TWO SIMULATION-BASED INVERTED CLASSROOM STRATEGY AND PRIVATE UNIVERSITIES PRE-DEGREE STUDENTS' LEARNING OUTCOMES IN PHYSICS IN SOUTHWESTERN NIGERIA

BY

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CERTIFICATION

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DEDICATION

This thesis is dedicated to the Sovereign and Almighty God for the gift of life. It is also dedicated to the two women of rare virtues who are the pillars behind my academic achievements: my mother, Mrs. Eunice Ihekoronye and the wife of my youth, Mrs. Ugonna Ihekoronye.

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ABSTRACT

Physics is an important science subject in pre-degree science programmes in Nigerian universities. However, reports have shown that pre-degree students in private universities in southwestern Nigeria have poor learning outcomes in Physics. Previous studies focused largely on student-related factors influencing learning outcomes in Physics, with less attention paid to intervention. This study, therefore, was carried out to determine effects of Simulated Video-based Inverted Classroom (SVBIC) and Virtual Laboratory-based Inverted Classroom (VLBIC) strategies on pre-degree students' learning outcomes (Attitude, Achievement and Problem solving skills) in Physics in southwestern Nigeria. The moderating effects of gender and spatial ability were also examined.

Cognitive Constructivist and Engagement theories provided the framework, while the pretest-posttest control group quasi experimental design of 3x2x3 factorial matrix was adopted. Six private universities (Adeleke, Achievers, Afe Babalola, Babcock, Caleb and Lead City) offering pre-degree science programmes were purposively selected. Participants who had digital electronic gadgets to view and download simulations were purposively selected and were randomly assigned to SVBIC (83), VLBIC (51) and control (70) groups. The instruments used were Attitudes towards Physics Questionnaire ($\alpha = 0.88$), Students' Achievement Test in Physics ($r = 0.75$), Spatial Ability Test ($r = 0.81$), Problem- solving Skills Scale ($r = 0.83$), Availability and Accessibility of Digital Gadgets Inventory and Instructional guides. Treatment lasted 14 weeks. Data were analysed using Analysis of covariance and Bonferroni pairwise comparison test at 0.05 level of significance.

The participants' age was 17.01 ± 2.00 years, and 57.8% were females; their spatial ability (88.2%) was high. There were significant main effects of treatment on attitude ($F_{(2;187)} = 3.68$; partial $\eta^2 = 0.04$), achievement ($F_{(2;187)} = 44.06$; partial $\eta^2 = 0.32$), and problem-solving skills ($F_{(2;187)} = 5.01$; partial $\eta^2 = 0.05$) in Physics. The students in the SVBIC ($\bar{x} = 71.42$) had the highest post-attitude mean score, followed by those in the VLBIC ($\bar{x} = 66.15$) and control ($\bar{x} = 64.12$) groups. The students in the VLBIC had the highest post-achievement mean score ($\bar{x} = 16.35$), followed by those in the SVBIC ($\bar{x} = 14.00$) and control ($\bar{x} = 9.36$) groups, while the students exposed to VLBIC had the highest post problem-solving skills mean score ($\bar{x} = 25.23$), followed by those in the control ($\bar{x} = 19.13$) and SVBIC ($\bar{x} = 16.85$) groups. Gender and spatial ability were not significant on students' learning outcomes. There was a significant two-way interaction effect of treatment and gender on students' achievement ($F_{(2;187)} = 3.10$; partial $\eta^2 = 0.03$) in favour of the female students ($\bar{x} = 12.99$) from the VLBIC group. There was a significant two-way interaction effect of spatial ability and gender on students' achievement ($F_{(2;187)} = 3.85$; partial $\eta^2 = 0.04$) in favour of the female students ($\bar{x} = 13.40$) with high spatial ability. Two-way interaction effects of treatment and spatial ability and three-way interaction effects were not significant on students' attitude, achievement and problem-solving skills.

Simulated-video and virtual laboratory-based inverted classroom strategies improved pre-degree students' attitude, achievement and problem-solving skills in Physics in southwestern Nigeria. Lecturers should adopt these strategies for improved learning outcomes in Physics among pre-degree students.

Keywords: Simulated Video-based Inverted Classroom Strategies, Virtual Laboratory-based Inverted Classroom Strategies, Pre-degree students, Private universities in southwestern Nigeria

Word count: 459

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Physics is a science subject which involves the study of the nature and properties of matter, energy and how various forms of matter interact with one another. It is fundamental to gaining understanding of Applied or Physical Science and Technology in the 21st century. The technological development of any nation is dependent on the extent to which physics is explored. Hence, physics education plays pivotal roles in the pursuit of developing the nation through insights into the dynamics of nature which occur every day. Contemporary developments in Information and Communication Technologies (ICTs), medicine, the environment, crime control and security can be attributed to the underlying principles derived from the knowledge of physics. Consequently, it has been a building block for all other physical sciences such as Chemistry, Cosmology and Mathematics. Against this background, physics is an indispensable subject for students who aspire to pursue any science-related course in Nigerian tertiary institutions. This implies that physics is important at the senior secondary school level and in physical science departments in higher institutions in Nigeria.

Nonetheless, in comparison to other science subjects, there is a relatively low enrollment in studying physics at both ‘O’ Level and higher institution level (Erinosho 2013; Omosewo 1999). For example, in many Nigerian universities, the Departments of Physics and Physics Education experience poor enrollment of prospective students (Erinosho 2013). The ripple effect of this is that there has been a paucity of certified physicists and physics teachers. This dearth of qualified teachers has given many secondary schools off to employing persons knowledgeable in other science subjects to teach physics albeit inefficiently, thus, worsening the entire situation (Erinosho 2013; Ogunleye and Babajide 2011; Ogunleye 2009).

The West African Examination Council (WAEC) Chief Examiner’s report on physics indicated a low enrollment of students for the subject in many of the Nigerian senior secondary schools for the May/June Senior Secondary School Certificate Examination (SSSCE) between 2011 and 2017. In other words, records indicate that less than 39% of the total registered students for SSSCE for the seven-year period registered for physics. This (challenge of low enrollment) may be attributed to both the teaching methodologies used for physics and the perceived negative attitudes of students toward the subject.

Likewise, Ibeh, Onah, Umahi, Ugwuonah, Nnachi and Ekpe (2013) corroborated this point of view when they noted that physics students’ negative attitudes hinge on poor instructional approach, incompetent teachers, disadvantaged learning environment and gender effect, amongst others. Angell (2004), in Godwin and Okoronka (2015), further reiterated that students’ negative attitude towards physics pre-laboratory studies also accounts for the low enrollment as only a meagre percentage (3%) have their preference in physics over other science subjects. Physics as a subject is characterized by formulas, scientific theories and many practical sections with mathematical calculations which are usually carried out in the laboratory within a time frame which oftentimes is insufficient for the mastery of the required contents.

Every student who registers for physics as one of the subjects in a qualifying examination would aspire to be in one of the science based careers. These careers need precision and exactness, and professionals who have expertise in application. Thus, these students must be able to score good grades in such a subject preferably at the distinction level in order to maintain a high level performance in their chosen careers and use the knowledge to extend the frontiers of knowledge in the sciences as well as contribute to national development. It may be reiterated that students’ entry requirements in physics influence their overall performance in physics related courses.

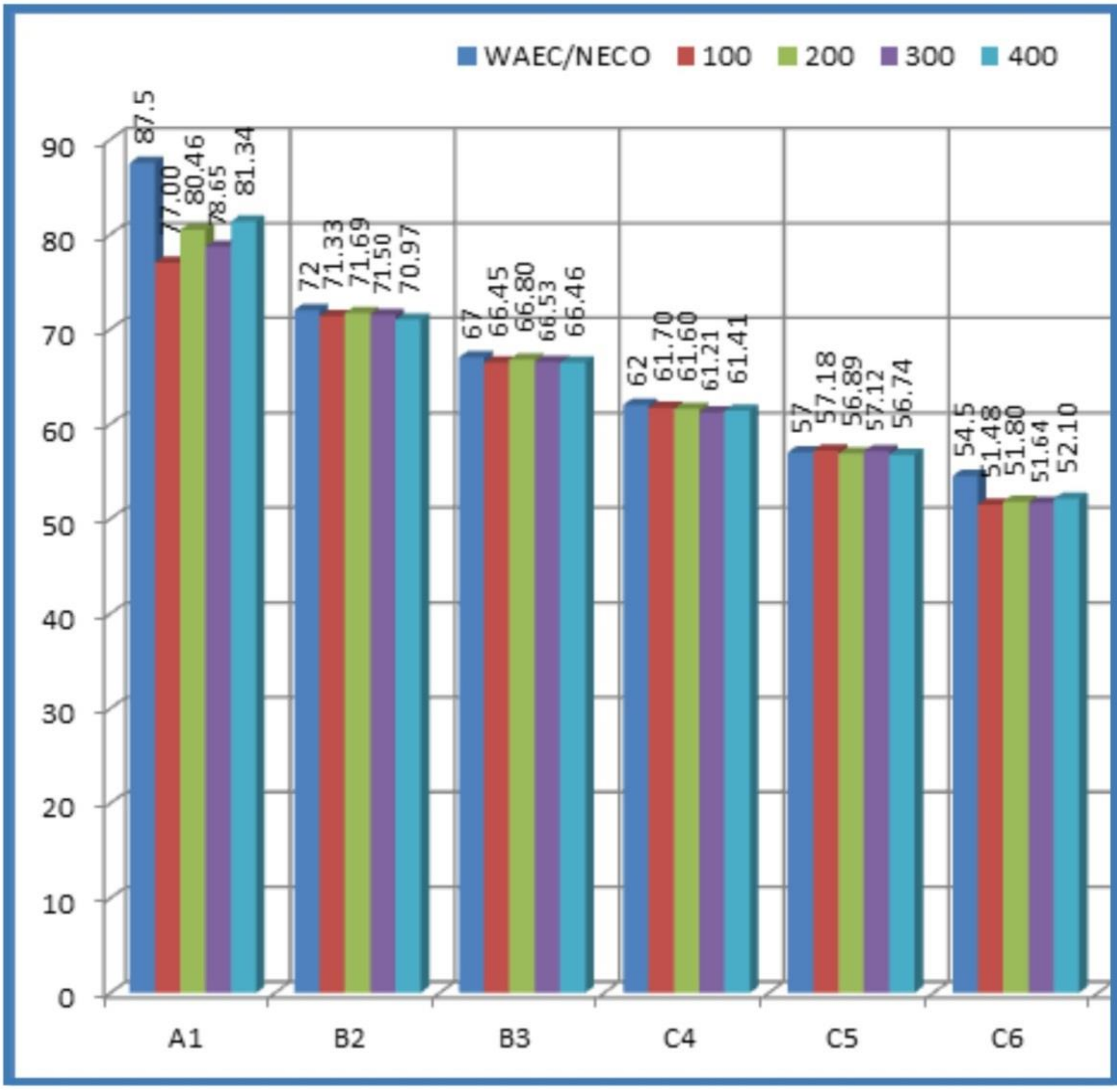

Fig 1.1: Chart of Students' Mean Entry Requirement in Physics against their Performance in Physics Undergraduate Program

Source: Field work (2018) NB: Name of Universities in Appendix 9

Figure 1.1 shows that students with entry grade “A1” in O-level physics had the least mean achievement in their Physics undergraduate program at 100 level (77.00), those with entry grade “B3” and “C4” were even better than those with entry grade “A1” (66.45 and 61.70 respectively). Students with entry grade “C5”. had the highest mean score (57.18) in comparison to its mean (57.0) and this is closely followed by those with entry grade B2, B3 and C4 (71.33, 66.45 and 61.45). This implies that there is no correlation between students’ grade levels and their undergraduate academic performance in physics. Specifically, the students with entry grade “A1” in the O-level result, as indicated in figure 1.1, had a low undergraduate academic achievement in physics while on the average, students with relatively low grade levels in O-level physics performed better at the undergraduate level than their colleagues. It is therefore safe to imply that students’ overall performance in physics at both secondary and undergraduate levels is dependent on the teaching-learning process and the strategy adopted by the teachers or instructors. Any distortion in the teaching-learning strategy may have an impact on students’ perception of and performance in the subject.

Consequently, the performance rate of students in physics in qualifying examinations such as SSCE and National Examinations Council (NECO) is an indication that many students have challenges learning physics as a subject.

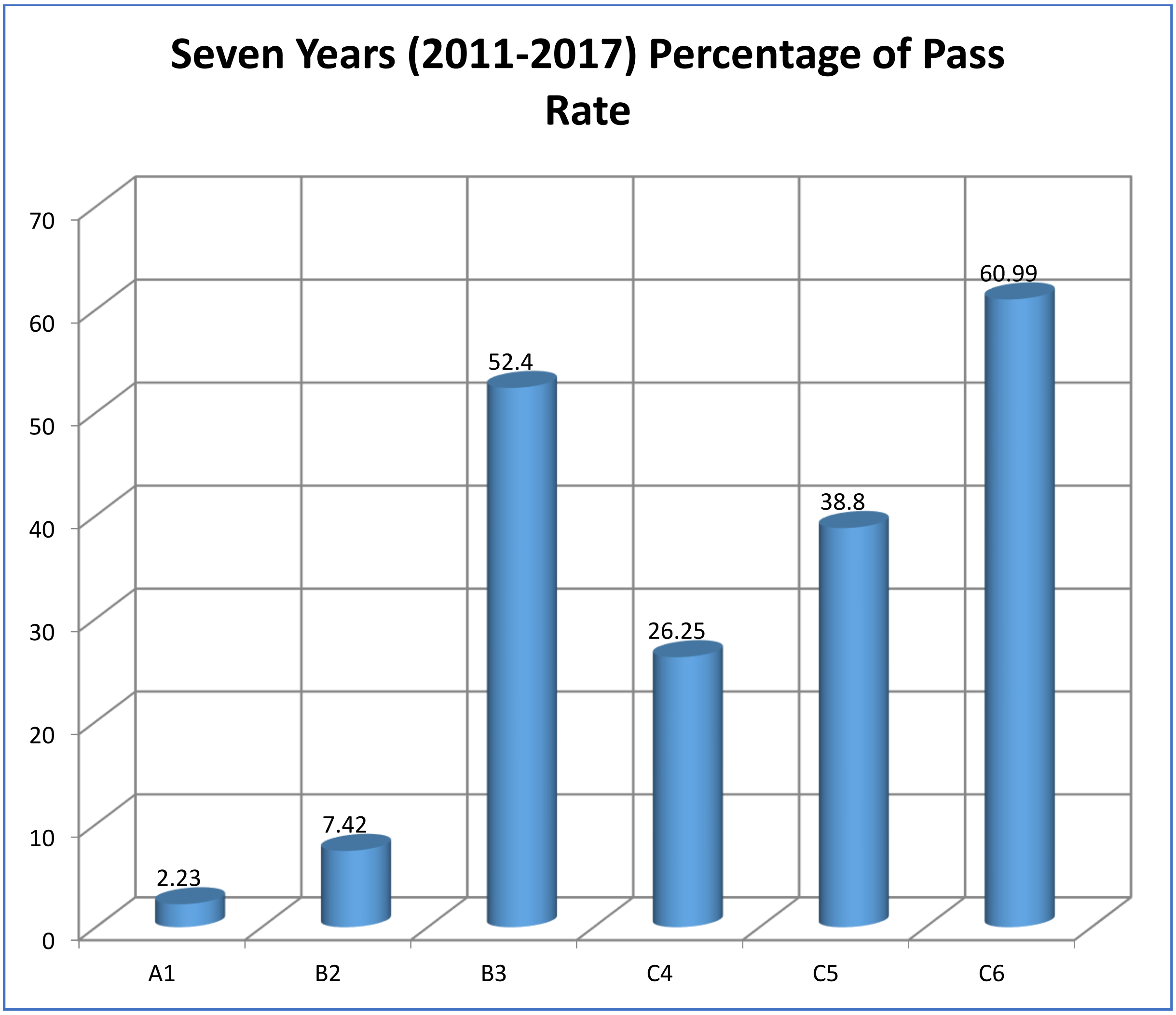

Fig 1.2 A Bar Chart Representation of Pass Rate Performance of Candidates in SSCE Examination from 2011 - 2017
Source: WAEC Report 2018.

In Fig. 1.2, there is an indication that students with grade level "A1" in physics, in the period under review, had an average performance in SSCE when compared with the result of students with grade level "C6". Moreover, over 37.84% of the students did not make a minimum credit pass that could qualify them to gain admission into any tertiary institution of learning to study courses that are physics-related. Incidentally, the number of students in this category increases by the year.

It is important to note that an excellent result in physics in SSCE, NECO and other qualifying examinations is required for admission to study related courses in any tertiary institutions of learning.

Furthermore, according to the chief examiners' report (2018), students with grade levels "D7" – "D8" form the majority of students that require remedial classes in physics, and some of them are found in the pre-degree program of many universities. The pre-degree program is a transition point in higher education where students are well groomed through remedial and enrichment courses in order to produce high quality undergraduate experiences and performances. A baseline study of undergraduates' perceived difficult areas in physics in selected Southwestern universities in Nigeria (Fig.1.1.) identifies the following grounds for students' poor performance in physics: the subject is too abstract, there are too many formulae to know by heart, difficult-to-solve problems, difficult-to-comprehend concepts, plethora of calculations that are mathematical, the subject is not interesting, constructing meanings of taught concepts are incomprehensible, there are very few practical work, amongst others.

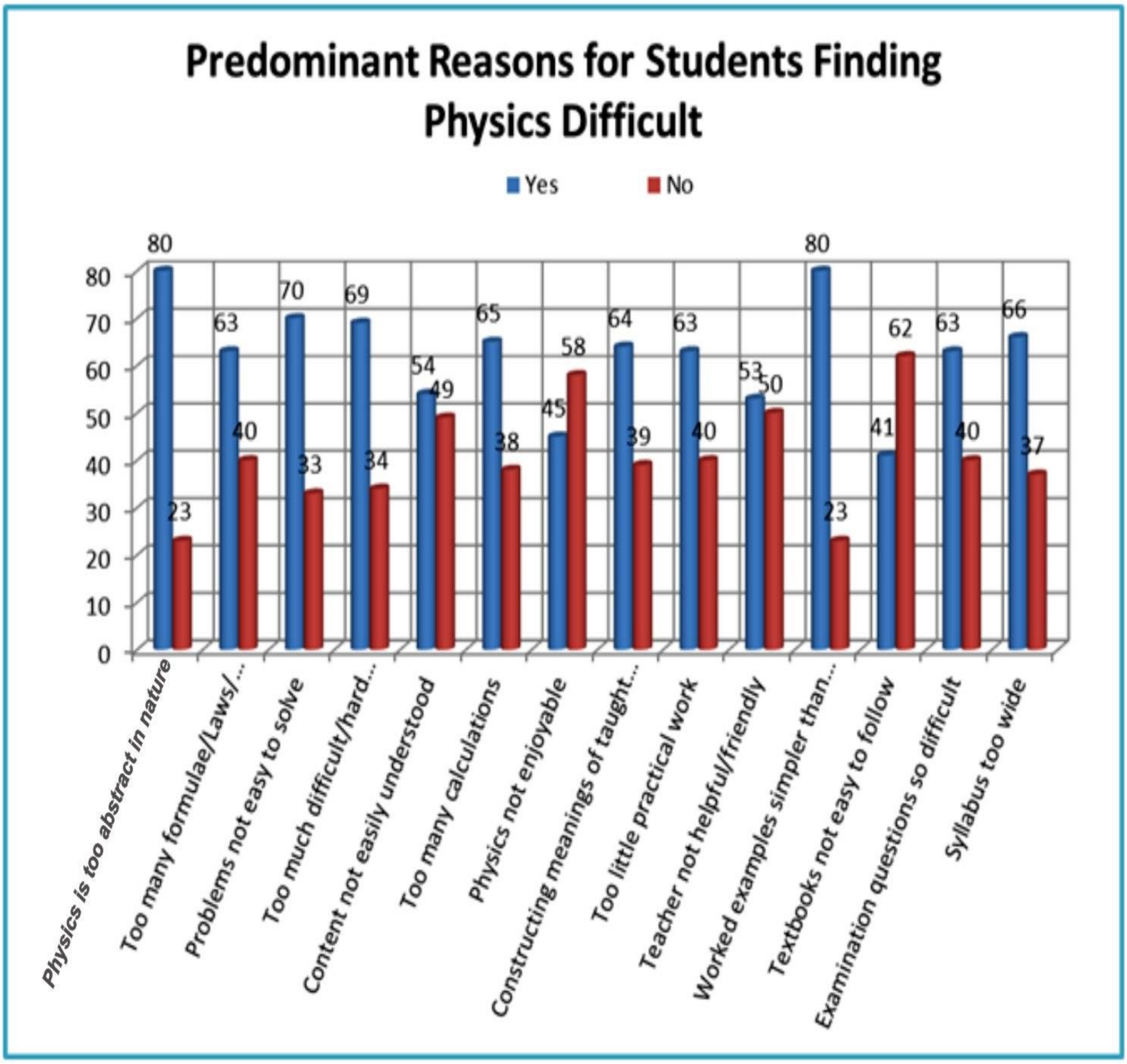

Fig.1.3. Responses from undergraduate Physics students' predominant reasons for finding Physics difficult from three Universities in South-western Nigeria
Source: Ihekoronye, Odwan, and Aremu, (2016),

NB: Names of Universities in Appendix 9

Data presented in Figure 1.3 show that physics is too abstract in nature (80%), worked examples are simpler than class works (80%), it is very difficult to solve problems (70%), too many difficult/hard formulae (69%), the syllabus too wide to cover (66%), too many calculations (65%), there is difficulty in making meaning from taught concepts (64%), too many formulae/laws/ contents to memorize (63%) and too little practical works (63%). These are indications that there are problems or difficulties of learning physics in Nigerian schools. It can, therefore, be deduced that the abstract nature of concepts in the subject may account for such perceptions among students. This can also be traced to the ineffective teaching method employed in teaching physics at this level, as an ineffective teaching approach leads to poor performance by the learner (Agharuwhe and Ugburugbo 2010).

It thus implies that a learner's challenges with understanding a concept, can be attributed to the teacher, the student or the teaching methods, which can be improved upon through a more effective instructional strategy that is learner-centered and is usually preferable to a passive teacher-centered method. Physics is an important core subject for any science and engineering-related discipline. Therefore, providing solutions to many of the challenges with learning the subject as well as addressing the inherent attitudinal issues is important. Such solutions will include finding a means of making the concepts and elements of the subjects less abstract.

. Also, it is pertinent to correct students' negative impression about physics at the pre-degree program before they proceed for a degree program where the subject will be crucial to their overall performance in their courses of study.

Pre-degree program is a part of the foundational programs in many universities that equip students with requisite knowledge and credentials needed for their passage into the undergraduate program towards their educational and career pursuits. It entails that this program serves as a springboard to harnessing students’ academic potentials in their quests to be high performers in various chosen fields of study or to improve their grades in physics and in other fields of science during their undergraduate (degree) programs.

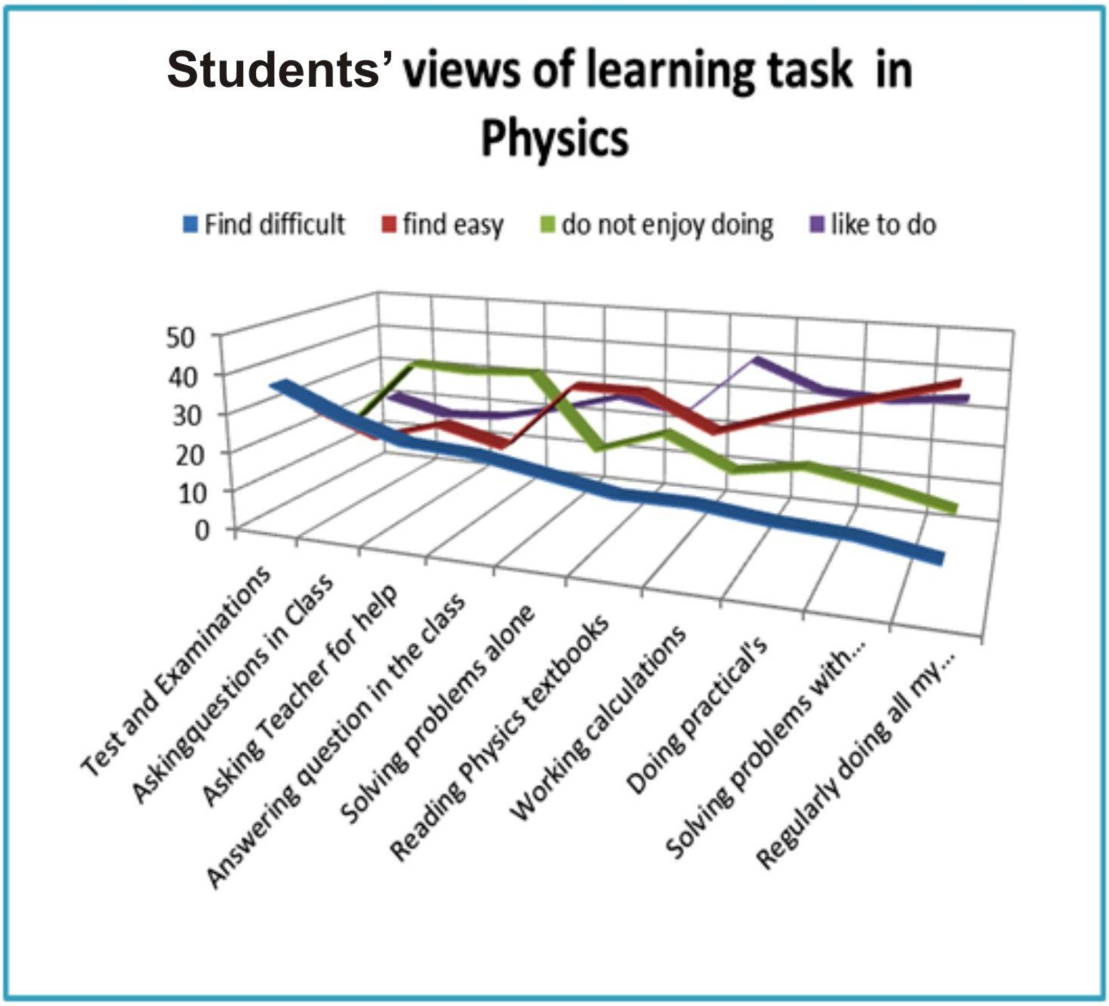

Fig 1.4. Responses from Undergraduate Physics Students' Views of Learning Task in Physics from Three Universities in South-western Nigeria
Source: Ihekoronye,et al, (2016)

From the students’ views on the learning tasks they like to do (in fig 1.4), working calculations in physics ranked the highest and it is followed by the view of regularly doing their assignments as they also find this same task ‘‘easy to do’’. Working calculations, solving problems with other students and regularly doing all their assignments reveal more of the activities carried out by students outside the classroom. On the other hand, the result on activities done in the classroom such as asking questions in class reflects that students ‘‘do not enjoy doing’’ such activities. This indicates boredom in students, as there are little or no engagements in the classroom due to the nature of the method applied in the teaching physics.

Thus, the ‘‘concern’’ is how to explore these same avenues that show what students ‘‘like to do’’ and find ‘‘easy to do’’ to complement their teaching-learning process with digital technologies for a better instruction. The use of digital technologies can be seen as motivating in that the students acknowledged the need to develop skills involved in utilising such technological devices (Lefever and Currant 2010; Anagnostopoulou and Parmar 2008; Edirisingha et al 2007). Students develop attitudes that make them to revisit learning materials as they stimulate interest and motivation which help them to stay focused. It is envisaged that this digital integration will improve students' attitude to the subject thereby enhancing students’ performance and solving the problem of enrollment, as well as serving as both remedial and enrichment instructional medium to spur students to achieve better performance. Therefore, this study investigated and proffered an instructional strategy, which is hinged on the use of innovative digital technologies (Simulation) to influence students’ positive attitude and achievement in physics. Also, since there are several opinions surrounding the use of the face-to-face method (traditional method) of teaching physics which is said to be ineffective in this era of technology advancement, it therefore becomes imperative that a more effective approach in the teaching of physics subject be proposed.

Moreover, many research results have acknowledged more problems associated with the dearth of resources, administrative issues, ineffective capacity building of teachers, lack of incentives, classroom and laboratory mismanagement, untrained laboratory staff, demeaning disposition of students to the subject of physics, lack of adequate background in mathematics to cope with the subject, the nature of the subject and its curriculum/assessment, as well as lack of opportunities for teachers to improve their skills through workshops and seminars (Anka, Anka, and Anka, 2014; Chukwuneye, 2014; Erinosho, 2013; Adegoke, 2010; Kuti, 2006). According to Gutulo and Tekello (2015), there are other problems relating to school facilities, teachers, students and the extent to which the school is conducive for practical activities, inadequate pre-university preparation, weak mathematics background, and poor teacher qualification as well as pedagogical content knowledge. All these factors have made the conventional (face-to-face) method of teaching physics seem inefficient in this era, thereby resulting in a shift in emphasis of physics instruction classrooms to modalities supported by digital technologies. In another related study, Norman and Wills (2015) reported that there are more evidences to support the argument that the traditional method of teaching is not the most proficient method of instruction. In higher education, instructional delivery is mostly lecture-driven, and this has posed a hindrance to effectiveness (Aremu and Salami, 2013; and Agoro, 2012).

The conventional method of teaching physics is no longer appropriate for the digital age, because in this era the new generation of students who represent the future of learning need to acquire relevant and applicable knowledge and skills through digital technologies that provide hands-on experience and can modify attitude. As a matter of fact, these evidences are obvious and they show that any researcher involved in physics education research believes physics instruction is at risk and needs fixing. According to Physics Education Research (PER, 2015), a body that provides relevant information and direction towards the ultimate goal of investigating students' and teachers' understanding of physics, so many instructional approaches which modify attitudes have been advocated for to provide solutions to the challenges of physics students. The attitude modifying instructional approaches range from modeling, modified textbooks and modified classroom environments (SCALE-UP) and Computer Based Instruction and Physics Educational Technology (PheT) interactive simulations from physics educational technology (Chukwuneye, 2014; Chase, 2013; Chabay and Sherwood, 2011; Jackson, Dukerich, and Hestenes, 2008; Etkina, Warren and Gentile, 2006; Beichner, Saul, Allain, Deardorff and Abbortt 2000). All for which their learning outcomes show that interactively based instructions are better than conventional instructional styles (Lasry, Gasevic, Ordonez de Pablos and Huang, 2008). Adenugba (2000) revealed the benefits and drawbacks of computers in physics education. He argued in favour of using computers for the practical designing of multi-stage opera amplifier, which turned out to improve students' performance in physics. However, digital technology empirical-based instructional strategies vary between instructors, most of which have proven that there are increases in learning outcomes, especially in the positive attitude of students towards Physics (Turpen and Finkelstein, 2009). Although, Henderson, Dancy and Niewiadomska-Bugaj (2012) argued that one-third of physics instructors who implemented research–based instructional strategies discontinued their use, many of them cited students' complaints about time, not easy to use and the complex nature of steps involved in its implementation as part of the reasons. In spite of efforts made in the use of digital technology in afore-mentioned strategies, it is mostly to serve as a content delivery mechanism inside or outside the classroom, and not form the ideology of mastery of the knowledge gained from the same process as that is a gap to be covered. Recently, more instructional strategies that take cognizance of the interests of both the student and teacher are evolving.

Amid the various instructional strategies that employ the use of technologies are computer based instructions, cloud computing, web questing, podcast, mobile learning, and flipped learning or inverted classroom among others, as promulgated through educational technology to ensure and actualize an actively engaging learning culture in the 21st century higher education. Inverted classroom (a reversed instructional process where learners are exposed to studying or reading materials outside of class time and working on its application activities within the class) is one that is rapidly gaining the attention of practitioners and researchers. This is because this instructional strategy maximizes the learning experience by giving learners the opportunity of being in charge of their learning, develop critical thinking, collaboration and increasing engagement as a result of the major activities done outside classroom with its discussion done in the class. It offers learners more time in the classroom for doing the extended activities that really allow students to move from learning content to attaining mastery of knowledge gained earlier. This aligns with the advocacy of the Federal Republic of Nigeria (FRN): that learning activities shall be centered on learners for self-development, teaching shall be practical and driven by information technology (FRN, 2014: 15).

The concept of the "inverted classroom or flipped classroom" is not new. Daniel Pink (2010) traced the practice of flipping to a Colorado mathematics teacher, Karl Fisch, who recorded his lectures and gave it to students as homework. For example, Jonathan Bergmann and Aaron Sams recorded their chemistry lectures in 2007. In addition, in the 1990s, Harvard professor, Eric Mazur invented the idea of peer instruction with the purpose of transforming his teaching method from the heavy dependence on lecturing. Some studies have emphasised the influence of inverted learning on students' engagement and learning outcomes (Murphree, 2014; McLaughlin, Griffin, Esserman, Davidson, Glatt, Roth and Mumper, 2013; Rowe, Frantz, and Bozalek, 2013; Tune, Sturek and Basile, 2013; Strayer 2009;). Este, Ingram and Liu (2014) opined that inverted classrooms hold the promise for helping students achieve meaningful learning outcomes as well as help instructors to make efficient use of class time. Therefore, it seems that the inverted learning can also be used to resolve the problems of not only poor performance but also improve students' attitude towards physics and other sciences at any level of education.

Also, the method of students studying course materials for their lessons before the contact class time is not entirely a new approach to learning in the field of education. In Nigeria, recent studies in inverted classroom or flipped classroom and its effectiveness in teaching and learning have advocated for its adoption as an innovative teaching strategy for 21st century higher education (Gbadamosi 2017; Adedoja, Ogundolire and Adebayo 2017; Oyekola 2017; Akingbemisilu 2016). Awodun and Jegede (2015) observed that non-conventional teaching approaches such as using out-door activities enhance students' attitude towards physics. Hence, it should be adopted as a new teaching approach to physics.

Inverted classroom bears semblance with an effective advanced organizer as the latter is an organized set of activities given to students in class in order to facilitate teachers' control of the contents, but differs from an inverted classroom strategy in its implementation. As reading materials, simulation or simulated-videos are given to learners prior to the class as homework filled with activities to be checked and discussed in the class while the duty of the teacher changes to a facilitator in an inverted classroom strategy. The integration of digital technologies for instruction and technological applications in education is gaining more attraction. Unsurprisingly, the adoption of the inverted classroom strategy-based on simulations (simulated-videos and virtual laboratories) as a means of learning has been intensely championed by scholars in the field of education. Simulations are forms of graphical contents in motion that imitate the appearance of a physical concept or phenomenon. Studies reveal that videos or simulations possess a great deal of influence over still photographs because they provide detailed information and can promote a deeper understanding of the contents being delivered (Kurtz, Tsimerman, Steiner-lavi, 2015; Jukes, McCain and Crockett, 2010; Mayer, 2005).

