



## Optimising Students' Retention of Difficult Physics Concepts Using Design-Thinking Approach in STEM Learning Context: Implication For A Gender- Inclusive Pedagogy

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### ABSTRACT

The study investigated the effect of using design thinking approach in STEM learning context on optimizing students' retention of achievement in difficult physics concepts. Study was carried out in an afterschool environment which necessitated the researcher using a single group quasi experimental research design conducted in purposively selected secondary schools. Intact classes of physics students comprising of 48 male students and 41 female students overall were used in the study. A 25 item Physics Learning Achievement Test (PLAT) used in the study was validated by experts in STEM fields at pilot test. Reliability coefficient of validated PLAT using test retest method by Kuder-Richardson (KR-20) was established at 0.86 for the multiple choice test and Pearson product moment reliability coefficient for the semi-structured questions at 0.81. The modules combined the elements of STEM learning and design processes of empathy, ideation, brainstorming prototyping, testing and retesting to learn selected physics concepts for three months. Prior to its use, students were administered a pretest and a posttest after the study intervention using PLAT. A delayed-posttest was later administered to participants after two weeks of posttest using PLAT. Result obtained from statistical analysis using the paired sample t-test and a one-way ANCOVA revealed that there were no significant differences between the posts – test and delayed post-test of mean score of achievement in physics learning for male students as well as for female students. Conclusion and relevant recommendations were therefore made in the study.

**Keywords:** Retention, Design-thinking, STEM, Delayed-posttest, Male, Female.

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### INTRODUCTION

A major concern of educators today is the meaningful retention of knowledge and consequently making such acquired knowledge relevant to real world situations [1]. Physics concepts taught to students according to Udo and Ubana [2] were not retained by them because there is a noticeable perceived difficulty of such physics concepts. This according to them by extension is related to how concepts in physics are being taught. Collaborating this is the assertion of Nwachukwu [3] that poor learning achievement and retention of science concepts is related to students' inability to link previous learning experience to the present one. Therefore, meaningful retention of physics concepts which implies students' ability to have the knowledge of concepts stored in long-term memory in such amanner that it can be readily retrieved when needed cannot be relegated to the background.

Moreover, over a long range of years, physics has been perceived to be a difficult subject and that achievement in physics at the secondary school is disheartening because of such difficulty students do associate with understanding physics concepts [4, 5 & 6]. Difficulty in learning physics occurs when students cannot relate physics concepts to real-world situations because of its abstract nature [7]. Poor performance of students in physics as compared to other science subjects justifies its difficult nature.

Besides, Obafemiet al. [6] reported that students have difficulty in understanding some important physics concepts which invariably over time had led to poor achievement. Some of these perceived difficult physics concepts in line with the study reports of Okpala and Onocha [8]. Obafemi et al. [6], Jegede and Adebayo [9] as well as that of Kiptum [5] are force,energy, Newton laws of motion, velocity, motion and acceleration.

Moreover, on gender, studies reported that male students were more successful than their female peers at learning physics. Besides, numerous studies have also confirmed that male students do typically outperform female students in physics [10]. Inyang and Joiaash [11] asserts in their study that there exist a difference by gender in physics achievement

.In fact, Udo et al. [2] affirmed that students' retention in physics concepts is not the same at all levels of gender. This according to them implies that male and female students did not show the same retention capacity in physics concepts.

On pedagogical gap, the teaching of physics is experiencing some dilemma both for the students and teachers, thus affecting students' achievement which can be deeply minimized by selecting appropriate and suitable instructional method [12]. They asserts that there has been no suitable instructional material for learning physics .This is in the wake of physics instruction been fundamentally a panacea towards achieving scientific literate citizens for a sustainable economic development [13]. The traditional physics instruction, which is normally conducted based on a theoretical basis, together with the teacher-centered approach, has been shown to heighten the dislike for studying physics amongst students, which in turn causes difficulty in understanding and retention of physics concepts [14, 15].This is further confirmed by Akinbobola [16] who observed that in Nigeria, students' poor achievement in physics have been attributed to poor teaching methods and gender effects.

Therefore, this study in an attempt to maximize retention of achievement in difficult physics concepts for male and female students used design thinking approach in STEM context pedagogy as an active learning process in which students were expected to acquire physics knowledge by making sense of the concepts by themselves. It is not merely transferring information from the teacher to the students. It is a diversified teaching and learning technique for knowledge acquisition in an attempt to improving retention of perceived difficult physics concepts in male and female students.

### ***Purpose of the study***

The specific objectives of this study was to:

- To investigate the effect of design thinking approach in STEM context on the retention of achievement in physics learning for male students.
- To investigate the effect of design thinking approach in STEM context on the retention of achievement in physics learning for female students
- To investigate the effect of design thinking approach in STEM context on the retention of achievement in physics learning between male and female students

### ***Design Thinking Pedagogical Approach and Its Philosophical Model***

In the design thinking revolution, Schon [17] introduced the concept of reflection-in-action to explain how the process of problem-solving is framed by designers. The notion of design as a way of thinking in the sciences can be traced to Herbert A. Simon's book, the Sciences of the Artificial [18]. Nigel Cross [19] in contrast, examines the designer's abilities and how designers act and think differently. He believes that the designer's task includes both solving problems and producing the solution.

