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Co-designing a framework for a persuasive educational technology tool for motivating female students for enrolment into Science, Technology, Engineering and Mathematics disciplines

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Goal five of the United Nations Sustainable Development Goals calls for increased female participation in socioeconomic growth and development. Achieving this goal requires promoting females' participation in fields such as science, technology, engineering and mathematics (STEM) which facing a dire shortage of personnel. However, existing efforts to increase female participation in STEM professions in Nigeria are limited in two ways: firstly, they are not focused on young females between the ages of 11 and 18. Secondly, most existing studies are not focused on the affective aspect of learning. Given the claims in existing literature that females' disinterest in STEM professions is affective rather than cognitive, this article employs the attitude-change approach, also known as the persuasion approach, to motivate females to pursue STEM pathways. We conducted an empirical study among young female students, STEM teachers and STEM professionals from Nigeria. Based on the empirical study, a framework indicating the key components that educational technology designers should consider when developing technologies to motivate young females in Nigeria to pursue STEM professions is presented.

Transdisciplinary contribution: This study is unique in that it combines strategies from various fields. The framework's persuasive strategies are drawn from the field of psychology, the innovative pedagogies are drawn from the field of education and the design science research approach is drawn from the field of information systems. This implies that increasing female participation in socioeconomic growth requires transdisciplinary research. This also has implications for how other United Nations Sustainable Development Goals can be met through transdisciplinary research.

Keywords: female students; STEM; education; attitude change; persuasion; technology.

Introduction

The need for individuals to take up science, technology, engineering and mathematics (STEM) jobs to keep up with the increasing demands of today's world is evident in research.[1,2] According to the 2022 global gender gap report, the demand for professionals in computer science, medicine and engineering increased by more than 9 million between 2012 and 2022 and will continue to rise.[3] The risk of a STEM skills shortage is that technologies and processes will become obsolete, leading to stagnation in the economy, food production and healthcare.[4] For instance, a study of 35 European countries between 1995 and 2019 revealed that the gross domestic product (GDP), GDP per person, employment, labour productivity and expenditures for research and development increased with an increase in STEM skills.[5] Reading[6] also predicted the GDP of Australia to increase by $57.4 with just 1% of its workforce switching to STEM-related jobs.

With the increasing number of female students enrolling in school,[7] one would expect that the number of personnel to fill the gap in STEM fields would continue to increase, but this is not the case. Research shows that many female students are opting for non-STEM professions over STEM professions.[8] In Nigeria, the problem is even more worrying, only 17% of STEM researchers are women.[9]

Females' preference for non-STEM professions over STEM professions has been attributed to factors such as their perceived inability to succeed in STEM disciplines[10] as per the prevailing societal norms,[11] and stereotypes about STEM professions being for a select group of people

with whom they do not identify.[12] Globally, no study has found any difference in brain composition or function between males and females.[13] This suggests that the gender difference in professional choice is not cognitive but rather affective.[14]

As a result, there is advocacy for researchers to focus on the affective aspect of learning to motivate female students to take up STEM disciplines in school so as to increase the number of students skilled in STEM.[15] The affective aspect of learning deals with students' motivation, interests, values, attitudes and beliefs about learning.[16]

Problem identified

Despite the strong advocacy for research to focus on the affective aspect of learning to promote females' participation in STEM fields, no research in Nigeria aimed at increasing female participation in STEM fields has employed the attitude and behaviour change process, also known as the persuasion approach.[17]

Persuasion is 'an interactive process through which a given message alters an individual's perspective by changing the beliefs, or attitudes that underlie that perspective without using deception or coercion'.[18] In the learning domain, it is often argued that teaching is an act of persuasion in that tutors and educators are often faced with the need to reinforce or strengthen certain beliefs or attitudes in students to promote positive learning experiences.[19] With the advancement in technology, persuasive cues, from the field of psychology, have been converted into design features and integrated into technologies, and such technologies are today known as persuasive technology (PT).[20] Today, PTs are defined as tools deliberately designed to change people's attitude and behaviour without coercion.

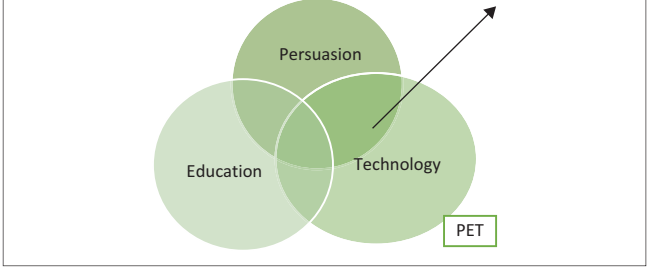
At present, studies outside Nigeria have designed PTs to motivate positive learning behaviour among students.[21] For example, Orji et al.[22] designed a PT to motivate undergraduate students in a Canadian university to increase their engagement in their online learning activities. There is currently no PT designed to promote positive learning attitudes or behaviour among Nigerian students.[23] Hence, motivated by the United Nations Sustainable Development Goals, specifically, Goal 5 which calls for increased participation of women in socioeconomic growth and development, this paper advocates for PTs designed to motivate junior secondary school female students in Nigeria to select the STEM fields when they proceed to senior secondary classes to help increase the number of STEM-skilled people in the country. The problem, however, is that there are limitations in the applicability of the available PT frameworks such as the 8-step Persuasive Technology Design framework,[24] the Functional Triad framework[25] and the Persuasive System Design (PSD) framework:[26]

- The 8-step framework failed to provide persuasive cues that designers can employ.[27]
- The Functional Triad framework provided persuasive cues but failed to describe how the persuasive cues can be converted to actual system features.[26]
- The PSD framework described how to convert persuasive design principles into actual system features but was not domain specific.[28] It provided broad design guidelines, hence designers would need to resolve domain-specific issues on their own.

Given these issues, context-specific PT frameworks are required. According to Murillo-Muñoz et al.[29] context-specific PT frameworks will provide a more detailed level of design guidelines for specific contexts. A framework for designing PT for motivating young female students in Nigeria to enrol in STEM is important to address the peculiarities surrounding young Nigerian female students' enrolment into STEM pathways. As a result, this article developed a PET4STEM framework for persuasive educational technology (PET)-based tools, so that designers can use the framework to design PTs for motivating young Nigerian female students to enrol in STEM disciplines.