Also, further studies have revealed that the retention rate of students using computer mediated learning (simulations-based learning) is 30% percent greater than the rate achieved by students using the traditional method (Oguntade, 2014; Okoye, 2010). With the advent in science and technology, it is believed that visualizations are very pivotal for students to learn the sciences. The adoption of this method of teaching, by many schools attests to the effectiveness of using digital technology such as simulations, video-taped lecture and virtual laboratories in the learning of science subjects (Ukessays, 2014).

The idea of using simulations to teach the sciences gives the learners the opportunity to view the lessons at any time. It also gives room for replaying the simulations and simulated-video lectures many times thereby allowing the learner acquire deeper conceptualisation of lessons. In simulations based inverted classroom, there is a change of focus in the classroom from a typical teaching process to the students' active learning environment as it eliminates pressure while learning, since it is influenced by self-learning. This method has proven to be beneficial to active teaching and engagement of students in their studies. The benefits of the digital technology solutions to learning are numerous. But it is worth reiterating that the adoption of this teaching method imposes the responsibility on learners to actively engage with contents at their pace in an inverted classroom setting.

Keengwe and Onchwari (2016); Papa (2015) reported that the notion of an inverted classroom draws on such concepts as active learning, student engagement, hybrid course design, and course podcasting. The implication of this is that learners would have more and flexible time to explore course materials and also receive both peer and tutor guidance. Consequently, when teachers use simulations in an inverted classroom learning mode as a tool, it gives learners the ability to view science phenomenon in different dimensional forms. Restad (2013) observed that inverted classroom learning is a fitting option for science education because the class interaction and other learning activities support in-depth content delivery which gives room for students to build 21st century skills, namely, communications skills, critical thinking skill, creativity, problem-solving skills and collaborative skills. Many studies have revealed greater success in learning outcomes in the use of computer simulated experiments for practical works in physics (Chukwuneye, 2014; American Physics Society, 2011; Surrendramath, 2011; Adegoke, 2010; Yu Fen-lee, Yu Ying Guo and Hsiang-H, 2008; Dumanoglu and Stanbulu, 2007; Kun-Yuan Yang and Jia-Sheng Heh, 2007; Yang and Hey, 2007) these studies reflect conscious efforts made in improving students' achievements through the teaching of physics with digital technologies.

Clyde and Nancy (2013) used videos for an inverted classroom as a new model for case study teaching. Chula and Chris (2015) employed e-Learning and flipped instruction integration in business education. Donna and Andrew (2012) evaluated the impact of an inverted classroom on international students' achievement in economics course while Charles-Ogan and Cheta (2015) compared inverted classroom with conventional classroom in learning mathematics. Findings from these studies point to the effectiveness of inverted classroom as they employed the use of videos, animations and simulations but evidences supporting their application in physics are limited.

Akingbemisilu (2016) combined the use of video and animations media for flipped classroom strategy on students studying biology. His findings revealed great improvement in the students' achievements, but inverted classroom strategy using two modes-based simulations being carried out in science especially in physics is scarce. Furthermore, there are limited studies that combine the use of simulations in the teaching of the experimental and theoretical aspect of physics simultaneously, particularly as regards using inverted classroom setting in the pre-degree programs of higher education. In Nigeria, there is paucity of both delivery modes comparatively used in teaching physics in pre-degree programs of universities.

Physics is a practical-based (hands-on) subject, which requires more time for understanding its concepts in details. Based on this premise, it is difficult to present the theories and calculations of the subject in a way that the students can understand within the allotted period using the conventional approach. Considering the expansive nature of the curriculum, there is the need to use the inverted classroom approach (using simulations like video lecture and virtual laboratories) to compliment the traditional or conventional approach of teaching physics. Ihekoronye (2015) cited Freedman, (2015) and noted that at one time or the other, every physics instructor must have heard students complain about understanding the concepts but not being able to tackle associated problems. In order to solve these problems, students' understanding of the theories in physics is not enough, it also requires the use of fundamental concepts with equations and their derivations to make students to think like physicists. This implies that there is a difference between the performance of a student in pure conceptualization of theories, qualitative problems, and the performance in quantitative problems that are computational. A more effective instructional strategy is needed to redress the situation in order to create a sustained interest in physics.

It appears that many of the studies in physics, which are basically on simulations-based instruction or computer-mediated instruction have been carried out only on secondary school students, and particularly for the inadequacies in laboratory facilities in Nigeria. So, evidence to support learning outcomes in physics courses in pre-degree programs of private universities is scarce. Also, the use of combined digital technologies (simulation) based instruction for both teaching-learning and laboratory activities as a strategy in higher education in Nigeria is currently limited, particularly in the pre-degree programs of private higher institutions.

This study measured the effectiveness of the use of two modes of simulation based inverted classroom instructional strategy (simulated video lecture, and virtual laboratories) on learning outcomes of pre-degree students in higher education in Nigeria. The study's focus is to examine the strategy that would invariably improve the quality of physics instructional delivery in pre-degree programs in order to create a more favourable attitude that will enhance students' enrollment. The essence of the two modes of simulation is to make invaluable improvements in the teaching-learning process of physics. Also, it is to enhance students' learning experiences even outside the classroom and enable an extensive coverage of the curriculum in the pre-degree programs of the university. Invariably, these will influence the performance of students at the pre-degree level in the course of preparing them for advanced level examinations like (JUPEB Exams) which is an entry requirement to 200 level undergraduate degree programs in Nigerian universities. Moreover, the non-existence of such digital technologies in form of Simulations and Virtual laboratories for teaching-learning of physics and other sciences in the pre-degree programs of private higher institutions in Nigeria is another reason for the study.

The first of these instructional strategies uses simulated-video lecture for learning theoretical concepts in physics. It combines videos, texts, animations, pictures and graphics as a single delivery mode of teaching and learning physics. It replaces the traditional method of physics instruction in classroom as students are expected to watch the simulated-video lecture outside the classroom at their own convenience and pace and discuss the lesson contents in the class as the teacher acts as a facilitator. The second is the virtual laboratories presentational package. It is a highly interactive instructional package suitable for virtual practical laboratory activities adapted from the physics educational technology website (www.Phet.com). An alternative to practical activities which combines graphically calibrated measurements, pictures, animations in one delivery mode for experimental teaching-learning of practical-related concepts in physics laboratories. It can be viewed at home or in the hostel at a leisure time. All these simulations contain animated lectures on concepts in physics using graphics, pictures, texts and other different dimensional effects.

The two instructional packages are self-learning packages controlled with dexterity by individual students. These packages have been prepared to generate interactive question-based activities that the learners are expected to answer. This instructional strategy that involves the learning of theories and practical activities in physics outside the classroom time is innovative in nature. This strategy has the capacity to influence the attitude of students through digital integration because technology moderate's attitudes as almost every form of activity in the classroom is technologically-driven. From the foregoing, the instructional strategy and classroom activities have a crucial part to play in students' attitudes towards any subject. Undoubtedly, attitudes determine the patterns of interpretation of idea and information, and inadvertently also affect individual's performance (Oguntade, 2014 cited Okwiligwu, 2000; Olagunju

1996). The achievement of a favourable attitude is a relevant factor in the teaching and learning of any subject/course, including physics. Once the internal motivation affects academic achievements and students' participation in school, it definitely affects the attitude of the students (Visser, 2007). It brings to bear the reasons for investigating the attitude of students toward physics in the study as a dependent variable.

Furthermore, physics involves problem-based learning where students develop problem solving skills that are necessary for the 21st century; having gained some knowledge with content exposure outside the classroom. Also, acquiring skills that enable learners to solve numerical problems/questions can enhance their chances of gaining more understanding of the subject. Omiwale (2011) suggested that problem-solving skills are the ability to use information (knowledge) and reasoning powers to proffer solution to a problem. Inverted classroom brings up the notions of problem-based learning and experimental learning where a learner discovers how to acquire information and knowledge by themselves. Shute, Ventura and Ke (2015) argued that students' problem solving skills become more sharpened as they solve problems proportionate to their knowledge. Within the inverted classroom approach, there is a change from teacher-centeredness to student centeredness in the classroom.

Meanwhile, a lower-cognitive order of knowledge acquisition takes place at students' isolation; this makes it possible for higher level learning outcomes such as synthesis, application and evaluation to be focused on during class time. The reason is that the students work with course materials before class time, they thereafter apply the information in high-level discussions (MacDonald-Hill and Warren-Forward 2014). There are four sub-skills of solving problems skill considered in this study: First, analyzing givens and constraints; secondly, planning a solution pathway; thirdly, using tools (formulae) and resources effectively and efficiently and lastly; monitoring and evaluating progress.

Therefore, indicators are defined for each of the four sub-skills of problem solving skill by identifying observable, in-class and out-of-class activities that will provide evidences per sub-skill (Shute, Wang, Greff, Zhao and Moore 2016). Acquiring these skills is crucial to understanding of physics as it may improve students' cognitive ability and it can determine the level of progress towards studying physics as a course or discipline. This makes problem-solving skills relevant to this study as it influences students' general performance irrespective of their gender.

Kessels, Rau, and Hannover (2006) found that female students have a lower disposition to physics when likened to their male colleagues. This is as an aftermath of claims that physics is difficult to internalise, and that it appears to be male-oriented in nature. These claims seem controversial, and thus, makes gender a very important factor in this study. More differences in students' learning outcomes being influenced by gender is highlighted by Awoniyi (2000), Afuwape and Oludipe (2008). This is contrary to the findings that gender has no significant effect on students' achievements in computer-based instructional puzzle (Adedoja and Fakokunde, 2015; Aremu and John, 2005). Also, Efuwape and Aremu (2013) opined that there are no possible gender differences within males' and females' achievements in the use of computer-based packages. Subsequently, these strategies have the tendency to reduce the gender gap in science and technology. The result suggests that both sexes have equal opportunity in any learning environment aided by ICTs and their learning outcomes are not affected by their gender. A gender-inclusive teaching strategy is required to develop understanding and respect for difference, learner participation and success in their learning (UNESCO, 2004).

Sequel to this, Abimbade (2015) citing Jambulingam and Sorooshian (2013), Nurvitadhi (2005) affirmed findings in extant studies that have proven that there is a reduction in gender differences in the use of digital technologies (even mobile phones). Other scholars however maintain the presence of some significant differences (Attewell, Savil-Smith and Douch, 2009, Hartmann, 2008). The use of digital technologies in learning holds promises for an improved learning outcome for both male and female learners, although some studies opined that whenever instruction is enhanced using technology the males perform better than their female counterparts (Gambari 2017; Oginni 2013; and Koohang 2004). However, the influence of gender on student's academic performance has not been resolved and the fact that learners in this study are made up of males and females having equal access to study/reading materials outside the classroom supported by digital technologies, makes the issue of gender relevant as a variable in this study. Therefore, this study considered gender influence on learning outcome particularly when two modes of simulation based inverted classroom instructional strategy are applied on a group of learners.

Moreover, learners who are taught how to use inverted classroom instructional strategy visualize their learning content in different dimensional forms which can increase their spatial ability in physics. Thus, it is fitting to relate measures of spatial ability with success in the sciences (Hegarty, Crookes, Dara-Abrams and Shipley, 2009; Kozhevnikov, and Hegarty, 2007; Sorby, 2001). Feng, Spence and Pratt (2007) opined that playing an action video game enhanced performance on a mental rotation task, as the subjects indicated gains in spatial ability via mental rotation tasks, with females performing equal to males after training. Also, Alias, Black and Gray (2002) concluded that spatial visualization ability appears to be necessary to solving problems in physics and engineering related areas that require spatial as well as non-spatial strategies. Therefore, a good knowledge of this spatial ability should be potentially beneficial to physics students and other professionals in the field of science. Since this means that visual-spatial ability is one of the causes that may stimulate students' capacity to learn physics and improve students' attitude thereby influencing their performances while using two modes of inverted classroom instructional strategy, that is a germane variable considered in this study.

The deployment of the two modes of inverted classroom complements the conventional (traditional) method of teaching physics. The former does not because latter is outdated but for the need to improve upon traditional method so as to achieve the desired attitudinal change and excellent performance in physics. Also, this is pertinent so that the teaching method in Nigeria can be compliant with global best practices of teaching physics students in contemporary times. Concepts in physics would be better understood by students if a greater part of their class time is devoted to problem-solving activities which influence their higher order thinking and increased engagement. According to Serin (2011), computer-based instruction delivery makes teaching more interesting and efficient when compared with other conventional teaching methods. This is because computer-based instruction delivery is effective for giving information, implementing, evaluating and generating feedbacks.

It also greatly influences self-mediated learning and increases students' active participation during the learning process. The method equally brings about students' development of creative thinking skills, problem solving skills and makes them self-reliant learners regardless of their genders.

In this study, the concepts of physics selected are Quantum and Photoelectric Effect (Photon, Quantum Theory, Wave Function, Wave-Particle Duality and De-Broglie Wave Equation). The idea of quantum and photoelectric effect can explain nearly all the physical phenomena of everyday world as its applications cut across all forms of physical and applied sciences – transistors, lasers, chemistry and mathematics (American Institute of Physics, 2004). These topics were selected because they involve calculations and for the perceived difficulty students have in comprehending them and as such, the much time required to teach them. In addition, they are parts of the major topics in the pre-degree physics program in Nigerian universities. Also, students see these topics as problematic in the physics curriculum (fig 3.2). Students who understand the fundamental knowledge of quantum and photoelectric effects might constitute a category of those who appreciate physics as a subject.

Thus, based on the need to complete physics courses and also engage all students in their physics lessons in order to enhance a positive attitude towards the subject, to scale up students' performance in terms of achievement and to have a hands-on experience that involves problem solving skills, the study designed a Physics instruction on Simulated-video and Virtual laboratory presentations using the inverted classroom strategy of instruction to determine their effects on the attitude, achievement and problems solving skills of pre-degree physics students. Whatsoever direction the argument goes, this study seeks to identify whether the inverted strategy will consolidate aforementioned studies to enhance attitude, achievements in physics and improve student's problem solving skills or it will discredit the previous claims that simulation-based strategies cannot enhance instruction in pre-degree programs of Nigerian private universities. This study thus sets out to determine whether the inverted strategy using Simulated-video and Virtual Laboratory instruction packages will be able to influence students' attitudes, achievements and problem solving skills significantly thereby leading to resolving the problem of poor performance in physics and eroding the notion of abstract nature of Physics by students.

1.2 Statement of the Problem

Physics has fully established itself as a core subject among the science-oriented disciplines. Its value in technological advancement and social upliftment has never been in doubt. However, facts abound necessitating the need to urgently address some far-reaching challenges hindering the effective teaching and learning of the subject among which are; poor instructional approach, unconducive learning environment, gender effect, physics being too abstract in nature, physics problems not easy to solve, too many calculations, comprehending the many difficult formulae and laws, hard concepts/contents, too wide syllabus to cover in addition to less emphasis on practical works in physics. Therefore, this study investigated the potency of two simulation-based inverted classroom instructional strategy (Simulated-Video and Virtual Laboratory Based Inverted Classroom) in improving achievement, attitude and problem solving skills of Physics pre-degree students at private universities in Nigeria. This, if achieved, has the capability of influencing the attitude of students towards physics and in turn increase students' performance in the subject. Furthermore, the adoption of this strategy is pertinent in helping instructors overcome with ease, the difficulty of maximising the allotted time for greater students' engagement and positive learning outcomes adequately to cover the curriculum and achieve excellent performance in physics examinations by students. Similarly, the influence of the treatment on gender and spatial ability as moderating variable was also determined.

1.3 Hypotheses

As benchmark for significance at 0.05 level, seven null hypotheses were raised and tested.

$H_0$1: There is no significant main effect of treatment (instructional strategy) on students'

(a) Attitude to Physics

(b) Achievement in Physics

(c) Problem solving skills in Physics

$H_0$2: There is no significant main effect of gender (male and female) on students'

(a) Attitude to Physics

(b) Achievement in Physics

(c) Problem solving skills in Physics

$H_0$3: There is no significant main effect of spatial ability on students'

(a) Attitude to Physics

(b) Achievement in Physics

(c) Problem solving skills in Physics

$H_0$4: There is no significant interaction effect of treatment (instructional strategy) and gender on students'

(a) Attitude to Physics

(b) Achievement in Physics

(c) Problem solving skills in Physics

$H_0$5: There is no significant interaction effect of treatment (instructional strategy) and spatial ability on students'

(a) Attitude to Physics

(b) Achievement in Physics

(c) Problem solving skills in Physics

$H_0$6: There is no significant interaction effect of gender and spatial ability on students'

(a) Attitude to Physics

(b) Achievement in Physics

(c) Problem solving skills in Physics

$H_0$7: There is no significant interaction effect of treatment (instructional strategy), gender and spatial ability on students'

(a) Attitude to Physics

(b) Achievement in Physics

(c) Problem solving skills in Physics

1.4 Objective of the Study

This study aims to investigate the effect of simulation based-inverted classroom strategy on pre-degree physics students' learning outcomes within Southwestern Nigeria. In the past, the integration of digital technologies to teaching-learning of physics was basically to function as a formal mechanism for instructional delivery within the classroom. It however did not address the need for improving students' mastery of the knowledge gained. This gap is to be filled by this study, simply by using simulations-based inverted classroom instruction which gives room for learners to view their lessons anywhere and anytime according to their pace which may eventually enhance knowledge, skills and nurture positive attitude towards physics. Also, the use of this strategy in this study will tend to demystify the growing misconceptions about physics being too abstract in nature and also aid teachers' adequate preparations for their lessons as well as attain curriculum coverage resulting in an outstanding performance in physics examinations.

1.5 Scope of the Study

This included examination of the effects of two simulation-based (Simulated-video lectures and Virtual laboratory) inverted classroom instructional strategy and conventional strategy on pre-degree students' learning outcomes (achievement, attitude and problem solving skills) in physics in six purposively selected private universities in Southwest, Nigeria. The main and interaction effects of treatment, gender and spatial abilities on the learning outcomes of participants were determined. The study considered concepts of Quantum and Photoelectric Effect (Photon, Quantum Theory, De Broglie, Photoelectric, Wave Function and Wave-particle Duality) in physics which were perceived to be abstract and difficult to learn.

1.6 Significance of the Study

The findings of the research will contribute to the promotion of improved students' performance in physics and educational technology. This was achieved as the introduction of two modes of inverted classroom instructional strategies that had not been used with these students were employed. Since the two modes of inverted classroom instructional strategy have recorded relative success in the teaching of physics in developed countries as well as in some other disciplines in Nigeria, it was expected to achieve similar results in Nigeria.

The results from the study will serve as empirical evidences on the effectiveness of using inverted classroom in physics instruction in Nigeria among physics/science teachers at pre-degree programs of universities. It will also provide the basic guidelines to physics teachers in general on how to employ inverted classroom-based instructions in teaching Vectors, Mechanics, Optics, Heat, Thermodynamics, Modern Physics and other related science concepts. It will further serve as reference points and sources of information to curriculum and instructional designers, teachers and researchers who may be interested in the effectiveness of using two modes of inverted classroom in physics and science instruction generally. From this study, information will be provided that will assist the students to develop a better attitude towards physics at pre-degree program level in higher education of Nigeria at large.

1.7 Operational Definition of Terms

The following terms are defined for the purpose of this research work;

Achievement in Physics: This describes the pre-test and posttest scores obtained from the Achievement Test on Physics. These reflected in the students' scores in (SATP)

Attitude to Physics: This refers to students' interest and disposition towards the learning of Physics. These were measured using the students' score in Attitudes towards Physics Questionnaire (ATPQ)

Conventional Method of Teaching: This is the traditional face-to-face approach to facilitate learning within the physics classroom using the available teaching aids which does not involve the use of any digital or electronic gadgets to enhance the teaching procedure.

Engagement: This describes the interactions that is generated by the active participation of a learner with the lecture content in and out of the classroom on a given task during teaching-learning process both between learner-content, between learner-learners and learner–facilitator.

Inverted Classroom: This is an instructional approach which involves (Video-taped Lecture, Virtual Laboratories and Simulations) given to students to view ahead of the lesson while further discussions, participation and collaboration are done in the proper class time based on the subject matter.

Learning Outcomes: These are the cognitive, affective and psycho-motor learning outcomes of students, measured by Students' Achievement Test in Physics, Attitudes towards Physics Questionnaire and Problem Solving Skills Scale (Rubric).

Pre-Degree Programme: Advanced level of study especially before the undergraduate programme at any university (especially students in Joint Universities Preliminary Examination Board (JUPEB) Programme).

Problem-Solving Skills: It is a unique intellectual process of thinking behaviour that is involved in finding solutions to problems in physics. It was measured using Problem-Solving Skills Scale (PSSS) accompanied with a work sheet.

Simulation: This is a kind of virtual framework that uses graphical images in motion to represent the occurrences or activities of a physical concept or phenomenon which can be used during teaching-learning process of practical aspect of physics.

Simulated–Video Inverted Classroom: These are forms of videos having simulations (animations and videotexts) on the topics used for the experiment embedded in them to show concept or phenomenon to learners and are produced prior to the lesson period to expatiate on the rudiments of the subject matter in a more explicit and practical form.

Spatial Ability: This is the ability to view objects mentally in different dimensional forms simply by manipulating, rotating, twisting, or flip-flopping pictorially available stimulus objects. It was measured using Spatial Ability Test (SAT).

Virtual Laboratories Inverted Classroom: This is an auxiliary practical laboratory practice containing animations, sounds and graphics in form of interactive Java simulation interface for student activities in physics that engages them in an offline virtual experimental exercise, with the aid of digital device (computer, laptop, tablet, and large screen phone) which can be done anywhere at any time.

CHAPTER TWO

LITERATURE REVIEW

Literature reviewed include the following areas:

2.1 **The Theoretical Framework**

2.1.1 Cognitive Constructivism

2.1.2 Engagement theory

2.2 **Conceptual Framework**

2.2.1 The Nature of Physics

2.2.2 Physics as a Discipline

2.2.3 Methods of Teaching Physics

2.2.4 Physics Instruction and Teachers' Attitude towards Practical Lessons

2.2.5 Physics Instruction and Students' Attitude towards Practical Lesson

2.2.6 The Concept of Inverted Classroom

2.2.7 History of Inverted Classroom

2.2.8 Inverted Classroom Practices and Its Possible Benefits

2.2.9 Inverted Classroom and Simulated-Video Lecture

2.2.10 Inverted Classroom and Virtual Laboratories

2.3 **Empirical Review of Studies**

2.3.1 Major Research on Inverted Classroom Model

2.3.2 Simulated -Video based Inverted classroom Instruction and Attitude towards Physics

2.3.3 Simulated -Video based Inverted classroom Instruction and Achievement in Physics

2.1 Theoretical Framework

The theoretical underlying structures upon which this work was premised are:

a. Constructivist and Cognitive Constructivism Theories

b. Engagement Theory

Constructivism Theory

Constructivist Theories was propounded by Jean Piaget 1967 and Lev Vygotsky 1978. Both share a consensus on the belief that classrooms must be constructivist environments. In spite of this common ground, these scholars differ in their conceptions of how constructivism should be applied in classrooms. Constructivism is an innovation in education that underscores the fact that learners/students are better suited to understand self-constructed information. Constructivist theories posit that learning helps in social development. Learners are the focus.

Unlike the conventional classrooms, the Constructivist school of thought sees the teacher as a guide, who provides directions to the learner. In other words, from the Constructivist's points of view, the teacher helps the learner in a real-world setting. This, the teacher does by providing tasks that instigate creativity, and tasks would trigger novel techniques of learning. The Constructivist theorists' position has gained attraction with the introduction of PCs everywhere. PCs have been platforms for the individual student to watch video lectures in order to learn at his/her own pace.

The Piagetian Classroom approves a range of activities that test students' individual differences, enhance their enthusiasm toward learning, realize new concepts, and build their own knowledge.

The Vygotskian Classroom emphasizes self-creation of concepts, and personalising knowledge. The Vygotskian classroom support teacher-student and student-student interactions which lead to discovery. In these interactions, individuals could bring into the classroom strategies such as: questioning, predicting, summarizing and clarifying. Consequently, students are enriched with collaborations, resources, and project groups based on problem analysis. Both Piaget and Vygotsky acknowledged that knowledge is internal and can be built unlike the view that upholds knowledge as external and mechanical (rote memorization).

The Constructivist learning settings encourage the learner's ability to gather, screen, analyze, and ponder on provided information. The proposition of this theory is hinged on the justification that classrooms should no longer be reduced to a space for delivering of lectures. This argument is sustained by a body of literature on student-centered learning which is evidence-based proposition hinged on the theories of Piaget (1967) and Vygotsky (1978). The application of these theories and flipped classroom process reveal that learning occurs as result of giving the learner (student) responsibility for his/her own learning.

2.1.1 Cognitive Constructivism

Constructivism is an approach that allows the learner constructs his/her own understanding of ideas within a context in the knowledge domain (Kun-yuan and Jia Sheng, 2007). In order to accomplish this process, the learner must engage in a worthwhile task that can bring about learning, and must be interested actively with the content, in such a manner s/he learns from such engagement. The theory of cognitive constructivism was propounded by Jean Piaget in the 20th century. His view is that knowledge precedes neither solely from the experience of objects nor from an innate programming performed in the subject but from successive construction. Piaget further says that the mechanism of learning is the process of equilibration in which cognitive structure assimilates and accommodates in order to generate new possibilities when it is distributed based on human self-organizing tendency.

The theory of conceptualization explains the relationship between watching a video at home and bringing its lessons to bear in classroom activities through collaboration, engagement and problem solving that optimizes the class time resulting in the generation of further knowledge through interaction with student- to student or teacher-to-student.

2.1.2 Engagement Theory

The Engagement Theory was propounded in 1998 by Greg Kearsley and Ben Shneidermann. The theory posits that engagement occurs when students meaningfully undertake task related to their interest and competence, participate freely with (equals) associates, immerse themselves deeply and continue the task with persistence and commitment because of the value attributed to the work. Hence, the three components of this learning activity are: Relate-Create-Donate. It is a way of providing effective instruction strategy using digital technologies inside and outside electronic classrooms helping students to collaborate more effectively, thus shifting the teaching-learning balance from lecture-centered to learned-centered or team-centered approaches which one of the aims of using inverted classroom instructional strategy.

One the essential component of learning in an inverted classroom environment is an engaged classroom atmosphere where learners are always motivated to actively engaged beyond the class activity through the demonstrated positive attitude, emotion and cognitive engagement.

The relevance of this theory to this study is hinged on videos, and simulation offer immeasurable attraction to elicit the attention of the learner. Therefore, these are platforms of engagement that have proven effective beyond the limitations of the classroom space. The underlying proposition of this theory is that simulated video lectures effectively engage the learner. To this end, the Engagement Theory is very much relevant to inverted classroom. More so, when a study material is given as homework and assignment to students, it creates a form of engaging activities as it usually brings about teamwork and makes learning creative; the learner will have a sense of control over their learning.

Engagement theory is elucidated with the classroom activities through three elementary principles which is consistent with constructivist beliefs and shaped from elements of supplementary epistemologies; case-based learning, active learning, and problem-based learning**.**

There are three components in engagement theory: project orientation, collaboration, and authentic focus work concurrently to enable students to engage in important activities that inspire and motivate them.

2.2 Conceptual Framework

2.2.1 The Nature of Physics

The Greek word for Nature is “Physics”; as it was previously called natural philosophy. Raspanti, M. (2008) observed that most people know, at least in some vague way, that even technologies that are driving our society are fundamental discoveries of Physics. Physics is branch of science that deals with nature of matter, energy, motion and forces. Furthermore, it serves as building block from which other sciences emerges like cosmology, astronomy, geology, mathematics, chemistry and biophysics. All around us, the relevance of applications of Physics is quite visible and beneficial, ranging from transistors, lasers, computer, telecommunication, nuclear power and space travels that are so pervasive in our times and the role of those who explicitly reveal the meaning of these concepts to the populace is enormously demanding. The Physics teachers' professional preparation and experiences with science have channeled some ideas about the nature of Physics. This may inform how some theories are perceived, whether they would be permanent or otherwise. In fact, Physics teachers may see science and religion as same or conflicting.

Moreover, they may see science and technology as independent constructs or in close association. Physics teachers may or may not differentiate between science and pseudo-science. However, there are other ways of conceptualising the nature of Physics; content knowledge, pedagogical knowledge, teacher autonomy is necessary to translate the science teachers' philosophical ideas into appropriate instructional strategies and activities (Gess-Newsome and Lederman, 1995). Against this background, researchers suggest that teachers' perceptions do not affect their classroom practice (Myxter, 2014; Gonzalez-Espada, 2001). Furthermore, the introduction of inverted classroom in teaching physics is to optimize the classroom time which gives the teacher ample opportunity to interact, solve problems, collaborate and have meaningful engagement about the subject – matter.

2.2.2 Physics as a Discipline

The recognition of the nature, scope of physics and its relationship with other science subjects provide students with the capacity to describe some physical processes of nature. In other words, students' knowledge of physics makes it possible to use some physical quantities, like, velocity, energy, and momentum (Ihekoronye, Odawn and Aremu, 2016). To expedite learning, one of the most important principles that teachers practice is to appreciate students' knowledge. And as it is customary that leaners construct new knowledge from their past experience resulting in development of attitude which is helpful in facing learning challenges as it reduces the learners' anxiety levels. These descriptive capabilities make it possible to relate with other fields in the sciences.

Moreover, the knowledge of physics can help in scientific communication which could be through oral, symbols, diagrams, or in writing. Students' poor mathematical background is one of the foremost causes for the dismal performance in Physics examination (Erinosho, 2013). Other reasons include: inadequate qualified teachers, lack of motivation of students, and ineffective teaching methods which results in poor problem-solving ability (Omosewo, 1999). A teacher using the conventional method of teaching assumes that teaching students in the classroom as well as assigning of homework is enough to give the students the abilities to have complete understanding of the concepts in Physics. In view of these factors, there is need to introduce a more effective instructional method in Physics inform of the two modes of simulation based on inverted classroom instructional strategies that is viable in correcting such dismal performance seen at the introductory Physics course of University's pre-degree program.

The core of Physics at introductory level however, is supported by some students' claims that Physics is not their subject of study. Truly, many of the recipients of introductory Physics courses are going to domicile in the engineering, medicine, humanities.

2.2.3 Method of Teaching Physics Instruction

Physics is a fundamental science subject that explains natural phenomena and one that is a product of laboratories. It is for this reason that there is the need for a new approach for the interpretation of the subject in a manner that requires a sophisticated mathematical model such as (calculus-based, group theories, Fourier analysis, among others), counter-intuitive representations, probabilistic rather than deterministic interpretation are means of demystifying Physics concept like the duality of the light, atoms, and electrons as waves and particles (Keiner and Burns, 2010). Teachers have use various teaching methods in order improve the achievement and attitude of learners by extending their learning activities, without which learners may have a tendency to memorize every lesson tips instead of having conceptualizing the knowledge gained.

Studies have shown that there are other tested and proven methods of teaching physics and these are conventional teaching like the Classical lecture followed by laboratory activities on selected topics, Problem-Based Learning (PBL) and Peer-Instruction (PI) under instructors' supervision.

i. Conventional Teaching of Physics

Conventional teaching is the presentation of the material from textbooks and/or lecture notes. A traditional lecture is nearly always delivered as a monologue in front of a passive audience. Only exceptional lecturers are capable of holding students' attention for an entire lecture period in Physics classroom. It is even more difficult to provide adequate opportunity for students to critically think through the arguments being developed (Merrill, 2007). It has been observed from previous studies that about (83%) of instructional faculty use lecture/discussion as the primary instructional method for undergraduate classes in Physics classroom as it has not been effective for deep learning experience. The learners taught with conventional method of teaching in a seemly driven process has a like-hood of having inert recipients of knowledge because students are passive listeners only and it is teacher centered approach, whereas when simulation based instructional strategies are employed in teaching student's physics, it brings about more interactions due its student centeredness and teachers acts as facilitators.

ii. Problem-based Learning (PBL) in Physics

The problem-based learning (PBL) is a student-centered instructional strategy. The learning methodology ensures that students solve problems and engage in reflection in collaboratively order to match the real world when faced with similar challenges at work place (Nayak, 2013). This methodology of teaching physics was pioneered by Barrows and Tamblyn (1980). Problem based learning as a method of teaching physics is one of the best indispensable applications to relate the theory of constructivism in a classroom situation as it is centered on new information learning by employing the prior knowledge and skills, and excluding the current misconceptions by individuals and group work. It is an approach that develops active learning, collaborative skill, critical thinking and other psychomotive skills involved problem solving.

The underlying feature of PBL is that challenging open-ended problems learning occurs. Students work in groups, just as the role of the teacher changes to that of a "facilitator" of learning (Heron, Shaffer and McDermott, 2014). In this same way, problems are presented to learners by means of circumstances or scenario. A realistic scenario is very essential for learners' activity, comprises clues to help to accomplish the planned learning task, not having excessive information, and includes features which improves interest and motivation.

iii. Peer-Instruction (PI) which takes place under instructors' supervision

Eric Mazur, Harvard Professor, in the early 1990s popularized peer-instruction. It is an interactive teaching method that is evidence-based, and has been used in many disciplines all over the world (Eric, 1997). This teaching method was adopted in many schools and was used particularly to teach physics at the undergraduate level at Harvard University. As a result of its student-centeredness, which involves moving information transfer out and moving information assimilation, into the classroom, studies have established the effectiveness of peer-instruction over lecture-based methods (Crouch and Mazur, 2001). In addition, the Peer-Instruction is a learning system that emphasizes student's participation in terms of preparing them to learn outside of the classroom. This is often achieved when students are allowed to engage in pre-class readings which allow them to answer questions based on areas, they focused on in the course of reading by employing another method referred to as "Just in Time Teaching" (Novak, 1999). Then, in class, the instructor engages students by posing prepared conceptual questions or Concept-Tests that are based on student difficulties.

Eric (1997) outlines some question procedures to include the following:

- Facilitator raises question based on feedbacks elicited from students' pre-class reading
- There will be reflection
- Students comes up with personal views
- Facilitator does appraisals on student responses
- Students does peer-review
- Students reconstruct based on personal views
- Instructor reiterates appraisals to decide whether more explanation is required (Turpen and Finkelstein 2010; Eric 1997).

Today, Peer Instruction is used in various disciplines such as Philosophy, Psychology, Geology, Biology, Mathematics, Computer Science and Engineering.

iv. Experimental-Based Learning (EBL) in Physics

In this option of learning, the use of laboratory is involved as the central environment for understanding physical phenomena (Rames, 2004). It combines laboratory activities with lectures in a studio format, and alternates the theory, with solving-problem, and with hands-on experience. Learning is achieved via carrying out experiments, which allows for a better appreciation of the importance of physics and of the validity of theoretical models. The incorporation of simulated-video, virtual laboratory with some forms formative and summative assessments given to learners prior to the class extends the students’ preparation for the practical class activities.