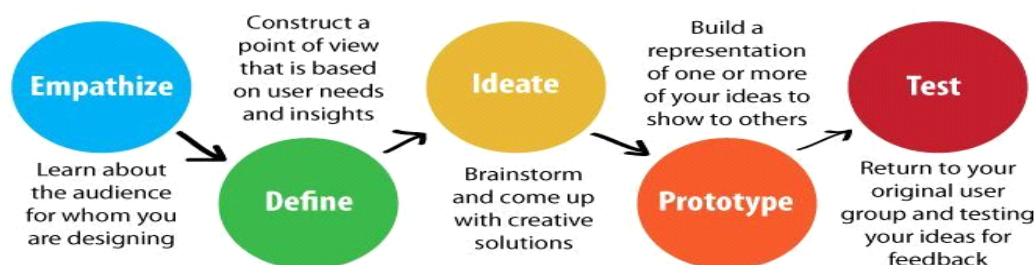
Design thinking approach according to Eftekhari [20] is a teaching and learning method which introduces a novel pedagogy potent in moving students beyond the traditional acquisition of knowledge toward the actual application of acquired knowledge to real life situations. Design thinking introduces a holistic approach such as encourages students to think across boundaries, thereby providing them with opportunities for fundamental and real world innovations. Design thinking is a creative method to excite learners about STEM by empowering the learners to solving problems and taking on new challenges. The problem-solving process of empathy, define ,ideate, prototyping and testing as in the design thinking process enables students to learn, collaborate, and generate effective and innovative solutions [21]. STEM-Design thinkers according to him are energized as creative problem solvers and as innovators as STEM-Design thinking provides learners with tools required for better achievement.

Design thinking approach to learning according to Kwek [22] focuses on developing the learners' creative confidence through hands-on projects by empathy, promoting a bias toward action, encouraging ideation and fostering active problem solving skills and competencies in learners. Design thinking is problem solving approach based on a complex of skills, mindsets and processes used to creating novel solutions to world problems. Design thinking is a user-centered, empathy-driven approach which aims at generating solutions through real insight into the users' needs [23]. Design thinking is an approach that focuses on real problem solving through empathy driven solution and promoting creativity confidence [24].

Currently, design thinking is fundamentally about the skills required for creative problem solving asserts that design thinking is used when solving problems in different life's endeavors in relation to organizations and individuals. Its' domain of knowledge is process-based and not content –based which emphasizes a learning -by –doing approach. Its potency lies in its ability to turning learners from passive learners to confident creators [23]. This philosophy is in line with that of John Dewey who was famously known for his views on progressive education and emphasized the necessity of learning by doing. Dewey asserts that people learn through a 'hands-on' approach and that it was necessary that people

experience reality. Dewey revealed that the learner must interact with their own environment such as is done in design thinking instructional approach in this study so that he later attained his place of pragmatism in the philosophy of education. Therefore, Dewey defined design thinking as the approach to learning which is concerned with active problem-solving through engagement with and transforming the world [25]. In Dewey's view, teachers must be ready to foster classroom environments that encourages learners through experience that help them to develop a better understanding of the curriculum and the learners' world thus making sense of the world for learners. Dewey's theory of learning through experience is essentially vital as it help instructors to efficiently emphasize and apply classrooms learning's to real world situations.

Design thinking in the view of Brown [26] is an iterative process which is potent in transforming problem situations into opportunities. A "good design" as an unproblematic process is described is characterized by the generation of innovations,, which produces predictable results while creating desirable solutions to the end users. Design thinking refers to creative strategies, designers employ during the process of designing [27]. There are various structures of the design thinking process in use today with numerous stages ranging from three to seven but are all based on the outlined principles in Simon's model of 1969 - The Sciences of the Artificial. However, this study adopted the five-stage model of empathy, [define](#) (the problem), [ideate](#), [prototype](#), and [test](#) as proposed by the Hasso-Plattner Institute of Design at Stanford as follows in figure 1:



**Figure 1:** Design thinking process model [28]

[Empath](https://www.interaction-design.org/literature/topics/empathy) [HYPERLINK "https://www.interaction-design.org/literature/topics/empathy"](https://www.interaction-design.org/literature/topics/empathy): In accordance to Hasso Platner [28], empathy is the first stage of the design thinking process model. It is crucial as it refers to the human centered counter piece of the design process.

It offers design thinkers the opportunity to gain insight into the users and their needs .It involves making some ample effort to understand the emotional needs of the users or people, the way they do things and why they are need, what they are thinking and what could possibly be beneficial to them. Since the problems of the design is not really his own, he must need possess some empathy so as to be able to design for the people. Empathy can take the form of watching, observing listening and engaging,

*Define*: The second stage of the design thinking process model is define. According to Hasso Platner [28], this is getting out all the information out of the designer's head, unpacking them and sharing with fellow designers. It involves mapping out using anything that captures impression and posting pictures of users. It helps to give clarity and focus to the entire design process. The main goal expectation of design is to draft a viable and meaningful problem statement. The define stage is referred to as point-of-view. The phrase "How will I..." is used to describe a point of view It involves bringing out a well-shaped articulated point-of-view that could generate solution to the users. It is about generating a guiding statement which focuses on insights and particular need of the users. This statement ends with a suggestion about how to make necessary changes such as will have influence on people's experiences. The define mode is one that deals with the designer's effort to synthesize his scattered findings into simple potent insights. It offers information of necessary criteria for competing ideas in the design process.

*Ideate* is the third and critical component stage of the design thinking process model. Accordingly, it is the stage of a design thinking process that focuses on ideas generation since ideas help designers to come about pushing for the widest possible range. It is brainstorming a variety of ideas. Ideating in design thinking process is embedded with fun and creativity. Students in the ideation phase are expected to generate a myriad of ideas in a single session. They become wishful thinkers, dreamers of the possible and the impossible as well as risk takers.