As illustrated in Figure 1, the concept of PET is based on three components: persuasion, education and technology.[30] The idea is that by integrating various persuasive cues[31] into teaching instructions and integrating these persuasive teaching instructions into a technology for the females to use, their attitudes towards STEM fields will change, and this will, in turn, increase their enrolment in STEM disciplines.[32] There are over 400 persuasive cues[33] that have been developed in the field of psychology. For example, the Authority Persuasive Strategy is a very popular persuasive cue[31] and it builds on the assumption that people are more likely to be submissive to people in authority. To integrate this strategy in learning instruction, authorities such as well-known experts in a field, respected religious leaders or government officials can be referenced when explaining concepts. Technological platforms such as interactive online learning applications with forums can accommodate such persuasive teaching instructions. Figure 1 shows the relationship between the concepts of PET.

This work offers three main contributions to STEM education for females in Nigeria. Firstly, at a theoretical level, this work develops a new framework, informed by the Design Science Research (DSR) approach, that provides information



PET, persuasive educational technology.

FIGURE 1: The concept of persuasive educational technology.

regarding important components that PT designers can consider when designing PTs for promoting STEM enrolment among junior secondary school female students in Nigeria. Secondly, at an empirical level, this work establishes the factors that influence junior secondary school female students' enrolment in STEM classes. There are limited studies that have empirically investigated the factors that affect the enrolment of female students in STEM at the junior secondary school level.[34] Results from this study can serve as a strong empirical base for future studies that are targeted at this population. Thirdly, it provides persuasive strategies that can be employed to mitigate the negative perceptions about STEM subjects that female students hold. These strategies can be used by schoolteachers, parents and researchers to help motivate young females in Nigeria to take up STEM pathways.

Literature review

In an attempt to increase females' participation in STEM fields, researchers have designed STEM instructional approaches and educational technologies to increase their participation in STEM fields. As regards the instructional approaches, this study realised that the researchers assumed that females have some personal qualities that need to be corrected for them to be able to participate in STEM fields,[35] as a result, they focused on correcting the individual-level characteristics of the female students.[35] For instance, going with the proliferation of low self-efficacy being the single most important factor affecting females' enrolment in STEM, Oinas-kukkonen and Harjumaa[36] designed and investigated the effect of a counselling intervention on 6th grade students' self-efficacy in mathematics. Also, in a project funded by the European Union's Horizon 2020, researchers of the Finnish Institute for Educational Research at the University of Jyväskylä, Finland, Mäkelä et al.[37] developed a framework relying on lack of motivation as the single factor influencing females' low enrolment in STEM fields. Similarly, Feng and Tuan[38] argued that lack of motivation was the single most important reason students opted out of taking chemistry courses and so they designed and investigated the effectiveness of a teaching approached named the attention, relevance, confidence, and satisfaction (ARCS) model at motivating and improving learning about acids and bases, in chemistry, among 11th-grade female students. Chittum et al.[39] on the other hand argued that female students had low expectations for success in STEM classes and did not value the outcome of pursing a STEM profession; hence, they developed a model called the MUSIC model and used it to design an after-school programme to foster students' participation in STEM classes. The MUSIC model is an acronym for eMpowerment, Usefulness, Success, Interest, and Care. Several other studies[40,41] also presented similar arguments. They focused on the individual-level characteristic of female students to increase their participation in STEM fields.

This study argues that it is imperative to consider the broader social context of this issue by looking at the sociocultural context surrounding female students.[42] This is because studies that investigate the factors that hinder females' participation in STEM fields[43,41] point to factors that revolve around a wide variety of areas such as school,[42] family,[43] culture[46] and individual characteristics[43,44,45] Factors such as STEM curriculum,[47] the absence of female STEM teachers[48] and weak government policies[49] are the most cited school factors that discourage females' participation in STEM fields, while parents line of work[50] is the most cited family factor. Concerning cultural factors, societal gender role belief that makes people feel that certain activities are more efficiently accomplished by one gender as compared to the other[46,51]was reported to significantly influence females' participation in STEM fields, while low self-efficacy[52] in STEM subjects, lack of social belonging in STEM fields,[53] lack of interest[54] and lack of career-driven[55] goals are the major individual factors.

As regards educational technology, the tools designed were mainly computer-assisted learning tools consisting of software packages designed to develop STEM skills like improving mathematics computation.[56,57] Based on the review, there is evidence that authors of these interventions have the notion that girls possess some underdeveloped cognitive abilities that require correction for them to be able to enrol in STEM disciplines. For example, Audu et al.[58] argued that the cognitive skills of students need to be stimulated for them to be able to understand and take up engineering courses. For this, they designed a stimulation software for understanding oil and gas instrumentation and control flow process for the students. These same authors also built a small-scale power plant and integrated it with a computer simulation to develop student cognitive stills. Sevari and Falahi[59] designed and evaluated the effectiveness of an educational software at aiding students to learn mathematics focusing on their cognitive aspect of learning. Mellore[60] also designed an educational game to help high school students better understand the concept of green chemistry while also focusing on the cognitive aspect of learning. Even though the authors reported the software improving students' cognitive ability, authors such as Escueta and Quan[61] have questioned their impact in the longer term which could lead to enrolling in STEM disciplines.

Although the contributions of these studies are acknowledged, there is room for more research work. There is a need for instructional pedagogy designers to consider the external factors that influence students' participation in STEM disciplines and education technology designers should be based on theory and practice of attitude and behavioural change process to help females build positive attitudes to challenge practices around them, rather than assume that females possess undeveloped cognitive capabilities; a misconception that needs to be corrected. In summary, the research gap identified in literature aimed at increasing females' enrolment in STEM fields is that there is little focus on the affective capabilities of students. There is a need to focus on the affective capabilities of students to help challenge both external and individual characteristics that influence professional choices of females. No research

has been conducted which focuses on an attitude change approach to increase females' enrolment in STEM disciplines in Nigeria. Hence, this study proposes a PET approach to motivate female students in Nigeria to take on STEM pathways.

The conceptual framework of the study

This article draws on Lents'[62] framework of social constructive career theory (SCCT) which has shown relevance in understanding students' interests and choices of academic disciplines.[63,64] The theory emphasises the influence of certain internal and external factors on academic choice. Social constructive career theory posits that the decision to choose to take a career path emerges from the interest in a career path and interest is built from a set of individual variables (self-efficacy and outcome expectation) that are formed through exposure to different learning experiences and environmental factors.