Several techniques and complex concepts can simply be demonstrated using simulated-videos, which is resourceful to learners in their preparation to the real laboratory activity (Owolabi, 2006). This also allows learners to comprehend the hazardous level related to laboratory work which aid in laboratory safety practices to avert such situations. Collaboration and creative thinking are potential application skills required to succeed in any experimental-based learning in physics.

2.2.4 Physics Instruction and Attitude of Teachers towards Practical Lessons

The study of teacher approach or enthusiastic teaching is a long tradition. There is a consensus among researchers that effective teaching could be informed by the teacher attitude. This is why the characteristics of effective instructors was interrogated by Witcher and Onwuegbuzie (2001) using pre-service teachers. They found out that attitude towards teaching is the second most important factor. This implies that teacher's attitude is considered as a major player in determining quality of instructions (Feldman, 2007; Brophy and Good, 2006; Shuell, 2006; Hattie, 2002). Attitude is derived from Latin, *aptus*. It defines outward and visible expressions and human perceptions. (Brown, 2010).

Attitude of teachers has been studied from different perspectives. Many of the studies conceptualized attitude as teacher's instructional behavior that enlivens materials presentation and class content (Keller, M and Schweinfurt, A. 2011). From the outset, behaviors that are nonverbal were considered, because it is part of what a speaker could use to express feelings and attitude towards a particular subject.

Attitude is described as the individual's dominant tendency to respond favourably or otherwise to a person or institutions (Cedrez de la Cruz, 2013).

Rosenshine (2009) identified three types of attitude based on empirical review thus:

- Questions variation
- praise and cheer and
- lively behaviour.

Murray's (2008), teachers' rating by students on low-inferential behaviors, from highly-, moderately- or not effective. Results showed some factors, for example, enthusiasm which has behavioral components of: being humorous, speaking assertively, movement with relevant gestures, smiles, having eye contact, not speaking softly, and not reading lecture notes verbatim.

In addition, "bond of connection" that exists between the teacher and the students is relevant to individual growth and interest as an outcome.

2.2.5 Physics Instruction and Students' Attitude towards Practical Lesson

Students' expectations in a typical physics course play a significant role in what they learn during the course, as this informs their choice during any form of instructional encounter. These expectations take different forms, and therefore make it difficult to identify. Especially in calculus-based physics course, research findings showed that conventional physics class makes students have misconceptions of mechanics (Viennot, 2010).

Other studies further revealed observations in areas such as optics, heat and thermodynamics, and electricity and magnetism (McDermott, 2010). Students' understanding of some basics in physics cum individual experience of the world inform how they develop many concepts of their own. Most times, there is misalignment in what is being taught and understood.

Aside concepts, students draw from their experience and display patterns of attitudes and assumptions about requisite skills and external expectations. Students' cognitive expectations becomes a focal point; which bothers on the structure of physics knowledge rather than about the content of physics itself. Perhaps, the expectation is that physics should be compact.

Belenky, Clinchy, Goldberger, and Tarule, (2011) and Perry (2010) explored the general cognitive expectations of adult learners; attitudes of students versus perceptions of women in different social and economic circumstances, over the period of their college career. Both studies noticed some development in students' attitudes about knowledge (Reif and Larkin, 2009).

Physics has many evolving concepts, and because of changing world conditions, there is need for continuous creation of new learning media in improving educational programs which could help in shaping attitudes. Undoubtedly, emotional expressions during learning process have a way of directing human behavior (Seferoglu, 2004; Sünbül, Afyon, Yağız, and Aslan, 2004). Students improve their skills to better understand concepts, and adapt them to daily lives as well as their personal skills, in order to provide a positive attitude towards physics lessons (Algan, 1999).

According to Hendrickson (2007), students' success can be predicted by attitudes. Hence, learning activities must be planned and executed in such ways that students could develop more positive attitudes (Pintrich, 2006). Determination of students' attitudes scales towards Natural Sciences have been developed; Nuhoğlu

(2008); Kind et al. (2007); Bozdoğan and Yalçın (2005); House and Prison (1998), Geban et al. (1994), Hewitt (1990). Attitude scale in other sciences have been developed; Chemistry lessons Kan and AkbaĢ (2005); GimĢek (2002); Biology laboratory, Ekici (2002); Chemistry laboratory, Budak (2001). All these are ways showing that planned activities can bring about positive attitude in students even in physics subject.

2.2.6 The Concept of Inverted Classroom

The concept of inverted classroom model or flipped classroom is relatively new and as such literature in this area is comparatively limited in Nigeria. Yarbro et al 2014 highlight awareness growth about flipped classroom (74% to 96%; two years), implementation (48% to 78%; two years), recommendation to other teachers (96%). This highlight makes the practice of inverted classroom or flipped classroom an evolving and novel concept adapted only by innovative 21st century teachers.

Although, there are contradictory definition of inverted classroom from different practitioners in education; some are of the view that it is the regular drill of giving videos or lecture content to leaner as homework while others pointed out that it goes beyond just giving videos or lecture content to leaners as homework as the activity in the classroom to initiate mastery of the content through active participatory learning, engagement, collaboration bringing about change in attitude and achievement. Flipped Learning Network (FLN, 2014) clarified that there is a little variation among the concept of inverted classroom and flipped learning. This bothers on the type of engagement put in place to ascertain if an approach is flipped or not.

The concept of inverted classroom is an instructional modus operando that is appropriate and convenient learning platform that delivers instructional content through the online medium, a process that should have normally taken place in a traditional learning environment. It involves allocating all class activities, including homework, into the classroom. In an inverted classroom, students watch online lectures, collaborate in online discussions from their respective location, or carry out research at home and engage in concepts in the classroom with the guidance of a mentor or instructor. The "Inverted Classroom," one of the latest buzzwords in education, but not a totally new concept or innovation. Often, teacher's carryout an inverted classroom by giving students readings and other study materials to use off classroom, and then set up measures that would enable conversations and interactions about the reading in class (Strayer, 2012). There are other aspects of inverted classroom that distinguish it from other strategies that employ digital technologies in teaching. In the inverted classroom, students are made to watch simulations or video-recorded lectures outside the class, so as to enable active learning and proper class interaction (Strayer, 2012). Though some variations may exist, "the 'flipped' or 'inverted' aspect of the inverted classroom ensures that students have access to lessons but with a change in location, at home (Fulton, 2012).

Online learning has different shades, notwithstanding, the purpose for video-taped lectures and simulations were originally to make curriculum accessible to all students especially to those who live far away from the school or those who could not make it to the lecture hall. Teachers realize that videos and simulations help both off-site students and those in attendance during lectures (Cascaval, Fogler, Abrams, and

Durham, 2008), though students complain that purely online classes have limited and indirect interaction and communication (Gecer and Dag, 2012). Despite that inverted classroom looks similar to online learning, there is yet some differences in that inverted classroom allows classroom discussions, interactions and individual help in a face-to-face mode.

Traditional classroom lectures are often regimented, but some teachers try to align their teaching style based on the feedback they get from students, because some of them assimilate lectures at a faster rate than others who are slow learners. Video-taped lectures and Simulations features in an inverted classroom mode support independent learning (Goodwin and Miller, 2013). Simulations and Videos allow lectures to be segmented into frame, unlike in traditional instruction (Brecht and Ogilby, 2008).

Through the Khan Academy website, with over 4,120 short educational videos, made the inverted classroom became popular (Thomas, 2013). The vision of Khan Academy was for young ones to watch instructional videos at home and work on problems in class (Kronholz, 2012). Students get support for their homework, and this approach has helped in modifying old practice to make it fitting for the present changing needs. (Khan, 2012). This method is paving way for a new approach to teaching of Physics

A number of educational institutions have flipped the classroom using Khan's videos. Students' exposure to video lectures has served as home-guidance, and students can have direct interaction with teachers and peers. Of course, this approach has resulted to teachers working more during school day because of the task in interacting with students.

Perhaps it is for this reason that Math teacher, Courtney Cadwell has this to say about it thus: Khan is not a one-size-fit-all (Kronholz, 2012). Activities should be tailored to initiate discussion as well as emphasise practical and applied side of Mathematics should be used to supplement Video lectures. In a flipped classroom, teachers must consciously and always interact with students to know which aspect of instruction to fine-tune; make the class lively and active, and design activities which complement the videos in order to create a wonderful scenario for effective learning.

Educational advocates have envisaged that technologies such as Videos, Simulations, Virtual laboratories and other ICTs will contribute immensely to the desired innovations in the educational system. The inclusion of ICTs in the curriculum is to jump-start educational reforms and innovation which can determine the progress within confines of traditional education. Although the significance of integrating ICTs to the accomplishment of a wide range of educational goals cannot be underestimated, nevertheless it cannot bring about immediate transformation in learning. Notwithstanding, the introduction of videos simulations and virtual laboratories into ICTs has evolved as instructional strategies acting as a sort of ‘‘panacea’’ through which educational reform can be achieved.

2.2.7 History of Inverted Classroom

Eric Mazur, a Harvard professor, was significant in the development of the inverted classroom for teaching through the evolvement of an instructional strategy he describes as “peer- instruction.” Mazur (1997) approach moved information transfer out of the classroom and information assimilation into the classroom. This method allows him to coach students in their learning instead of lecture (Crouch and Mazur, 2001; Eric, 1997). King's (1993) article focused on the importance of the use of class time for the construction of meaning rather than information transmission. King's work focused not on the concept of inverted classroom, but on the effective use of active learning in educational space (King, 1993). Lage, Platt and Treglia (2000) whose research was on inverted classrooms at the college level report that class time in an inverted classroom environment cannot be influenced to meet students' varied learning styles.

The effort of Salman Khan was seen as the most recognizable contribution to the inverted classroom. Khan started recording videos as a prompt response to a younger cousin he tutored because she felt that recorded lessons would let her skip segments she had mastered and replay parts that were troubling her (Thompson, 2011 and Carrier, 2011). This experience brought about the establishment of Khan Academy, which is based on the inverted classroom model. For some, Khan Academy has become synonymous with the inverted classroom; however, these videos are only one form of the Inverted classroom strategy.

2.2.8 Inverted Classroom Practices and Its Possible Benefits

One of the many benefits of case study teaching is its capacity for student engagement which result into development of critical-thinking skills. However, it requires more time for preparation, student resist novel teaching, and many teachers are worried about content coverage (Alpay and Gulati, 2010). The latter constitutes tremendous challenge to STEM instructors who think learning is synonymous to content coverage. They assert that in order to meet up with standardized examinations, inverted classroom also known as “flipped classroom” be introduced. Another benefit of the “inverted classroom” is its affordance to use of internet resources in audio and video formats to teach (Fulton, 2012). This also endears modern age students because of the videos and simulations features.

The inverted classroom model switches classwork as homework, and vice versa, using learning aids such as audio and video tapes. Bolliger, Supanakorn, and Boggs (2010) describes the inverted classroom which could adopt case studies, labs, games, simulations, or experiments as such that makes students do the doing in the classroom, and the listening/watching at home. A guiding practice of inverted classroom is that work typically done as homework (e.g., problem solving, essay writing) is better undertaken in class with the guidance of the instructor. Listening to lecture or watching videos or simulations is better accomplished at home; the basis for flipped or inverted classroom.

This technique of teaching is of immense advantage to institutions of higher learning, and studies have been carried out to establish these benefits. Kathleen (2012) identified these benefits as follow:

1. inverted classroom ensures that students move at their own pace;
2. students’ ability to do “homework” in class gives teachers better insight into student difficulties and learning styles;
3. using inverted classroom brings about increased levels of academic performance, interest, and engagement;
4. different learning theories support the new approaches used in inverted classroom; and

5. The use of technology is flexible and appropriate for "21st century learning."

In spite of these benefits, Clyde and Nancy (2012) identified two major problems associated with inverted classroom teaching thus:

1. Some students find it difficult to embrace the inverted classroom method due to the fact that it requires them to work remotely which denies physical contact with the subject matter in school.
2. Most teachers find it difficult with locating good quality videos. This led many teachers to depend on sources: Khan Academy (http://www.khanacademy.org) and Bozeman Science (http://www.bozemanscience.com/science-videos/). This led some teachers to create their own videos and simulations or instructional materials through the use of software programs like Camtasia, Paper Show, and ShowMe or apps on the iPad, such as Educreations and Explain Everything. After the creation of these instructional materials, they post them to social networking platforms or even course management systems like Blackboard or Moodle for students to easily access it timely. The reality is that teacher-expertise at creating video determines the quality of instructional video, and because creating these videos requires a significant amount of time.

Although, COVID-19 has fast-tracked the shift towards Educational Technology as a way to present a more flexible, personalized learning, dynamic and accessible education experience. The COVID-19 pandemic era has exposed how inverted classroom strategy implementation can also deliver an engaging, accessible and interactive opportunity for learners, especially as it has sparked much needed deliberation about the future of education, providing a unique opportunity for us to reconsider the method of delivering teaching and learning in the 21st Century.

2.2.9 Inverted Classroom Instruction and Simulated-Video Lecture or Simulation

Many educators have come to terms with the fact that inverted classroom is one and the same with the use of internet video technology (Overmyer, 2012). The use of video tapes as an instructional material is one of the methods helping learners catch up with possible fall-outs during instruction time. However, finding good quality video appears to be difficult for most of teachers. For example, most of the teachers in the study carried out by Overmyer (2012) confirmed that teachers prefer online videos over reading materials. It was also discovered that their students prefer video too. Video tapes or which is recently called "video podcasts" are audio-visual files distributed in a digital format through the internet using personal computers or mobile devices (McGarr, 2009), unlike the approach in MOOCs (Massive Open Online Courses), whose delivery is homogenously online. A number of research has been carried out on the effect of instructional video tapes or video podcasts, and findings from these studies from Hill and Nelson (2011); student behavior (Chester, Buntine, Hammond, and Atkinson, 2011); Bolliger, Supanakorn, and Boggs (2010) ; and student performance (Alpay and Gulati, 2010; Traphagan, Kusera, and Kishi, 2010; Vajoczki, Watt, Marquis, and Holshausen, 2010) have positive impact on student' attitude as seen in these studies: Findings from these studies affirmed their effectiveness in the inverted classroom as it reveals an increase in students' performance.

Swenson and Lents (2012) carried out a research on supporting an undergraduate analytical Chemistry course with the use of video tutorials. Findings highlight value, flexibility, and cost-effectiveness as indices of online video tutorials, which can be a tool for improving student's problem-solving skills in Chemistry.

Kay and Kletskin's (2012) study which led to the development of series of 59 problem-based video tapes or podcasts indicated usefulness, friendliness, and effectiveness in the podcast, because it helps them understand new material.

The Bologna Declaration (1999), called for the re-designing of academic curriculum of students with the integration of social-constructivist principles to ensure learners go into developing competences that have wide relevance, even at the face of the millennium challenges (Bologna Declaration, 1999).

From the foregoing, there is a need for capacity building for teachers to make them have competence for using active teaching and learning methodologies towards ultimate improvement in students' learning outcome. Though there has been a short tradition of adopting new learning methodology, simulation has been entrenched as a strategy in teaching-learning endeavour that brings about the development of professional competences (Ekker and Sutherland, 2009). Simulation affords learning space that support interaction, application of previous knowledge, and expression of skills to solve real-world problems (Angelini, García-Carbonell, and Martínez-Alzamora, 2015).

Moreover, simulations trigger the learning environment toward active participation that would result in interaction (Hertel and Millis, 2002). The relevance of simulations covers all disciplines. Thus, creating a natural atmosphere with different realities and problems. In another study where it was used for teacher trainees, they concurrently become conscious of social problems and also acquire relevant skills (Garcí a Carbonell and Watts, 2009; Sutherland, 2002).

This paradigm shift affects the roles of the teacher and learner, making teachers become facilitators that guides learners (Strayer, 2012). Albeit, providing materials ahead of classroom encounter does not suffice to assert flipped classrooms. There are four pillars that Flipped Learning Network embraces: flexible environment, learning culture, intentional content, and professionalism.

2.2.10 Inverted Classroom and Virtual Laboratories

There has been a massive rise in the computer-aided visualization and computation in recent years. Manual plotting and drawing approach to computation and computer visualization has been removed by computer algebra software's available at disposal in recent times (Hampel, Keil-Slawik, and Ferber, 2012). The increase in the number of universities around the world with their conventional training methods brought about a limitation in their capacities and financial support when it comes to Mathematics or physics as the case may be and the need to explore benefits of virtual laboratory to enhance learning outcome among students (Hampel and Keil-Slawik, 2011).

Jeschke (2005) opined that Virtual Laboratories is used to showcase interaction, exploration of learning tools for supporting lectures, hands-on training, homework assignments and research through an inverted classroom using online platform. Virtual Laboratories helps to bridge the gap between the theories and practices by enabling computer-implemented algorithms environment that either emulate real devices under ideal situations. By the affordance of this environment, there is so much flexibilities that could enable students work independent of time and location, either in the field of Mathematics or theoretical physics (Jeschke, 2005). Virtual Laboratory advocates learning by exploration as against ‘soaking’ concepts. Virtual Laboratory ought to be adaptive, such that caters for varied learning style of the individual user, ranging from undergraduate students to researchers (Tolga, 2012). Virtual Laboratory provides an atmosphere that trains students to solve problems on their own rather, and with a tone of creativity (Metropolis, Rosenbluth, Teller, and Teller, 2009).

Also, virtual laboratory should be integrated into an existing software infrastructure like Maple, Mathematica or Matlab by using typical mechanisms from the working environment. In this way, students would be prepared for the real-life and equipped to be professionals. And when it is used in inverted classroom setting, it serves as outdoor alternative to practical where student can practice with a hands-on experiment on his/her own without much ado or pressure.

2.3 Empirical Review

Clyde and Nancy’s (2013) research discovered that the use of videos in an inverted classroom is applicable to tackling real-world problems through case study teaching. The approach shows a reflection of a better strategy to learning with students’ advancement in learning as the focus. Derlina and Satria (2015) conducted a study in Indonesia, on attitude improvement toward students’ learning outcomes. Result showed that students' response to adopted learning model, lesson plan, teaching materials were positive.

Ashiq and Azra (2011) carried out a study on physics teaching methods: scientific inquiry versus traditional lecture in Pakistan. Finding showed that there is great impact of guided, unguided and combination of scientific inquiry on the students' achievement than traditional physics teaching method and their proficiency to apply the concepts of Chemistry in real situations. Tolga's (2012) study in Turkey on peer instruction showed that there were no significant differences in motivation between groups in an introductory physics course.

A research by Chula and Chris (2015) on E-learning and Inverted Instruction Integration in Business Education in West Florida, USA showed that online instruction could be viewed as being separate and distinct from traditional face-to-face instruction. This implies that, when E-Learning is incorporated into teaching strategies in a face-to-face class, the advantages of an online instruction tend to replace the disadvantages of face-to-face instruction.

The study of Donna and Andrew (2012) on the Impact of an Inverted Classroom on International Students' achievement in an Undergraduate Economics Course revealed an overall increase of 11.43% in the final grade of the Inverted class in comparison to the non-Inverted classroom. International students showed an increase of 13.23% and Canadian students 10.85% in the inverted class environment in comparison to their corresponding group in the non-inverted class.

Mercedes, Catherine, and Eric (2005) carried out a research on reducing the gender gap in the physics classroom. The primary concern of the study was to investigate if the gender gap in conceptual understanding in an introductory university physics course can be reduced by using interactive engagement methods that promote in-class interaction, reduce competition, foster collaboration, and emphasize conceptual understanding. Findings reveal that teaching with certain interactive strategies not only yields significantly increased understanding for both males and females, but also reduces the gender gap.

According to a study conducted in Berlin, Germany by Sabina, Thomas and Ruedi, (2005) on architecture of virtual laboratories for Mathematics and natural sciences which found that having an interface that enhances virtual laboratories requires the adoption and use of intelligent agents.

Charles-Ogan and Cheta's (2015) study found that those in Inverted Classroom had better scores in mathematics compared to those in the conventional classroom. In the works of Jeremy (2012) on how learning in an inverted classroom influences cooperation, innovation and task orientation. The study which compared the learning environments of an inverted introductory statistics class with a traditional introductory statistics class at the same university came up with the finding that classroom structure was a reason why some persons felt less satisfied in inverted classroom. The success of any course should therefore not be hinged on students' performance, but the issue of satisfaction could be looked into also.

2.3.1 Major Research on Inverted Classroom Model

There are studies to prove the effectiveness of the inverted classroom in the teaching of science and technology professions. Some of these studies are reviewed in the subsequent section of the study.

Clyde and Nancy (2012) conducted a research where very huge individuals from National Center for Case Study Teaching in Science Listserv were interrogated, and from this pool, two hundred case teachers stated inverted classroom as their teaching option, because: more time spent with students on authentic research; students get more time to work with scientific equipment that is only available in the classroom; students who miss class for debate/sports/and others can watch the lectures while on the road; the method “promotes thinking inside and outside of the classroom”; students are more actively involved in the learning process; and they also really like it. Studies on the impact of the inverted classroom on STEM student backs up the evidence highlighted by teachers in the Rudy by Clyde and Nancy (2012).

In another study by Strayer (2012) on the comparison of the Learning Environments of an Inverted Classroom Introductory Statistics Class with a Traditional Introductory Statistics Class,” it was discovered with the inverted classroom, students became more open to cooperative learning and innovative teaching methods over traditional classroom structure. From another study on inverted classroom, findings from the study indicated that the students’ evaluation showed positive impact of inverted classroom on students’ learning. Ruddick (2012) showed students in inverted class outperformed the ones in the regular class in final examination, with the reasons being that they found the materials useful. This helped them mitigate the threats in learning Chemistry.

Kay and Kletskin's (2012) findings were in the favour that the podcast' usefulness, friendliness, and effectiveness helped them understand new material. This may have been possible due to the audibility of the sounds from the podcasts and the dexterity involved in learning on their own pace.

Some studies reported downsides from both students and teachers, namely, variations in socio-economic background which somehow led to digital divide (Nielsen, 2012). In addition, when students are not from self-directed home learning environment, it may deter them from having a sense of responsibility toward learning, and thus lag behind their peers (Sahin, Muhammed, Fell Kurban and Caroline, 2016).

The learning environment has much influence on the students' learning pattern especially when conditions are tranquil and conducive for learning purpose.

2.3.2 Simulated Video –Based Inverted Classroom Instruction and Attitude towards Physics.

The inverted classroom model has been present in education enterprise, differing schemes, namely, 4400 instructional videos recorded and deposited the Khan Academy digital library (Chen, Wang, Kinshuk and Chen, 2014). Several teachers have depended on these videos to operate an inverted classroom model. The simulated videos containing subject content were accessed from dispersed locations.

In Nigeria, researchers have commended the use of inverted classroom approach to learning as some have concluded that the face-to-face approach is no longer relevant

(Gbadamosi, 2017). Adedoja (2016) extended this view that flip learning is not a new concept. In her study, pre-service teachers' attitude and challenges towards flip learning were examined. Results showed though pre-service teachers had positive attitude towards flip learning they noted some bottlenecks against its novelty, such as internet access and power supply. There are so many ways that the use of technology in learning has impacted the attitude of learner positively especially through inverted classroom which provides opportunity for learners to have prior exposure with content/material. Jenset (2011) corroborated this view when he investigated attitudes among student teachers toward using electronic resources in teaching. It was noted that despite positivity in attitude toward technology, the teacher training program did not have significant impact on their attitudes nor on their self-reported skills. Hobgood et al. (2010) in his study used simulated video to teach teamwork and collaboration. Using four teaching options with the teamwork group, there was no significant difference in any of the options. The researcher also found that all students had their attitude improved in the collaboration group. The aesthetic features seen in the simulated videos may have accounted for improvement in attitude regardless of learning styles and pedagogy even when different mode of inverted or flipped classroom would have been employed.

In a systematic review of literature; Vlachopoulos and Makri (2017) shows positive growth towards games and simulations, especially in post-interventions. These studies employed different approaches in the use of simulated videos in the classroom as its effectiveness was constantly tremendous.

Oyekola (2017) studied what effects two styles of flipped classroom instruction would have on pre-service teachers' attitude to and practice in microteaching in Lagos state, Nigeria. He observed that the treatment played significant role in the attitude of pre-service teachers towards their microteaching. This means that no matter, the variance or mode of flipped classroom instruction; it has a positive effect on attitude of pre-service teachers to microteaching. This may be traced to the fact that flipped classroom instruction provides the pre-service teachers opportunity to get a first exposure prior to classroom.

2.3.3 Simulated-Video based Inverted classroom Instruction and Achievement in Physics.

Many studies on inverted classroom and its effects on students' achievement are emerging though there is paucity of research in this area in physics. Most of the researches reflect the effectiveness of inverted/flipped approach towards improving students' academic achievement both in attitudes, problem solving skills, and perception. Rasmussen (2013) also noted that chemistry students' performance and perceptions in inverted classroom were higher and positive respectively, perhaps because instructional videos could be self-managed to support individualized learning investigated. Stacey-Roshan (2011) revealed that using the inverted/flipped class led to improvement in the students' performance and he emphasized that flipping the classroom was not about creating more work for the students, but changing the type of work that students do at home and changing the class experience.

Akingbemisilu (2014) study on the effect of flipped classroom strategy on Adekunle Ajasin University students' Achievement in Some Concepts of Biology revealed that though inverted classroom strategy slightly improved the students mean score in Biology at undergraduate level, it did not cause significant effect in their performance due to some factors. However, Flaherty and Philips (2015) indicated that there was much indirect evidence of improved academic performance as student and staff satisfaction increased with the flipped approach. But there is a paucity of conclusive evidence that it contributes to building lifelong learning and other 21st Century skills in under-graduate education and postgraduate education.

2.3.4 Simulated-Video based Inverted classroom Instruction and Problem-solving Skills in Physics.

In inverted classroom, direct instruction is substituted with problem-based learning material (video) (Bergmann and Sams, 2012; Hamdan, McKnight, McKnight, and Arfstrom, 2013). The simulation interactive nature reveal more evidence supporting its effectiveness towards problem-solving skills.

Osman, Jamaludin and Mokhtar (2014) reported in their study on the traditional and flipped classrooms in a Malaysian Polytechnic, on perceptions of lecturers and students. Findings indicated that perceptions varied according to the learning modes, and that students in the flipped classroom did better academically than those in the conventional mode. This could be because the lecturer spent more time on problem solving in the flipped class compared with the traditional class. In an inverted classroom approach, lower cognitive skills (Knowledge and Comprehension) are done outside the classroom whereas higher level cognitive skills in form of work are completed in the classroom through problem solving, discussion and collaboration. These have aided the acquisition of skills in solving problem especially in Physics where numerical calculations are usually involved to substantiate facts and some researchers supported the view that inverted classroom/ flipped classroom influences the mastery of problem solving skills because of the available time spent on engagement during the classroom.

Zanzali and Nam (2002) concluded in their research that a clear picture on the ability levels of problems solving skills among students and stated categorically the levels of content mastery and the skills necessary to carry out certain standard algorithms should be satisfactory. Although it has been revealed that mastery of problem solving skills among the students is still at low level, efforts to upgrade and thus help students to master the problem solving skills should be planned and implemented.

Merino, Vermeulen and Jooste (2017) engaged 38 two- or three-times course-repeaters in a part-time Management Accounting and Finance III students in a self-regulated learning classroom. Adopting a qualitative research approach, results show that exposing students to strategies and skills in an active learning environment assists them to take responsibility for their own learning and improved academic outcomes including problem solving skills.

2.3.5 Virtual Laboratory based Inverted classroom Instruction and Attitude Towards Physics.

Love, Hodge, Grandgenett, and Swift, (2014) reported the application of an inverted classroom approach for a unit of an applied linear algebra course and a traditional lecture approach for another unit of the course. Results indicated that the students in flipped classroom environment were quite optimistic about the course. In Gilboy et. al. (2015), sudden preference for the flipped method compared with the traditional classroom could be accounted for by the activities done outside the classroom that requires synthesis, application and evaluation. All this research finding showed evidence that instructiveness nature of inverted classroom gives it an edge in attitude formation over the traditional method of teaching, though integration of digital technology into the classroom contribution largely through interaction with simulations, hands-on experience, creative thinking by increasing the interest of learners during the process of learning in classroom.

Zimmermann (2013) observed that the growing interest in the use of technology among 200 level child development class in Northern Virginia is connected to effectiveness of virtual simulation based inverted classroom over the conventional method of teaching, which is ineffective in this era where the set of learners are digital natives and technology savvy. It is well known that learners in this dispensation are gradually inclined to the use of digital technologies like mobile phones, laptop and computers to improve their understanding about concepts within their environment.

2.3.6 Virtual Laboratory based Inverted classroom Instruction and Achievement in Physics.

Capone, Sorbo, and Oriana, (2017) study ‘‘a flipped experience in physics education using clil methodology’’ and reported that the experiment has shown that performance of secondary school students can benefit from flipped classroom strategy in learning difficult topics, such as quantum mechanics in CLIL methodology. The learning outcomes, very persistent in time, were gathered by a multiple-choice questionnaire and reports. Implication suggest that the level of difficulty experienced in quantum mechanics was erased due to responsibility on the learners to work more on virtual platform as their make personal discovery of some fact which may not be supplied in a traditional face to face classroom.

Ismail and Abdulla (2019) used the Virtual Flipped Classroom (VFC) to introduce a new pedagogical approach to investigate students' learning achievements and motivation in the Instructional and Learning Technology (ILT) department at the College of Education, Sultan Qaboos University (SQU). Findings uncovered a significant difference in learning achievement and motivation before and after applying the VFC model. It is obvious that the distinctive change found in the use of virtual flipped classroom existed due to the interactive nature of the strategies used, making physical phenomenon look so real thereby affecting their overall performance. Likewise, a setting that is technology-driven would significantly improve motivation and positive attitude of students. Consequently, this would turn out to influence academic achievement. An example of such technology-driven setting is virtual laboratories.

2.3.7 Virtual Laboratory based Inverted classroom Instruction and Problem solving Skills in Physics.

Information technology comes with many innovations that can stand-in as an educational environment. As a result of the popularity of virtual educational technology, the development and exploration of virtual learning environment therefore becomes important. The virtual laboratory increases the visibility of activities that can aid calculation and numerical actions involving problem solving skills in Physics. Science learning using IT is important because of certain experiments that are dangerous, costly to carry out, or demand time to execute.

Ivan and Avraham (2018) studied the impact of simulation-based training and flipped classroom methodology on students learning project management. Findings were grouped in theoretical and practical perspectives. Though both methodologies were theoretically enriching, but the virtual simulation-based training practically brought about improvement in results. The virtual laboratories when used in inverted classroom allows students to have access to learning materials while at home, with problem solving exercise and then situate interactions in a virtual synchronized classroom environment. By this, it gives room for active learning strategies such as find error, collaborative learning groups, and think-write-pair-share (Petrina, 2006), it allows students share ideas capable of solving problems posed by the teacher. The affordances in this is that repetition is allowed in the virtual laboratory lessons.

2.3.8 Inverted Classroom Instruction and Gender

Some researchers have worked on both effects and relationship of gender and inverted classroom, Eichler and Peeples (2016); Reid (2016). Overmyer (2007) observed that inverted classroom also has important implications for the gender imbalance reported among students and showed an interaction between gender and teaching method with regard to achievement. This result may largely have been affected by so many other intervening variables as events may have over taken such case in this dispensation.

Also, Chen, Yang and Hsiao (2015) exploring students' perceptions, learning outcome and gender differences in a flipped Mathematics course, indicate that male performance is significant compared to the female counterpart. Of course, this result may not likely be a surprise as the active nature of the dexterity in male can contribute to the result. Gross, Pietri and Anderson (2015) in their research captioned highlighted that pre-class preparation influences student outcome in the flipped classroom, depicting that at a least on two out of the three exams, the flipped classroom format was alleviating the gender disparity on exam scores. As this position is corroborated, technology – gender gap is closing up over the years (Abimbade, 2015; and Aremu and Fasan 2011). The issues of gender and inverted classroom cannot be discounted as the instructional method involves the delivery of the content outside the classroom which is determined by the peculiarity of students' activity outside the classroom.

2.3.9 Inverted Classroom Instruction and Spatial ability

Alias, Black and Gray (2002) observed that spatial experiences contribute to variations in spatial visualisation abilities. Spatial experiences in non-academic subject's correlate with spatial visualization ability among students in engineering (Deno, 1995). Any attempt to improve spatial visualization ability it would influence the acquisition of one aspect of it. Interestingly, Braukmann and Pedras (1993) deduce that spatial activities do not necessarily bring about difference on spatial ability since the same experience is recorded in traditional and modern ways in enhancing spatial skills in engineering students. However, Sorby and Baartmans(1996a) proscribed that students improved greatly in spatial visualization ability as measured by The Purdue Spatial

Visualization Test while exposed to diverse spatial activities; modifying of concrete models to computer visualization activities. Though, there are inconclusive arguments about spatial ability but the varying nature of visualization activities involved in each simulation based inverted classroom may give rise to changes in learning outcomes. This could be another reason why this present study explored spatial ability as one of the variables.

2.3.10 Spatial Ability and Attitude towards Physics

Olaitan (2017) who studied teacher and student variables in predicting learning outcomes in organic chemistry in Ibadan metropolis, found that there were significant composite contributions of the students' variable (spatial ability) to the prediction of the dependent variable (students' attitude to organic chemistry). There were correlations between spatial ability and ability to infer the motion of different 7 working machine components (Hegarty and Sims;1995). In Kozhevnikov, Hegarty and Mayer (2002), there were correlations between psychology undergraduate students' spatial visualization and performance on qualitative problems.

Huk, Steinke and Floto (2003) investigated students' attitude alongside spatial abilities towards videos and animations. Using two versions of animations with varied quality participants more positive attitude was recorded of those with high spatial ability had. This might have been possible due to the measure of spatial ability before applying the treatment on the participants which could have elicited some behavioral pattern in them.

As graphics educators Sorby et al (2006a) routinely tested the 3-D spatial skills for university-aged students using standardized instruments, and reported a significant amount of connection between spatial skill components and attitudes leading towards increase in enrollment, implying that there is an underlying spatial ability.

2.3.11 Spatial Ability and Achievement in Physics

Acknowledging the relevance of spatial visualization and thinking methods in science, it is obvious that spatial ability is associated with learning outcomes in science. A longitudinal study of gifted students showed that spatial ability is responsible for significant change among science students (Shea, Lubinski and Benbow, 2001; Webb, Lubinski and Benbow, 2007). Visual-spatial thinking is crucial to several scientific fields and careers; in Physics there are speculations about the movements of objects within a space, and this requires spatial illustrations such as drawings, charts, representations, and plans to characterize the objects of study.

Many studies in spatial ability both within and outside of the classroom have initiated reflects that student are better grounded in grasping concepts after being exposed to multi-representational displays like spatial virtualization and mental rotation of images (Wu, et al., 2001, Stieff and Willensky, 2003; Olaitan, 2017). The dimensional virtualization images in form of videos, virtual laboratory and animations helps students get illusion of understanding and reason for student to ‘see’ what they visualize to be true rather than what is really true. The studies have suggested that through the development of visual spatial ability, the learners ‘retention rate and success in learning of sciences can be increased.