*Prototype* is the fourth stage of the design thinking process model which entails bringing forward ideas to generate solutions. A prototype is anything that the users do interact with. It could be a a role playing activity, particular gadget,

wall of post it notes. The mode is the iterative Prototyping helps to build to think. Prototyping in design process is a rough and rapid section. A prototype could be a sketch model or a cardboard box. It is a fast path conveying an idea of the design process. Students at this phase, learn that it is better to fail early and often times.

*Test and feedback* is the fifth stage of the design thinking process model. Accordingly, this stage designer test and get feedback on the prototypes created. Testing is part of an iterative process which provides the students with a feedback to learn what works and what doesn't work and after wards iterate and thereafter make some necessary modifications based on feedback .It helps to make decision on whether to refuse or accept the prototypes and solution so as to learn more about the user. Testing may be helpful to know whether the problem statement was well stated or not. It informs about the next iteration of prototypes whether to go back to the drawing board or not. It helps to see what ought to have been done that was not done. It ensures that students learn in the design process for the users what works and what doesn't work as enumerated by Efeoglu, Miller, Serie and Boer [29].

Therefore, from the above review the researcher was informed that the design processes model is of several stages having their basis on the foundational model of Herbert Simon. Thus, the model guided the researcher on the main processes of empathy, define, ideate, prototyping, testing and feedback in the design thinking approach. It has guided the researcher to focus, adopt and adapt the Hasso Platner design thinking model in the development of the instructional module which has its foundational basis on the pioneering model and framework of Herbert Simon.

### ***Integrated STEM Elements for Optimal Learning and Retention of Difficult Physics Concepts***

STEM learning according to Jolly [30] is an interdisciplinary learning approach which eliminates traditional barrier that separates the disciplines of science, technology, engineering and mathematics thus integrating them into rigorous, real-world relevant experiences for learners. In this study, STEM learning is defined as the context for learning selected physics concepts of force, energy, motion, speed, velocity and acceleration with their relevance to the interdisciplinary approach of science, technology, engineering and mathematics for optimal retention.

Learning physics in the context of STEM according to Fischer [31] minimizes learning around the facts thereby changing the paradigm. Teaching and learning physics according to him must go beyond the facts and the theories. To draw as close as possible to understanding the cause effect realities of the natural world is the goal of science. It is never the "facts" or the "truth" because and "facts" and "truth" could have different meanings to different people. The conventional methods teachers use in teaching physics has been by stressing only the facts or theories without emphasizing active learning. This is collaborated by Fischer [31] who observed that conventional science instruction such as physics learning is not effective as expected. Only 10 to 20 percent of lecture content are being retained by the students, to the dismay of the instructors who had spent much time clarifying only the facts to their students.

STEM learning is an interdisciplinary and applied approach for instructing students. It is based on the four disciplines of science, technology, engineering, and mathematics. Jolly [30] defined each of the four disciplines which makes up the interdisciplinary approach of STEM as follows: *S-Science* (Understanding the natural world around us), *T-Technology* (Creating products to solve human problems), *E-Engineering* (Design process to solve human problems) and *M-Mathematics* (Numbers, quantities in every activity).

STEM learning is essential because it occupies every endeavor of human life. Besides, the necessity for STEM learning in today's ever changing world is becoming more and more apparent [32]. STEM learning in the 21<sup>st</sup> century is an approach for making learning more connected to real-world situations and relevant to the learners. It increases science literacy, enables the next generation of innovators by developing critical thinkers. Innovation no doubt leads to new products and processes potent enough to sustain our economy. Such innovation and science acquisition depends on a solid knowledge base in the STEM areas [33]. It encourages creativity which promotes innovative thinking. STEM activities avail hands-on and minds-on lessons for learners. It makes learning mathematics and science interesting so that students do much more than just learn [34]. Such peculiarity of STEM in learning science and mathematics with fun could make learning of difficult concept less stressful thereby enhancing optimal achievement and retention. Besides, it encourages a student- centered environment as well as improves problem solving higher level thinking skills and retention of concepts.

### ***Gender Schema Theory and Retention of Difficult Physics Concepts***

The Gender schema theory emphasis that cultural influences does largely impact on how children develop their own ideas about what it means to be a boy or girl, a male or female, man or woman. Gender schema theory is such that explains that children do learn from the culture in which they live about what it means to be a boy or girl. According to Bem [35, 36 & 37], the theory emphasizes that children usually adjust their own behavior to fit into cultural and gender norms of their culture. From Bem's theory, children observe culture and people around them. They imbibe and learn the

existing associations with masculinity and femininity. From such associations with their own culture they develop some peculiar gender –linked characteristics, while maintaining and transmitting same to others within the society.

Moreover, what influences a gender schema's development theory is the beliefs of the society about what really constitutes male and female traits. The theory therefore reflect both on how social information is processed as well as on people's beliefs, behaviors and attitudes. The Bem's Gender schema theory describes what characterize each gender and how each gender is treated by the society as well as societal roles which outlines what physical differences is between male and female. Society here could mean the schools, parents, peers and media. All these have the potential to exert cultural effect and influences on gender schema. This can be seen in a traditional culture, where a child learns that man's role is that of industry and a woman that of caring and raising of children. Besides, children form schema related to how women and men should behave through their observations of traditional cultures.