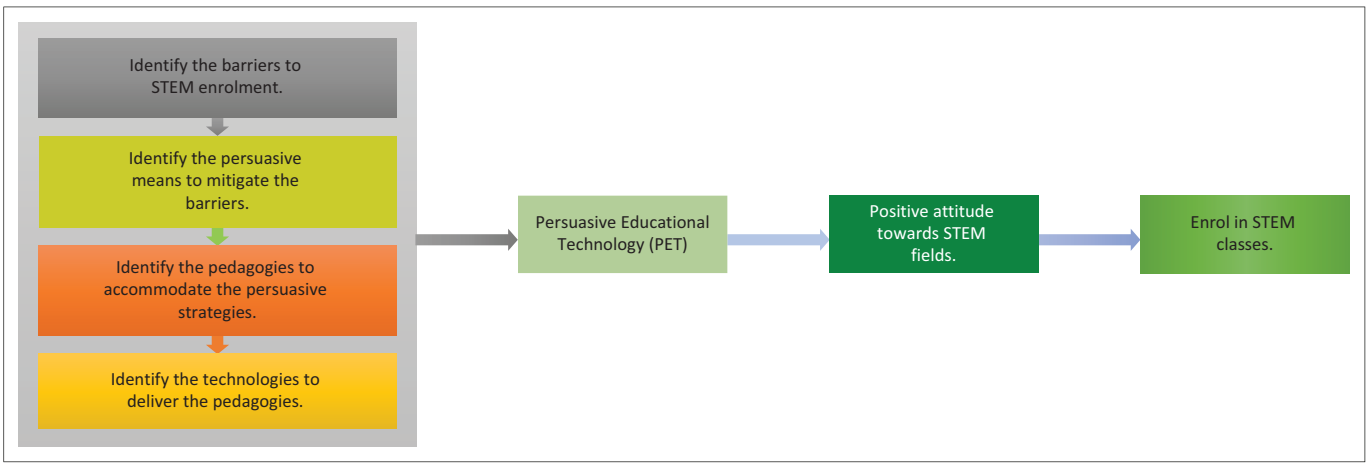
This article also draws on the Theory of Reason Action (TRA)[65] which posits that students' academic choice can be predicted by their attitude towards choosing an academic pathway and how they think other people will view them if they choose the pathway (subjective norm). The TRA agrees with the SCCT in that subjective norm reflects the influence of the external environment on an individual's decision-making or actions, while attitude reflects the individual character. Both theories emphasise the influence of both external and internal factors on students' choice of academic discipline.

The article also leans on the Behavioural Learning Theory (BLT)[66] which argues that before a behavioural change can occur, people need to be stimulated. Behavioural Learning Theory was explained in the famous experiment with dogs by Ivan Pavlov where he would present the dogs with food, and they would begin to salivate.[66] He then began to ring a bell whenever the food was presented and after several repetitions, Pavlov realised that ringing the bell alone would make the dogs salivate without the food being presented. This explained human learning behaviour as well. In our day-to-day affairs, we are often exposed to conditions that shape our future attitudes and behaviour. In school, a teacher with a biased way of teaching may condition a student to develop a dislike for the subject and even for the school entirely and vice versa.

From the BLT the researcher realised that humans have a natural ability to learn and therefore an external stimulus such as a motivational push can eventually begin to trigger humans' natural ability to learn different things when the learning process is rightly stimulated. This was similar to Pavlov's experiment where the dog's natural ability to salivate was successfully paired with the ringing of a bell and the same result was obtained. This theory implies that a motivational push in PET can serve as an external stimulus to female students to participate in STEM professions.

These theories were mentioned because they provided a foundation for arguing that certain external factors work to influence students' attitudes towards STEM professions, and it is their attitudes towards STEM that determine whether they choose to partake in STEM fields in the future. To counter the effects of these factors, students need to be subtly persuaded to change the attitudes built from these influences. Hence, a PET tool is argued as a suitable tool to help increase the number of females participating in STEM professions. As illustrated in Figure 2, to design such PETs, designers need to be aware of four key components. These components are:

- Barriers to enrolling in STEM pathways: Designers must be aware of the barriers that hinder female students' enrolment into STEM disciplines. This is because very little can be accomplished concerning solving a problem if the causes of the problem are not first identified. None of the existing frameworks mentioned in Section 1 of this article identified the limitations or barriers to the desired behaviour that they are affecting their audience towards.[67] Hence, the PET4STEM framework fills this gap.
- Persuasive knowledge: Designers must be informed of the persuasive strategies that young females in Nigeria are more susceptible to. This is because what motivates



STEM, science, technology, engineering and mathematics.

FIGURE 2: Conceptual framework of the study.

one individual may not motivate another and what motivates in one domain may not motivate in another.[68] Although existing frameworks mentioned in Section 1 provide suggestions for persuasive strategies they were not specific to any problem.

- Pedagogical knowledge: Designers must know of the teaching and learning approaches that can accommodate the persuasive strategies and are suited to teaching STEM subjects. This is because the curriculum, learning objectives, ways in which instructional contents are sequenced and how ideas are interconnected differ for every discipline. The existing frameworks mentioned in Section 1 were generic and therefore did not provide any context-specific considerations.
- Technology knowledge: Designers must know the technologies that can accommodate the teaching and learning strategies for the effective delivery of the instructional content. The technologies should also be those that female students will embrace, those that will accommodate, and those that persuasion communications can be integrated into. Again, the existing frameworks mentioned in Section 1 did not provide any technologies for designers to use. Figure 2 presents the conceptual framework that guides the design of the actual PET4STEM framework.

Research methods and design

This study targets female students in junior secondary classes in Nigeria. This is the class where students choose one of three possible academic paths to follow – science, arts or commercial studies. The rationale behind selecting this population is that this is the phase in their education where their choices define their career path. Subsequent transitions such as from senior secondary classes to undergraduate or from undergraduate to postgraduate levels allow them to further specialise within the broader discipline. There has been a huge advocacy for females to be targeted at a young age to nurture their participation in STEM fields.[13]

Research approach and strategy

This study used a qualitative research approach that targets gaining deep insights into the phenomenon being studied from a small number of information-rich participants.[69] In this study, abstract phenomena, such as participants' perceptions, feelings and attitudes are investigated, making the qualitative approach ideal.

The research strategy employed was the DSR strategy. Design Science Research is a research strategy that focuses on the creation of socio-technical artifacts to change existing societal circumstances into desired ones.[70] The rationale behind choosing DSR is its multiple iteration phases that ensured rigour and relevance in the framework design and development.[70] Following the DSR strategy the PET4STEM framework went through four design phases.

Phase 1: The first phase was based on interviews with 15 junior secondary school female students to investigate the four components discussed earlier. The basis for using interviews is that it allows the researcher to collect self-reported data from the students that accurately represent their perceptions. Interviews also allowed the researcher to observe their expressions, gestures and tone of their voices to better understand their responses. The data gathered from the students were used to design an initial framework.