2.3.12 Spatial Ability and Problem-Solving Skills

There is relationship between spatial abilities and problem solving in mechanics. Three additional spatial factors were highlighted in Hegarty et al (2006); closure speed, flexibility of closure, and perceptual speed which deals with the ability to identify a stimulus or part of a stimulus that is either embedded in or obscured by visual noise, and scanning to find figure or symbols. These set of spatial factors may be responsible for dexterity of skills involved during problem solving in physics by students which enables them to identify the givens and constraint, also determine level of progress through evaluation.

Kozhevnikov et al (2007) could relate spatial visualization to solving kinematics problems. Results show some limitations with low-spatial students. This is to establish the important relationship between spatial visualization ability and solving kinematics problems with multiple spatial parameters. In assessing students' understanding of the laws of mechanics, Kinematics Problem Solving Test reflecting extrapolation, graph, and frame translation problems, was administered. All these reveals to a large extent the relationship between spatial ability and problem-solving skills which seem to enable higher level of mastery of gained knowledge through solving numerical questions in physics.

2.3.13 Gender and Attitude towards Physics

Students' attitude towards learning defines how well they understand the course being taught and are also majorly influenced by their gender. Usman (2004) posits that academic performance of students in science could be attributed to poor attitude, but implicitly gender-influenced. Possible reasons for this observation are external factors, such as but not limited to: dearth of teaching-learning resources (Fenstermacher, 1996); teacher's attitude to their job, unpleasant and discouraging morale-damaging comments about student's performance (Morakinwa, 2003). However, low academic performance was determined most probably by perception patterns according to gender, as some consider some courses as 'hard' and 'soft'; reflecting in male dominance in the physical sciences and technical courses, and the Biological Sciences, Home-related and administrative courses were regarded being dominated by female (Nzewi, 2003). With such an ideology student tend to be complacent about some courses thereby giving priority to some courses over the other as it affects their attitude to those courses.

And students' past experience and exposure with their peers may have contributions their interaction level which has tendency to affect their attitudes toward a particular course.

2.3.14 Gender and Achievement in Physics

There are so many researches that have focused on gender difference and achievement in science learning. Illiya (2007) noted that girls are not achieving as much as they should as compared to boys in the physical science; Physics and Chemistry. Possible explanations have been attributed to social, educational and personal reasons (Olorukooba, 2008). Further explanations are hinged on the teaching styles. While there exist many intervention programs to encourage more girls and women in science (Ayina, 2006), in physics, limited involvement in learning opportunities, low levels of achievement, and lack of interest eventually affect their under-representation. This study is, therefore, aimed at determining the relative effects of inverted classroom strategies on their academic performance in physics with bias in gender.

Alao and Abubakar (2010) did not find landmark variation in academic performance between female and male students' academic performance in college Physics. It was showed that there was no statistical substantiation. This result gave rise to recommendation that teachers should scale up pedagogical skills. This retreated more facts about gender and achievement as crucial when adopting strategies for teaching sciences in higher education in Nigeria.

2.3.15 Gender and Problem Solving Skills

There is a paucity of research in the influence of gender on problem solving skills of students generally. Apata (2011) investigated the influence of students' gender on numerical proficiency in secondary school Physics in Kwara State. Numerical Proficiency Test that covers practical physics and physics theory was administered to 81 secondary school III physics students. Results showed that in both theory and practical sessions, males did better than female. There are other researches that support these views; Ogunkunle (2007) and Nworgu (1988). However, Anagbogu and Ezeliora (2007) found better performance in science subjects with female students over the male. In the midst of these, some researchers have reported similar performances of males and females (Salman, 2004; Aiyedun 2000; Daramola, 1983). The discrepancy only reveals the inconsistency of gender influence on problem solving skills of students in Physics. It is undisputed that in a process where two set (female or male) of learners are involved, there are likely going to be a pattern of solving skills that reflect superiority. Numerical proficiency is a factor that helps in the instructional delivery of physics (Adegboye, 2007). The dexterity of learners' cognitive ability whether male or female may determine his/her level of problem-solving skills in physics which also would impact learners' attitude towards physics and the level of achievement in Physics.

2.3.16 Conceptual Framework

The conceptual framework in Fig. 2.1 explicitly explains the inverted classroom strategy; it is an approach that brings about engagement and active learning pedagogy to undergraduate instruction in physics. This method of teaching is often called inverted classroom or flipped classroom, that is, giving learning materials (in form of simulations) as homework to student for study before the proper class time. This approach to classroom inversion may have different models of inverted classroom or reversed class approach (for example, Iqbal, 2015; Katatrepsis, 2014 and Sams, 2011), but this study incorporated the use of two modes of simulations (simulated video lecture and virtual laboratory) for lectures outside of class, that enable the transmutation of classrooms into panorama of inquiry, active learning and engagement as the teacher plays the role of a facilitator.

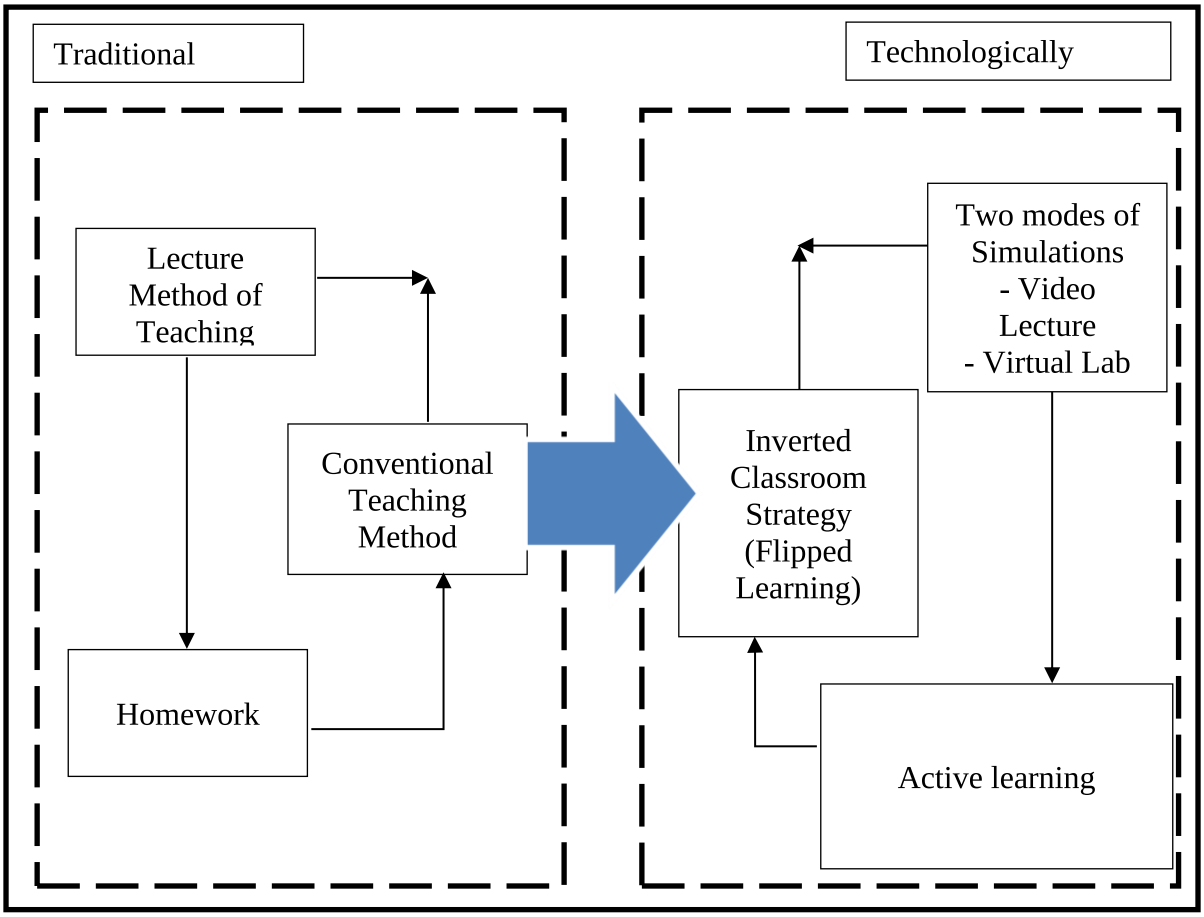

Fig.2.1Conceptual framework for Traditional and Inverted classroom strategy using two modes of simulations (Simulated video and virtual laboratory) for Physics Instruction.

2.4 Appraisal of Literature Review

The literatures reviewed have shown significant gains of deploying simulation based inverted classroom instructional strategy in various disciplines. Also, the instructional strategy has been effective in the teaching of other subjects in experimental studies. This strategy is in line with frequent appeals to make teaching-learning process, student-centered and supported by digital technologies in order to comply with the demands of 21st century educational system. The two modes of simulation-based inverted classroom instructional strategies (Simulated-Video and Virtual Laboratory Based Inverted Classroom) have also been proved to hold promises to individualize and make collaborative, instructional delivery modes when implemented in Physics and other Science subjects. Nonetheless, the application of two modes of simulation based inverted classroom instructional strategies in Nigeria has, however, not been reported especially in Physics education.

The results of the past findings from literature reviewed showed that the retention rate of students using computer mediated learning (Simulations based Inverted Classroom) is up to 30% percent greater than the rate gained by students using traditional method. Moreover, it increases student's creativity, critical reasoning/thinking, and retention as all gears towards quality problems solving skills. Hence, this study aim to consider the effect of the two modes of simulation-based inverted classroom and compared it in terms of instructional benefits in student's achievement, attitude to and problem-solving skills in Physics. Gender and spatial ability served as the moderator in each of the strategies on students have been reviewed from the perspectives of findings from earliest studies. As the literatures reviewed on these variables showed that their influence on students' academic achievement is inconclusive, because where there is the existence of general record of statistical significant effect, and there exist also few findings that oppose such beliefs. Therefore, there is a need to contribute to the existing information about these variables.

Also, this study aimed at providing Physics students and teachers with necessary information about the most valuable simulation-based inverted classroom instructional strategy for learning and teaching Physics, since the conventional method of instruction in Physics seem ineffective in equipping learners' attitude and skills essential in this 21^{st} century digital era of technological advanced teaching and learning. The effort made in the past to integrate digital technologies to learning of Physics was majorly to serve as another instructional delivery mechanism without much consideration for mastering of the knowledge gained. This study filled this gap by using simulations-based inverted classroom instruction that could be viewed by students anywhere and anytime according to their pace, and eventually improve knowledge, skills and foster positive attitude towards Physics. Also the use of simulations-based inverted classroom instruction would help reduce the growing impression students conceived about Physics being too abstract in nature and also aid the coverage of curriculum as well as attaining an excellent performance in Physics examination.

Furthermore, a gap created in the available reviewed literature, which this study intends to fill is that no established studies have been carried out on the private Universities especially in the pre-degree program (which sometimes serves as a rallying point in transition into undergraduate program of the Universities) as major studies in

Nigeria carried out on inverted or flipped classroom are from government owned Universities and Colleges of Education.

CHAPTER THREE

METHODOLOGY

This chapter describes the methodology used in the study and entails the following: research design, variables of the study, selection of participants, instrumentation, research procedure, data collection, and data analysis methods.

3.1 Research Design

The study adopted pretest-posttest control group quasi experimental design.

The design is denoted thus:

O_a X_1 O_b Experimental group I

O_c X_2 O_d Experimental group II

O_e X_3 O_f Control group

Where O_a, O_c, and O_e denote experimental groups pretest scores 1, 2, and 3 control respectively, while O_b, O_d, and O_f represents experimental groups posttest scores 1, 2, and 3 control group, respectively.

X_1 - Treatment for group I involving Simulated-Video Based Inverted Classroom Instructional Strategy (SVBIC)

X_2 - Treatment for group II involving Virtual Laboratory Based Inverted Classroom Instructional Strategy (VLBIC)

X_3 - Treatment for control group involving conventional method of teaching

The study used factorial matrix of 3x2x3 as indicated in Table 3.1:

Table 3.1: Factorial Matrix of the Design: 3x2x3 Factorial Matrix of the Design

Treatment: /Inverted Classroom Instruction at 3 levels	**Spatial Ability**	**Gender**	
		Male	**Female**
Simulated-Video Lecture Strategy	High		
	Moderate		
	Low		
Virtual Laboratory Strategy	High		
	Moderate		
	Low		
Conventional Lecture Instructional Strategy	High		
	Moderate		
	Low		

3.2 Variables in the Study

A. The Independent Variables at 3 levels:

i. Simulated-Video Based Inverted Classroom Instructional Strategy (SVBIC)

ii. Virtual laboratory Based Inverted Classroom Instructional Strategy (VLSBIC)

iii. Conventional Lecture Instructional Strategy

Moderator Variables:

i. Gender Male and Female Levels

ii. Spatial Ability at Low, Moderate, and High Levels

Dependent Variables: there were three (3):

i. Students' Attitude to Physics

ii. Students' Achievement in Physics

iii. Problem Solving Skills in Physics

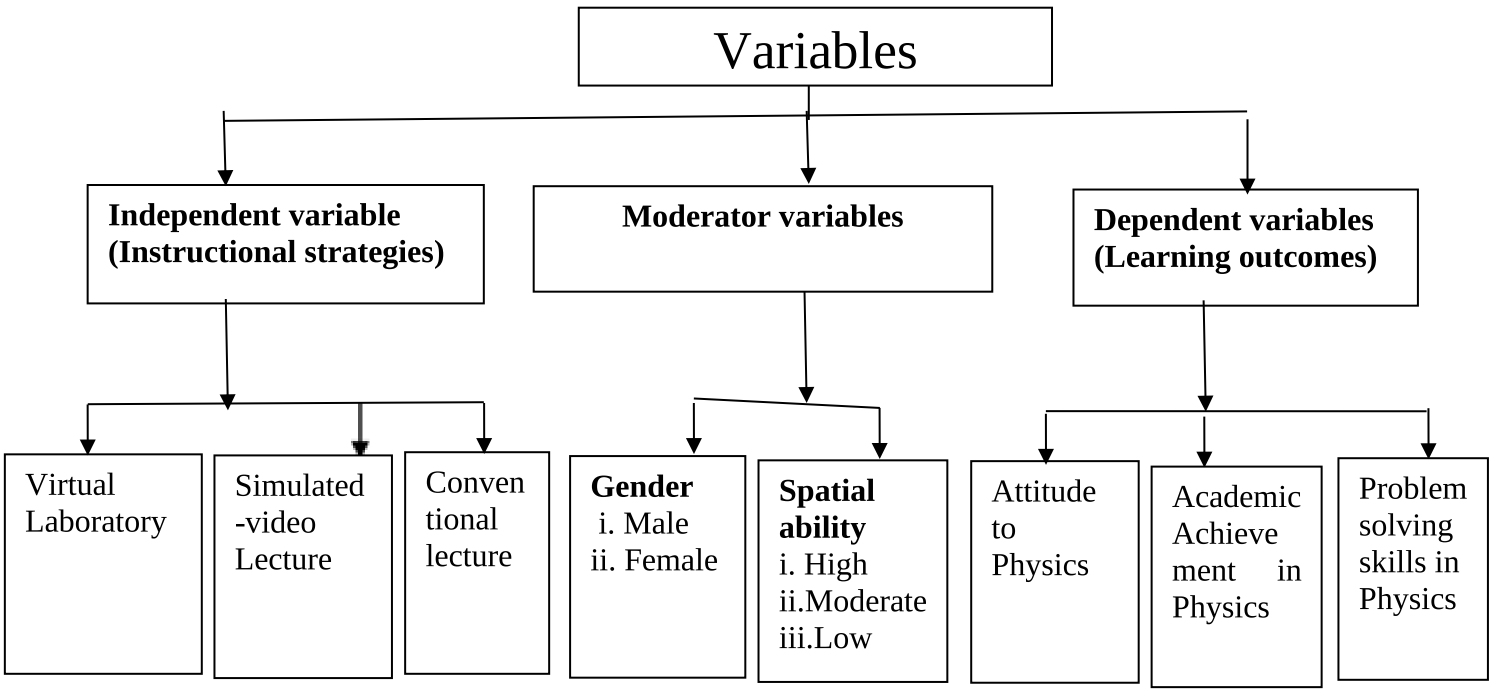

Fig. 3.1 The Variables of the Study

3.3 Selection of Participants

The target population of this study comprised all Pre-degree students in selected private universities in Southwestern Nigeria. The selected participants (pre-degree students especially those in JUPEB program) were considered for this study because they form the majority of students that require remedial tutelage for advancement into an undergraduate program (200 level). The participants were those learning Introductory General Physics 004 as a pre-degree course in six (6) randomly selected private universities out of the thirty-one (31) private universities in Southwestern Nigeria and constituting 19.4% based on private universities currently offering a pre-degree program especially the Joint Universities Preliminary Education Board (JUPEB) programme.

The purposive sampling technique was adopted to sample these participants that were pre-degree students (JUPEB). The selection of participants was based on access to or possession of any digital device (laptops, iPads, phones, and computers) that can share (through WiFi, Bluetooth, CDs and flash drive) or download Simulated-Video and Virtual Laboratory online. In order to ascertain the number of participants having access to and possession of any of the digital devices (large-screen phones, iPads, personal computer, and laptop), a questionnaire on availability and accessibility was administered to the students.

The selected topics that were taught are Quantum and Photoelectric Effect (Photon, Quantum Theory, De Broglie, Photoelectric, Wave Function and Wave-particle Duality). These topics were considered appropriate for pre-degree students because they are the basic concepts in their general introductory physics and contents selected from JUPEB program since the private universities involved in this study run the same program. The conditions for the choice of private universities for the study were based on network availability/access, affordability of such digital gadgets and its frequent usage by students in these universities. The availability of well-functioning ICTs centers and uninterrupted power supply on campus required to aid the delivery of instructions to learners any time of the day was also considered in the selection of these private universities.

Based on these factors, the following private universities were used for the study:

1. Babcock University, Ogun State.
2. Adeleke University, Osun State.
3. Lead City University, Oyo State.
4. Achievers University, Ondo State.
5. Caleb University, Lagos.
6. Afe Babalola University, Ekiti State

Residency status was another condition for proximity to facilitate collaboration among the students and to be in an environment where there is regular power supply even at night time. These factors are also parts of the prerequisite by NUC for establishing a private university. Participants who had digital electronic gadgets to view and download simulations were purposively selected and were randomly assigned to SVBIC (83), VLBIC (51) and control (70) groups. A total of two hundred and four (204) pre-degree students participated in the study; eighty-three (83) in the simulated video group, fifty-one (51) in virtual laboratory group and Seventy (70) in control group as intact class was used to assign group. Also, six research assistants and six teachers were involved in the study.

3.4 Criteria used in Selecting the Concept in Physics for the Study

Driven by the findings from the baseline study, certain criteria (like perceived difficult topics) were used in selecting the physics concepts used for this study, which showed

‘‘Quantum/Quantization’’ as the most difficult physics topic by 73 (13%). Data were elicited from students in universities in Southwestern Nigeria.

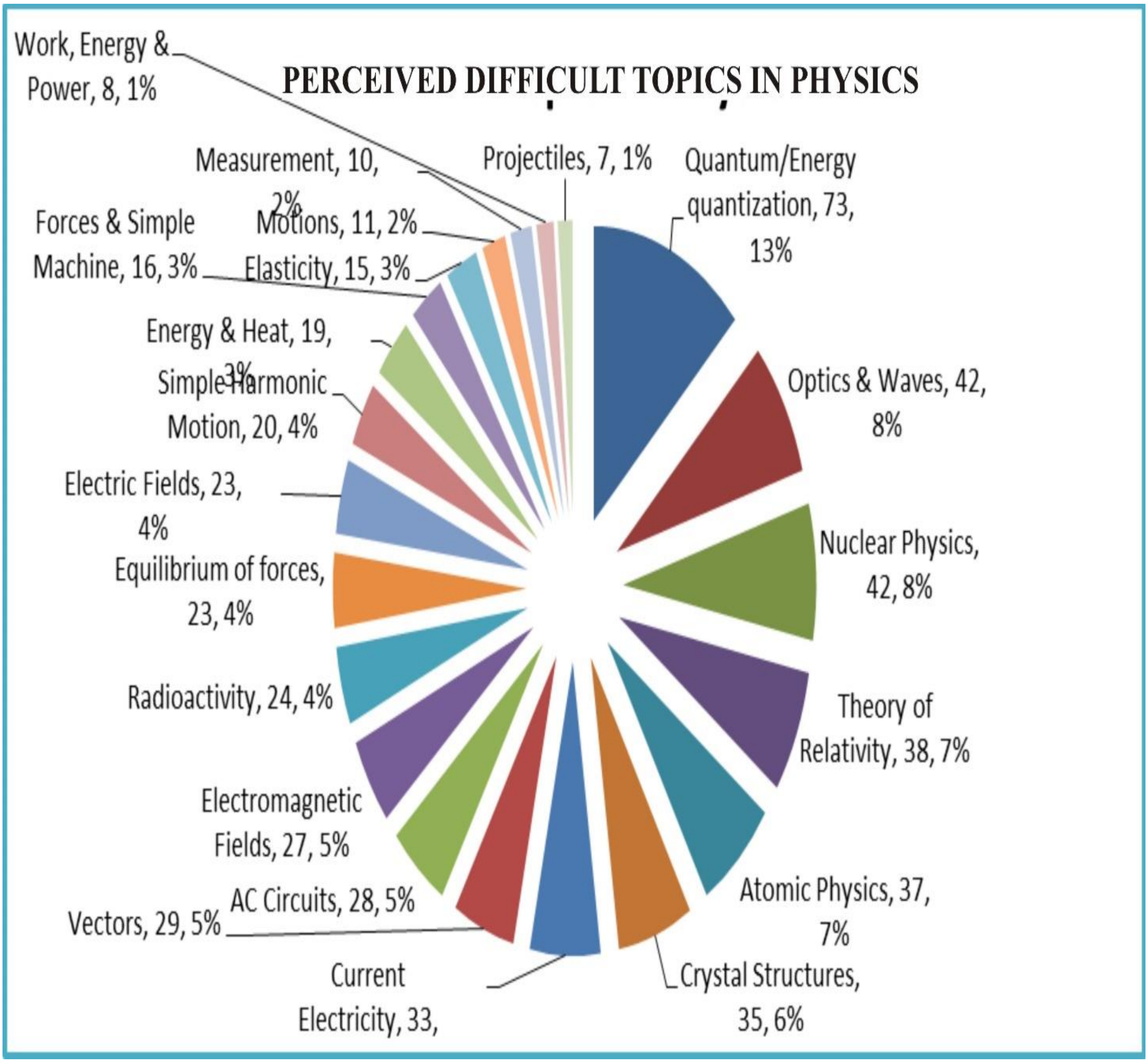

Fig. 3.2 Perceived Difficult Topics in Physics by Science Students
Source: Field work (2016) in three universities in Southwestern, Nigeria. Appendix 9.

Thus, the concepts in physics selected for this study were aspects of Quantum and Photoelectric Effect (as it includes Particle Physics). The rationale for the selection of these areas in physics was because it cuts across almost every aspect of the subject; Physical Quantities and Units, Theory of Light, Einstein's Wave-Particle Duality, Quantization, Kinematics, Charge, Wave Motion, Electromagnetic Wave, Nuclear Atom, Coulombs Law.

Quantum and Photoelectric Effect are one of the main topics for pre-degree students in physics related courses in pre-degree at the JUPEB program. It is pertinent to note that the photoelectric effect is the ‘‘Cornerstone’’ of Quantum Physics which depicts the uniqueness of the subject, yet students find it difficult to comprehend (Clayton, 2014; Jenkins, 2015; Liu and Pipoin, 2016). An aspect of Quantum Physics such as the concepts of Photoelectric Effect which has to deal with the ejection of electrons from cold metal surface when electromagnetic radiation of sufficiently high frequency falls on it, is one of the abstract topics in physics which is usually difficult to comprehend.

From the base line study, students perceived quantum physics as too abstract in nature, whereas its applications had great impact in electronic revolution of the 20th and 21st centuries. It is the most counter-intuitive theories of physics because it solves problems that classical physics faced at the beginning of the 20th century (Mbakop, 2009). However, because the equipment and resources required to teach students these concepts are not available in many universities it then becomes very difficult to present the concepts within the conventional period of teaching students for proper understanding. Thus, the need to use the two modes of simulation-based inverted classroom instructional strategy complimented with offline collaborative classroom sessions. The concepts selected were taught in a semester of fourteen (14) weeks. The inverted classroom approach involved in teaching the concept during these periods comprised the use of Simulated-Videos and Virtual Laboratories given to students to view ahead of the lesson while further discussions, participation and collaboration were done in the proper class time based on the subject matter.

3.5 Research Instruments

The study used three (3) stimuli and five (5) response research instruments. The Response instruments were: Attitudes towards Physics Questionnaire (ATPQ), Students' Achievement Test in Physics (SATP), Spatial Ability Test (SAT), Problem Solving Skills Scale (PSSS), Availability and Accessibility of Digital Gadgets Inventory (AADGI). The Stimuli instruments used were; Simulated Video-Based Inverted Classroom Instructional Package (SVBICIP), Virtual Laboratory Based Inverted Classroom Instructional Package (VLBICIP) and Conventional Lecture Instructional Guide (CLIG).

These were:

i. **Attitude towards Physics Questionnaire (ATPQ):** The ATPQ was used to determine the students' attitude to physics adapted version from Weinburg and Steele, (2000) as twenty-five (25) original questions were retained and terminologies amended to suit physics. ATPQ was classified into two sections: Section A sought information on age, gender, what you do after school hour, position held in school as a student and hobbies. Section B consisted of twenty items rated on four Likert type ordinal scale ranging from Strongly Agree (SA) - 4 to Strongly Disagree (SD) – 1 for positively worded statements. The Scoring of items on the scale that are negatively worded was graded on points ranging from Strongly Agree (SA) - 1; Agree (A) – 2; Disagree (D) – 3; to Strongly Disagree (SD) – 4 (Appendix 3).

The ATPQ was adapted from Weinburg and Steele, (2000). The terminologies were rearranged to be in congruence with the subject-matter "physics" and twenty-five (25) original questions were retained as suggested by four subject-matter experts in physics (from the University of Ibadan and Babcock University) who subjected it to necessary validation process: content and face. The reliability of ATPQ was carried out to obtain a reliability coefficient index using Cronbach Alpha when administered to at least (35) thirty-five students at Babcock University Pre-degree Program who were not part of members in the main study. The value yielded 0.88.

ii. **Students' Achievement Test in Physics (SATP):** SATP was self-developed in the multiple-choice format, to measure students' knowledge of selected concepts in physics based on the first three levels of cognition (Okpala, 1985). The instrument comprised of two sections. The first section sought demographic information about the respondents, while the second section consisted of twenty (20) multiple choice items, which had one correct answer and three distracters each (Appendix 4). The items were drawn from the concepts of ''Quantum Physics'' in the physics curriculum. A table of specification was used for the test on (i) History of Photoelectric Effects (ii) Significance for Practical Application (iii) Calculation on Effect of Visible Light (iv) Nature of its Wavelength and Calculation (v) Fundamental Principle of Quantum Mechanics (vi) Calculation on Energy of Emitted Electron (vii) Calculation of Frequency of Electron (viii) Optical Intensity (ix) Discrete Nature of Light (x) Calculation on the Existence of Quanta (xi)

Calculation on Secondary Emission (xii) Calculation on Kinetic Energy of the Emitted Electrons.

The validation of the instrument was done by subject-matter experts' review from Babcock University and the reliability co-efficient was computed using KR-20 formula. The reliability value was 0.75 and an assumed level of average item difficulty level was at (1.00/2 = .50).

Therefore, the optimal difficulty level is .50+(1.00-.50)/2 = .75. This showed that the test items used were not too simple or too difficult.

Table 3.2: Table of Specification for SATP

Topic and Sub-topics	**Remembering**	**Understanding**	**Thinking**	Total
Photoelectric effects	**(2)**1,2		**(1)**7	3
Effect of visible light	**(1)**10		**(1)**5	2
Principle of Quantum mechanics and quantum theory	**(1)**12	**(1)**11		2
Energy of emitted electron	**(1)**3	**(1)** 9	**(1)**14	3
Frequency of electron and de Broglie waves	**(1)**4			1
Optical intensity			**(1)**18	1
Discrete nature of light / wave-particle duality	**(1)**16	**(1)**20		2
Photon and Existence of quanta		**(1)**13	**(1)**19,	2
Secondary emission and Work function	**(1)**15			1
Kinetic energy and emitted electrons.	**(1)**8	**(1)**6	**(1)**17	3
Total/Percentage	**9**(45.0%)	**5**(25.0%)	6(30.0%)	**20**

iii. Spatial Ability Test (SAT): Four spatial ability tests were administered to measure students' spatial ability before the treatment: two measuring spatial relation (SR) and two measuring Visualization (VZ). These tests were selected from Newton and Bristol (2012) spatial ability test, owing to the premise of the pilot study in which students were exposed to visualization of dimensional forms of objects, structures and images occurring in Simulations, Virtual laboratory and Simulated-Video lecture, It was subsequently adapted and modifications were done to accommodate students' bio-data and familiar spatial representations. The instrument contained 30 multiple choice items. It was designed to measure the spatial orientation and spatial visualization of the students (Appendix 1).

The instrument was reviewed by four Educational Technology lecturers from the University of Ibadan, Ibadan, Nigeria. From their contributions, the entire 30 items were modified. The final draft was later administered to 20 students (Eleven (11) males and nine (9) females) who were not part of the main study. The reliability coefficient of 0.81was obtained using KR-21.

Table 3.3: Table of Specification for SAPSS

S/N	Skills	Indicators	Items	Total/Percentage
1	Analyzing givens and constraints.	-Identifying known and unknown quantities -Analyze and imagine the problem -Separate each variables or givens	**(4)**1, 8, 7, 18	(**4**) (19.0%)
2	Planning a solution pathway,	-Locate task in your mind -State formula -Provide alternative methods	**(7)**2,3,4,12,14,16,17	(**7**)(38.1%)
3	Using tools (formulae) and resources effectively and efficiently	-Insert values against variables -Draw diagram and sketches -Use given values to solve arithmetically	**(5),** 5, 6, 9,11,13	(**5**) (23.8%)
4	Monitoring and evaluating progress	-Creating a reasonable value for answer -figure out accelerated ways to solve the same problem - check for accuracy	**(4)**,10,15,19,20	(**4**)(19.0%)
		Total	20	20

iv. **Problem Solving Skills Scale (PSSS):** PSSS was self-developed by the researcher and it did go through a content validity process by experts specialized in Test and Measurement and lecturers from Babcock University. It was used with students' answer sheet for this study by matching up each skill alongside indicators with point scale showing the level at which skills were developed in the learner. The PSSS is a rubric and a multi-purpose scoring monitor for measuring students' skills (products) and enactments by the researcher to use before and after the treatment. This instrument works in various ways to improve student learning, and has many potentials in particular for digital natives and the generation of technology-based learners. Rubrics help to generate data that are valid for assessment (Wolf 2007). The main skills assessed were four; analyzing givens and constraints, planning a solution pathway, using tools (formulae) and resources effectively and efficiently, and monitoring and evaluating progress. Each facet of skills identified has three (3) or more indicators attached to it as shown in Appendix 6. The Problem Solving Skills' Scale (PSSS) was accompanied by a problem solving worksheet common to all the groups in Appendix 6.

The content validity was done as it was scrutinized and reviewed by two lecturers from the University of Ibadan and Babcock University respectively. The instrument was further subjected to a degree of reliability according to the rating scale indicators or criterion in order to determine the scot pie coefficient (Kappa). The final draft was administered to 28 students (13 males and 15 females) who did not participate in the main study. The Scot pie coefficient of 0.83 was obtained as the Kappa score.

v. Availability and Accessibility of Digital Gadgets Inventory (AADGI)

This is a self-developed inventory in three sub-divisions. The first sub-division inquired about information on bio-data, ownership and awareness of digital gadgets from the participants, while Section B consisted of 10 items on availability of digital gadgets to students. Students' mode of reactions to the items was the closed response mode on a four point Likert scale of Strongly Disagree (DA), Disagree (D), Agree (A), and Strongly Agree (SA). Section C comprised of five (5) items on accessibility of digital gadgets to students. Students' response approach to items remained the closed response mode on a four point Likert scale of: Often, Sometimes, Rare, and Never. This instrument measured and ascertained the level of availability and accessibility of ICTs/ digital gadgets meant to be majorly used by participants in experimental group I and II for their learning (study) as shown in Appendix 5.

The instrument was verified for face and content validity by two Computer Science lecturers from Babcock University. Experts in the field of education also assessed the instruments for appropriateness and ensured its content and face validity. The reliability of AADGI was administered to students in order to obtain a reliability coefficient index using Cronbach Alpha when administered to at least (28) twenty-eight students at Babcock University undergraduate program who would not be part of the participants in the main study. The value yielded 0.78.

The Instructor/Lecturer Instructional Package (I/LIP) comprised of:

i. **Simulated Video-Based Inverted Classroom Instructional Package (SVBICIP):** This was adapted from different simulations to form Simulated-video Lectures instructional package as prepared by the researcher to guide in the teaching-learning process for the first experimental group. The adaptation was necessary as the peculiarities of learners at this level were taken into cognizance. It was used to demystify the rigorous traditional (face-to-face) method of teaching-learning physics. It contained images, pictures, texts, sounds (audio made from an indigenous voice) and illustrations to help the students quickly grasp the contents of the lectures. The videos were in four modules in single delivery mode for students to freely share, download and watch at their convenience before the class time. There was also an immediate task performed by the students after watching clips of the video. The instructor based his/her discussions on the contents from the video as narrated by a student impelled them to corroborate one another's idea since they all participated in the class.

ii. **Virtual Laboratory Based Inverted Classroom Instructional Package (VLBICIP):** This is an alternative version of the practical class section adapted from http://phet.colorado.edu/ as the instructional package prepared for the second experimental group. The adaption became necessary because the researcher identified the need to customize the contents of the instrument to accommodate and reflect the peculiarities of Nigerian students' (learners') practical works at the A-level and pre-degree program. The Virtual Laboratory Based Inverted Classroom Instructional Package (VLBICIP) is a self–tutored learning package students engaged with individually and at their convenience.

The instructional package uses an interactive Java simulation interface which contains animations, sound, graphics and pictures all in three dimensions in a single delivery mode which can be viewed on individual students' personal computers, laptops, tablets, large screen phones and desktop computers as means of learning instructions at their pace and time in their hostels/homes. The VLBICIP contains two major modules. In one of them, students were expected to watch experimental procedures and the nitty-gritty of all the activities involved in the Virtual Laboratory as well as observe how questions were answered in accordance with the way students were expected to perform virtual experiments on their own in the second module.

iii. **Conventional Lecture Instructional Guide (CLIG):** CLIG was self-designed to facilitate the control group. Concepts/topic selected for the study were focused on contents (in notes and textbooks). Physics instructors (six research assistants) were trained and were involved in ensuring uniformity during the preparation of the contents of this instructional guide.