Study investigating the relationship between gender and physics achievement by Gamze [38] reported that male students had higher achievement in physics than their female colleagues in comprehending concepts in physics. Similarly, Akanwa and Kalu-Uche [39] reported that there is a wide gap in boys and girls achievement in science and technological fields. Moreover, In a study conducted on investigating the relationship between gender and achievement of 494 senior secondary (SS III) students in physics in 6 zones of Enugu state, Nigeria by Ugwu [40], a weak negative relationship between gender and achievement in the Test of Understanding of Physics Concepts (TOUPC) was reported signifying poor retention of concepts compared with their male counterparts. Conclusively, the study's theoretical perspectives of assimilation and gender schema theories established a model for male and female learning outcomes in the students' own sociocultural and constructivism environments while learning physics concepts in STEM context.

## **RESEARCH METHODOLOGY, RESULTS AND DISCUSSIONS.**

### ***Research Design***

Study intervention was carried out as an after school environment so that study could not randomize nor use a control group but used existing intact group of classes and employed a single group research design in the quasi-experiment. In line with the assertions of Kazdin [41], a single-group design was employed because it was sensitive to means of groups being often primarily used to determine a program or study's intervention's effectiveness. Beside, Borg and Gall [42] justified the use of a single group design in situations when schools do not make possible provisions nor allow the researcher for control groups. Using the single-group design was further justified in line with the assertions of Thompson [43] that it is highly flexible and highlights individual differences in response to effect of study's intervention.

### ***Study Sample and Sampling Technique***

Study used an intact class of physics students comprising of 89 with 48 being male and 41 female students purportedly selected from two senior secondary schools (SSS 2) in Kwali Area Council, Abuja, Nigeria. These were schools that allowed an afterschool school environment after some ethical considerations. Participants' average age was 16 years old and were of comparable socio-economic background.

### ***Instrumentation***

Study conducted a pilot test on the 25 item multiple choice and semi-structured Physics Learning Achievement Test (PLAT) which was to be used for the intervention. PLAT was validated by experts in physics and STEM fields. Split test reliability on PLAT using odd and even strategy in line with Anikweze [44] was estimated to determine the level of error in the multiple choice achievement test by Kuder-Richardson formula (KR-20) at .86. Also to determine the test –retest reliability for the semi-structured questions, the coefficient of stability using Pearson product moment correlation was estimated at .81.

Besides, the researcher's developed STEM-Design thinking modules used at intervention was validated by experts in physics and STEM fields. Rational for developing the modules rather than adopting one for use was because most STEM instructional learning materials in schools give much attention on the science and mathematics of STEM, without the inclusion of all the various elements of Science, Technology, Engineering, and Mathematics so that the Engineering and Technology were neglected in such version of STEM learning. On the other hand, most STEM instructional materials such as 'Engineering by Design' developed by the Center for Advancement for Teaching, Technology and Science (CATTS), 'Invention, Innovation and Inquiry' by International Technology Education Association (ITEA), 'Engineering is Elementary (EIE)' by the National Center for Technological Literacy (NCTL) all placed emphasis on engineering and technology with little or no emphasis on the science and mathematics.

However, in this study, the developed STEM-Design thinking modules used the combined elements of STEM learning, namely the science, technology, engineering and mathematics. This was integrated into the design processes of empathy, define, ideation, brainstorming, prototyping, testing, improving and retesting for learning physics concepts of force, motion, energy, speed, velocity, Newton laws of motion and acceleration for three months. Rational for selection

of concepts as perceived difficult physics concepts was in line with the reports of Okpala and Onocha [8]. Obafemi et al. [6], Jegede and Adebayo [9] as well as that of Kiptum [5] who reported these concepts as difficult physics concepts among others. Besides, the feasibility in the implementation of the developed STEM-Design thinking instructional modules for the quasi-experimental intervention was ascertained through interviews and observational technique analysis from students and experts respectively at pilot study.

### **Procedure**

Using the validated STEM- Design thinking modules for the quasi-experimental intervention, students were made to learn the selected physics concepts of force, motion, energy, acceleration, velocity and speed with emphasis on the science, technology, mathematics and engineering (STEM) knowledge while engaging on the design activities. The modules consist of the zip line, truss bridge design challenge activities for learning physics concepts. Prior to study's intervention, students were administered a pretest and similarly after an intervention a posttest using PLAT. The scores obtained at the pretest and posttest were therefore statistically analyzed by gender for understanding of the study's effect on male and female's achievement in the selected difficult physics concepts. The procedure of the design processes are as follows:

*Empathy*-At this stage of the design process, use of the instructional modules presented the participants with a zip line deliveries and truss bridge design tasks while making them to develop deep insights into the users and their needs. The main goal in the zip line challenge was to identify some problems using a story line of some children in a refugee camp in a thick jungle. These refugees who live down the mountain sides had no access road for use, bartered with hunger, uncertainties of life, lack of basic clothing supplies and routine lifesaving medicines for malaria, tuberculosis, pneumonia and HIV/AIDS treatments. Participants therefore, were allowed to develop deep insights into the needs of these children refugees, putting themselves in their place so they can consequently generate some solutions to the problem of these children by designing a carrier for them as user. The consensus insight arrived at by the participants and the facilitator was a design that can travel down a zip line.