Phase 2: The second phase was based on interviews with five STEM teachers. The reason for interviewing the teachers is to find out if they agreed with the responses of the girls and if they wanted anything to be added or removed from the framework. Again, an interview was the best means to collect this information because it allowed the researcher to interact with the teachers and observe their true expressions. Their responses were used to update the initial framework and design an intermediate framework.

Phase 3: The third phase was based on interviews with five STEM experts working in different STEM fields in Nigeria. The rationale behind interviewing the professionals was to find out if the four components of the framework were relevant and if they agreed with the responses of the girls and the teachers. Their responses were used to design a penultimate framework.

Phase 4: Then a focus group session was conducted with the same junior secondary school female students (n = 15) to discuss the penultimate framework with them. A focus group was chosen as the method of data collection here because it allowed the researcher to identify and extract relevant and interesting reactions beyond what was obtained in the interview. The information gathered was used to redesign the final PET4STEM framework.

Sampling method

The sampling techniques employed were convenience, purposive and key informant sampling. Convenience sampling was used to select three government secondary schools in Nigeria. The reason for using convenience sampling to select the three schools is that it is a very easy and economical sampling technique.[71] From these schools, purposive sampling was then employed to select the 15 junior secondary school female students. The reason for using purposive sampling to select the junior secondary school students is because it allowed the researcher to identify and select participants who have the characteristics that are needed in the study[72] (junior secondary school girls and senior secondary school girls were not needed). Also, purposive sampling was used to select the five teachers who take these students' basic STEM subjects. The reason for using purposive sampling to select the teachers is that only the teachers who taught the junior secondary school girls selected were needed. Lastly, key informant sampling was used to select five STEM professionals from different STEM institutions. The reason for using the key informant sample

to select the STEM professionals is because it allowed the researcher to select information-rich STEM professionals who can provide deeper and unbiased information, ensuring the study's quality.[73]

The rationale behind selecting 15 female students is that the qualitative approach used in this study is not aimed at selecting a representative case for broad generalisations but rather the empirical data collection is to gain deeper insights into the situation so that the idea that is conceptualised or components that are identified can be generalised or further explored across similar cases.

The justification for the adequacy of the sample size (n = 25) is based on literature[69] where it was recommended that at least one out of three criteria must be met to justify the adequacy of a research sample size. In this study, two criteria were met: (1) Sample size must be based on suggestions from qualitative methodologists and (2) the sample size must tally with those of prior research in the same field with a similar research problem, and methodology. The sample size in this study was based on references from qualitative research methodologists,[74,75,76] who recommended 6 to 10 interviewees for qualitative research,[77] recommended at least six interviewees and[78] recommended at least three to five interviewees. Similar studies have also used similar sample sizes. Angkananon et al.[79] used three to validate the framework they designed to enhance technology interaction,[80] used 6 teachers and 14 students to investigate the distractions caused by educational technologies in the classroom and Tshuma[81] used nine interviewees to investigate the use of educational technologies in a university.

Participants' profiles

The female students' age ranged between 11 and 18 years. For confidentiality purposes, their schools are represented as SCH-A, SCH-B and SCH-C. Table 1 presents the demographics.

In regards to the teachers, two were from school-A, two from school-C and one from school-C. Their age ranged between 25 and 47. One of the teachers has a master's degree, three have a bachelor's degree and one has a diploma. All the teachers have teaching experience above 4 years. All the teachers were males. For confidentiality purposes, the teachers are represented as TCH-1, TCH-2 and so on. Table 2 presents the demographics.

Out of the STEM experts, three are university lecturers, one was from a research institute and one works in an electricity distribution company. Their age ranged from 36 to 61. Two of the experts have master's degree, while three have doctoral degrees. All the experts have work experience of above 8 years. This is presented in Table 3. For confidentiality purposes, the experts are represented as EXPERT-1, EXPERT-2, EXPERT-3 and so on.

TABLE 1: Female students' demographics.

Student	School	Class	Age	Choice of profession
STUDENT-1	SCH-A	JSSII	14	Law
STUDENT-2	SCH-A	JSSII	13	Medicine
STUDENT-3	SCH-A	JSS1	15	TV broadcasting
STUDENT-4	SCH-A	JSSIII	15	Teaching
STUDENT-5	SCH-A	JSSIII	18	Catering
STUDENT-6	SCH-B	JSSI	12	Social work
STUDENT-7	SCH-B	JSSII	16	Medicine
STUDENT-8	SCH-B	JSSII	14	Medicine
STUDENT-9	SCH-B	JSSI	14	Journalism
STUDENT-10	SCH-B	JSSIII	16	Fashion designing
STUDENT-11	SCH-C	JSSI	12	Medicine
STUDENT-12	SCH-C	JSSIII	16	Lab technology
STUDENT-13	SCH-C	JSSIII	16	Law
STUDENT-14	SCH-C	JSSII	14	Banking
STUDENT-15	SCH-C	JSSI	11	Journalism

Data analysis

Semi-structured interviews and a focus group session were conducted among junior secondary school female students, STEM teachers and STEM experts in Nigeria and what was gathered was analysed using content analysis and was used to develop the PET4STEM framework that provides designers with more specific design considerations that will equip them to make junior secondary school female students view STEM subjects differently and consequently enrol in STEM pathways. The rationale behind using content analysis was that it allowed the systematic coding and categorisation of large amounts of textual data, retrieved from the interviews, and a focus group, to determine trends, frequency, relationship and discourse of communication.[82] The steps followed to analyse the data are outlined next:

- Familiarising with the data: A considerable amount of time was spent reading the transcripts repeatedly. This step allowed for an initial understanding of the data which are essential for a more detailed analysis.[82] Atlas.ti and Microsoft Word were the main software application tools that facilitated data analysis in this study.

TABLE 2: Science, Technology, Engineering and Mathematics teachers' demographics.

Interviewee	School	Gender	Highest level of education	Age	Classes taught	Years teaching
TCH-1	SCH-A	Male	Master's degree	34	JSSI to SSII	8
TCH-2	SCH-A	Male	Bachelor's degree	26	JSSI to JSSIII	5
TCH-3	SCH-B	Male	Bachelor's degree	25	JSSI to JSSIII	6
TCH-4	SCH-B	Male	Diploma in Teachers College	47	JSSI to SSIII	20
TCH-5	SCH-C	Male	Bachelor's degree	38	JSSI to SS1I	14

TABLE 3: Science, Technology, Engineering and Mathematics experts' demographics.