3.5.1 Reliability and Validity of Research Instruments

3.5.2 Reliability of Research Instruments

To ensure the reliability of the instruments that were used for this study, the right version of the validated instruments was administered to the set of students who had just concluded their pre-degree program and were aspiring to be freshmen in a university (100 Level) and as a result would not be part of the study. The Cronbach Alpha was used to establish reliability co-efficient of the instrument. The collated data on achievement test scores were subjected to internal consistency using Kuder-Richardson (KR 21) method while the Rubrics was subjected to Scot pie coefficient (Kappa).

3.5.3 Validity of Instruments

In establishing the validity of the instruments that were used for this study, a draft of the questionnaire; the prototype of the instructional packages and the test items were presented to the researcher's supervisor and other experts in the Educational Technology Unit, Department of Physics, Test and Measurement of the University of Ibadan, and lecturers at Babcock University Pre-degree School for an adequate assessment of contents and the validity of instruments. Remarks and suggestions from their assessment and validations were carefully examined and adapted for the appropriateness of the instruments' quality.

3.6 Research Procedures for the Study

Table 3.4: The work schedule summary

Week	Activities	Topic
1	Familiarising with the universities selected; to seek approval from authorities.	
2	Participant's selection	
3 and 4	Training of selected research assistants	
5	Administration of pretest	
6-13	Treatment; main treatment using the instructional packages on Simulated-Video lecture based inverted classroom and Virtual laboratory simulation based inverted classroom, and Control group.	Quantum, Photoelectric Effect, Photon, and Wave – Particle Duality
14	Administration of post-test across all groups	

3.6.1 Training Guide for Research Assistants

The third and fourth weeks of this study were designated for the training of the selected research assistants that participated in this study. This was to bridge all possible gaps in knowledge and competence across all groups. Also, this was to ensure their competencies in their randomly assigned groups. The training took place in their various institutions and had the following segments.

Segment 1: The general set up of the study and specific nature of each instructional strategy was explained to the research assistants especially as it concerned them. The advantage of the respective guide/package that was assigned to each research assistant was explained to them. This was to ensure that each of them would have the understanding that the guide/package assigned to them could achieve the best result if properly used.

Segment 2: The six research assistants were assigned to each instructional group (one per group). The general guideline to follow in conducting an inverted classroom session was explained to the participating research assistants. They were not expected to do the teaching per se in the contact classes; instead, they were supposed to be facilitators, lead the discussion sessions, guide students' contributions and their attempts to complete assignments. Each contact lesson activities for the eight weeks were carried out thoroughly by the participating research assistants. They avoided skiving, rate fixing and the use of negative reinforcements with the students; instead, they positively motivated the students and created an engaging active learning environment.

3.6.2 Administration of Pre-test

The instruments that were used for the pre-test are:

i. Attitude Towards Physics Questionnaire (ATPQ)
ii. Students' Achievement Test in Physics (SATP)
iii. Spatial Ability Test (SAT)
iv. Problem Solving Skills Scale (PSSS) accompanied by a problem solving worksheet.
v. Availability and Accessibility of Digital Gadgets Inventory (AADGI)

The procedure works for the two groups are represented in Table 3.5:

Table 3.5 Procedure of Work for the Experimental Groups

Procedure	Simulated-video Based Inverted Classroom Instructional Package (SVBICIP)	Virtual Laboratory Simulation Based Inverted Classroom Instructional Package (VLSBICIP)
Stage 1	The research assistants shared the videos through flash drives/ CDs or instructed students to download them from a particular youtube.com page. They also instructed them to go through the videos when they got to their hostels/homes.	The research assistants shared the virtual laboratory simulation through flash drives/ CDs or instructed the students to download them from a particular youtube.com page. They also asked them to go through them when they got to their hostels/homes.
Stage 2	In the contact group/class, the research assistants facilitated the class activities and also welcomed questions/answers from the students, based on the simulated-video lecture taken home. The research assistants then instruct students on the task for the day and guide the students on collaboration in problem-solving. The research assistants encouraged a high order-thinking and collaborative efforts leading to engagement in dealing with the task	In the contact group/class, the research assistants facilitated the class activities and then s/he answered questions from the students, based on the lecture from the virtual laboratory simulation taken from the homes/hostels. Then he/she instructed them on the tasks for the day and guided the students
Stage 3	The research assistants collected the students' findings and inspected them to solve problems as their assignments.	The research assistants collected the students' findings and inspected them to solve problem as their assignments.
Stage 4	In the following week, the research assistants shared the simulation-video lecture on flash drives/CDs or yotube.com to the participants at the end of the present contact class.	The research assistants distributed the virtual laboratory simulation on youtube.com/flash drives/ CDs, in the following week, to the participants at the end of the present contact class.

Table 3.6 Guidelines for Activities in the Simulated-Video Based Inverted Class and its Contact Class Sessions

WEEK	ACTIVITY		TOPIC/SUB-TOPICS
	SIMULATED-VIDEO BASED INVERTED CLASS	**CONTACT CLASS**	
1.	**Simulated-Video** lesson on Definition of Photon and Quantum were **viewed** and **studied** at home/hostel by the students	Discussions in the contact class were based on **identifying** effects of Photon and Quantum on Matter and **answering** questions on the Uses of Quantum, based on the reactions to the questions. Further deliberations on the Uses of Quantum and Photon, were done by students with the guidance of the research assistants	Definition of Photon and Quantum
2.	**Simulated-Video** based lesson on Quantum and Photoelectric Effects with relevant practical examples were **viewed manipulated and studied** at home/hostel by the students	Students were expected to **work** on their **worksheet** and **solve problems**, associated with Photoelectric Effects and Quantum. **Deliberations and Engagements** among students were done while discussing some prominent feats achieved by Albert Einstein in Physics	Photoelectric Effects with appropriate illustrations
3.	**Simulated-Video** based lesson on Photoelectric: Electron-volt, Threshold Frequency and Escape Velocity were **viewed and studied** at home by the students	Students were prepared to **give answers** to evidences supporting Photoelectric Effects using the Simulated-Video package as a guide	Photoelectric: Electron-Volt Threshold Frequency and Escape Velocity
4.	**Simulated-Video** based lesson on Wave Function and Quantum Theory with relevant examples were **viewed and studied** at home by the students	Students were made to **identify** the Wave Function of different metals. **Discussions** among students were also focused on the importance of each metal’s wave function.	Wave Function and Quantum Theory with different metals.
5.	The students **watched and studied Simulated-Video** based lessons on De-Broglie Wave Equation in their various homes/hostels	Students were prepared to **give illustrations** revealing the claims on the behaviour of matter using the Simulated-Video package as a guide	De-Broglie Wave equation

WEEK	ACTIVITY		TOPIC/SUB-TOPICS
	SIMULATED-VIDEO BASED INVERTED CLASS	**CONTACT CLASS**	
6.	**Simulated-Video** based lesson on Wave-Particle Duality: Description of Light as Wave were **viewed and studied** at home by the students.	Students were made to **answer questions** and **give evidences** supporting Light as a Wave using the Simulate-Video package as a guide	Wave-Particle Duality: Description of Light as Wave.
7.	**Simulated-Video** based lesson on Wave-Particle Duality: Description of Light as Particle were **viewed and studied** at home by the students.	Students were made to answer questions as they **experimented and observed** light particle in a dark room as test to view light particle in real live situations and using the Simulate-Video package as a guide	Wave-Particle Duality: Description of Light as Particles.
8.	**Simulated-Video** based lesson on Wave-Particle Duality were **viewed and studied** at home by the students.	Students were expected to **answer questions** posed by the lead discussant on Wave-Particle Duality based on instructions in the video, which would bring about **active learning** through **collaboration** using the Video package as a guide.	Wave-Particle Duality.

Table 3.7 Guidelines for Activities in the Virtual Laboratory Based Inverted Class and its Contact Class Sessions

WEEK	ACTIVITY		TOPIC/SUB-TOPICS
	Virtual laboratory Based Inverted Class	**CONTACT CLASS**	
1.	**Simulation on Virtual Laboratory** practice on demonstration of the experimental procedures involved were **viewed** and **studied** at home/hostel by the students	Discussion in contact class focused on the nitty-gritty of the experimental procedures as students were expected to **name** each of the **steps** involved	Introduction of Experimental Procedures on Quantum and Photoelectric Effects.
2.	**Virtual Laboratory** practice on Photon and Quantum was **practiced** and **studied** at home/hostel by the students	Dialogue in contact class was based on **identifying** Photon and Quanta and **answering** questions on the Uses of Quantum. Based on the reactions to the questions, further deliberations on the Uses of Quantum and Photon were done by students with the guidance of the research assistants	Definition/Demonstration of Photon and Quantum
3.	**Virtual Laboratory** based lesson on Photoelectric Effect and Wave Function with relevant examples from different metals were **practiced and studied** at home by the students	Students were prepared to **give answers** to evidences supporting Photoelectric Effects and Wave Function. **Discussions** were encouraged among students to promote **collaboration** under the guidance of the research assistants.	Photoelectric and Wave Function: Electron-Volt Threshold Frequency and Escape Velocity
4.	**Virtual Laboratory** based lesson on Quantum and Photoelectric Effects with relevant practical examples were **viewed, manipulated and practiced** at home/hostel by the students	Students were expected to **work** on their **worksheets** and **solve problems**, associated with Photoelectric Effects and Quantum. **Deliberations and Engagements** among students were also made to feature prominent feats achieved by Albert Einstein in Physics.	Photoelectric Effects with appropriate illustrations.

5.	**Virtual Laboratory** based lesson on Wave-Particle Duality: Description of Light as Wave were **viewed and practiced** at home by the students.	Students were made to **identify** the wave function of different metals. **Discussions** among students also focused on importance of each metal's wave function.	Wave function with different metals like Zinc, Copper, Platinum, Calcium and Soduim.
6.	**Virtual Laboratory** based lesson on Wave-Particle Duality was **viewed and studied** at home by the students.	Students were prepared to **give illustrations** revealing the claims on the behaviour of matter as guided by research assistants	De-Broglie Wave Equation.
7.	**Virtual Laboratory** based lesson on Graph of Current Vs. Battery Voltage will be **manipulated and practiced** at home by the students.	Students were to reveal their **observations** after **manipulating** the variables. **Discussions** among the students took place under the guidance of the research assistants	Measuring and plotting graph of Current Vs. Battery Voltage (Introduction of Wave-Particle Duality)
8.	**Virtual Laboratory** based lesson on Graph of Current Vs. Light Intensity and Electron Energy Vs. Light Frequency were **manipulated and practiced** at home by the students.	Students were expected to **answer questions** posed by lead discussants on their **observations** of the variable used in the experiment, which brought about **active learning** through **collaboration** under the guidance of the research assistants.	Further discussions on Wave-Particle Duality Evaluating and Plotting Graph; i. Current Vs. light Intensity ii. Electron Energy Vs. Light Frequency

Table 3.8 Guidelines for Activities in the Conventional Class and its Homework Activities

WEEK	ACTIVITY		TOPIC/SUB-TOPICS
	CONTACT CLASS	HOME WORK	
1.	The research assistant introduced and defined Photon and gave more explanations on Quantum Theory.	Students complete the assignments to define Photons and state Quantum Theory explanation using different authors as well as mention their relevance to technology and everyday life	Definition of Photon and Quantum Theory
2.	The research assistant stated and explained Photoelectric Effect as a concept with vivid illustrations	The research assistant instructed the students to read more on the concept and other examples based on the discussions in class. Students were asked to draw a diagram depicting a Photoelectric Effect experiment.	Photoelectric Effects with appropriate illustrations
3.	The research assistant defined and solved some calculations related to: Electron-Volt Threshold Frequency and Escape Velocity	The students complete the given assignment to calculate the values of these concepts in given problems. They stated how these concepts are related to the concept of Photoelectric Effects.	Photoelectric: Electron-Volt Threshold Frequency and Escape Velocity.
4.	The research assistant explained the Quantum Theory and the concept of Wave Function using different metals.	The research assistant instructed the students to find out the wave function of at least five different metals.	Wave Function and Quantum Theory with different metals.
5.	The research assistant marked students' assignments on Photoelectric Effects, Wave Function and corrected them where they had made mistakes, then, he/she explained De-Broglie Wave Equation	The research assistant instructed the students to read more on De-Broglie Wave Equation.	De-Broglie Wave Equation
6.	The research assistant explained the procedures involved when light behaves like a wave.	The students took instructions to answer questions based on the description of light as wave.	Wave-Particle Duality: Description of Light as Wave.

7.	The research assistant explained the procedures involved when light behaves like a particle	Students were expected to perform the experiment in a dark room showing light as particle. Students were expected to also read more on the evidences of light existing as particle	Wave-Particle Duality: Description of Light as Particles.
8.	The research assistant buttressed the duality of wave-particle nature and also explained the procedures involved in the tests for Wave- Particle Duality.	The students were instructed to read more on the tests for Wave-Particle Duality.	Wave-Particle Duality.

Treatment Stage

All research assistants involved were expected to replicate the dexterity of the experimental groups as indicated in instructional guides for one hour per week and treatment lasted for eight weeks. The researcher visited research locations to check research assistants' operations.

3.6.3 Administration of Post-test

i. At the thirteenth week of the treatment, there was the administration of the post-test instrument: Experimental group one (Simulated-Video Based Inverted Classroom Instructional Package), experimental group two (Virtual laboratory Simulation Based Inverted Classroom Instructional Package) and conventional lecture based (control) groups. The instruments that were administered for the posttest were: Attitude towards Physics Questionnaire (ATPQ), Students' Achievement Test in Physics (SATP), and Problem Solving Skills Scale (PSSS) which was accompanied by a problem solving worksheet common to all the groups. The post-test was conducted as it was done in the pre-test.

3.7 Methods of Data Analysis

Data collected were analyzed using inferential statistics involving computing Analysis of Covariance (ANCOVA) to test all stated null hypotheses, while the Bonferroni Pairwise Comparison was carried out to explain the sources and contributory variables responsible for the significant main effect in the study. To ascertain the size of the mean score across the groups, the Estimated Marginal Means (EMM) was used while effects graphical representations were also used to interpret relevant interactions.

CHAPTER FOUR

RESULTS AND DISCUSION OF FINDINGS

The results in this study are presented and discussed in this chapter in line with the formulated hypotheses.

4.1 Test of hypotheses

Hypothesis 1a: There is no significant main effect of treatment on pre-degree students' attitude towards Physics.

Table 4.1 Analysis of Covariance of Students' Posttest Attitude towards Physics by Treatment, Spatial Ability and Gender

Post Attitude						
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1834.466[a]	16	114.654	2.739	.001	.190
Intercept	9570.803	1	9570.803	228.635	.000	.550
Pre Attitude	10.256	1	10.256	.245	.621	.001
Treatment	308.292	2	154.146	3.682	.027*	.038
Spatial Ability	70.861	2	35.430	.846	.431	.009
Gender	24.140	1	24.140	.577	.449	.003
Treatment * SA	140.444	3	46.815	1.118	.343	.018
Treatment * Gender	1.614	2	.807	.019	.981	.000
SA * Gender	69.083	2	34.541	.825	.440	.009
Treatment * SA * Gender	48.801	3	16.267	.389	.761	.006
Error	7827.941	187	41.861			
Total	951463.000	204				
Corrected Total	9662.407	203				

a.R Squared = .190 (Adjusted R^2 = .121); SA= Spatial Ability

Table 4.1 revealed a significant main effect of the treatment on pre-degree students' attitude towards physics with an effect size of 3.8% [$F_{(2,187)} = 3.682$; $p < 0.05$; $(\eta_p^2) = 0.038$]. Thus, hypothesis 1a was rejected. In order to understand the magnitude of the posttest attitude mean scores of different treatment groups, the result of estimated marginal means of the treatment groups is presented in Table 4.2.

Table 4.2The Estimated Marginal Means of Physics Posttest Attitude According to Treatment

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Virtual Laboratory Strategy	66.151[a]	1.791	62.617	69.685
Simulated Video Strategy	71.418[a,b]	1.927	67.618	75.219
Conventional strategy (Control)	64.119[a]	1.731	60.704	67.535

a. Covariates appearing in the model are evaluated at the following values: PreAtt1 = 67.2794.

b. Based on modified population marginal mean.

The estimated marginal means Table 4.2 reveals that pre-degree students exposed to simulated video instruction had the highest posttest attitude mean scores ($\bar{x}$ = 71.418), followed by those exposed to virtual laboratory ($\bar{x}$ = 66.151) and the least posttest attitude mean score was obtained by the pre-degree students exposed to conventional instructional strategy.

Table 4.3 Bonferonni Pairwise Comparison of the Treatment Groups

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]	
					Lower Bound	Upper Bound
Virtual Laboratory	Simulated video	-5.268[a]	2.630	.140	-11.620	1.085
	Conventional (Control)	2.031	2.491	1.000	-3.985	8.048
Simulated video	Virtual Laboratory	5.268[b]	2.630	.140	-1.085	11.620
	Conventional (Control)	7.299[b,*]	2.590	.016	1.043	13.555
Conventional (Control)	Virtual Laboratory	-2.031	2.491	1.000	-8.048	3.985
	Simulated Video	-7.299[a,*]	2.590	.016	-13.555	-1.043

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. An estimate of the modified population marginal mean (J).

b. An estimate of the modified population marginal mean (I).

c. Adjustment for multiple comparisons: Bonferroni.

Table 4.3 shows that the posttest attitude mean score of the pre-degree students exposed to simulated video is significantly different from that of those in the control group but not significantly different from the posttest attitude mean score of the pre-degree students exposed to the virtual laboratory. On the other hand, the posttest attitude of the pre-degree students exposed to the conventional instructional strategy and the virtual laboratory are not significantly different. This result is largely due to the group's exposure to simulated video.

Hypothesis 1b: There is no significant main effect of treatment on pre-degree students' achievement in physics.

Table 4.4 ANCOVA of Achievement by Treatment, Spatial Ability and Gender

Post-Achievement						
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2138.346[a]	16	133.647	33.889	.000	.744
Intercept	1645.695	1	1645.695	417.301	.000	.691
Pre-achievement	2.339	1	2.339	.593	.442	.003
Treatment	347.504	2	173.752	44.058	.000*	.320
Spatial Ability	7.462	2	3.731	.946	.390	.010
Gender	12.666	1	12.666	3.212	.075	.017
Treatment * SA	22.953	3	7.651	1.940	.125	.030
Treatment * Gender	24.417	2	12.208	3.096	.048*	.032
SA * Gender	30.339	2	15.169	3.847	.023*	.040
Treatment * SA * Gender	21.444	3	7.148	1.813	.146	.028
Error	737.466	187	3.944			
Total	40508.438	204				
Corrected Total	2875.812	203				

a. R Squared = .744 (Adjusted R Squared = .722) * Denote significant difference at 0.05 level of significance.

Table 4.4 revealed a significant main effect of the treatment on pre-degree student's achievement in physics with a large effect size of 32% [$F_{(2,187)} = 44.058$; $p < 0.05$; (η_p^2) = 0.32]. Thus, hypothesis 1b was rejected. In order to understand the magnitude of the posttest achievement mean scores of different treatment groups, the estimated marginal means of the treatment groups was calculated to give the result presented in Table 4.5.

Table 4.5 Estimated Marginal Means of Physics Posttest Achievement According to Treatment Post Achievement

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Virtual laboratory Strategy	16.345[a]	.550	15.260	17.431
Simulated video Strategy	14.003[a,b]	.591	12.836	15.169
Conventional Strategy (Control)	9.361[a]	.532	8.312	10.411

a. Covariates appearing in the model are evaluated at the following values: Pre-Achievement = 9.0245.

b. Based on modified population marginal mean

The estimated marginal means in Table 4.5 shows that the pre-degree students exposed to simulated video instruction had the highest posttest achievement mean score in physics ($\bar{x}$ = 16.345), followed by those exposed to the virtual laboratory ($\bar{x}$ =14.003) and the least posttest achievement mean score was obtained by the pre-degree students exposed to the conventional instructional strategy ($\bar{x}$ = 9.361).

Table 4.6 highlights a significant difference in the posttest physics achievement mean score of the pre-degree students that were given the simulated video across control group and the posttest achievement mean score of the pre-degree students exposed to the virtual laboratory. Similarly, the posttest physics achievement mean scores of the pre-degree students exposed to the virtual laboratory is significantly different from that of those in the conventional instructional strategy. This result is largely due to the group exposed to simulated video and virtual laboratory respectively.

Hypothesis 1c: There is no significant main effect of treatment on the students' problem solving skills in physics.

Table 4.6 Analysis of Covariance of Problem Solving Skills by Treatment, Spatial Ability and Gender
Post-Problem Solving Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3944.887[a]	16	246.555	5.655	.000	.326
Intercept	899.391	1	899.391	20.630	.000	.099
Pre Problem solving skills	102.035	1	102.035	2.340	.128	.012
Treatment	437.167	2	218.583	5.014	.008*	.051
Spatial Ability	61.392	2	30.696	.704	.496	.007
Gender	81.302	1	81.302	1.865	.174	.010
Treatment * SA	316.353	3	105.451	2.419	.068	.037
Treatment * Gender	17.045	2	8.523	.195	.823	.002
SA * Gender	54.774	2	27.387	.628	.535	.007
Treatment * SA * Gender	19.081	3	6.360	.146	.932	.002
Error	8152.447	187	43.596			
Total	113848.000	204				
Corrected Total	12097.333	203				

a. R^2 = .326 (Adjusted R^2 = .268)

Table 4.6 reveals that the treatment had a significant main effect on the pre-degree students' problem solving skills in physics with an effect size of 5.1% [$F_{(2,187)} = 5.014$; $p < 0.05$; (η_p^2) = 0.051]. Thus, hypothesis 1c was not accepted. In order to understand the magnitude of the posttest physics problem solving skills mean scores of different treatment groups, the estimated marginal means of treatment groups is presented in Table 4.7.

Table 4.7 The Estimated Marginal Means of Posttest Physics Problem Solving Skills According to Treatment

Post-Problem Solving skills

Treatment	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Virtual laboratory strategy	25.234[a]	1.944	21.398	29.070
Simulated video strategy	16.848[a, b]	1.968	12.964	20.731
Conventional strategy (control)	19.134[a]	2.040	15.110	23.157

a. Covariates evaluated at the following values: Pre-Problem Solving skills = 13.5821

b. Based on modified population marginal mean.

The estimated marginal mean in Table 4.7 shows that the pre-degree students exposed to the virtual laboratory instructional strategy had the highest posttest physics problem solving skills mean scores ($\bar{x}$ = 25.234), followed by those exposed to the conventional teaching strategy ($\bar{x}$ =19.134) and the least posttest physics problem solving skills mean score was obtained by the pre-degree students exposed to simulated video instructional strategy ($\bar{x}$ = 16.848).

Table 4.8 Bonferonni Pairwise Comparison of the Treatment Groups

Post-Problem Solving Skills

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]	
					Lower Bound	Upper Bound
Virtual Laboratory	Simulated video	8.386[*,b]	2.741	.008	1.764	15.009
	Conventional(control)	6.100	3.049	.141	-1.266	13.466
Simulated Video	Virtual laboratory	-8.386[*,c]	2.741	.008	-15.009	-1.764
	Conventional(control)	-2.286[c]	2.872	1.000	-9.224	4.652
Conventional (Control)	Virtual laboratory	- 6.100	3.049	.141	-13.466	1.266
	Simulated video	2.286[b]	2.872	1.000	-4.652	9.224

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. An estimate of the modified population marginal mean (J).

c. An estimate of the modified population marginal mean (I).

d. Adjustment for multiple comparisons: Bonferroni.

Table 4.8 shows that the posttest physics problem solving skills mean score of the pre-degree students exposed to the virtual laboratory is not significantly different from that of those in the control group but significantly different from the posttest physics problem solving skills mean score of the pre-degree students exposed to the simulated video. On the other hand, the physics problem solving skills mean score of the pre-degree students exposed to the conventional instructional strategy and the virtual laboratory are not significantly different. Hence, the significant main effect of treatment on the pre-degree students' posttest physics problem solving skills mean score is largely due to the group exposed to the virtual laboratory and the conventional teaching strategies respectively.

Hypothesis 2a: There is no significant main effect of the spatial ability on the pre-degree physics students' attitude towards physics.

From Table 4.1 shows that the main effect of students' spatial ability on the pre-degree physics students' attitude towards physics was not significant [$F_{(2,187)} = 0.846$; $p>0.05$]. Hence, hypothesis 2a was accepted. Therefore, the spatial ability has no significant main effect on attitude towards physics.

Hypothesis 2b: There is no significant main effect of the spatial ability of the pre-degree physics students on their achievement in physics.

From Table 4.4 the main effect of students' spatial ability on the pre-degree physics students' achievement in physics was not significant [$F_{(2,187)} =0.949$; $p>0.05$]. Hence, hypothesis 2b was retained.

Hypothesis 2c: There is no significant main effect of the spatial ability on the pre-degree physics students' problem solving skills in physics.

Table 4.7 shows that the main effect of students' spatial ability on the pre-degree physics students' problem solving skills was not significant [$F_{(2,187)} = 0.704$; $p>0.05$]. Hence, hypothesis 2c was accepted. Therefore, the spatial ability has no significant main effect on the students' problem solving skills.

Hypothesis 3a: There is no significant main effect of gender on the pre-degree physics students' attitude towards physics.

From Table 4.1 the main effect of gender on the attitude of pre-degree physics students towards physics was not significant [$F_{(1,187)} = 0.577$; $p>0.05$]. Hence, hypothesis 3a was accepted. Therefore, gender has no significant main effect on attitude towards physics.

Hypothesis 3b: There is no significant main effect of gender on the pre-degree physics students' achievement in physics.

From the result in Table 4.4 the main effect of gender on the pre-degree physics students' achievement in physics was not significant [$F_{(1,187)} = 3.212$; $p>0.05$]. Hence, hypothesis 3b was retained.

Hypothesis 3c: There is no significant main effect of gender on the pre-degree students' physics problem solving skills.

Table 4.7 shows that the main effect of gender on the pre-degree physics students' problem solving skills was not significant [$F_{(1,187)} =1.865$; $p>0.05$]. Hence, hypothesis 3c was accepted.

Hypothesis 4a: There is no significant interaction effect of treatment and spatial ability on the pre-degree physics students' attitude towards physics.

From Table 4.1 it is evident that the interaction effect of treatment and the students' spatial ability on the pre-degree physics students' attitude towards physics was not significant [$F_{(3,187)} =1.118$; $p>0.05$]. Hence, hypothesis 4a was retained. Therefore, the main effect of treatment on students' attitude to physics was not sensitive to the spatial ability of the pre-degree students.

Hypothesis 4b: There is no significant interaction effect of treatment and spatial ability on the pre-degree physics students' achievement in physics.

From the result in Table 4.4, interaction effect of treatment and students' spatial ability on the pre-degree physics students' attitude towards physics was not significant [$F_{(3,187)} = 1.94$; $p>0.05$]. Hence, hypothesis 4b was retained. Therefore, the main effect of treatment on students' achievement in physics is not sensitive to the spatial ability of the pre-degree students.

Hypothesis 4c: There is no significant interaction effect of treatment and spatial ability on the pre-degree students' physics problem solving skills.

It is evident from Table 4.7 that interaction effect of treatment and students' spatial ability on the pre-degree physics problem solving skills was not significant [$F_{(3,187)} = 2.419$; $p>0.05$]. Hence, hypothesis 4c was retained. Therefore, the main effect of treatment on students' physics problem solving skills was not sensitive to the spatial ability of the pre-degree students.

Hypothesis 5a: There is no significant interaction effect of treatment and gender on pre-degree physics students' attitude towards physics.

Table 4.1 shows that an interaction effect of treatment and gender on the pre-degree physics students' attitude towards the subject was not significant [$F_{(2,187)} = 0.019$; $p>0.05$]. Hence, hypothesis 5a was retained. Therefore, the main effect of treatment on students' attitude to physics was not sensitive to the gender of the pre-degree students.

Hypothesis 5b: There is no significant interaction effect of treatment and gender on pre-degree physics students' achievement in physics.

Table 4.4 shows that the interaction effect of treatment and gender on the pre-degree physics students' achievement in physics, with an effect size of 3.2%, was significant [$F_{(2,187)} = 3.096$; $p<0.05$; (η_p^2) $=0.032$]. Hypothesis 5b was rejected. Therefore, the main effect of treatment on students' achievements in physics is sensitive to the gender of the pre-degree students. In order to understand the direction of the interaction effect the result of estimated marginal means of the treatment groups is presented in Table 4.10.

Table 4.9 Estimated Marginal Means of Posttest Achievement according to Treatment and Gender

Post Achievement					
				95% Confidence Interval	
Treatment	Gender	Mean	Std. Error	Lower Bound	Upper Bound
Virtual Laboratory	Male	16.018[a]	.945	14.153	17.883
	Female	16.673[a]	.564	15.560	17.785
Simulated Video	Male	12.475[a,b]	1.013	10.476	14.474
	Female	15.531[a,b]	.614	14.319	16.743
Conventional (control)	Male	9.336[a]	.780	7.796	10.875
	Female	9.387[a]	.723	7.961	10.812

a. Covariates are evaluated at the following values: PreAchievement = 9.0245.

b. Based on modified population marginal mean.

Table 4.9 showed that the interaction effect favours the female pre-degree students in the virtual laboratory instructional strategy group ($\bar{x}$ =16.673) and simulated video instructional group ($\bar{x}$ =15.531) compared to their male counterparts ($\bar{x}$ =16.08) and ($\bar{x}$ =12.475) in their respective treatment groups.

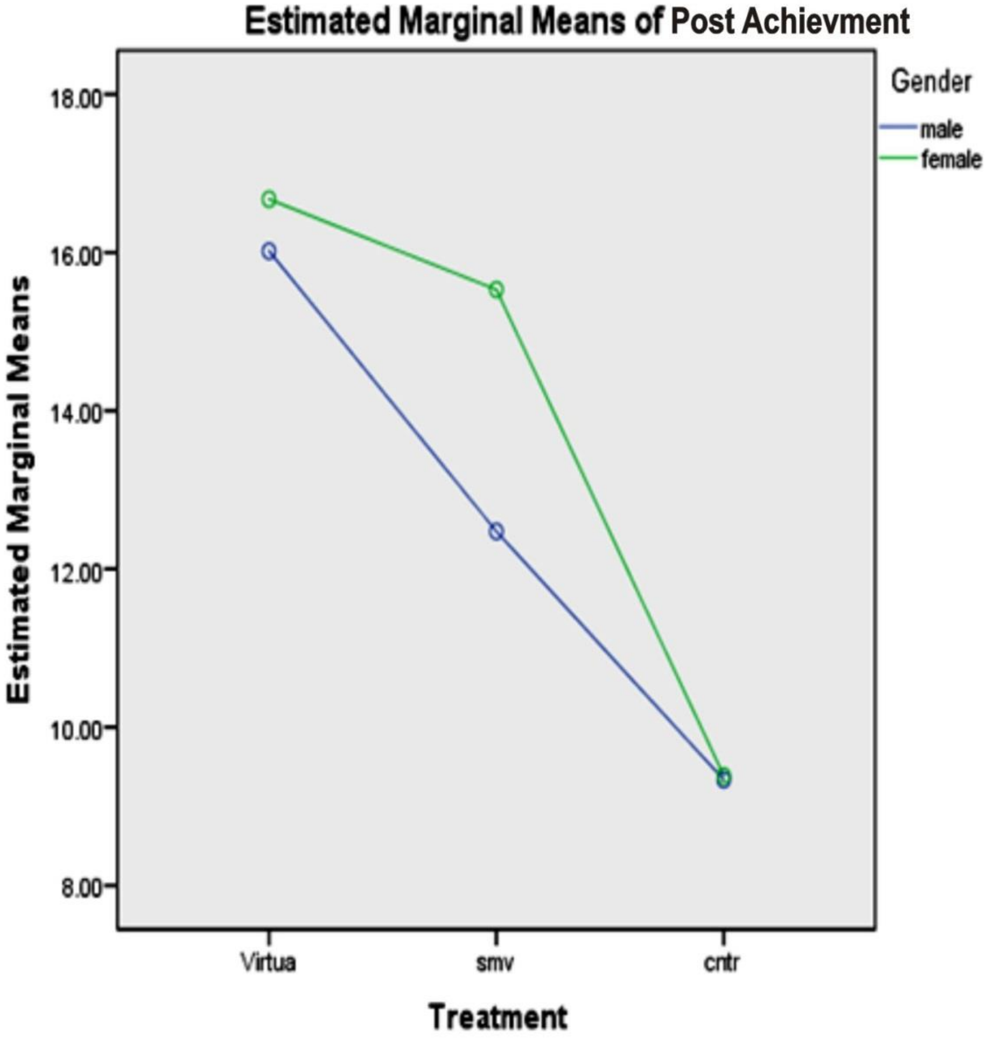

Figure 4.1: Graph Showing Treatment, Gender with Achievement and their Interaction Effect

The details in Figure 4.1 show that the interaction effect was ordinal across all the three groups as the females were ahead of their males' counterparts. It can be deduced that female students exposed to a virtual laboratory as well as female students exposed to simulated video benefited more when compared with the males.

Hypothesis 5c: There is no significant interaction effect of treatment and gender on pre-degree students' physics problem solving skills.

Table 4.7 shows that interaction effect of treatment and gender on the pre-degree physics students' problem solving skills was not significant [$F_{(2,187)} = 0.195$; $p>0.05$]. Owing to this, hypothesis 5a was accepted. Therefore, the main effect of treatment on students' physics problem solving skills is not sensitive to the gender of the pre-degree students.

Hypothesis 6a: There is no significant interaction effect of spatial ability and gender on the pre-degree physics students' attitude towards physics.

Table 4.1 shows that the interaction effect of spatial ability and gender on the pre-degree physics students' attitude towards physics was not significant [$F_{(2,187)} = 0.825$; $p>0.05$]. As a result, hypothesis 6a was accepted.

Hypothesis 6b: There is no significant interaction effect of spatial ability and gender on pre-degree physics students' achievement in the subject.

Table 4.4 shows that interaction effect of spatial ability and gender on the pre-degree physic students' achievement was significant [$F_{(2,187)} = 3.847$; $p<0.05$, (η_p^2) =0.040]. As a result, hypothesis 6b was retained. In order to fully comprehend the direction of the interaction effect, the result of the estimated marginal means of the treatment groups is presented in Table 4.10.