The second design task borders on building a rural community sturdy bridge challenge. The main goal was identifying through a story- line some problems with a Nigeria Railroad Corporation which had just acquired a fleet of trains for transportation of persons, goods and services across the country. However, a narrow river exist in one section of the railroad plan which runs through a deep valley which makes the construction of an additional railroad for the trains to cross the valley in a populated local community a problem. Participants therefore, were avail the opportunity to develop deep insights into needs of these railway corporation in this community by putting themselves into their place so they could generate some solutions to the problem. A consensus through deep insight was reached by participants and their facilitators to design a sturdy truss bridge for the users above the river and deep valley.

*Define*: Define the problem in a human-centered manner. It entails identifying the design challenges, stating clearly the problem and what possible potential solution could be achieved just as engineers do it entails finding what problem is it. The study therefore using the developed STEM- design thinking module enabled study participants to brainstorm and write down what they can invent as a solution to the identified problem and how it will work out. This pertained to the zip line deliveries, truss bridge design challenge tasks. In the zip line challenge, the main goal was to identify some problems with some children in a refugee camp in a thick jungle. The participants therefore were expected to clearly state the problem as does engineers and thereafter spelling out how to possibly work out the solution to bringing daily deliveries to this children in the thick jungle. Similarly, in the building of a rural community sturdy bridge challenge, participants were made to identify, write down and brainstorm on how to offer solution in a rural community where construction of an additional railroad for the trains to cross the valley was a problem.

*Ideation*: This refers to various techniques as brainstorming, identifying possible solutions or ideas to the design challenge. It involved sketching, drawing diagrams or taking pictures as does engineers. Also involved listing the materials needed for creating solutions to identified problems facing the users. Therefore, participants after brainstorming chooses the best ideas of the numerous ideas they generated.

*Prototypes*: This stage involved participants creating solutions as they produce varieties of inexpensive versions of the product. They build a model – either full-size or scale – of their design based on their plans which is an important step of an engineering design process. On using the first developed instructional module, the study the facilitator asked the study participants about what type of zip line they know after going through their own sketches on paper. Facilitator also shows the participants some zip line designs activities by online interactive resources. Thereafter, participants were allowed to create prototype, build a model of a zip line. On the second design challenge, facilitator asked the participants about what type of bridge they know and thereafter go through their paper sketches. Facilitators also shows participants some truss bridge design activities by online interactive resources. Thereafter, participants were allowed to create prototype, build a model of a truss bridge design.

In the zip line challenge, participants were guided to describe and design a model of a zip line. As participants engaged in the design task, concepts of kinetic energy, potential energy, gravitational acceleration, transforming gravitational potential and the Newton law of universal gravitation were reasoned out with clear cut discussion on how the acceleration of a given object is affected by it. Participants were guided in applying mathematical formula of average speed=distance /time as well learnt conversion of units for physics concepts. Besides, the concepts of friction and forces in two dimensions, vector components, coefficient of friction of the ropes and torques in solving the zip challenge were highlighted. Participants therefore knew and acquired better understanding of physics concept as science and engineering principles involved in zip lines structures.

In the truss bridge design, participants were guided to learn and apply the concept of force associated with designs of bridges namely as force of reaction, weight of bridge and their associated mathematical calculations as they engaged in building the prototype bridge. As they engage in the design task they learnt and understood basic fundamental principle of engineering and coupling together of bridge design( the technology). Besides, the participants learned and applied the Newton’s third law of motion as engineers in designing bridges, the concepts of equilibrium, static and dynamic loads, vibrations, and resonance while building their bridges (the Science). They also learnt while designing the prototype of truss bridge about tension and compression forces (the science) while determining the effective geometric shapes used in bridge design (the mathematics).

*Testing:* Test it out. This step offers the participants the opportunity to see potential flaws, challenges or glaring opportunities that were not visible in a two-dimensional drawing. In this stage, participants as designers test the finished products using the best identified solutions in accordance with Siang [45]. Participants test their own prototypes of the zip line structure in design challenge as well as of the truss bridge challenge.

*Improving and Retesting:* Study participants repeated the design process step several times, by going back to previous steps and starting over. It is the way to go in the design process as there is no right or wrong way to going through the solutions. For the truss bridge design participants viewed to check out if their invention or designs can be improved. They check if the prototypes can be modified. They check out if it will hold more weights as in the case of the truss bridge design task. They tried more challenging levels by increasing the distance to more than 1 meter, 2 meters and so on. They reviewed the design steps for quality assurance. In the same vein for the zip line deliveries challenge, study participants repeated the design process step several times, by going back to previous steps and starting all over again to check out if their designs or inventions could be improved upon. They check to see if their prototypes could be modified of the zip line for deliveries while increasing or decreasing the distance on the line to calculate new values for riders’ speed, velocity and acceleration with respect to gravity on the zip line.

## RESULTS AND DISCUSSIONS

**Table 1:** Mean and Standard Deviation of the Post-test and Delayed-Posttest of Male and Female Students’ Achievement in Physics Learning

Gender			Mean	N	Std. Deviation	Std. Error Mean
Male	Pair 1	Posttest (Achievement)	17.69	48	2.64	.38
		Delayed-posttest (Achievement)	18.06	48	2.96	.43
Female	Pair 1	Posttest (Achievement)	17.37	41	2.93	.46
		Delayed-posttest (Achievement)	17.39	41	2.43	.38

From Table 1 , a total of 48 male students was with mean and standard deviation of Post-test and Delayed-posttest physics achievement of post-test(M=17.69, SD=2.65) and Delayed-posttest (M=18.06, SD=2.96). Similarly, a total of forty-one(41) female students with a mean and standard deviation of Posttest and Delayed-posttest physics achievement were posttest(M=17.37, SD=2.93) and Delayed-posttest(M=17.39, SD=2.43).