Experts	Field of expertise	Gender	Highest level of education	Age	Practice field	Years of work
EXPT-1	Computer science	Female	Master's degree	36	University	11
EXPT-2	Civil engineering	Male	Master's degree	38	University	12
EXPT-3	Biochemistry	Male	Doctoral degree	61	Research Institute	21
EXPT-4	Mathematics	Male	Doctoral degree	41	University	11
EXPT-5	Electrical engineering	Male	Doctoral degree	49	Electricity company	9

- Coding the data: After a good understanding of the data, then coding was performed. The idea behind coding is to reduce the size and complexity of the initial transcript while retaining the contextual meaning of the original data.[82] The transcripts were thoroughly and repeatedly read and then relevant words and sentences that represent a common idea were shortened and labelled with shorter phrases. The codes generated are summarised in Table 4.
- Moving from codes to categories. Next, the researcher and the data analyst separately reviewed the codes and came up with a separate list that grouped the codes into categories. The two lists were then compared to come up with a consolidated set of categories that were of contextual meaning to the study. The categories generated are summarised in Table 4.
- Moving from categories to themes. Generating themes was guided by the components of the conceptual framework.[82] The themes generated are summarised in Table 4.
- Producing reports: After grouping categories into themes, the researcher came up with an argument to respond to the research question of the study. The report is presented in the results and discussion section. Table 4 is a summary of the codes, categories and themes generated in the content analysis.

Ethical considerations

Ethical approval was obtained from the University of South Africa's Research Ethics Committee. Ethical clearance number is 2022/CSET/SOC/013.

Results and discussion

The findings are presented with a focus on the four key components that PET designers should be aware of: (1) barriers that prevent young females in Nigeria from opting for STEM pathways, (2) the persuasive strategies that can be used to motivate them to opt for STEM pathways, (3) the pedagogical approaches that can accommodate the strategies and (4) technologies that can deliver the pedagogies. Each of these is discussed one after the other.

Barriers to female students choosing Science, Technology, Engineering and Mathematics disciplines

The series of interviews and a focus group session conducted with the research participants lead to the identification of the barriers to junior secondary school female students' enrolment into STEM disciplines. With this, designers will be aware of the specific barriers that they should be addressing. The barriers identified were grouped under the school, sociocultural, family and individual factors.

TABLE 4: A summary of the codes, categories, and themes generated in the content analysis.

Theme	Categories	Codes
Influencers of STEM enrolment	School factors	• Barriers: Absence of female STEM teachers, teachers' lack of expertise, and inadequate exposure to practical work in STEM classes.
		• Enablers: Teacher encouragement, Peers
	Sociocultural factors	• Barriers: Gender role belief, Societal expectation
		• Enablers: Societal expectation
	Family factors	• Barriers: Parents' perception of STEM being for males.
		• Enablers: Parents' encouragement, Parents are science-oriented, and value education and hard work
	Individual factors	• Barriers: STEM being things-oriented, lack of social belonging, being lazy, unambitious, having less desire for excessive wealth, low self-efficacy in STEM subjects, and inherent desire towards working with people than with things.
		• Enablers: The need to help, Motivation, high self-efficacy, and hard work
Strategies for persuasion	Competition persuasive strategy	• Competing in quizzes, competing in projects, Fun features, and game features.
	Social comparison persuasive strategy	• Being aware of what peers are doing, showcasing project works, viewing the work of others, and comparing the progress of peers.
	Collaboration persuasive strategy	• Group work, collaboration, and online meetings.
	Reminder persuasive strategy	• Prompts to continue to work, reminders to complete tasks, awareness.
	Suggestion persuasive strategy	• Getting prompts on the next steps to take, prompts to inform them of their hard work, prompts to tell them they can do better.
	Authority persuasive strategy	• Quoting people with authority, Respected leaders
	Verifiability persuasive strategy	• Proof what is taught, find out the source of information and link to real-life examples.
	Commitment persuasive strategy	• Goal setting, start with small steps.
	Likening persuasive strategy	• Using familiar faces, similar people.
Engaging teaching and learning approaches	Project-based learning pedagogy	• Hands-on learning, practical, projects.
	Conventional learning pedagogy	• Lecture-based approach
	An integrated STEM learning approach	• An integrated STEM learning approach
	Formative assessment	• Formative assessment
Technologies for persuasive systems	Virtual reality technologies	• Artificial environments, Computerised manipulation, Virtual reality.
	Simulation technologies	• Virtual laboratory, videos, modelling, visualisation.
	Interactive online technologies	• Video conferences, Online chat, e- forums, online assessment
	Collaborative applications	• Teamwork application, collaborative work.
	Learning management system.	• Technologies to upload and download content and access material asynchronously.
	Gamified systems	• Fun applications, applications where they can compete, and educational games

STEM, science, technology, engineering and mathematics.

- *School factors*: The school factors are: Absence of female STEM teachers, teachers' lack of expertise in teaching STEM subjects and insufficient educational materials for practical works in STEM classes. These factors have also been found to be barriers in prior studies.[41,83]
- *Sociocultural factor*: The sociocultural factor includes societal beliefs about STEM fields being for men. This factor has also been found to be a barrier in prior studies.[47,84]
- *Family factor*: The family factor is the parental perception that STEM is for men. Not many pieces of literature reported this; Ikkatai et al.[85] found this as a parental factor.
- *Individual factors*: The individual factors are: The females' perception that STEM fields are things oriented; the females' lack a sense of social belonging in STEM fields; and the females' lack of motivation to partake in STEM fields. This finding is in agreement with those of earlier studies.[47,86]

The crux of the barriers to females' participation in STEM fields can be argued to be the societal belief about STEM fields being for men as indicated strongly by one of the female students: 'In my understanding, I think men are supposed to do that job because our culture doesn't want us to do that career' (SCH-B, Student-10, JSSIII). Many of the individual factors can be linked to their societal belief about STEM fields being for men. For instance, the perception that STEM fields are things-oriented can be argued to be built from the way society portrays these fields. The media show advertisements of male engineers working with heavy machinery; [47] this can impede the females' sense of social belonging and reinforce the sense of STEM being things oriented.[47] Their parents' beliefs can also be argued to have been conditioned by the societal gender role belief. This is not surprising as the literature suggests that societal beliefs are consumed by the small units of families within society.[87] The school, which is supposed to buffer the effect of these perceptions has only exacerbated the effect of society. The female students see few or no female STEM teachers, as most of the females are teaching non-STEM subjects because that is their area of specialty. Again, female teachers' choice of specialty can be argued to be influenced by the societal belief about STEM fields being for men.[83] Figure 3 presents the relationship between the barriers to female students' participation in STEM fields.