Table 4.10 Estimated Marginal Means of Posttest Achievement According to Spatial Ability and Gender

Post-Achievement					
				95% Confidence Interval	
Spatial Ability	Gender	Mean	Std. Error	Lower Bound	Upper Bound
Low	Male	11.499[a, b]	1.404	8.729	14.269
	Female	12.999[a, b]	1.216	10.600	15.398
Medium	Male	12.050[a]	1.012	10.053	14.047
	Female	14.348[a]	.554	13.255	15.441
High	Male	13.954[a]	.230	13.500	14.408
	Female	13.399[a]	.207	12.990	13.808

a. Covariates are evaluated at the following values: PreAchievement = 9.0245.
b. Based on modified population marginal mean.

Table 4.10 reveals that females with low ($\bar{x}$ = 12.99), medium ($\bar{x}$ = 14.348) spatial ability were better than their male counterparts ($\bar{x}$ = 11.499) and ($\bar{x}$ = 12.050) respectively, in the posttest achievement in physics. While the males with high spatial ability ($\bar{x}$ = 13.954) had a higher posttest achievement in physics than the female pre-degree students ($\bar{x}$ = 13.399).

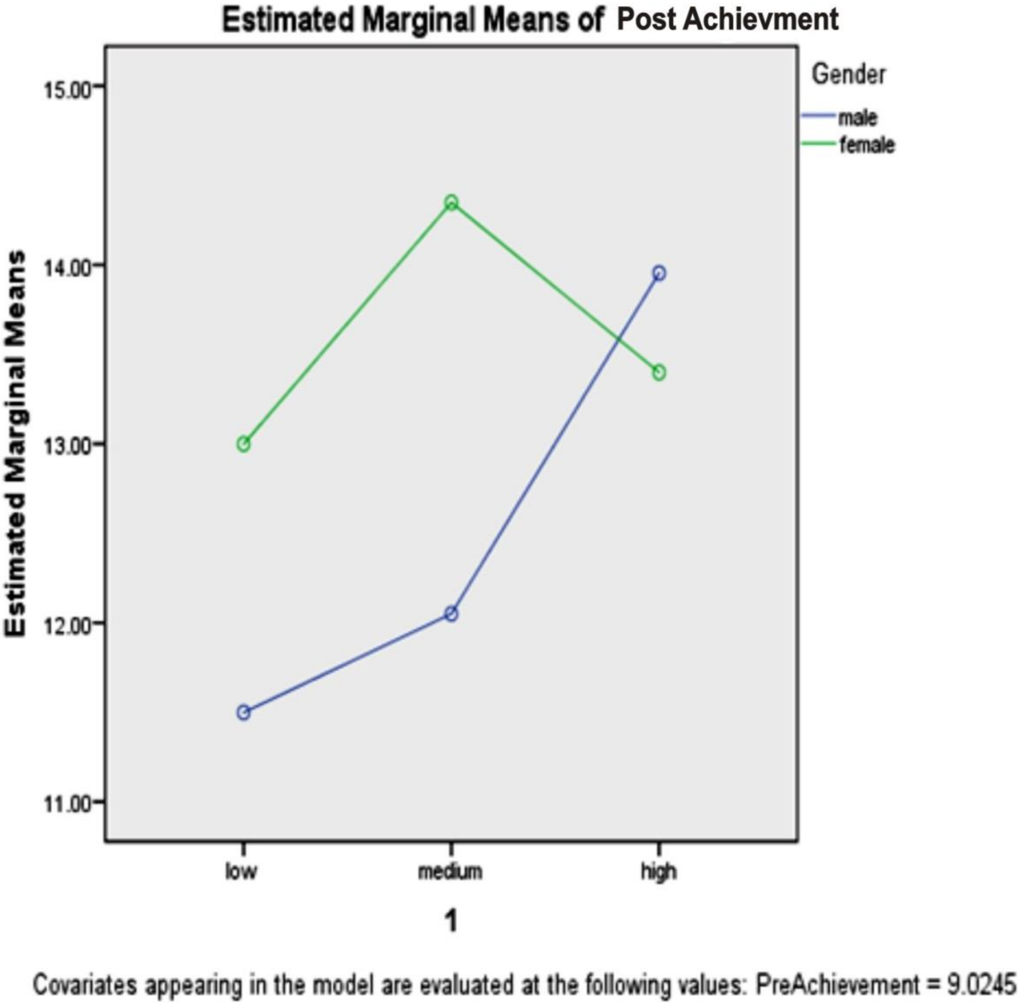

Figure 4.2: Graph of the Interaction Effect of Spatial Ability with Achievement

Figure 4.2 shows the interaction effect is disordinal. Spatial ability interacted disordinaly with gender such that females with low and medium spatial abilities were found to do better in terms of their achievements in physics compared to their male counterparts. On the other hand, males with high spatial ability were better than females in terms of their posttest achievement in physics.

Hypothesis 6c: There is no significant interaction effect of spatial ability and gender on pre-degree students' physics problem solving skills.

Table 4.7 shows that interaction effect of spatial ability and gender on the pre-degree physics problem solving skills was not significant [$F_{(2,187)} = 0.628$; $p > 0.05$]. As a result, hypothesis 6c was accepted.

Hypothesis 7a: There is no significant interaction effect of treatment, spatial ability and gender on pre-degree physics students' attitude towards the subject.

Table 1 shows that the interaction effect of treatment, spatial ability and gender on the pre-degree physics students' attitude towards physics was not significant [$F_{(3,187)} = 0.389$; $p > 0.05$]. Thus, hypothesis Ho7a was accepted.

Hypothesis 7b: There is no significant interaction effect of treatment, spatial ability and gender on pre-degree physics students' achievement in physics

Table 4.4 shows that the interaction effect of treatment, spatial ability and gender on the pre-degree physics students' achievement in physics was not significant [$F_{(3,187)} = 1.813$; $p < 0.05$]. As a result, hypothesis 7b was retained.

Hypothesis 7c: There is no significant interaction effect of treatment, spatial ability and gender on pre-degree students' physics problem solving skills.

Table 4.7 shows that the interaction effect of treatment, spatial ability and gender on the pre-degree students' physics problem solving skills was not significant [$F_{(3,187)} = 0.146$; $p > 0.05$]. As a result, hypothesis 7c is not rejected.

4.2 Summary of Results

Table 4.11 Tabular Presentation of Summary of Results

Significant status	Variables	Variables	Variables
Significant main effect of treatment on	1. The students' attitude towards physics	2. The students' achievement in physics	3. Students' problem solving skills in physics
No significant main effect of treatment on	4. Spatial ability on the students' attitude towards physics, achievement in physics as well as their problem solving skills in physics	5. Treatment (instructional strategies) and gender on students' attitude towards physics and problem solving skills in physics	6. Treatment and level of spatial ability on students' attitude and their problem solving skills in physics.
No significant interaction effect occurred	7. Treatment (instructional strategies) and gender on students' attitude towards problem solving skills in physics	9. Spatial ability level and gender on students' attitude towards and problem solving skills in physics	
significant interaction effect	8. Treatment (instructional strategies) and gender on students' achievement in physics	10. Spatial ability level and gender on students' achievement in physics	
No 3-way interaction effect	11. Treatment (instructional strategies), gender and level of spatial ability on the students' attitude towards, achievement and problem solving skills in physics		

4.3 Discussion of Findings

4.3.1 Main Effect of Treatment on Attitude, Achievement and Problem Solving Skills in Physics

The findings of this study indicated that the main effect of treatment (instructional strategies) on the pre-degree students' attitude towards physics was significant and this main effect is largely due to the posttest attitude of the pre-degree students exposed to the simulated video instructional strategy. This is possibly as a result of the students demonstrating more excitement after viewing the videos whose visual contents tapped into the visceral psyche of the learner, as well as the graphic imageries in motion and audio contents which may have aroused their interest and exhilaration while learning with simulated video. The strategy also gives room for critical thinking, engagement, interactions and reflections among the students, as it creates a curiosity that leverages between what the learners know and what they want to know thereby compelling them to take actions and have deep reflections on the subject matter.

This finding supports Piaget's Cognitive Constructivism Theory which further explains that the mechanism of learning is the relationship between mental process (perception, memory, attitude and decision-making) and social behaviour suggesting that students are active learners who possess internal impulses and display a specific pattern of development. Hence, students have the ability to construct their own world and a sense of reality that is capable of adapting to whatever environment they find themselves in as its leads them to a change in attitude. This corroborates the findings in previous studies; Gbadamosi (2017); Oyekola (2017); Vlachopoulos and Makri (2017); Adedoja (2016); Chen,Wang, Kinshuk and Chen (2014); Aremu et al 2013, Jenset (2011), and Hodgood et al 2010 that when simulated-videos are used in any active learning process including inverted classrooms, there are positive changes in the attitudes of the learners towards their studies. Another reason for the effectiveness of the strategy is that most students in this age group are digital natives and interaction with ICTs gadgets is already a part of their everyday life activities. Furthermore, the students' access to and engagement with these technological tools brings about excitements in any learning situation where inverted or flipped classroom strategy is involved, a contradiction to the boredom which is usually experienced by the students exposed and limited to the conventional strategy. Also, the findings of this study are in accordance with those of Oyekola (2017) and Akingbemisilu (2016), who found out that flipped classroom strategy has a significant main effect on students' attitude.

Similarly, the main effect of treatment (instructional strategies) on pre-degree students' achievement in physics was found to be significant, this is largely due to the group exposed to the virtual laboratory and the simulated video respectively. This suggests that no matter the modification or mode of inverted classroom instruction, simulated video has a positive effect on the pre-degree students' achievements in physics. More importantly, the nature of the concepts presented through the videos, such as Photoelectric Effect and Wave-Particle Duality, and the mode of presentation reduced or minimized the abstractness associated with concepts. This finding lends credence to Piaget Constructivist Theory whose idea of knowledge is that which comprises of symbolic mental representation, such as propositions and images (either graphic imageries in motion likened to video or still images), with a mechanism that operates on those representation as knowledge is actively constructed. When students are exposed to such knowledge contents (in form of videos) and they make personal interpretations which lead to an increase in their learning outcomes and overall achievements.

The result agrees with the findings by Adedoja (2016); Akingbemisilu (2016); Flaherty and Philips (2015); Gladys (2015); Aremu and Obideyi (2014); and the observed impact may be traced to the student's interaction with simulations or videos and discussion with peers. In a situation like this, students are motivated to get more engaged in learning activities through which they develop more interest and become more active learners. This finding is in line with Stacey-Roshan (2011) who observed that using the inverted/flipped class leads to an improvement in students' performances and highlighted that flipping the class room was not about creating more work for the students, but changing the classroom experience and the type of work that the students do at home. This finding however contradicts the result of Kim et al. (2014) which reported that there was no evidence that flipped learning had improved students' grades.

Also, the findings of this study revealed that the main effect of treatment (instructional strategies) on the pre-degree students' problem solving skills in physics was significant, and this is largely due to the different types of treatment given to the group exposed to virtual laboratory and conventional teaching strategies respectively. And it can be inferred that the hands-on activities may have increased the dexterity of the students involved in the experimental practice using a virtual laboratory strategy, whereas in the conventional strategy students are already accustomed to the normal drill and practice and as such have no significant improvement in their learning competence. This finding supports the view of Ivan and Avraham (2018) who found out that the virtual simulation-based training and flipped classroom methodology practically bring about improvement in results. The virtual laboratory is ahead of the conventional strategy because it has been established that the lecturer spent more time in problem solving in the flipped classroom situation.

This finding supports the principles of a typical Vygotskian classroom in which dynamic support and considerations are given to meeting the learner's needs without any form of coercion. In the Vygotskian classroom students are encouraged to discuss, collaborate, and share electronic information resources. Also, the inverted classroom strategy involves the same process of discussion, interaction, collaboration and problem solving. This is in agreement with the findings of Merino et al. (2017) who studied an alternative journey towards flipping the classroom through Self-Regulated Learning (SRL) skills. The research results suggested that role-modelling SRL strategies and skills in an active learning environment (flipped classroom) helps student to take responsibility for their own learning and leads to positive academic outcomes including improved problem solving skills. It is acknowledged that students seem to battle with breaking down and solving practice questions in bits, they instead attempt the entire problem at once thereby encountering more complexities in the problem-solving process.

On the other hand, Osman et al. (2014) found out that lecturers deployed more commitments to problem solving in the flipped class. This is probably as a result of the fact that learners' lower cognitive skills (knowledge and comprehension) are employed outside the classroom whereas the higher level cognitive skills (application, analysis, synthesis and evaluation) in form of actions are concluded in the classroom through problem solving, discussions and collaborations in the flipped classroom strategy, thus, improving their problem solving skills.

4.3.2 Main Effect of Spatial Ability on Attitude to, Achievement in and Problem Solving Skills in Physics

The main effect of students' spatial ability on the pre-degree physics students' attitude towards the subject does not have any significant effect. The obvious reason for the negative attitude may be attributed to a heavy demand on the spatial working memory (the ability to accurately respond to a series of targets appearing in random locations) leading to less interest and engagement in activities in the classroom. Students with a high spatial ability do not have much motivation and they participate less in school engagements. This is attributed to the presence of oral and mathematical orientations in the curriculum (Webb, lublnski and Benbow 2007). This finding however differs from that of Olaitan (2017); Bolen (2011); Sorby et al 2006; Huk, Steinke and Floto (2003); Kozhevnikov, Hegarty and Mayer (2002); Hegarty and Sims (1995) who reported that spatial ability has a strong contribution to motivation and attitude.

Also, the findings of this study indicated that the main effect of students' spatial ability on the pre-degree physics students' achievement in physics is not significant. The simple explanation for this may be that students' individual drive could affect an initial deficiency in spatial skills as an external factor. This finding leads credence to Liner (2012) who reported that there is no statistical correlation between spatial ability and achievements in physics. This finding contradicts Olaitan (2017); Webb, Lubinski and Benbow (2007); Stieff and Willensky (2003); Shea, Lubinski and Benbow (2001); Wu et al. (2001) who observed that spatial ability significantly contributed to the students' achievements. Also, the finding is contrary to Pellrand and Seeber (1984) who reported that spatial ability significantly causes an increase in students' achievements in physics. Bolen (2011) also reaffirmed that spatial ability is a major predictor of academic performance in the sciences.

Likewise, the main effect of spatial ability on the pre-degree physics students' problem solving skills in physics was not significant. This finding differs from Kozhevnikov et al. (2009); Hegarty et al. (2006); Kozhevnikov and Thornton (2006) who found out that there is a relationship between a measure of spatial visualization ability and mechanics of problem solving. This is probably as a result of the nature of the problem solving technique which does not require the skill of arranging things in space which can impede the mastery of its component thereby resulting in the absence of problem solving skills. Based on the findings of this study, it can deduced that the noticeable improvements in students' attitude towards, achievement in and problem solving skills in physics was not due to the spatial ability.

4.3.3 Gender Main Effect on Attitude to, Achievement in and Problem Solving Skills in Physics.

The results from this study revealed that gender has no significant main effect on the attitude towards physics. This suggests that all the instructional strategies had the same effect on the pre-degree physics students, despite gender biases. The implication of this is that the instructional strategies are appropriate to both genders as it shows no biases to either the males or females. This may be explained by the notion that access to technological tools within the home and at school has a reasonable influence on students' attitudes towards technology

This is in accordance with Usman (2004); Morakinwa (2003); Nzewi (2003); Fenstermacher (1996) who showed a similar result that the attitude of students is not affected by their gender. Also, the result of this study is similar to Akingbemisilu (2016) which shows that the main effect of gender on students' attitude to biology was not significant. The bias of this study is physics. This denotes that there is no significant advantage in being a male or a female in relation to the attitude and achievements of students learning physics, when these strategies are used.

Another finding of this study indicated that the main effect of gender on achievement is not significant. This finding is in line with Adedoja and Fakokunde, (2015); Efuwape and Aremu (2013). Also, the findings of Alao and Abubakar (2010) which focused on gender enrolment gap and the academic performance of college physics students revealed that there was no statistically significant difference in the academic performance of female and male students. On the other hand, this contradicts Illiya (2007) which noted that girls were not achieving as much as they should in physics compared to the boys, as a result of the strategy used in teaching them.

The findings of this study showed that there is no significant main effect of gender on the pre-degree physics students' problem solving skills. This finding contradicts the findings of Apata (2011); Ogunkunle (2007); Anagbogu and Ezeliora (2007); Adegboye (2007); Salam (2004); Aiyedun (2000); Nworgu (1988) and Daramola (1983) which show that males perform better than females in any numerical proficient skills or problem solving skills, given that all the learners possess a level of dexterity or cognitive ability which invariably defines the problem solving skills. Furthermore, they all have an equal learning opportunity and ability to use their skills to solve problems numerically thus, yielding a better learning outcome.

4.3.4 Treatment and Spatial Ability Interaction Effect on Attitude to, Achievement in and Problem Solving Skills in Physics.

The treatment's (instructional strategies) main interaction effect on students' attitude to physics is not linked to the spatial ability of the pre-degree students. It can be inferred that irrespective of the treatment used with students of varying spatial abilities, the students' attitude towards physics is not affected. This is in line with Braukmann and Pedras (1993) who showed that spatial activities do not necessarily bring about an increase in spatial ability since the same experience is recorded in the conventional method of teaching. This implies that the relationship between the students and the instructional materials during the learning activities will encourage cognitive and emotional engagements resulting in a change in the behaviour (attitude) of the students. The implication is that pre-degree students' attitude to physics is only dependent on the teaching strategy deployed and not their spatial ability. This contradicts the findings of Alias, Black and Gray (2002); Sorby and Baartmans (1996a) whose views are that students improved greatly in any spatial visualization when exposed to diverse spatial activities like those found in simulation based inverted classrooms. Also, this is not in line with the research carried out by Fennell and Rowan (2001), who worked on "Representation" as an important process for teaching and learning mathematics and found out that using representations whether drawings, mental images, concrete materials, or equations—helps students organize their thoughts and try various approaches that may lead to them having a clearer understanding and a solution to their problems.

Also, the findings of this study indicate that the treatments' (instructional strategies) interaction effect on students' achievements in physics is not linked to the spatial ability of the pre-degree students. This is not in line with the finding of Zavotka (1987) who is of the view that spatial ability and inverted classroom contributes to students' learning outcomes. In this current study, the interaction effect of treatment (instructional strategies) on the students' physics problem solving skills is not linked to the spatial ability of the pre-degree students. Based on this finding, the treatment (instructional strategies) combined with spatial ability does not contribute significantly to students' attitude, achievement and problem solving skills thereby contradicting the findings of Alias, Black and Gray (2002) who found that the flipped classroom with spatial ability has significant difference on students' learning outcomes.

4.3.5 Treatment and Gender, their Interaction Effect on Attitude to, Achievement in and Problem Solving Skills in Physics.

The findings of this study showed that the interaction effect of treatment (instructional strategies) on students' attitude towards physics is not linked to the gender of the pre-degree students. This implies that treatment (instructional strategies) combined with gender has not contributed to the students' attitude towards physics thereby negating the findings of Abimbade (2015); Gross, Pietri and Anderson (2015) who found out an increase in pre-class preparation (attitude) of students.

The findings of this study showed that the interaction effect of treatment on students' achievement in physics was linked to the gender of the pre-degree physics students. This implies that the interaction effect was ordinal across all the three groups as the females were ahead of males. The simple explanation for this may be innate ability females have to multi-task aided by the strategy employed which involves the use of digital technologies in the teaching-learning process. This has bridged the gender gap of females feeling inadequate in physics classroom thus eliminating the tendency of underrating their knowledge of physics and problem solving ability. This is supported by Aremu and Fasan (2011); Overmyer (2007) who opined that the inverted classroom has vital implications for the gender imbalance reported among students. However, this finding contradicts Chen,Yang and Hsiao (2015), that males did better compared to the females in an inverted classroom setting. The findings of this study showed that the interaction effect of treatment (instructional strategies) on students' physics problem solving skills is not linked to the gender of the pre-degree students. This implies that the treatment used is suitable for physics problem solving skills for both male and female students without any bias.

4.3.6 Spatial Ability and Gender, their Interaction Effect on Attitude to, Achievement in and Problem Solving Skills in Physics.

The findings of this study showed that the interaction effect of spatial ability and gender on the students' attitude towards physics was not significant. This implies that the gender of the learners did not influence their spatial ability, whether positively or negatively, with regards to an improved attitude towards physics. Thus, the interaction effect of spatial ability and gender on students' achievement in physics is significant. Spatial ability interacted disordinaly with gender such that females with low and medium spatial abilities were found to be better in terms of their achievements in physics compared to their male counterparts. This implies that the colourful illustrations and visual displays abundant in the learning materials were more appealing to the females thereby affecting their orientation of cognitive ability and working memory which in turn enhanced their achievements. On the other hand, males with high spatial abilities were better than females in terms of their posttest achievements in physics. Findings still indicated that the interaction effect of spatial ability and gender on students' physics problem solving skills was not significant. This implies that the combined effect of spatial ability and gender did not influence students' problem solving skills in physics. Based on this finding, it can be inferred that the treatment (instructional strategies) is favourable to male and female learners with respect to achievement more so as females with low spatial ability had higher scores than the males. This implies that for the male students with low and medium spatial ability, there is a need to arouse their spatial ability before administering the instructional strategies to them.

4.3.7 Treatment, Spatial Ability and Gender Interaction Effect of on Attitude to, Achievement in and Problem Solving Skills in Physics.

The findings of this study showed that the interaction effect of treatment (instructional strategies), spatial ability and gender on students' attitude towards physics is not significant. This translates to the fact that treatment (instructional strategies), the spatial ability and the gender of student do not help students' attitude towards physics. Findings indicated a non-significant effect in the interaction among treatment (instructional strategies), spatial ability and gender on students' achievement in physics. This implies that the treatment (instructional strategies) and the gender of students did not in any way obstruct or give any enhancement to the potency of the treatment on students' achievement. The findings of this study revealed that the combination effect of treatment (instructional strategies), spatial ability and gender on students' physics problem solving skills was not significant. This simply means that the adoption of treatment (instructional strategies) irrespective of the spatial ability and the gender of students has no significant effect on student's problem solving skills. Furthermore, the implication is that the experimental treatments used in the study were effective on their own, regardless of the students' spatial ability or gender.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the Study

This study determined the effect of Simulated-Video and Virtual Laboratory-Based Inverted Classroom strategies on private universities pre-degree physics students' attitude, achievement and problem solving skills in Southwest, Nigeria.

Cognitive Constructivism and Engagement Theories provided the theoretical framework for the study. Seven null hypotheses were tested at 0.05 level of significance. Pretest-posttest control group quasi experimental research design of 3x2x3 factorial matrix was adopted. Eight research instruments comprising five response and three stimuli were used in the study. Data collected were statistically analysed using descriptive and inferential options.

Findings from the study showed that Simulated-Video and Virtual Laboratory-Based Inverted Classroom strategies can be used to remediate performance deficiencies in and improve students' attitude, achievement and problem solving skills in physics. These strategies can also be used to enhance female students' performanance in physics as the strategies have proven to be more beneficial especially to females' achievement scores in physics. The study has also proven that the Simulated-Video and Virtual Laboratory-Based Inverted Classroom strategies favours females with low and medium spatial ability who found the resources appealing. However, male students with high spatial ability were also observed to be favoured by the same strategies too, only indicating a need to arouse the male students' spatial ability before applying the same strategies.

5.2 Conclusion

Based on the findings from the analysed data, the researcher concluded that using Simulation-based inverted classroom instructional strategy in teaching pre-degree students' physics will positively enhance their attitude, achievements and skills at solving problem. The fallouts of the study have shown that both the virtual laboratory and simulated video-based inverted instructional strategies are more effective in improving students' attitude to, achievement in, and problem solving skills in physics than the conventional method is. This means that the ''abstract nature'' of physics attributable to the boredom students experience in the classroom and which sometimes lead to poor performance in physics can be effectively resolved by the application of the virtual laboratory and the simulated video-based inverted instructional strategies. The study similarly asserts that the virtual laboratory and the simulated video-based flipped instructional strategies can help to enrich students' attitude, which will invariably translate to an improvement in their academic achievements and problems solving skills. This strategy allows learners to be in charge of their learning, because of its features which include that it can be personalized, it is mobile, portable, and accessible anytime and anywhere.

5.3 Implications of the Findings

This study validated that there were problems in the way physics is being taught at the pre-degree programmes of the universities and offered appropriate solutions that would help in overcoming the recurrent problems. The virtual laboratory and the simulated video based flipped classroom instruction strategies are effective for resolving the problems related to the negative attitude of students towards physics attributable to such reasons as: the abstractness of the subject, laws and formulae memorization deficiencies, difficulties in solving physics problems, the challenge of comprehending and understanding voluminous mathematical calculations. The enhanced learning outcomes from the two modes of inverted classroom instructional strategies are indications that these strategies have the potency to resolve these learning problems in physics. The following are the pedagogical implications for this study:

i. The two modes of inverted classroom instructional strategy justify the hype on the flipped classroom strategy as it is progressively reshaping physics education making it more interactive, personalized and hands-on.
ii. The deployment of the inverted classroom instructional strategy allows students to interact, while involved in virtual laboratory activities and simulated video activities. The strategies worked the same way for both male and female students in terms of improving their achievements in physics.
iii. The shift in emphasis on the need for the teaching-learning process to be a student-centered approach was sustained by the use of simulations based inverted classroom instructional strategy as it involves more of student-to-student interaction than teacher-to-student interactions.

5.4 Recommendations

In view of the fallouts from this study the following recommendations are hereby made:

i. Physics instructors/lecturers should be encouraged to adopt the virtual laboratory and the simulated video based inverted classroom instructional strategies in the physics classroom.
ii. Instructional designers and curriculum developers should be encouraged to design and develop more appropriate simulations that will aid self-learning and which can be used in the inverted classroom instructional strategies for other topics in physics education.

iii. The National University Commission (NUC) and Joint Universities Preliminary Education Board (JUPEB) should, as a matter of urgency, adopt the inverted classroom instructional strategies as one of the appropriate methods for teaching and learning physics in Nigerian universities.

iv. Teachers at all points of service should be trained and retrained regularly so they can have well-grounded knowledge of the simulations based inverted classroom instructional strategies. Seminars, conferences and workshops can be organized for them so they can be exposed to and become conversant with the required features of the strategies in order to improve their classroom practices as this will also enhance students' achievement in physics.

5.5 Contributions to Knowledge

i. The study has suggested better ways of teaching physics effectively other than the conventional instructional strategies.

ii. Students will develop a positive attitude to physics through the use of the virtual laboratory and the simulated video based inverted classroom instructional strategies.

iii. The study showed an increase in problem solving skills suggesting that it may be well-suited for the sciences as it involves hands-on practical skills and creative thinking.

iv. The study showed that simulated videos are superior to virtual laboratories particularly when a mode of inverted classroom instructional strategy is employed.

v. The study also added to the limited and scanty empirical findings supporting the effectiveness of inverted classroom instructional strategy in Nigeria.

5.6 Limitation of the Study

1. Other topics in physics other than Quantum and Photoelectric Effect were not taught in the course of this research.
2. Also, the study considered only six private universities' pre-degree programmes in South-Western Nigeria (Babcock, Adeleke, Lead City, Achievers, Caleb and Afe Babalola).
3. However, there are many other variables that can affect constructs on attitude to, achievements in and problems solving skills in physics which this study did not put into consideration.
4. The unstable calendar for the pre-degree programme of each private university, caused for example by the observation of holidays, schools' festivals or ceremonies and students' population caused a delay in the administration of instruments.

5.7 Suggestions for Further Study

1. Further research may explore other moderator variables such as class size, engagement, school type and cognitive style.
2. A replication of the study can be carried out in federal and state-owned universities' pre-degree programmes, either also in physics or in any other subject, provided ICT facilities are available and functional in such universities.
3. The study can also be extended to all the six geopolitical zones in Nigeria including all the states and their private higher institutions, in order for further generalization to be made.
4. A further study on the implementation of inverted classroom instructional strategy can be made in public universities if ICT facilities and electronic gadgets are available in these public Universities.

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APPENDIX 1

SPATIAL ABILITY TEST (SAT)

INSTRUCTIONS: Time allowed: 1 Hour (60minutes)

SECTION A

This test is aimed at testing your spatial ability based on spatial visualization and rotation. This multi-faceted ability helps science students to conceptualize links between reality and the abstract model of that reality.

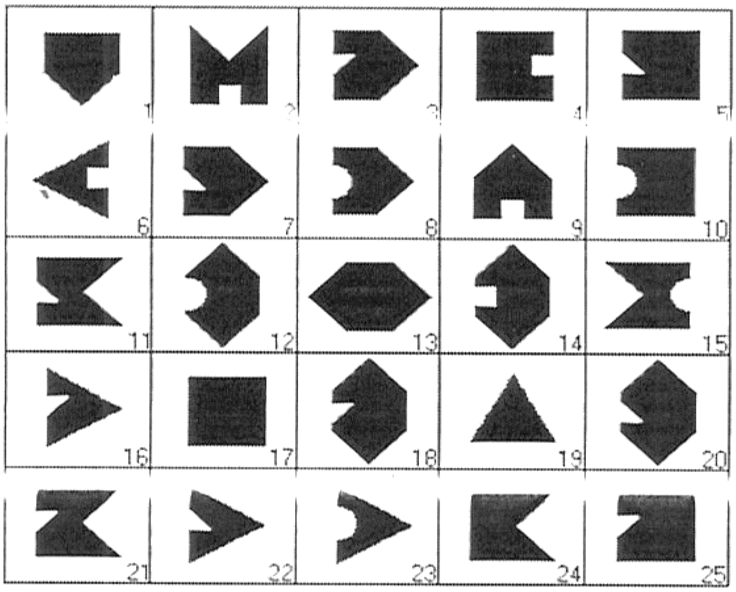
Indicate the correct answer from A-D options provided.

SECTION A1: Please kindly indicate the following information

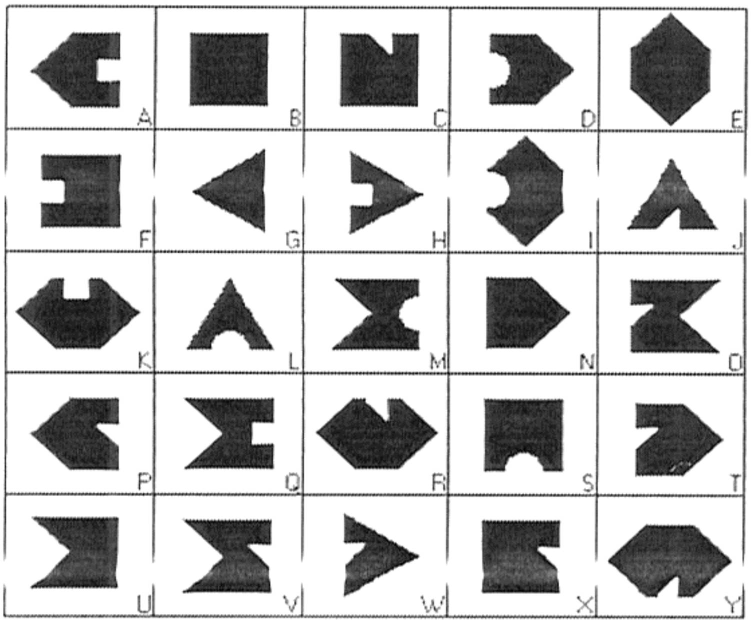
a) Name of University…………………………………………………………

Which shape in Category 2 corresponds to the shapes (1 to 25) in Category 1, even when rotated.

Category 1



Category 2

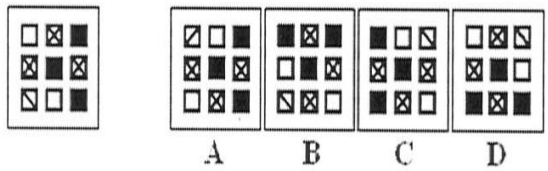


1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12.

13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24.

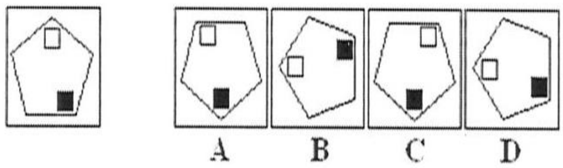
25. In the figures shown below, one of the shapes (A-D) is identical to the first figure but has been rotated.

26. Which figure is identical to the first?



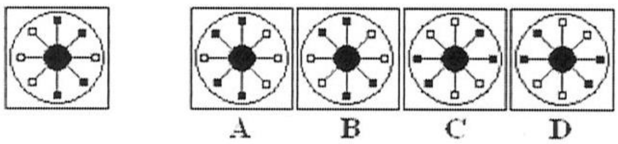
A B C D

27. Which figure is identical to the first?



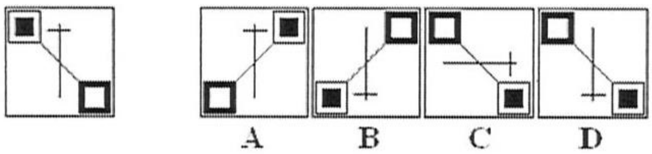
A B C D

28. Which figure is identical to the first?



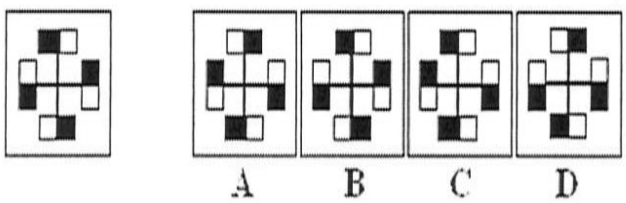
A B C D

29. Which figure is identical to the first?



A B C D

30. Which figure is identical to the first?



A B C D

APPENDIX 2

Self-Assessment of Problem Solving Skill (SAPSS)

Kindly complete this questionnaire with all sense of sincerity, as this is needed for the success

of the study on students' Assessment of Problem Solving Skill in physics.

Skills are identifying known and unknown, locate task, analyzing the problem and evaluating answer

All information provided will be kept confidentially. Thank you.

Section A. Name of your Institution: *Level:* *Sex:*

Department/Course of Study:

Section B: Kindly indicate appropriately.

S/N	Items	Often	Sometimes	Rarely	Never
1	After reading the assignment I make a list of known and unknown quantities.				
2	I endeavor to select an equation largely because the equation has the same variables as the list of known and unknown				
3	I attempt to find similar task in textbook, notes or elsewhere				
4	I attempt to recall if we did some experiment similar to the task in the lecture				
5	I strive to solve the task step and divide it into smaller sub-problems				
6	First, I solve the task in my mind and then I do arithmetic.				
7	I try to imagine the problem in the real situation				
8	I think about the ideas and physics concepts involved in the problem				
9	I endeavor to draw some diagram (sketch, chart ….e.t.c)				
10	When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.				
11	It is useful for me to do lots and lots of problems when learning physics.				
12	After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic				

13	When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.				
14	I feel there is usually only one correct approach to solving a physics problem				
15	If I get stuck on a physics problem my first try, I usually try to figure out a different way that works				
16	In physics, it is important for me to make sense out of formulas before I can use them correctly.				
17	If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.				
18	I find carefully analyzing only a few problems in detail a good way for me to learn physics.				
19	I can usually figure out a way to solve physics problems.				
20	It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct.				