**Table 2:** Paired Sample Test between the Post-test and Delayed-posttest of Male Students’ Achievement in Physics Learning

Paired Samples Test <sup>a</sup>				
Gender	Paired Differences	t	df	Sig. (2-

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		T	df	Sig. (two-tailed)
					Lower	Upper			
Male	Posttest (Physics Achievement)								
Pair 1	Delayed-posttest(Physics Achievement)	-.38	4.2	.61	-1.59	.84	-.62	47	.54

a. Gender = Male

In testing the null hypothesis  $HO_1$  which states there is no significant difference between the posttest and delayed-posttest of achievement in physics for male students, a paired sample t-test was carried out. This was to determine whether a statistically significant difference existed between the mean score of achievement in physics for male students at post -test and delayed-posttest which is the posttest 2 administered after the intervention namely the use of STEM-Design thinking modules. Before the analysis, an assumption of normality test was conducted which indicated that there was no gross violation of assumptions.

The result of the paired t-test as shown in Table 2 was found not significant at  $t(47) = -.62, P > .05$  (two-tailed). Meaning there was no significant difference in mean score of male students' physics achievement at posttest and delayed-posttest. The observed non-significant increase in physics achievement scores from the post-test ( $M=17.69, SD=2.65$ ) to the Delayed-posttest ( $M=18.06, SD=2.96$ ). to the delayed-posttest was a mean of 0.38 with the 95% confidence level interval for differences between the means of -1.59 (lower bound) to .84(upper bound) so that the researcher fail to reject the null hypothesis  $HO_1$ . This implies that there was no significant difference between the posttest and delayed posttest of mean sore of achievement in physics learning for male students.

Furthermore, a paired sample t-test analysis was conducted in order to statistically proffer answer to the research hypothesis ( $HO_2$ ) which states there is no significant difference between the posttest and delayed- posttest of achievement in physics for female students as follows:

**Table 3:** Paired Samples Test between the Posttest and Delayed-Posttest of Female Students' Achievement in Physics Learning

Gender	Pair 1	Posttest (Achievement)	Paired Differences					T	df	Sig. (2-tailed)
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
						Lower	Upper			
Female		Delayed posttest (Achievement)	-.02	3.38	.53	-1.09	1.04	-.05	40	.96

In testing the null hypothesis  $HO_2$  which states that there is no significant difference between the posttest and delayed- posttest of achievement in physics learning for female students, a paired sample t-test was carried out. This was to determine whether a statistically significant difference existed between the mean score of achievement in physics for female students at posttest and delayed-posttest. Before the analysis, an assumption of normality test was conducted which indicated that there was no gross violation of assumptions. The result of the paired t-test as shown in Table 3 was found not significant at  $t(40) = -.05, P > .05$  (two-tailed). Meaning there was no significant difference in mean score of female students' physics achievement at posttest and delayed-posttest. The observed non-significant increase in physics achievement scores from the post-test ( $M=17.37, SD=2.93$ ) to the Delayed-post-test ( $M=17.39, SD=2.43$ ) was a mean of .02 with the 95% confidence level interval for differences between the means of -1.09 (lower bound) to 1.04(upper bound) so that the researcher fail to reject the null hypothesis  $HO_2$  thus implying that there was no significant difference between the posttest and delayed posttest of mean sore of achievement in physics learning for female students.

Similarly, a One-Way ANCOVA analysis was conducted in order to statistically proffer answer to research hypothesis ( $HO_3$ ) which states there is no significant difference between the Delayed-posttest achievement of male and female students in physics learning after the effect of pretest is controlled as follows:

**Table 4:** Result of One-Way ANCOVA for differences between Male and Female Students Achievement in Physics Learning at Delayed- Posttest.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	13.07 <sup>a</sup>	2	6.53	.87	.42	.02
Intercept	2912.33	1	2912.33	388.01	.00	.82
Pre-test	3.07	1	3.07	.41	.52	.01
Gender	12.71	1	12.71	1.69	.20	.02
Error	645.50	86	7.51			
Total	28708.00	89				
Corrected Total	658.56	88				

a. R Squared = .020 (Adjusted R Squared = -.003)

A one-way between-groups analysis of covariance (ANCOVA) was carried out in an attempt to test the null hypothesis  $H_{03}$  which states that there is no significant difference between the Delayed-posttest achievement of male and female students in physics learning after the effect of pretest is controlled. The independent variable was the intervention which is the use of STEM-Design thinking approach while the dependent variable was the scores on physics achievement at Delayed-posttest administered to participants after the intervention. The pretest which is participants' score in physics achievement before the intervention was used as the covariate in the statistical analysis. After adjusting for the pre-test on students' achievement in physics, there was no significant difference between male and female students on Delayed-posttest achievement scores as shown in Table 4 indicating that the researcher fail to reject the null hypothesis  $H_{03}$ .  $F(1, 86) = 1.69, P > .05$  (two-tailed) and  $\eta_p^2$  (partial eta squared) = .02.