As illustrated in Figure 3, the societal factor influences the school and family factors which then influence the individual characteristic. Also, the societal factor can directly influence individual characteristics. This illustration is significant as designers should be aware that they should not be focusing on just individual characteristics.

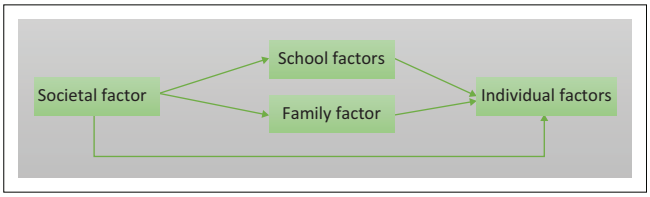


FIGURE 3: Relationship between barriers.

The argument presented above is supported by Meece et al.[88] who said that individuals begin to identify themselves at an early age with their family and sociocultural values and this influences their beliefs, attitude and behaviour towards the choice of career paths. Spelke[89] also asserts that the career choices of women are because of sociocultural factors, such as subtle gender expectations during childhood which influence occupational identities and aspirations. This argument also aligns with that of the social cognitive carrier theory that environmental factors work to affect individual factors, which in turn affect career choices.

This explains why among the 15 female students interviewed only five wanted a career in STEM. The others wanted a career in journalism, law, catering, banking and social work. They chose professions that they felt resonated with their identity within their milieu as indicated explicitly by a student:

> '[S]ome of them since from their upbringing the society has already shown them that this is for boys and this is for girls, you should choose this and not go to that.' (SCH-B, Student-6, JSSI)

They recognise the fact that society views them to be more interpersonal and inherently caring so they channel their interest to professions where they feel they can interact with people and make people happy. As indicated by one of the students who wants to be a journalist 'I cannot be doing engineering work when people need doctors in the hospital to help the sick' (SCH-A, Student-2, JSSII). They would rather save their people from the hands of bad politicians than develop phones. This was similar to the five females who indicated that a career in STEM wanted to be medical doctors.

This argument also applies to those who chose non-STEM professions. All five want to be medical doctors where they can interact with people and help care for them. This argument is supported by studies[90,91] that show that even within the medical profession, female doctors show an inclination towards paediatrics and gynaecology subspecialties where they get to treat the more vulnerable people (women and children) in society, in comparison to male doctors who practiced in a broader range of specialties. The authors claim that the penchant for these specialties is in the bid to align with being interpersonal and inherently caring.

Even though these factors are argued to develop from a sociocultural belief about STEM fields being for men, it is pertinent to identify means to mitigate against all the factors identified from the interview sessions. Hence, the next subsection discusses the persuasive strategies, pedagogical approaches and technologies to mitigate against each of these factors.

The absence of female STEM teachers

To mitigate against the effect of the absence of female STEM teachers through a PET, students should be helped to discern that there are females involved in teaching STEM. The persuasive strategies that should be employed to achieve this are:

- Social facilitation persuasive strategy: This strategy involves providing means for discerning other users who are performing the desired behaviour.[26] To implement this strategy for this barrier, designers can create a network of available female STEM teachers and female STEM professionals, in and outside Nigeria, who are interested and willing to respond to students' concerns and answer their questions.
- Social role persuasive strategy: This strategy involves designing a persuasive system to mimic the social behaviours of humans.[26] To implement this strategy for this barrier, designers can make virtual female STEM teachers that teach STEM subjects, answer questions and praise the students for good work.
- Similarity persuasive strategy: This strategy involves persuading people by imitating them in some specific ways.[26] This is based on the idea that people are more likely to be persuaded by those who are similar to them. To implement this strategy for this barrier, designers can design virtual female STEM teachers in their PETs and make the avatars have Nigerian female names, wear local clothes and speak in Nigerian languages.

Pedagogies that can accommodate these strategies are:

- An inquiry-based learning environment where different learning scenarios trigger students to ask questions and share ideas with these teachers and STEM personnel.[92]
- A problem-based learning environment where students respond to open-ended questions and will need to explore different solutions and seek support from these teachers and STEM personnel towards searching and arriving at a reasoned solution can also accommodate these persuasive strategies.[93]

A technological platform that can accommodate these proposed pedagogies for this barrier is Learning Management Systems (LMS) and Interactive online learning applications with chat, video conferences and forum features.

Teachers' lack of expertise in teaching STEM subjects

To mitigate against the influence of teachers' lack of expertise in teaching STEM subjects through a PET, students should be taught using enhanced instructional methods. The persuasive strategies that should be employed to achieve this are:

- Reduction persuasive strategy: This strategy involves breaking down complex activities into manageable steps to make the activity attractive.[26] To implement this strategy for this barrier, designers can break STEM topics into chunks. For each chunk, start by introducing concepts to students using things they are already familiar with. Then allow students to explain the concepts based on their experiences. Then go ahead to teach the topic. Designers can also use charts, pictures, audio and videos to aid understanding.
- Simulation persuasive strategy: This strategy involves providing real-world experience through a virtual environment.[26] To implement this strategy for this barrier, designers can use simulation models to explain abstract and difficult concepts and allow students to manipulate values themselves to observe how they behave.
- Tunnelling persuasive strategy: This strategy involves making a persuasive system provide means for action that brings its users closer to the target behaviour.[26] To implement this strategy for this barrier, designers should show students a model of the outcome of each task before they start it. Then, with the finished model in hand, walk students through each stage of the task.
- Self-monitoring persuasive strategy: This strategy involves providing means for users to track their performance.[26] To implement this strategy for this barrier, designers should allow students to present what they have learned periodically. This allows them to reflect on what they have learned and come up with new ideas. Also, designers should integrate features that track students' data to determine areas they may need assistance and areas they may excel.
- Suggestion persuasive strategy: This strategy involves providing suggestions to individuals while they are engaging in the desired behaviour to make the activity easier.[26] To implement this strategy for this barrier, designers should prompt resource materials that will enhance understanding and provide solutions to different problems.
- Collaboration persuasive strategy: This strategy involves enabling users to collaborate in the behaviour change process.[26] To implement this strategy for this barrier, designers should allow the students to work together in groups so that those with better understanding can assist others.
- Expertise persuasive strategy: This strategy involves providing competent information.[26,64] To implement this strategy for this barrier, when explaining concepts, the information provided, and the examples given should be authentic, have variety and be based on current happenings to enhance understanding.
- Reliability persuasive strategy: This strategy involves making systems readily available to users.[26,64] To implement this strategy for this barrier, updates, and maintenance work on the app should be conducted during hours when students are not likely to be using the app. As indicated by an expert 'for example between 02:00 and 04:00 to avoid disrupting students' engagement with the app' (EXPT-5, male, PhD).

