-2018].
[76] O. Dele-Ajayi, A. Pickard, R. Strachan, and J. Sanderson, "Exploring Gender Diversity and Engagement with Digital Educational Games by Young People," 2018.
[77] O. Dele-Ajayi, R. Strachan, J. Sanderson, and A. Pickard, "A modified TAM for predicting acceptance of digital educational games by teachers," in *IEEE Global Engineering Education Conference, EDUCON*, 2017.
[78] J. M. Keller, "Development and use of the ARCS model of instructional design," *J. Instr. Dev.*, vol. 10, no. 3, p. 2, 1987.
[79] E. Fennema and J. A. Sherman, "Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males," *J. Res. Math. Educ.*, vol. 7, no. 5, pp. 324–326, 1976.
[80] M. Tavakol and R. Dennick, "Making sense of Cronbach's alpha,"

Int. J. Med. Educ., vol. 2, p. 53, 2011.
[81] C. Seale, *Researching society and culture*. Sage, 2004.
[82] Y. S. Lincoln and E. G. Guba, *Naturalistic inquiry*, vol. 75. Sage, 1985.
[83] L. Archer, E. Dawson, J. DeWitt, A. Seakins, and B. Wong, "'Science capital': A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts," *J. Res. Sci. Teach.*, vol. 52, no. 7, pp. 922–948, 2015.
[84] L. Mohamed and H. Waheed, "Secondary students' attitude towards mathematics in a selected school of Maldives," *Int. J. Humanit. Soc. Sci.*, vol. 1, no. 15, pp. 277–281, 2011.
[85] H.-Y. Cheng and S.-Q. Zhang, "Examining the relationship between holistic/analytic style and classroom learning behaviors of high school students," *Eur. J. Psychol. Educ.*, vol. 32, no. 2, pp. 271–288, 2017.
[86] A. J. Rissanen, "Active and peer learning in STEM education strategy.," *Sci. Educ. Int.*, vol. 25, no. 1, pp. 1–7, 2014.
[87] I. Kongmee, R. Strachan, A. Pickard, and C. Montgomery, "A case study of using online communities and virtual environment in massively multiplayer role playing games (MMORPGs) as a learning and teaching tool for second language learners," *Int. J. Virtual Pers. Learn. Environ.*, vol. 3, no. 4, pp. 1–15, 2012.
[88] O. Dele-Ajayi, R. Strachan, A. Pickard, and J. Sanderson, "Girls and science education: Exploring female interests towards learning with Serious Games: A study of KS3 girls in the North East of England," in *Proceedings of 2015 International Conference on Interactive Mobile Communication Technologies and Learning, IMCL 2015*, 2015.
[89] J. McCambridge, J. Witton, and D. R. Elbourne, "Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects," *J. Clin. Epidemiol.*, vol. 67, no. 3, pp. 267–277, 2014.

OPEYEMI DELE-AJAYI (M'2018) received a Bachelor of technology in computer science from the Federal University of Technology, Akure, Nigeria in 2011 and a MSc degree in IT Management from the University of Sunderland, UK in 2014. He got his PhD in computer science from Northumbria University, Newcastle, UK in 2018.

He currently works as a Research Fellow at the digital learning laboratory, Northumbria University, Newcastle, UK. From 2015 to 2017, he worked as a Research Assistant with NUSTEM - a science outreach programme based in Newcastle upon Tyne, UK. His research interests are widening participation, technology-enhanced learning, digital inclusion and STEM education.

Dr. Dele-Ajayi is a professional member of the British Computer Society (BCS), an associate member of the Institution of Engineering and Technology (IET).

REBECCA STRACHAN (M'2015) was born in Leicester, UK in 1962, She received her BSc. in Chemistry from the University of Sheffield in 1984, her MSc (distinction) in Computing from Sheffield Hallam University in 1987 and her PhD in Computer Science from Leeds Beckett University in 1991. From 1991 – 2000 she was a lecturer in Leeds before moving to Sheffield Hallam where she led their postgraduate provision in the Faculty of Arts, Computing, Engineering and Sciences.

In 2008 she moved to Northumbria University to take up an Associate Dean role and is now the Associate Pro Vice Chancellor for Knowledge Exchange in the Faculty of Engineering and Environment at the University. Professor of Digital Technology and Education, she coordinates the Digital Learning Lab and is a leading expert in the exploitation of digital technologies to improve daily life and believes we should be using technology in transformational ways to support student learning.

Professor Strachan has developed a keen interest in gender, diversity and STEM, and supports equality of opportunities for all. Internationally she is a committee member of the IEEE Education Society and was part of the team that developed their MOOC on Open Education.

ALISON JANE PICKARD was born in Kibblesworth in 1961. She received her Diploma in Performing Arts from Nonnington College, Kent in 1980, her Bachelors in Library and Information Science in 1996 and her PhD in Information Science both from Northumbria University, Newcastle, UK in 2001.

She is currently Director of Recruitment, Widening Participation and Outreach within the Faculty of Engineering and Environment at Northumbria University. She teaches Information and Digital Literacy; Learner Support and Research Methods. She has completed a number of research projects funded by the JISC, AHRC, British Academy, Leverhulme Trust and CETL. Her main research interests are; Information and Digital Literacy and Learning; User Information Seeking Behavior, particularly in children and young people; Research methods in LIS, in particular qualitative measures of value and impact; Behavioural studies and Information trust.

Dr. Alison is author of a research methods text book now a core text on LIS programmes internationally and a member of a number of journal and conference editorial boards.

JONATHAN J. SANDERSON was born in Hull, East Yorkshire, UK in 1972. He received the M.A. degree in Natural Sciences (Physics) from the University of Cambridge in 1997. Between 1994 and 2006 he worked primarily in broadcast television, as a Researcher, Producer and later Series Producer on documentary, popular factual and particularly children's science and engineering television programmes.

He collected more than 250 production credits for broadcasters including the BBC, ITV, Channel 4, Five, RTÉ, and Discovery. From 2006 he worked as a Consultant and Project Manager in informal STEM education, with clients including NESTA, the National Coordinating Centre for Public Engagement, the Wellcome Trust, the Royal Institution and Edinburgh International Science Festival. In 2014 he joined Northumbria University, Newcastle, UK as a Senior Lecturer, working on education outreach, widening participation and informal education initiatives. His research interests include digital making, tinkering, and informal computer science learning.

Mr. Sanderson received a Royal Television Society Education Award (1998) and a BAFTA nomination (2005).