## DISCUSSION

From the results obtained in the statistical testing of generated null hypothesis  $H_{01}$  shows that the researcher failed to reject the null hypothesis ( $H_{01}$ ). This implies that there was no significant difference in the mean score of male students' physics achievement at post-tests and delayed-posttest. Although there was slight improvement in achievement of male students from posttest to delayed posttest. This means that male students were able to retain content of physics concepts of force, motion, acceleration, speed, velocity learnt when design thinking approach in STEM context was used. This is consistent with the research report of Talbot (2014) in investigating gender differences in STEM knowledge acquisition. Study reported that male students both gained and retained contents of STEM knowledge in the out-of-school-time STEM program. This implies there was improvement in knowledge acquisition for male students from posttest to delayed posttest. Study findings is in line with the findings of Mbanjo and Nolan [46] in their study on increasing access of students in STEM learning. They found that student-active pedagogies improved retention in male students. This also is line with Ausubel's theory of assimilation that when learners' previous ideas is assimilated into the new one such as when using STEM-Design thinking processes for learning difficult physics concepts, new potential learning takes place which enhances meaningful long-term retention of concepts. In this study using learning environment in which learning activities using the design thinking in STEM context allows past experiences and acquired learners' ideas from a variety of real-life situations is connected and assimilated into the new learning, there is a potent contribution on achievement and meaningful retention of information learned. Ausubel's assimilation theory for retention further confirmed study findings that when a learner is learning a new information, the brain try to associate the information or concept with previously stored knowledge through assimilation. When the student learns something new, the brain creates a new neural pathway so that repetition becomes vital when engaging in learning to retaining or store such information in long-term memory. In this study, the test-retest stages of the STEM- Design thinking processes availed the learners' the opportunity to optimize meaningful retention of difficult physics concepts.

Moreover, finding is in line with the affirmations of King and Wiseman [47], and Stohlmann, Moore, Tamara and Roehrig [48] that interdisciplinary STEM learning upholds students' retention. This also agree with the report of Meyrick [49] that STEM learning context has the capacity to provide learners with true mastery of concepts.

Furthermore, the statistical testing of the generated null hypothesis  $H_{02}$  shows that the researcher failed to reject the research hypothesis  $H_{02}$ . This implies there was no significant difference between the post-test and delayed post-test of achievement in physics learning for female students. Study findings shows that female students did not experience

significant improvement in physics learning achievement from posttest to delayed-posttest. Although they retained the knowledge acquired in learning selected physics concepts. Although, their level of achievement did not increase significantly from posttest to delayed-posttest. But content of physics concepts were retained. Study finding is consistent with that of Standish, Christensen, Knezek, Kjellstrom and Bredder [50] who compared the mean scores at pretest and posttest in an attempt to determine the effects of an instructional module. Their study found out that females gained a large amount of knowledge on the concepts of sound and waves.

Findings is consistent with the research results of Talbot [51] in investigating gender differences in STEM knowledge acquisition in which study result shows that female students both gained and retained contents of STEM knowledge in the out-of-school-time STEM program after 60 days period. Moreover, study findings is also in line with the report findings of Mbanjo et al. [46] in their study on increasing access of female students in STEM learning. They found out that student-active pedagogies improved retention in female students. Again this study's findings which shows that female recorded meaningful retention of concepts is line with Ausubel's theory of assimilation which established that when learners' previous ideas is assimilated into the new ideas or concepts such as when using STEM-Design thinking processes for learning difficult physics concepts, a new potential learning takes place which enhances meaningful long-term retention of the physics concepts. The learning activities using the design thinking in STEM context allowed past experiences and acquired learners' ideas from a variety of real-life situations to be connected and assimilated into the new learning, resulting to a potent contribution on achievement and consequently a meaningful retention of concepts learned.

Furthermore, study from the statistical testing of generated null hypothesis  $H_{03}$  shows the researcher failed to reject the null hypothesis  $H_{03}$ . This implies that there was no significant difference between the delayed-posttest achievement of male and female students in physics learning after the effect of pre-test was controlled. Notwithstanding, findings shows that the male students had higher achievement scores in physics learning than the female students based on comparison on the delayed-posttest achievement scores. This means that level of retention of physics concepts for male students was higher than that of their female counterparts although both had their retention of physics contents enhanced by the use of design thinking in STEM context.

Study findings is supported by that of Talbot [51] in a study investigating the effect of out-of school STEM learning on knowledge reported that there was no significant difference between the achievement of male and female at the post-post-test but that the males had higher achievement scores than their female counterparts.

Besides, findings are not concomitant with the study findings conducted by Oludipe [52] to investigate gender difference in students' achievement in STEM related learning. Study reported that female students' mean scores achievement was observed to be slightly higher than that of their male counterparts. Although they observed no statistically significant differences in delayed – posttest mean scores achievement of male and female students. Conclusively, male students had higher achievement scores in physics learning than the female students on the delayed-post-test achievement scores. Reason for this difference between male and female for which males had higher achievement scores in physics learning than their female counterparts may be adduced to the views of Bian, Leslie and Cimpian [53] in their study on gender stereotypes about intellectual ability. According to them, intellectual ability emerges early and influence children's attention. As early as age 6 both male and female children already imbibed the perception for gender stereotypes that males generally have higher-level intellectual capacity and ability in STEM learnings and are so labelled as genius. Thus such gender stereotypes which associates the males with high-level intellectual ability has a potential influence in affecting the male participants to wanting to boost their egos to measure up to this stereotype, influencing them positively but rather influence the females negatively. The females will always perceive due to such stereotype that their male counterparts are always better than them in STEM learnings achievements.

Furthermore, Guo, Parker, Marsh and Morin [54] in their study on achievement reported that implicit or explicit gender stereotypes depicts the idea that STEM learning are mainly male-dominance which negatively affects the achievement and engagement of females thereby making them perform lower than their male counterparts as obtained in this study. Hoffman, Gneezy and List [55] also observed why male outperform their female counterparts in STEM learning achievements. Their reason was because males are believed to have better cognitive skills than their female counterparts which according to them could probably be due to the family environment that provides the males with more opportunities to put their skills to practice.