Pedagogies that can accommodate the proposed strategies for this barrier are:

- Design-based learning approach.[93] Through its iterative design phases, students can investigate the related and

relevant phenomena that they are already familiar with, in chunks, by identifying a problem, defining a solution, implementing the solution and testing and evaluating the solution.
- A project-based learning environment where topics are being taught in chunks as mini projects.[94]

Technologies that can accommodate the proposed pedagogies are:

- Virtual labs where students can conduct virtual projects individually and in groups.
- Simulation technologies where students can watch simulated videos.
- Interactive online learning applications with conferences for students to upload pictures of their live projects and discuss what they have done. Video presentation features can also be integrated for students to present their works as a group or individually and then discuss what they have learned.

Insufficient educational materials for practical work in STEM class

To mitigate against the influence of insufficient educational materials for practical work in STEM classes using a PET, students should be involved in practical activities via a persuasive system. The persuasive strategies that should be employed to achieve this are:

- Simulation persuasive strategy: This strategy involves designing a persuasive system to provide real-world experience through a virtual environment.[26] To implement this strategy for this barrier, designers can use simulation models to explain abstract and difficult concepts and allow students to manipulate values to observe how they behave.

A pedagogy that can accommodate the proposed strategy is:

- A project-based learning environment: Topics and skills can be taught as projects and projects should be connected to the students' lives.

Technologies that can accommodate this pedagogy are:

- Virtual reality technologies with technologies like virtual laboratories can accommodate these strategies, where students can practice basic computer programming.
- Simulation technologies where students can watch simulated videos can also support these strategies.

Societal and parental beliefs about STEM fields being for men

To mitigate against societal and parental beliefs about STEM fields being for men through a PET, awareness should be created that STEM fields are for everyone. The persuasive strategies that should be employed to achieve this are:

- Authority persuasive strategy: This strategy involves referring to people in the role of authority when trying to persuade an individual.[26] To implement this strategy for this barrier, designers can include statements or quotes from religious and traditional leaders in Nigeria who have a positive view about females' enrolment in STEM.
- Verifiability persuasive strategy: This strategy involves providing means for the person that is been persuaded to be able to verify the information that they are getting.[26] To implement this strategy for this barrier, the contact details (emails, phone numbers, website) of the authorities should be provided for students to verify the statements.
- Third-party endorsement: This strategy involves providing endorsement from respected sources to support the persuasive message being communicated.[26] To implement this strategy for this barrier, designers can provide links or statements from individuals that are well-known and respected amongst their audience, like celebrities, countering the misconception that STEM fields are for males only.
- Collaboration persuasive strategy: To implement this strategy for this barrier, designers can organise quiz competitions or hands-on project competitions where students and their parents work together. This will allow parents to see what their daughters can do while boosting the morale of the girls.
- Role model persuasive strategies: This strategy involves using mentors who will help people set goals and find opportunities for networking with others.[26] To implement this strategy for this barrier, designers can have willing female STEM personnel serve as role models to the girls, to help them set goals and find opportunities to network with other role models.

Creating awareness that STEM fields are for everyone does not require any specific pedagogy, but technologies that can accommodate the proposed strategies are:

- Interactive web-based learning applications where students can follow events, access links, send emails and read blog posts.
- Gamified applications, interactive online applications or virtual laboratory applications can accommodate any of these pedagogies to implement the collaborative persuasive strategy.

The perception that STEM fields are things oriented

To mitigate against the effect of the perception that STEM fields are things-oriented through a PET, different STEM learning activities that go with the interests of female students should be developed. The persuasive strategies that should be employed to achieve this:

- Personalisation persuasive strategies: This strategy involves providing personalised content and services to users.[26] To implement this strategy for this barrier, designers can link the outcome of STEM knowledge and skills to the educational motivation of the students, such as improving people's lives and making people happy. This is one of the major educational motivations of the girls that were interviewed as indicated by one student: 'Yes because my ambition is to really help the society, not financial motivation' (SCH-C, Student 12, JSSIII).

- Tunnelling persuasive strategy: To implement this strategy for this barrier, designers should share ideas about STEM jobs that relate to students' interests or offer hints that would lead students to connect concepts taught in the classroom to their everyday activities like cooking, sewing, cleaning, washing, childcare.
- Reduction persuasive strategy: To implement this strategy for this barrier, designers should break down all the job roles in STEM fields and emphasise those that are less physically strenuous and are more indoors. These align with the students' cultural beliefs.

Pedagogies that can accommodate the proposed strategies are:

- A project-based, inquiry-based and problem-based learning pedagogy can support the collaboration persuasive strategies.[94,45]

Technologies that can accommodate this pedagogy are:

- Interactive web-based learning applications where students can follow events, access links, send emails and read blog posts.
- Virtual labs where students can conduct virtual projects individually and in groups can also accommodate these pedagogies.

The lack of social belonging

To mitigate against the effect of lack of social belonging through a PET, a female-inclusive learning environment should be created. The persuasive strategies that should be employed to achieve this are:

- Social facilitation persuasive strategy: To implement this strategy for this barrier, designers can create a network of females in STEM disciplines in secondary school, undergraduate and postgraduate levels and practitioners so that students can interact with them.
- Social proof or social learning persuasive strategy: This strategy involves enabling users to learn by viewing the activities of other users.[26] To implement this strategy for this barrier, designers should provide continuous information and means for students to observe and follow projects about STEM women who are making a difference in the environmental, agricultural and security sectors.
- Likening persuasive strategy: This strategy involves making a persuasive system have a look and feel that appeals to its users.[64] To implement this strategy for this barrier, learning materials should reflect who the students are. Images should be for females, colours should be bright (pink, orange and turquoise blue) and font style should be stylish.

These persuasive strategies do not require a pedagogy to implement but a technology that can accommodate these strategies is:

- Interactive online learning: Learning management systems, chat applications, forums and conference applications.

The lack of motivation to choose STEM disciples

To mitigate against the influence of the lack of motivation through a PET, female students should be encouraged to set goals for themselves and to persevere in attaining the goals. The persuasive strategies that should be employed to achieve this are:

- Commitment and consistency persuasive strategy: This involves leading a user to make a small initial commitment, and then this small commitment will lead to bigger action.[64] To implement this strategy for this barrier, designers can set short-term achievable goals for students and make them note their progress as they work on the goals.
- Social facilitation persuasive strategies: Designers can let students see successful women in STEM within Nigeria and from around the world to inspire them to become ambitious.
- Self-monitoring persuasive strategy: Designers should integrate features that track students' data to determine areas they may need assistance and areas where they excel.
- Competition persuasive strategy: This strategy involves allowing users to compete to achieve their target.[26] To implement this strategy for this barrier, designers can set quiz competitions and structure quizzes in levels so that students advance from one quiz level to another.
- Reward persuasive strategy: This strategy involves providing virtual rewards to users as they progress in the task.[26] To implement this strategy for this barrier designers can give students rewards like points, and badges after winning quizzes to make learning fun and engaging.
- Scarcity persuasive strategy: This strategy involves showing the scarcity or needs for something to increase interest in it.[26,64] To implement this strategy for this barrier, designers can show reports or statistics of the shortage of technology and engineering skills and their impact on people's lives.

Pedagogies that can accommodate these strategies are:

- A project-based learning environment can accommodate the commitment and consistency of persuasive strategies: Students can be asked to write down step-by-step objectives to accomplish a task. This serves as small voluntary agreements that will lead to achieving a bigger goal.
- A formative assessment method can support this strategy where periodic feedback on student progress is provided.
- A context integration learning pedagogy can accommodate the tunnelling strategy where elements from other subjects or other STEM subjects that interest students are used to make the content of other STEM subjects more relevant.
- A collaborative learning environment can accommodate competition and reward persuasive strategies where students are grouped into teams to compete against each others' teams and earn rewards for their team.

TABLE 5: PET4STEM framework.

Factors	Barriers to female students' enrolment in STEM	Educational technology means to mitigate the barriers	Relevant persuasive strategies to employ for mitigating the barriers	Pedagogical approaches to accommodate the persuasive strategies	Technology platform to accommodate the pedagogical approaches
School factors	Absence of female STEM teachers.	Helping the students discern that there are females involved in teaching STEM.	Social facilitation, Social-role and, Similarity persuasive strategies.	An inquiry-based learning approach and a problem-based learning approach	Learning management system (LMS) and Interactive online learning applications.
	Teachers' lack of expertise in explaining topics and concepts in STEM subjects.	Teaching students using enhanced teaching practices	Reduction, Tunnelling and, Expertise persuasive strategies.	Design-based learning approach and Project-based learning approach	Virtual labs, Simulation technologies, and online learning applications.
	Insufficient educational materials for practical works in STEM class.	Involving students in simulated practical activities.	Simulation persuasive strategy.	A project-based learning pedagogy	Virtual reality technologies and Simulation technologies
Cultural and family factors	Societal and family beliefs about STEM fields being for men.	Creating awareness that STEM fields are for everyone	Authority, Verifiability, Collaboration persuasive strategies.	Creating awareness that STEM fields are for everyone does not require any specific pedagogy.	Interactive web-based learning applications, and gamified applications.
Individual factors	STEM fields being things oriented.	Designing different STEM learning activities that go with the interests of female students.	Personalisation and Tunnelling persuasive strategies.	Cultural relevant learning pedagogy, and Context integration learning pedagogy.	Interactive online learning applications, LMIs, and Virtual labs.
	Lack of social belonging.	Creating a female inclusive learning environment	Social facilitation and Likening persuasive strategies	These persuasive strategies do not require a pedagogy to create a female inclusive learning environment.	Interactive online learning applications with forums, and conference features.
	Lack of motivation	Encouraging female students to set goals for themselves and persevere to achieve the goals.	Commitment, Self monitoring Competition, Reward, and Scarcity persuasive strategies.	Formative assessment method, collaborative learning, and inquiry-based learning environment.	LMSs, Interactive online learning, Gamified educational learning applications, Virtual labs, and Simulation technologies.

STEM, science, technology, engineering and mathematics.

- The inquiry-based and problem-based learning environment can accommodate learning scenarios where the need for STEM skills is discussed.[92]

Technologies that can accommodate these pedagogies are:

- LMSs and interactive online learning applications can accommodate context integration learning.
- Gamified educational learning applications can accommodate collaborative learning pedagogy.
- Interactive online learning applications with chat, video conferences and forum features.
- Simulation technologies can also support these pedagogies for students to watch simulated models of the impact of the shortage of technology and engineering skills.
- Virtual labs where students can conduct virtual projects individually and in groups. Table 5 presents the framework in a diagram.

Limitation

This study, like all research studies, has limitations. The researchers acknowledge that the number of female students and STEM teachers recruited for the study could have been more. However, the qualitative approach used in this study is not aimed at pursuing a large sample size for broad generalisations to be made but rather the empirical data collection is to gain deeper insights into the situation so that the idea that is conceptualised can be generalised across similar cases. According to Polit and Beck[96] qualitative research rides on gathering data from a small number of information-rich participants that can illuminate the phenomenon under study. Hence the limited number of female students and STEM teachers. However, future works can focus on the quantitative approach where findings from a larger number of participants can be generalised.

Conclusion

In this work, we identified the barriers to female students' enrolment in classes leading to STEM professions in Nigeria. We then proposed persuasive strategies, pedagogical approaches and technological platforms to employ to mitigate each identified barrier. How the strategies can be implemented in a PET were suggested and were based on information gathered from female students, STEM teachers and STEM experts. This was done to make the content suited to female students and to STEM subjects. This framework may not have exhausted all the persuasive strategies, pedagogical approaches or technologies in the literature, but in practical terms, one PET cannot integrate all of what was suggested in the framework. What is advised is that a PET selects a couple of barriers they want to address and then implements the suggestions from the framework.

It is worth noting that, although non-transdisciplinary research (TDR) has been effective for societal problems that have relatively little ambiguity, they have become less effective in the context of complex societal problems such as the low participation of women in STEM fields. According to Lawrence et al.[95] TDR addresses wicked problems in information systems (IS), these are societal problems that are multi-faceted in nature and hence can only be solved in multiple ways; hence, this article shows the significance of TDR. There are challenges with TDR, and one is that there is little cross-fertilisation among the different disciplines that research employs.[95] In this study, the close interaction between the methods and knowledge from the fields of persuasion, technology and education led to the development of a new concept: 'PET'. This indicates that a high level of engagement among the different disciplines in TDR can lead to the development of what can eventually be considered a new academic discipline, with its characteristic knowledge,

approaches and boundaries. This is one of the main contributions of this article to the TDR community.

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Authors' contributions

A.M.A. conceived, planned and conducted the experiments. B.C. verified the analytical methods and supervised the findings of this work. Both authors discussed the results and contributed to the final manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author, A.M.A, upon reasonable request.

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