Moreover, Steinke [56] collaborated on the reason for males having higher scores than the females as possibly due to gender stereotypes from media which most often do influence female students' ability, achievement and their aspirations in STEM learnings and professions. Steinke [57] further asserts in a study on adolescent girls' STEM identity formation and media images of STEM professionals that watching television programs, posters, video games, film, sci-fi movies

that show images that promotes traditionally male dominance, may pose a threat to gender-STEM compatibility for the females. Gender schema theory therefore provides the understanding of how and when gender stereotypes popular media may affect adolescent girls' STEM formation of their identity by giving attention to the dominant role of gender schemas during information processing which invariably turn out to affect their own ability and achievement in STEM leanings.

Besides, McDaniel [58], Spearman and Watt [59], Kolmos, Mejlgard, Haase and Holgaard [60] all in their study reported that girls are less advantaged in STEM learning achievements compared to their male counterparts. This according to them is due such as the gender, cultural and social norms. These influence females and males' up bringing as they interact with peers, teachers, parents and the society at large. These norms according to them sharpens their learning behaviours, beliefs, identity and their choices and invariably makes them think and perform lower compared to their male counterparts to their interactions with variety of factors within the learning and socialization processes.

Moreover, Thomas, Kovas, Meaburn and Tolmie [61] reported in their study that there is no evidence for male and female genetic differences in their cognitive abilities. This implies that male and female cognitive abilities are not determined by genetic differences between them. According to them, as male and females interact with their environment, family, classroom and the society at large may determine to what extent their genes does influence their cognitive abilities. In order words the interaction of the female participants with their immediate environment affects their construction of learning in line with the constructivist cognitive learning's view. This has the capacity to determine their lower cognitive abilities and retention of physics concepts when compared to their male counterparts.

### ***Implications for a Gender-Inclusive Pedagogy***

The study intervention provided a type of an inclusive pedagogy in which facilitators and learners creates a supportive environment where they were actively engaged together in design tasks that availed each participant equal opportunity to meaningful learning, promoting thoughtfulness and creativity of ideas generation for solutions to human problems. Use of developed STEM-Design thinking modules which was student-centered had the capacity to improve female students' achievement in STEM learning because the design tasks were related to social environments that provided favorable social negotiations in terms of ideas, human relationships, language and relevance of topics taught and applied to their social environment from where they construct their knowledge. This nevertheless enhanced better female students' achievement in physics learning like their male counterparts in line with Kelly [62] who asserts that female students acquire meaningful learning in classroom with keen interest when topics of instructions have some social relevance. This is in line with the study reports of Baker [63] that certain teaching strategies such as are student-centered, inquiry-based and participatory strategies such as the STEM-Design thinking approach for learning physics concepts has the potential to inspire females. Study findings of Yang [64] reported that female learners prefer learning environments that offer them opportunities to connect learnings of concepts to real life situations. In this study, female participants' actively engaged in the STEM-design thinking activities in the zip line and truss bridge design tasks that allowed them relate what is learnt to real life situation which therefore optimized their achievement in physics learning within the constructivism environment. The implication of this therefore revealed the need for the schools to provide innovative training to sensitize physics teachers on how to develop and use a gender-inclusive pedagogy such as the STEM -design thinking modules in physics learning through relating difficult concepts to real life situations in a bid to creating learning opportunities that will optimize male and female learners' meaningful learning and retention of such difficult physics concepts. This is because females preferred constructivism learning environment than their male counterparts and this resulted to optimizing meaningful retention of achievement levels.

***Limitation of Study:*** The study basically was limited to enhancing students' optimal retention of achievement in some selected difficult physics concepts using the design thinking approach in the context of STEM learning. Selected difficult concepts were limited to concepts of force, energy, motion, acceleration, Newton laws of motion, velocity, and force. Study was limited to only 12 weeks with only 89 male and female students as study participants who were purposively selected from two senior secondary schools in Kwali Area Council, Abuja, Nigeria.

***Competing Interest's statement:*** The authors wish to express that there were no competing interests as regards their involvement in this research.

## **CONCLUSION**

The study revealed that the use of STEM-Design thinking modules sustained and retained male and female students' achievement scores were although the male students exhibited higher retention ability at delayed-posttest on achievement in physics learning than their female counterparts. Furthermore, study findings clearly revealed that using the pedagogical and theoretical approach of design thinking for male and female students does enhance learning of physics concepts in STEM context is effective although with the males having higher scores than their female counterparts in achievement scores at delayed- posttest. The study showed that the STEM-Design thinking approach positively impacted students' achievement and optimized knowledge retention in difficult physics concepts of male and female students in

physics learning. Study findings also shows that there were not much differences in male and female's retention of achievement after study interventions at delayed- posttest and where there were differences, the differences were quite moderate.

Therefore, study recommended that to maximize the positive impacts of learning difficult physics concepts using the design thinking approach in STEM context, education policy should give attention to an after school environment that would optimize meaningful retention of physics concept This in turn will also provide students with ample opportunity to gain 21st century skills for solutions to real-world problems. Study could also be carried out using this intervention in learning other physics concepts and be replicated in other parts of the country for generalization.

In conclusion, study result showed that both male and female students retained physics knowledge alike because both male and female students recorded no significant difference on delayed-posttest achievement scores in physics learning of difficult concepts

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