APPENDIX 3

Attitudes Towards Physics Questionnaire (ATPQ)

Section A

Dear student, please enter the right information that applies to you by simply ticking (√).

Do not write your name

Age	16 years old ☐	17 years old ☐	18 years old ☐	More than 18 yrs. Old ☐
Gender	Male: ☐		Female: ☐	
What do you do after school hours?				
Do you hold any special position in the school? If yes, what?				
Hobbies:				

Section B

STRONGLY DISAGREE = 1 **DISAGREE** = 2 **AGREE** = 3 **STRONGLY AGREE** = 4

It is important that you respond to *every statement*, and that you fill in only one number per statement.

S/N	**Item Statements**	**SD** (1)	**D** (2)	**A** (3)	**SA** (4)
1.	Physics lessons help solve the problems of everyday life. +				
2.	Physics is a subject that I enjoy very much. +				
3.	I would like to do some extra or un-assigned reading in Physics. +				
4.	Physics as subject is easy for me. +				
5.	When I hear the word Physics, I have a feeling of dislike. -				
6.	Students should study Physics concepts very deeply than we are taught in the class. +				
7.	Sometimes I read ahead in our Physics textbook. +				
8.	Physics is helpful in understanding technological advancement in the society. +				
9.	I usually understand what is being taught in Physics class. +				
10.	I like Physics because my teacher(s) make the lessons interesting. +				
11.	No matter how hard I try, I cannot understand practical aspects in Physics -				
12.	I feel tense when it is time for Physics lesson. -				
13.	Physics teachers present lessons in a clear way. +				
14.	I often think, “I cannot do this,” when a Physics assignment seems hard. +				
15.	Physics is of great importance to technological development. +				
16	It is important to know Physics in order to function well in the society. +				
17.	I like the challenge of Physics assignments. +				
18.	It makes me nervous to even think about doing Physics assignment. -				
19.	It scares me when I am called to answer question during Physics class. -				

S/N	Item Statements	SD (1)	D (2)	A (3)	SA (4)
20.	I like Physics because my teacher is willing to give me individual help. +				
21.	It is important to me to understand the work I do in Physics class. +				
22.	I have a good feeling toward Physics. +				
23.	Physics is one of my favorite subjects. -				
24.	I have a real desire to learn Physics practical. +				
25.	I do not do very well in Physics examinations. -				

Note: + = positive attitude while - = negative attitude

APPENDIX 4

Students' Achievement Test in Physics (SATP)

Name…………………… Institution of study……………………….

Level………. Age…… Sex…….

1. Name the Electromagnetic radiation that is required to fall on a cold metal surface for Photoelectric effect to occur. (A) sufficiently high frequency (B) low frequency (C) Moderate frequency (D) All of the above
2. Which of the following is identical to Photoelectric effect?

   (A) Work function (B) thermionic emission (C) threshold frequency (D) work emission
3. State the maximum frequency of the incident radiation required to cause the emission of photoelectrons from the metal surface. (A) threshold frequency (B) Net frequency (C) apparent frequency (D) None of the above
4. Identify this equation $E_{max}=(1/2)\ m(V_{max})^2 =(hv – W) =h(v - v_o)$, where m= mass of an electron and V_{max} =maximum velocity of a photoelectron . (A)De- Broglie (B) Einstein's equation (C) wave equation (D) All of the above
5. Light Photons of energy 3.4 eV each are incident on a plane cathode of work function 2.4 eV. Parallel and close to the cathode is a plane anode. Both the Cathode and Anode are inside an evacuated tube. Calculate the maximum kinetic energy, in eV, of the photoelectrons emitted from the cathode. (A) 10.2 eV (B)9.0 eV (C) 12.2 eV (D) 7.9eV
6. Locate from the above question 5. Find the minimum value of the potential difference which should be applied between the cathode and anode in order to prevent photoelectrons of maximum kinetic energy from reaching the anode if the electrons are emitted at an angle of 30^o to the cathode. (A) 0.25 V. (B) 1.50V (C) 2.45V (D) 3.50V
7. Theorize that photoelectric current is …….to the intensity of illumination. (A) Indirectly proportional (B) directly proportional (C) None of the above (D) All of the above
8. Associate the fact that the maximum Kinetic energy of the Photoelectrons is determined by the frequency of the………………..,i.e maximum kinetic energy=$hv - hv_o$. (A) incident radiation (B) voltage supply (C) zinc plate (D) All of the above
9. Deduce what happens in photoemission from a metal, if the wavelength of the incident radiation is increased? (A) decrease in the ejection of electrons (B) increase in the ejection of electrons (C) None of the above (D) Both increases and decreases electron

10. Assume in a photoelectric emission experiment, a metal surface in an evacuated tube is illuminated with monochromatic light. If the experiment is repeated with light of the same wavelength but of twice the intensity, how does this affect the energy of a photon? (A) The energy of a photon remains unchanged. (B) The energy of a photon changed continuously. (C) Nothing happens (D) All of the above
11. Explain from the above question, how does this affect the maximum kinetic energy of the photoelectrons? (A)remains constant (B) None of the above (C) keeping changing (D) changing but slowly
12. Formulate from the above question 10, how does this affect the work function of the metal, (A) it keeping changing (B) it remains unchanged. (C) None of the above
13. Interpret from the above question 10, how does this affect the photoelectric current? , Ans = the photoelectric current is doubled, hence the rate of emission of photoelectrons is doubled and so is the current. (A)Yes(B) No (C) Halved (D) None of the above
14. Show that a metal illuminated by monochromatic radiation of wavelength 248 nm, the maximum kinetic energy of photoelectrons emitted is found to be 8.6 x 10^{-20} J. find the work function of the metal. (A) 2.5 eV. (B) 25.0 eV (C) 1.25eV (D) 3.0 eV
15. Ascertain that work function W of a metal is the ………………..needed for a free electron in the metal to escape from the metal surface. (A) maximum Voltage (B) minimum Voltage(C) maximum energy (D) potential difference
16. Employing Einstein assumption that light of frequency f contains packets, or quanta, of energy hf. On this basis, light consists of particles – photons. The number of photons per unit area (of cross-section of the beam of light) per unit time is proportional to …………… (A) its frequency (B) its intensity (C) its Energy (D) None of the above
17. Assume the equation h(= E_k + W. where h is Planck's constant, (is the frequency of the light, E_k is the………?, W is the work function. (A) kinetic energy of the ejected electron (B) Net energy in the system (C) Maximum Energy of ejected electron. (D) Free electron
18. Relate what perfectly describes the movement of an electromagnetic wave across the region where electrons were located which allowed the electrons to be excited? (A) Wave motion (B) Photon (C) Photoelectron (D) All of the above
19. Predict which of the studies in Physics that won Einstein the Nobel Prize in Physics.
    (A) Wave-particle duality (B) the Photoelectric effect (C) Relativity (D) Electricity
20. Deduce the fact about light, a collection of waves or particles? (A) Both (B) Neither (C) Waves (D) Particles

APPENDIX 5

UNIVERSITY OF IBADAN

Department of SMT Education

Availability and Accessibility of Digital Gadgets Inventory (AADGI)

Section A

Dear student, please enter the right information that applies to you by simply ticking (√).

<u>Do not write your name</u>

Age	16 years old ☐	17 years old ☐	18 years old ☐	More than 18 yrs. Old ☐
Gender	Male: ☐		**Female:** ☐	
Do you own any digital gadgets for studying			Phone ☐ Laptop ☐ Desktop ☐ Ipad ☐ Tablet ☐	
Do you personally have access to any this gadgets			Phone ☐ Laptop ☐ Desktop ☐ Ipad ☐ Tablet ☐	

Section B

***STRONGLY DISAGREE** = 1 **DISAGREE** = 2 **AGREE** = 3 **STRONGLY AGREE** = 4*

It is important that you respond to every statement, and that you fill in only one number per statement.

S/N	Item Statements	SD (1)	D (2)	A (3)	SA (4)
1.	I have a personal laptop for studying and learning new things.				
2.	I do own Phones that can share and browse or download material				
3.	I make use of Desktop computer available to me in doing my readings and assignment				
4.	The internet is always available to me for doing several of my assignment				
5.	My University have an ICT Resource center or Computer Room for teaching andlearning				
6.	In my University, Internet Facilities are available for surfing the web for documents				
7.	The phone i have is compatible to watch downloaded videos and simulations				
8.	I do have other means of charging my gadget e.g. Power-banks or Generators				
9.	There is regular power supply available to my disposal to keep my gadgets working				

S/N	Item Statements	SD (1)	D (2)	A (3)	SA (4)
10.	I have more than one gadget for watching any assigned video for academic purpose e.g. Phone, Laptop, Desktop, Ipad, Tablet				

Section C
The following statements are about the accessibility to Digital gadget.
***OFTEN** = 4 **SOMETIMES** =3 **RARE** = 2 **NEVER** = 1*
It is important that you respond to every statement, and that you fill in only one number per statement.

S/N	Item Statements	Often	Sometimes	Rare	Never
11	I usually have access to the internet for doing assignment and homework				
12	I watch Lecture-video and play game at my leisure time even online				
13	I do use my phone and several other devices to do many of assignment				
14	We are encouraged to use the digital library for several research study				
15	I make use of my laptop for personal study				

APPENDIX 6

UNIVERSITY OF IBADAN
Department of SMT Education

PROBLEM SOLVING SKILLS SCALE (RUBRIC) (PSSS)

Category of Skills	**Exemplary**	**Proficient**	**Partially Proficient**	**Incomplete**	**POINTS**
Analyzing givens and constraints	3 points	2 points	1 point	0 points	___/3
	Completely identifying all known and unknown quantities.	Identifying some known and unknown quantities but containing minor omissions or errors.	Partially identifying all known and unknown quantities with errors.	Unable to identify known and unknown quantities.	
	Perfectly analyze and imagine the problem logically with supporting evidence	Analyze and imagine the problem logically with minimal supporting evidence	Partial analysis and imagining the problem logically with no supporting evidence	Uneven analysis and unproductive imagination of problem showing no evidence	
	Separate each relevant variables or givens	Separate most of the relevant variables or givens.	Separate each variable or givens which are not relevant	Separate each irrelevant variables or givens.	
Planning a solution pathway.	3 points	2 points	1 point	0 points	___/3
	Selected concepts/principles that clearly and concisely with a logical progression of ideas and effective	Selected most of the concepts and principle with a logical progression of ideas and supporting evidence.	Selected concepts/principles which failed to maintain a consistent focus, showed minimal organization and effort, and lacked an adequate amount of supporting evidence.	All of the selected concepts and principles are inappropriate, unfocused, poorly organized, showed little effort and lacked supporting evidence.	
	Locate task in your mind accurately with stated proof.	Locate task in your mind with insufficient proof.	Locate task in your mind with no reasonable proof.	Unable to locate task in your mind with reasonable proof.	

	State formulae that is sufficiently adequate	State formulae that is suitable but absolutely correct	State formulae that is insufficiently adequate	State formulae that is inadequate	
	Provide alternative methods that is correct and can be used	Provide alternative methods that can also be used	Provide alternative methods that is likely correct and can be used	Unable provide alternative methods that can also be used	
Using tools (formulae) and resources effectively and efficiently.	3 points	2 points	1 point	0 points	___/3
	Perfectly used appropriate formulae in solving the problem without any form of mistake or error	Correctly used appropriate formulae in solving the problem with minimal errors (not more than one error)	Poorly and inconsistently used formulae with much errors (more than one error)	Used no appropriate Formulae in solving the problem	
	Insert relevant values against variables	Insert relevant values against variables with minimal error (not more than one error)	Insert relevant values against variables with error (less than three errors)	Insert irrelevant values (wrong values) against variables	
	Draw accurate diagram and sketches that vividly depicts the concept.	Draw diagram and sketches that vividly depicts the concept with not more than one error.	Draw diagram and sketches that vividly depicts the concept with many errors (more than two errors).	Unable to draw diagram and sketches that vividly depicts the concept with more than one error.	
	Use given values to accurately solve arithmetically.	Use given values to solve arithmetically with less than two errors	Use given values to inaccurately solve arithmetically.	Unable to use given values to solve arithmetically.	
Monitoring and evaluating progress.	3 points	2 points	1 point	0 points	___/3
	Creating a correct value for answer adequately and giving all their units.	Creating a correct value for answer without giving the unit	Creating a value for answer adequately but not all are correctly stated.	Creating an unreasonable value for answer.	

	Figure out more than one accelerated ways to solve the same problem.	Figure out just one accelerated way to solve the same problem.	Figure out wrong accelerated ways to solve the same problem	Unable to figure out any accelerated ways to solve the same problem	
	Check for accuracy adequately (without any error)	Check for accuracy inadequately (with one error)	Check for accuracy with much error (less than three errors)	Unable to check for accuracy	
				Total	___ /15

APPENDIX 7

UNIVERSITY OF IBADAN
Department of SMT Education

Problem Solving Work Sheet

Instruction: *Answers to the questions below are expected to be provided by all the students both in the treatment group and controlled group.*

{i}. Determine whether electrons will be emitted by the photoelectric effect from surface, when the work function of a metal surface is 3.5eV and light of wavelength 450nm is incident on the surface.
Provide Solution Here:

{ii}. An electron is accelerated in a vacuum from rest through a potential difference of 850v. Show that the final momentum of the electron is 1.6×10^{-23}Ns. Also calculate the De Broglie wavelength of this electron.
Provide Solution Here:

APPENDIX 8

THE WEST AFRICAN EXAMINATIONS COUNCIL

21,HUSSEY STREET
PRIVATE MAIL BAG 1022
YABA, LAGOS, NIGERIA
TEL: 08148272541

L/EC/STAT/47/VOL.VII/265

2nd February, 2016

Ihekoronye, C. Promise,
University of Ibadan,
Ibadan Nigeria.

Dear Sir,

RE: A LETTER OF REQUEST

Your letter dated 10th December, 2015 on the above subject refers.

As requested, please find enclosed the soft and hard copies of the statistics for WASSCE May/June Physics results for the periods 2010-2015.

Thank you.

Yours faithfully,

Dr. O.F. Dacosta
Officer – In – Charge
(Test Administration)

OLU I. ADENIPEKUN MNIM; FCAI
Head of National Office

Email: hnowaeclagos@yahoo.co.uk, hnowaeclagos@waecnigeria.org
Website:www.waecnigeria.orgwww.waecdirect.org www.waeconline.org.ng

WEST AFRICAN EXAMINATIONS COUNCIL

STATISTICS OF RESULTS BY GRADES FOR ALL CANDIDATES MAY/JUNE 2011

STATE: NIGERIA

SUBJECT	NO. OF CANDS. THAT ENTERED	NO. OF CANDS. THAT SAT	ABS	1	2	3	4	5	6	1-6	7	8	7-8	9	$
				NO. AND PERCENTAGE OF CANDS. THAT SAT AND OBTAINED THE GIVEN GRADES 1 TO 8											
PHYSICS	573040	563004	10036	9356	18719	103014	65189	52757 1	17950	366985	67789	51473 1	19262	69055	7701
		98.24	1.75	1.66	3.32	18.29	11.57	9.37	20.95	65.18	12.04	9.14	21.18	12.26	1.36

STATISTICS OF RESULTS BY GRADES FOR ALL CANDIDATES MAY/JUNE 2012

SUBJECT	NO. OF CANDS. THAT ENTERED	NO. OF CANDS. THAT SAT	ABS	1	2	3	4	5	6	1-6	7	8	7-8	9	$
				NO. AND PERCENTAGE OF CANDS. THAT SAT AND OBTAINED THE GIVEN GRADES 1 TO 8											
PHYSICS	638680	624492	14188	7610	17394	117801	82469	65570	138585	429429	72324	48053 1	20377	57448	17236
		97.77	2.22	1.21	2.78	18.86	13.2	10.49	22.19	68.76	11.58	7.69	19.27	9.19	2.76

STATISTICS OF RESULTS BY GRADES FOR ALL CANDIDATES MAY/JUNE 2013

SUBJECT	NO. OF CANDS. THAT ENTERED	NO. OF CANDS. THAT SAT	ABS	1	2	3	4	5	6	1-6	7	8	7-8	9	$
				NO. AND PERCENTAGE OF CANDS. THAT SAT AND OBTAINED THE GIVEN GRADES 1 TO 8											
PHYSICS	647562	637023	10539	957	3976	43208	43643	62068	144136	297988	85872	90906 1	76778	147510	14198
		98.37	1.62	0.15	0.62	6.78	6.85	9.74	22.62	46.77	13.48	14.27	27.75	23.15	2.22

STATISTICS OF RESULTS BY GRADES FOR ALL CANDIDATES MAY/JUNE 2014

SUBJECT	NO. OF CANDS. THAT ENTERED	NO. OF CANDS. THAT SAT	ABS	1	2	3	4	5	6	1-6	7	8	7-8	9	$
				NO. AND PERCENTAGE OF CANDS. THAT SAT AND OBTAINED THE GIVEN GRADES 1 TO 8											
PHYSICS	673717	665506	8211	4039	9915	91961	49775	81315	157174	394179	97518	71712	169230	87202	14814
		98.78	1.21	0.6	1.48	13.81	7.47	12.21	23.61	59.22	14.65	10.77	25.42	13.1	2.22

STATISTICS OF RESULTS BY GRADES FOR ALL CANDIDATES MAY/JUNE 2015

SUBJECT	NO. OF CANDS. THAT ENTERED	NO. OF CANDS. THAT SAT	ABS	NO. AND PERCENTAGE OF CANDS. THAT SAT AND OBTAINED THE GIVEN GRADES 1 TO 8										9	$
				1	2	3	4	5	6	1-6	7	8	7-8		
PHYSICS	664821	657575	7246	6395	12899	98975	49355	78173	144843	390640	90368	70398	160766	88641	15023
		98.91	1.08	0.97	1.96	15.05	7.5	11.88	22.02	59.4	13.74	10.7	24.44	13.47	2.28

APPENDIX 9

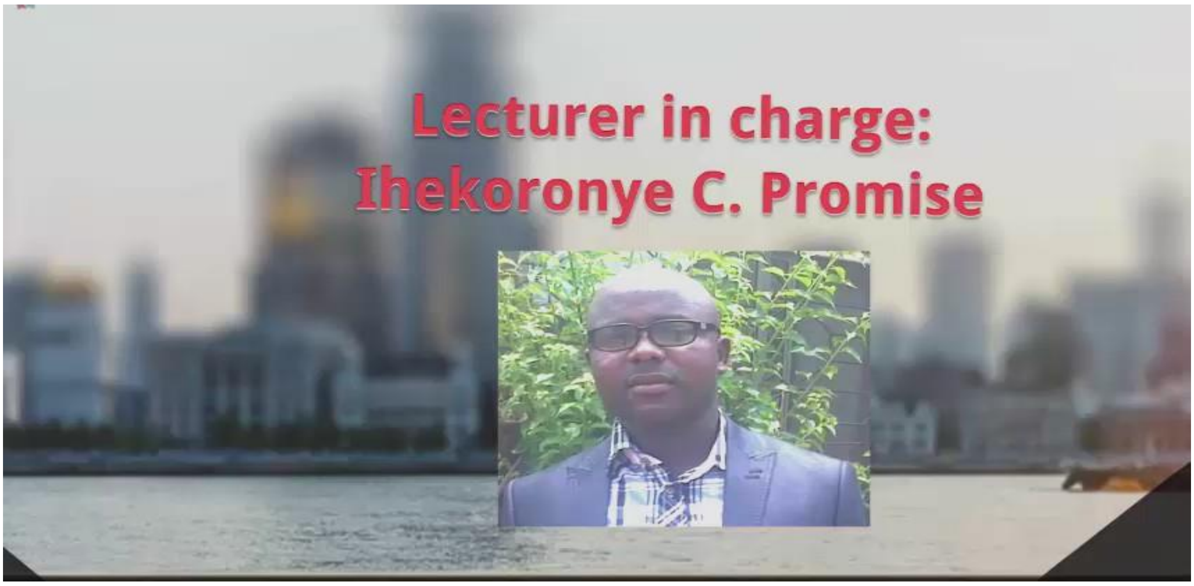
LIST OF UNVERSITIES USED FOR FIELD WORK

Field Work 2016: Three Universities from federal, state, and private are:

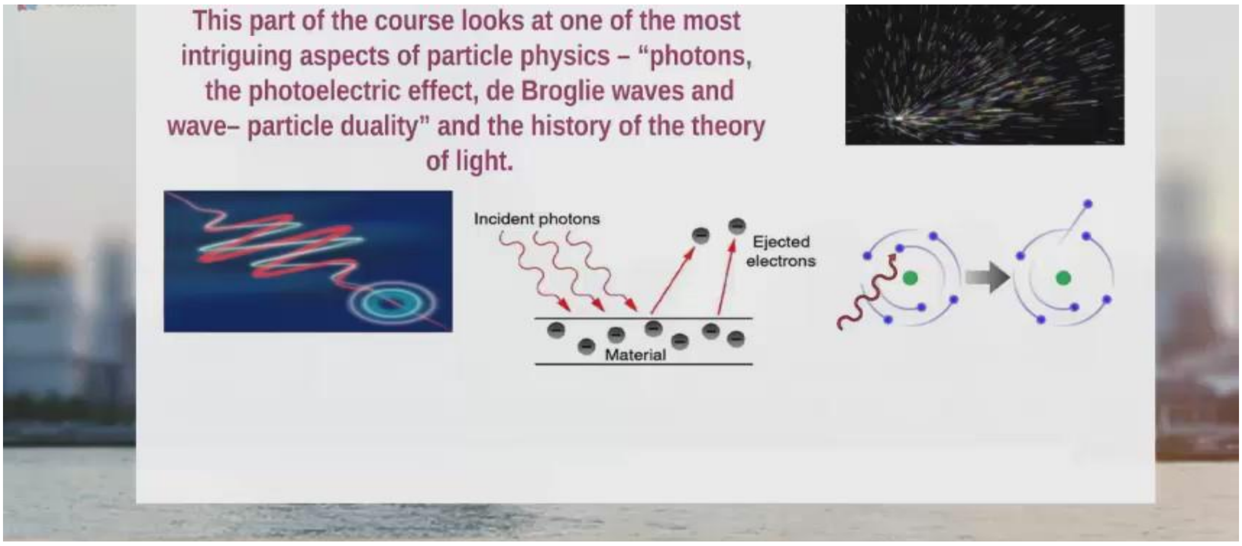
i. Federal University of Agriculture
ii. Olabisi Onabanjo University
iii. Babcock University

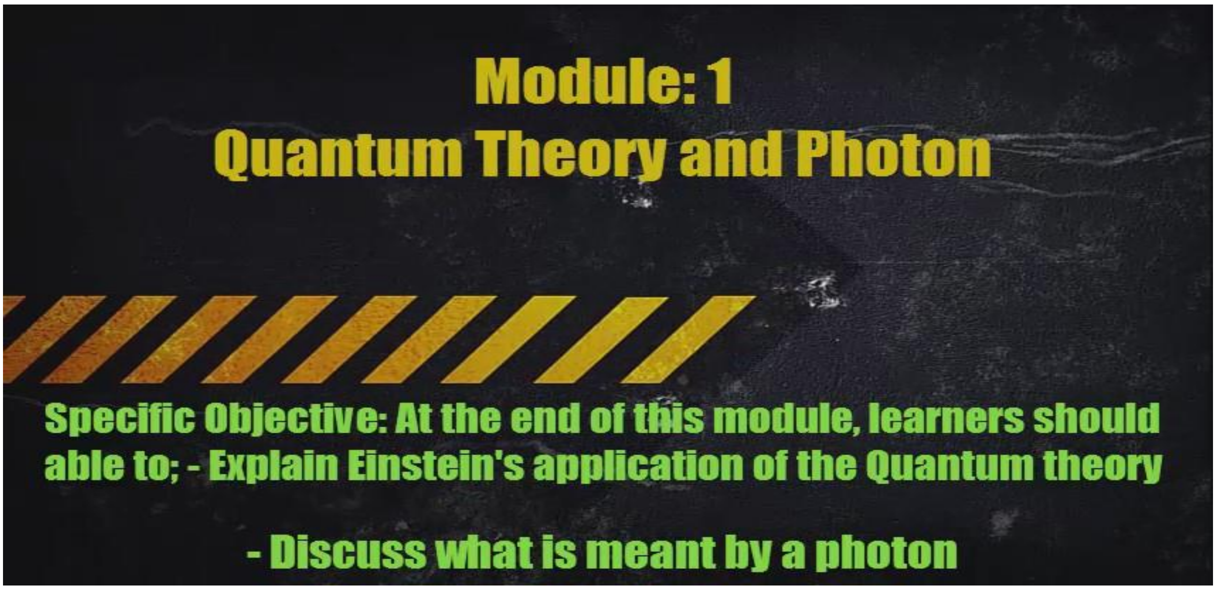
Field Work 2018: Federal University of Agriculture

APPENDIX 10
Cross-Section of Simulated- Video Based Inverted Classroom Strategy

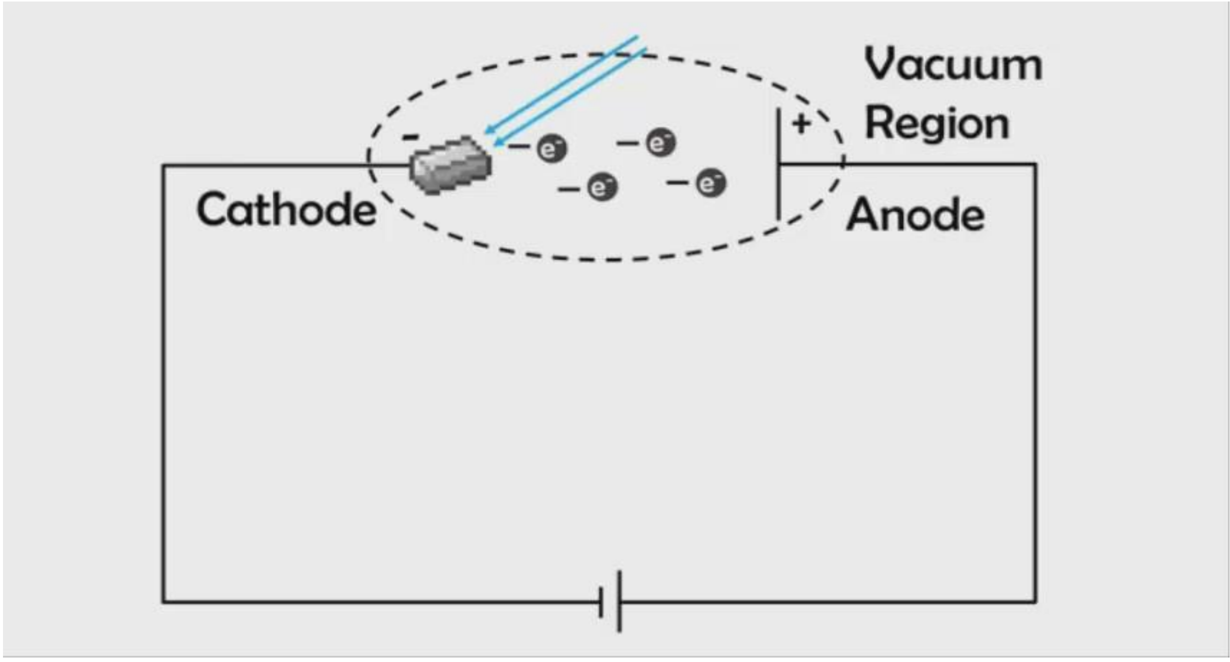


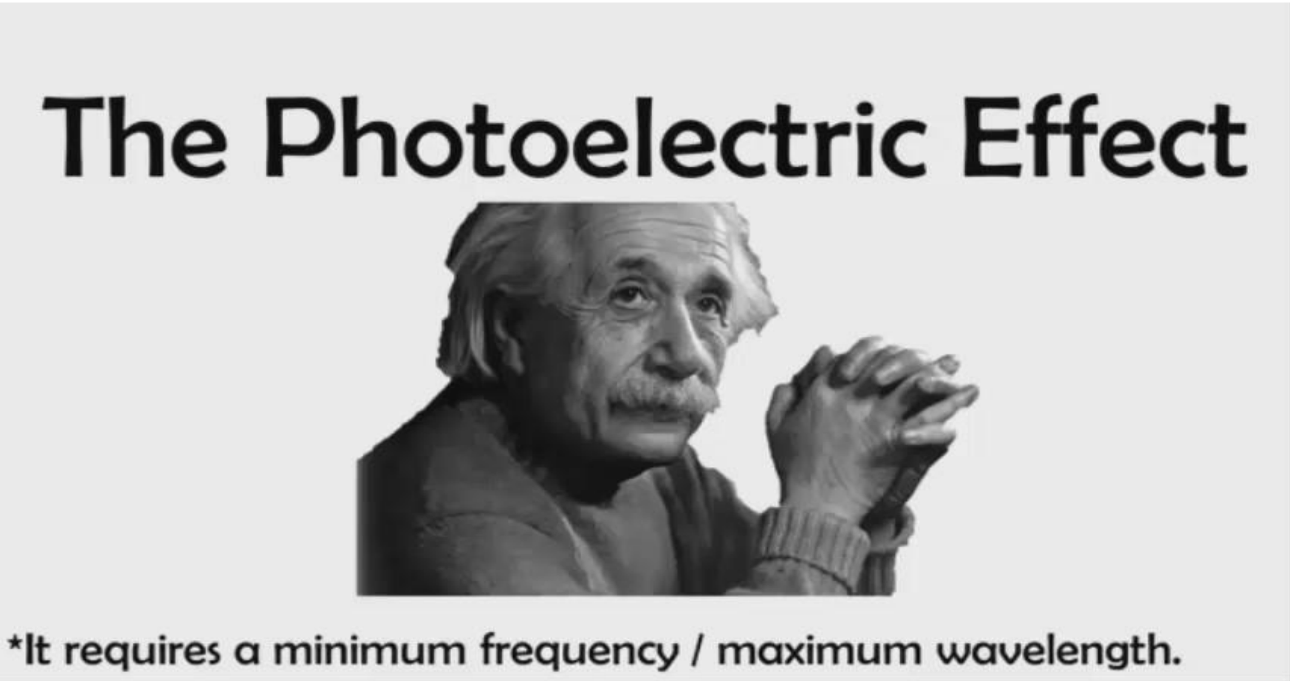
INTRODUCTION OF THE LECTURER



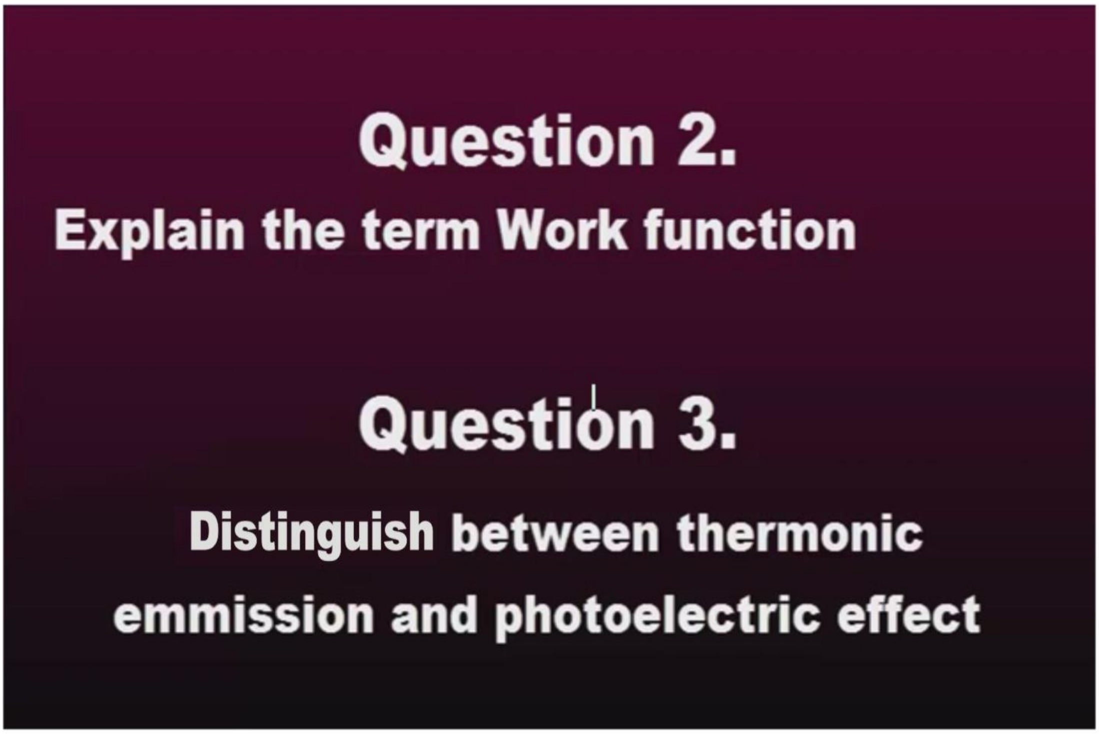


1. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION

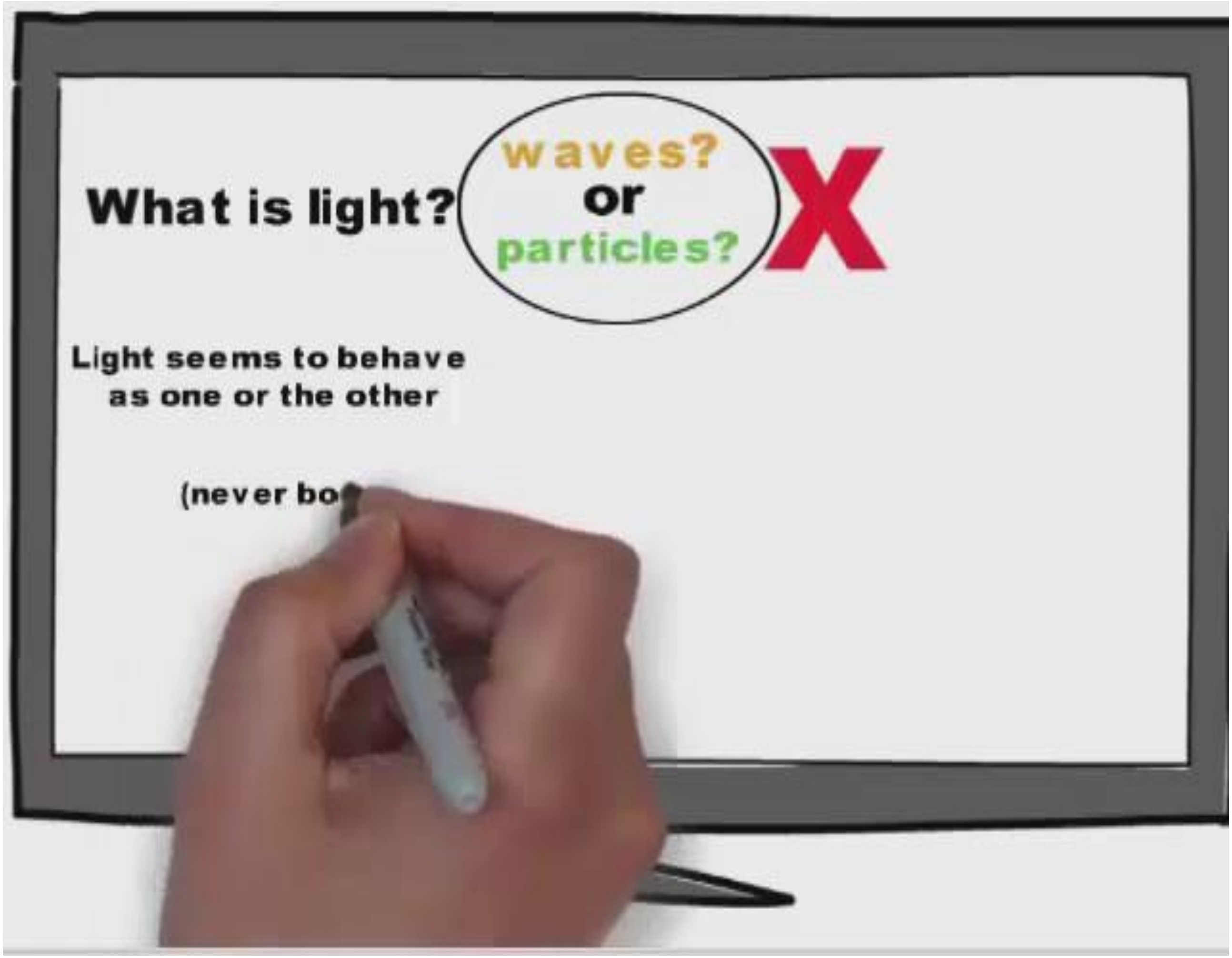




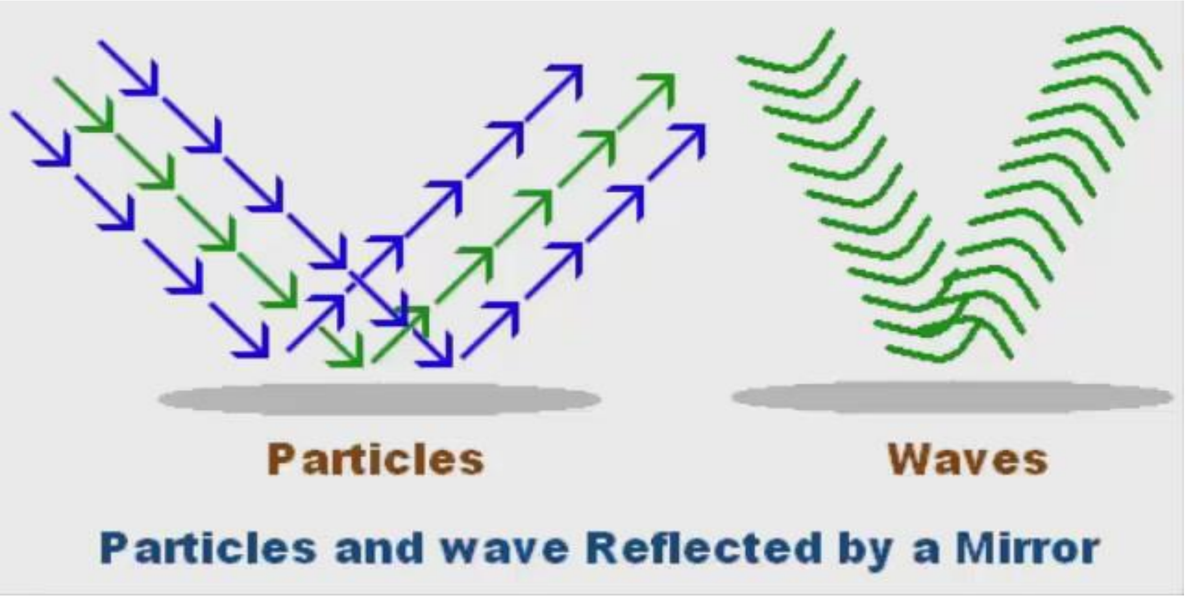
2. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION

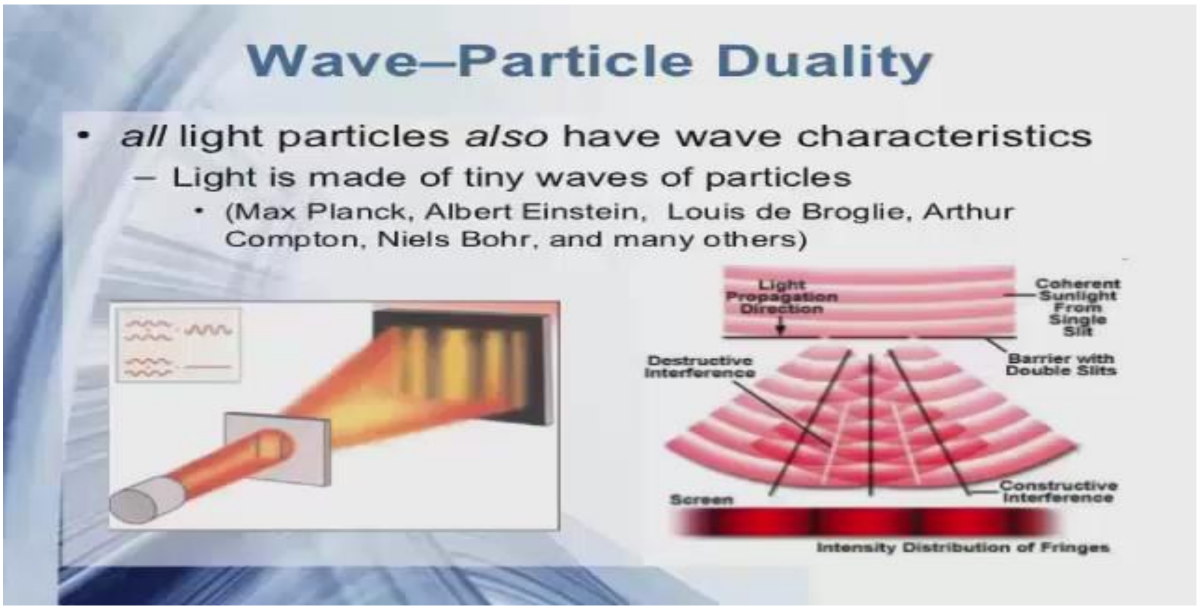


QUESTION TIME

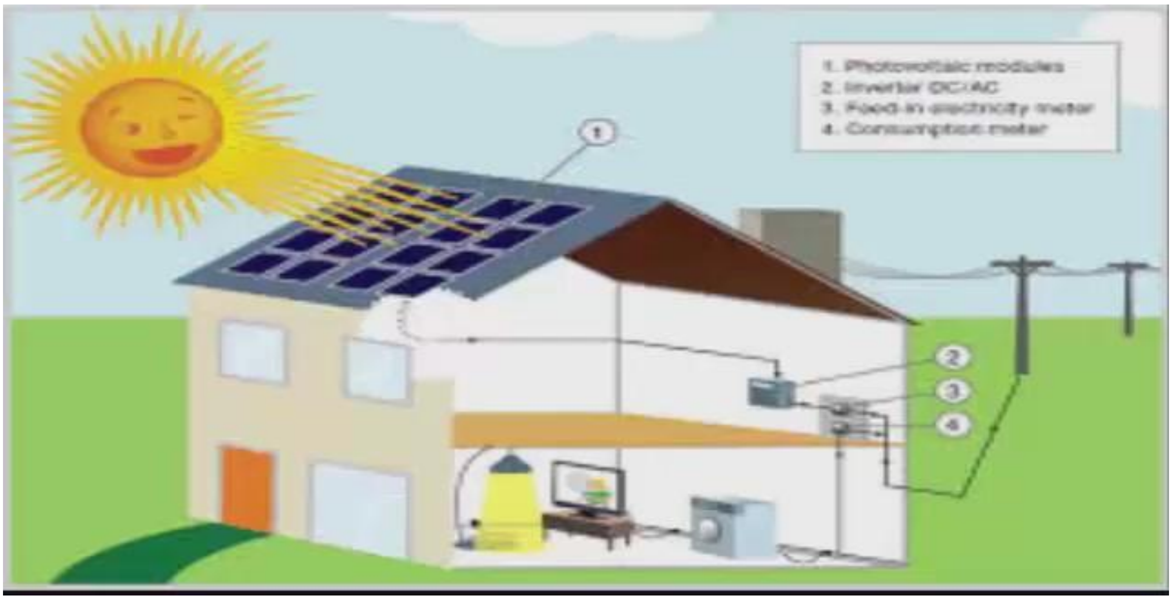


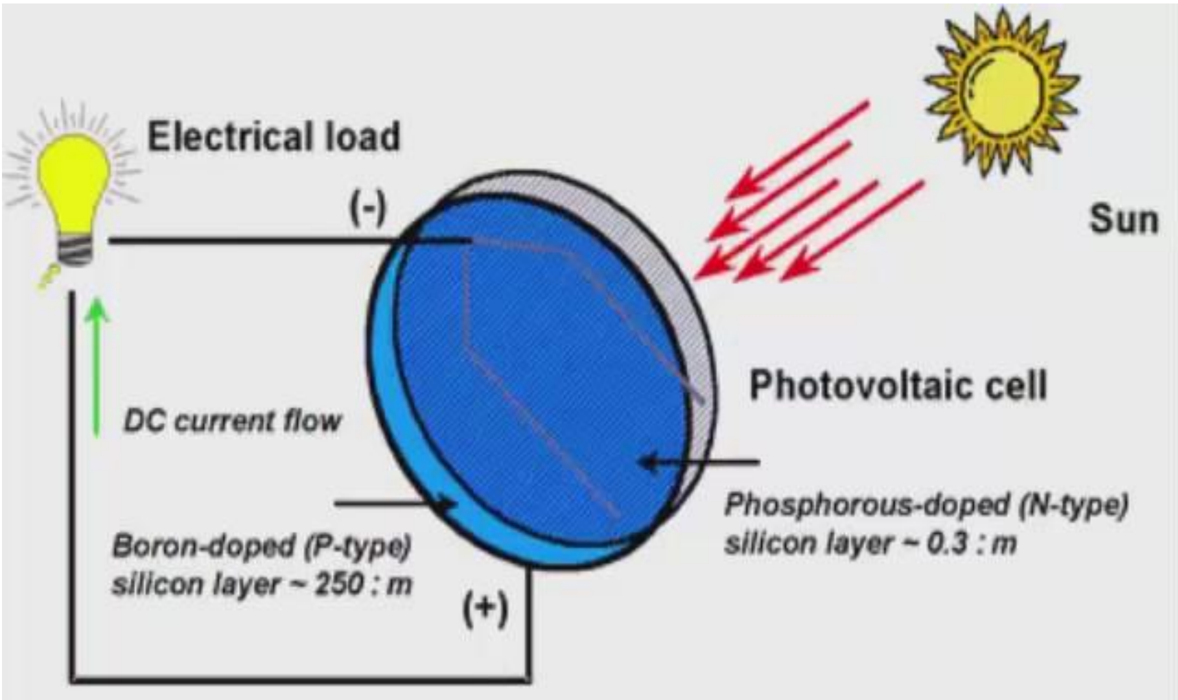
3. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION





4. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION





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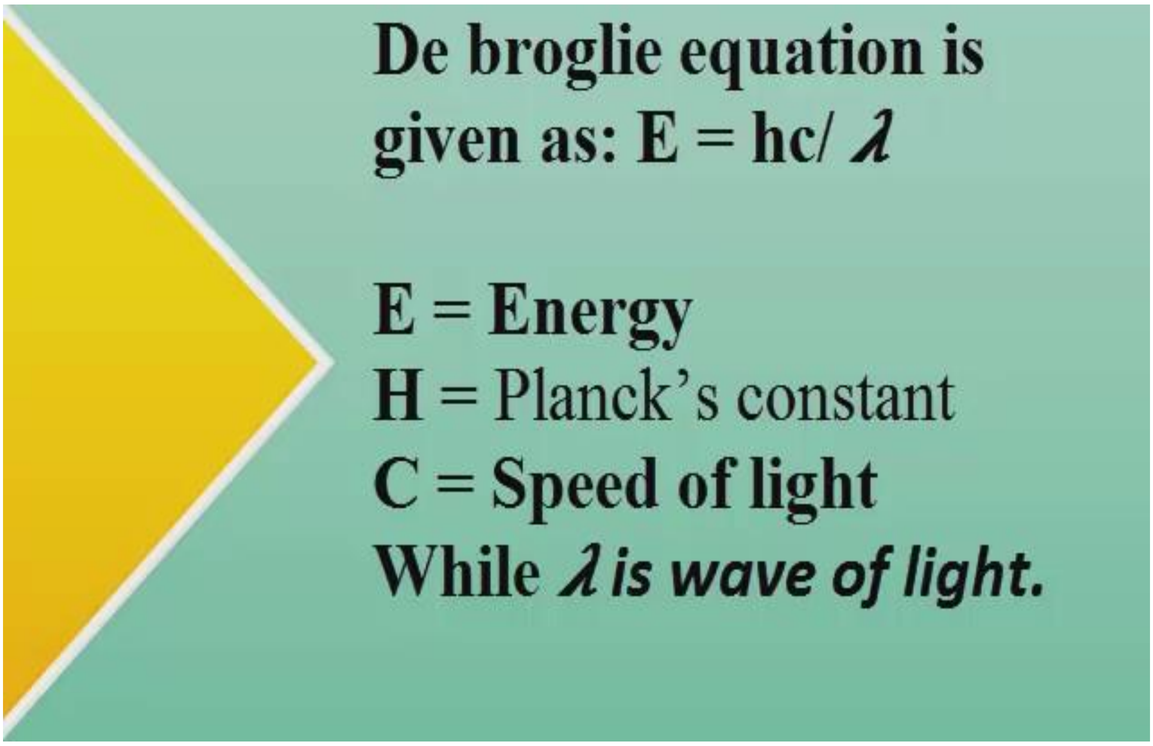

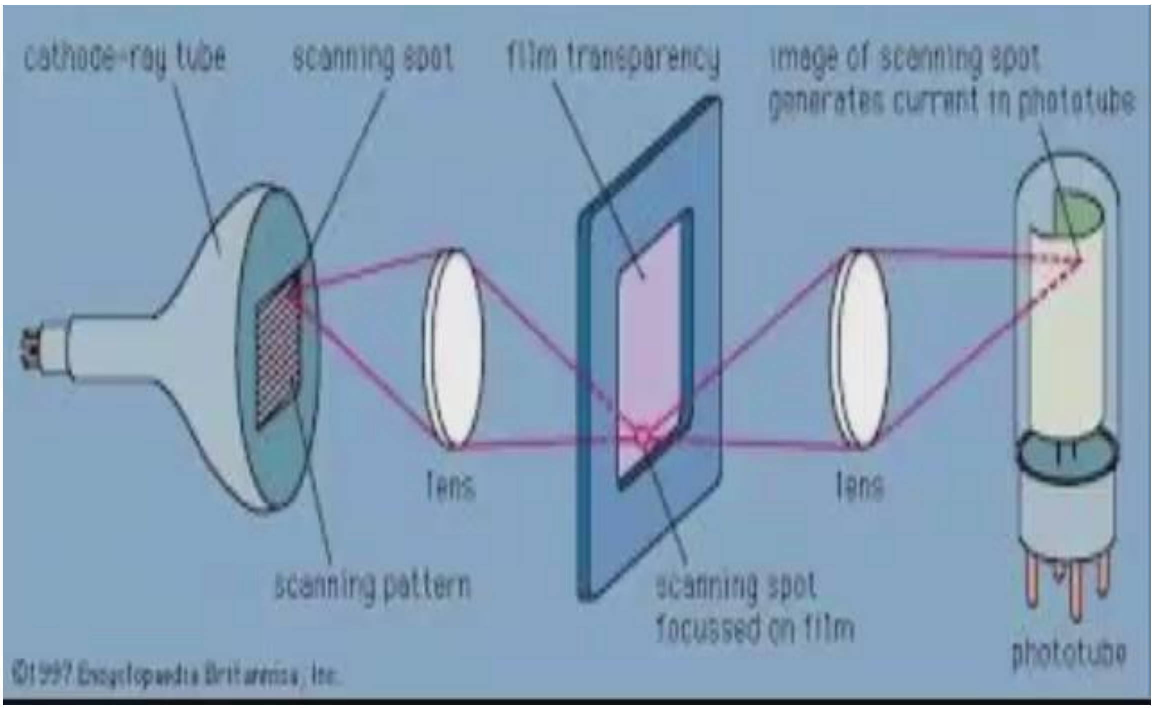

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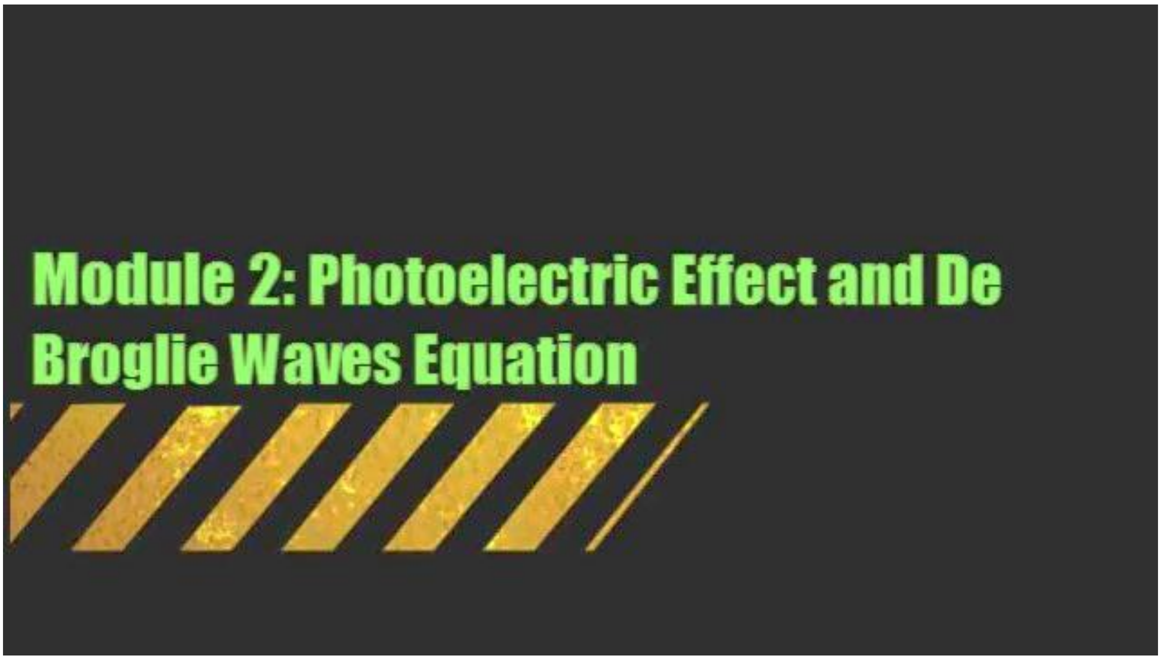
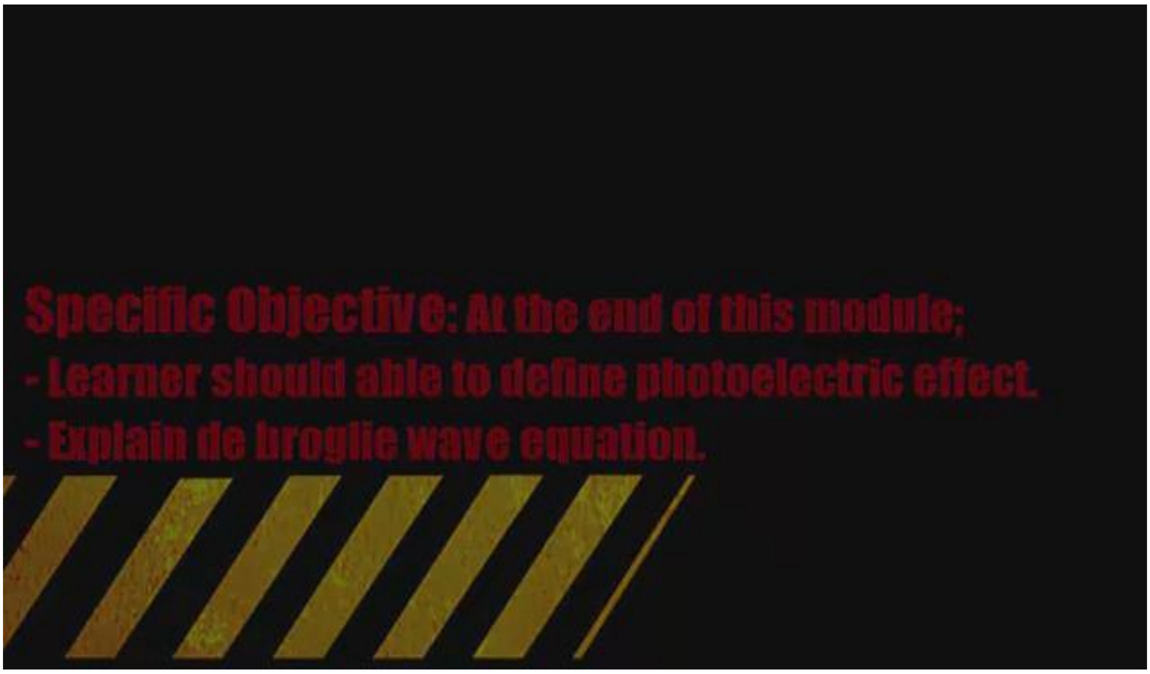
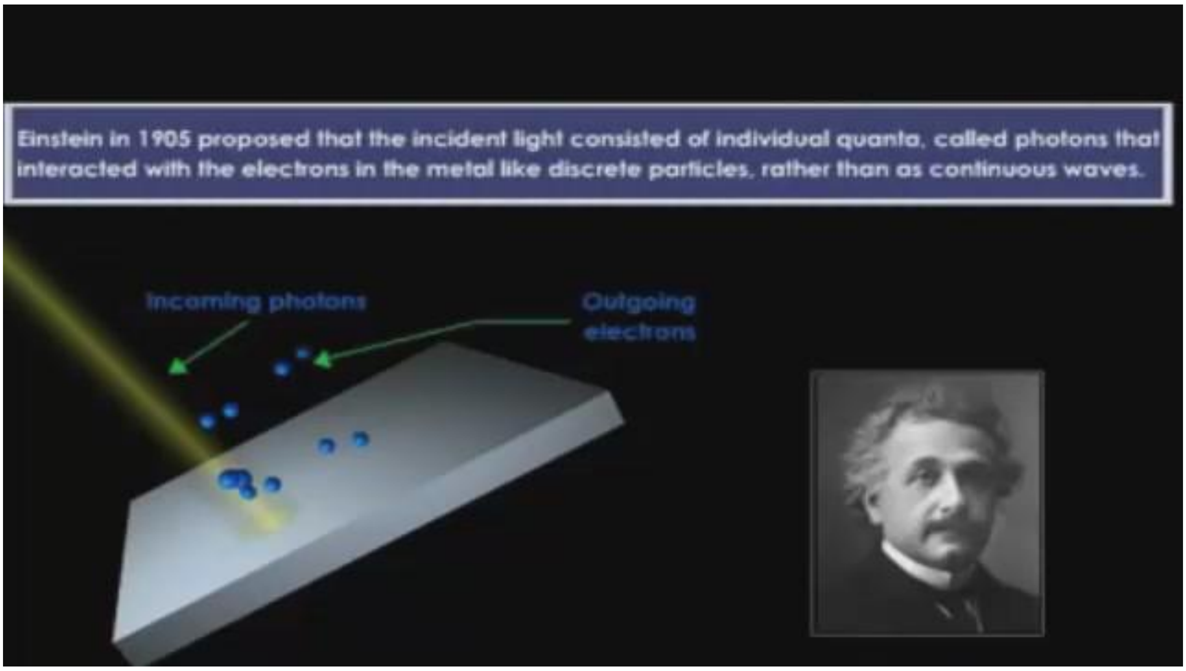
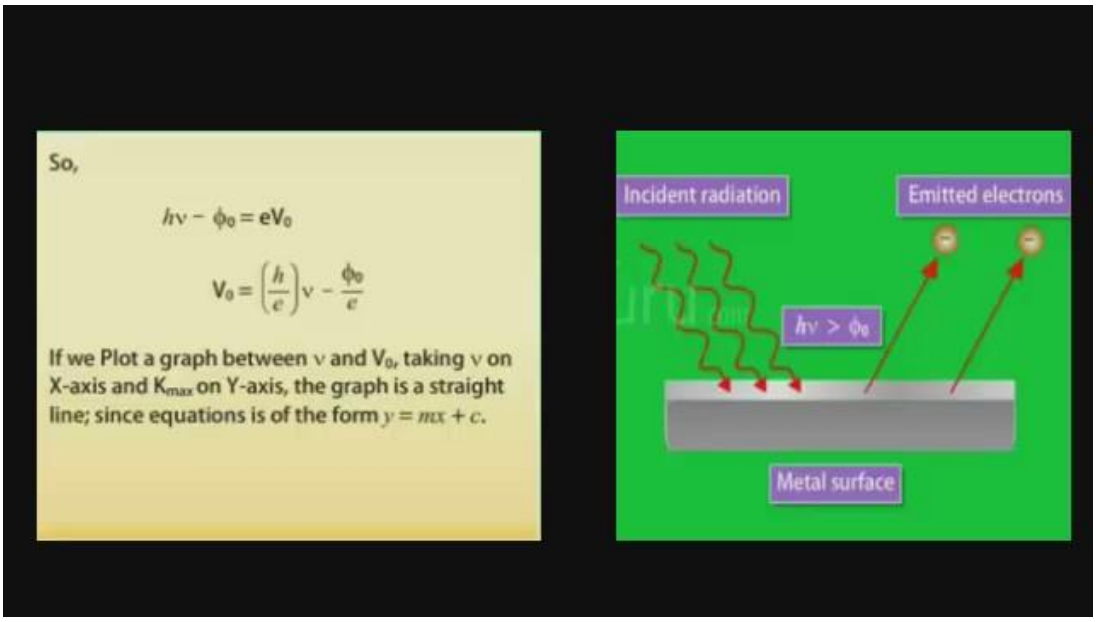
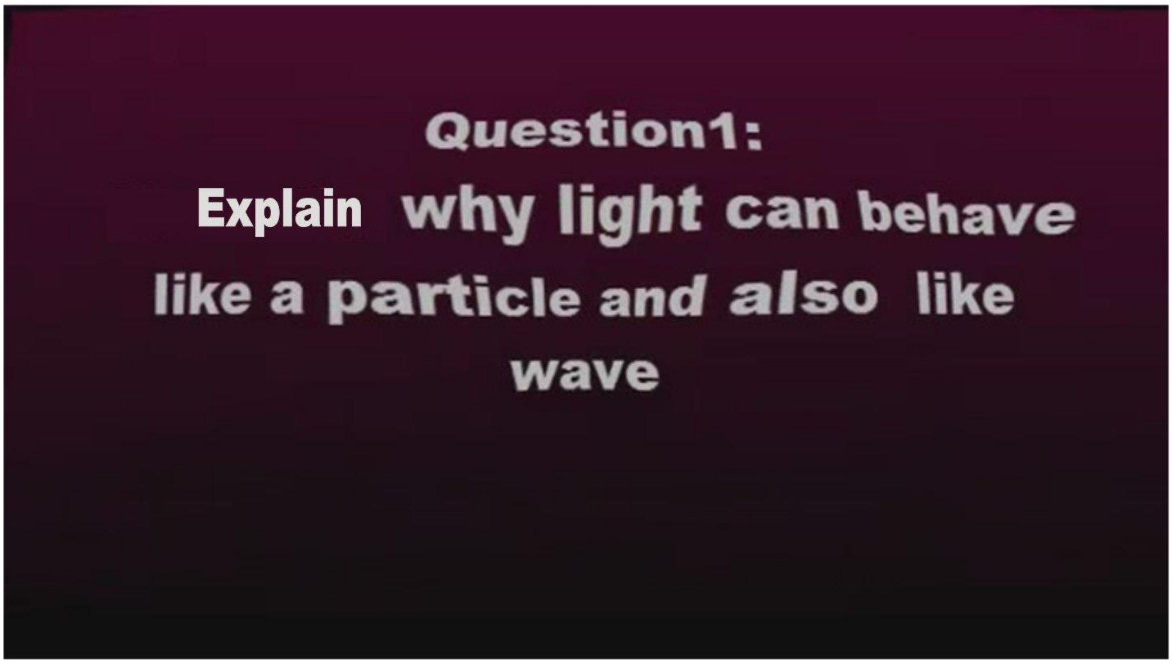

Module 2: Photoelectric Effect and De Broglie Waves Equation

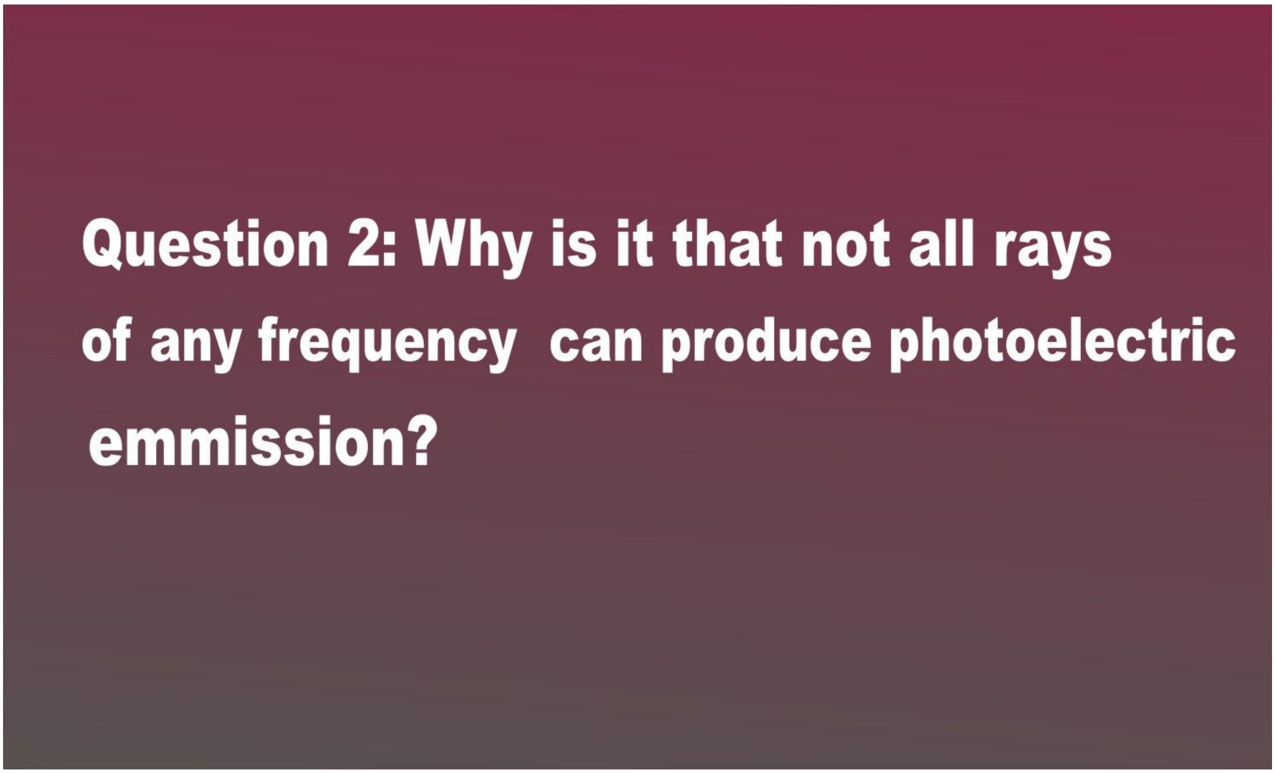

Specific Objective: At the end of this module;
- Learner should able to define photoelectric effect.
- Explain de broglie wave equation.



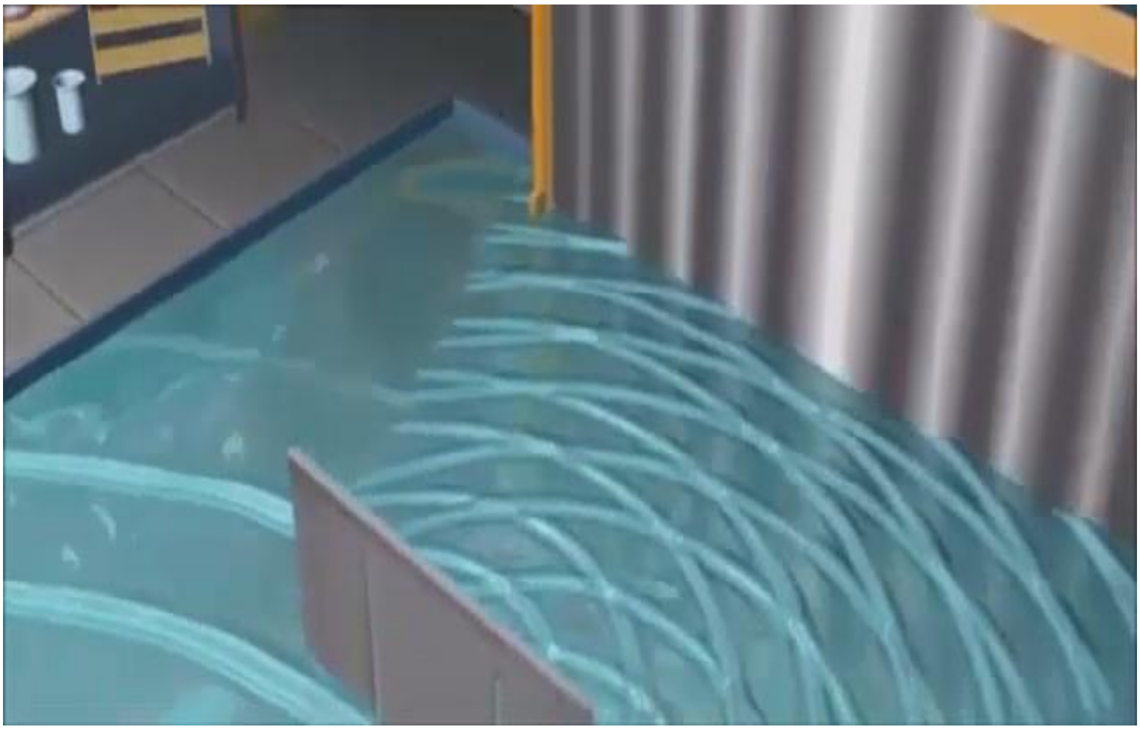


7. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION

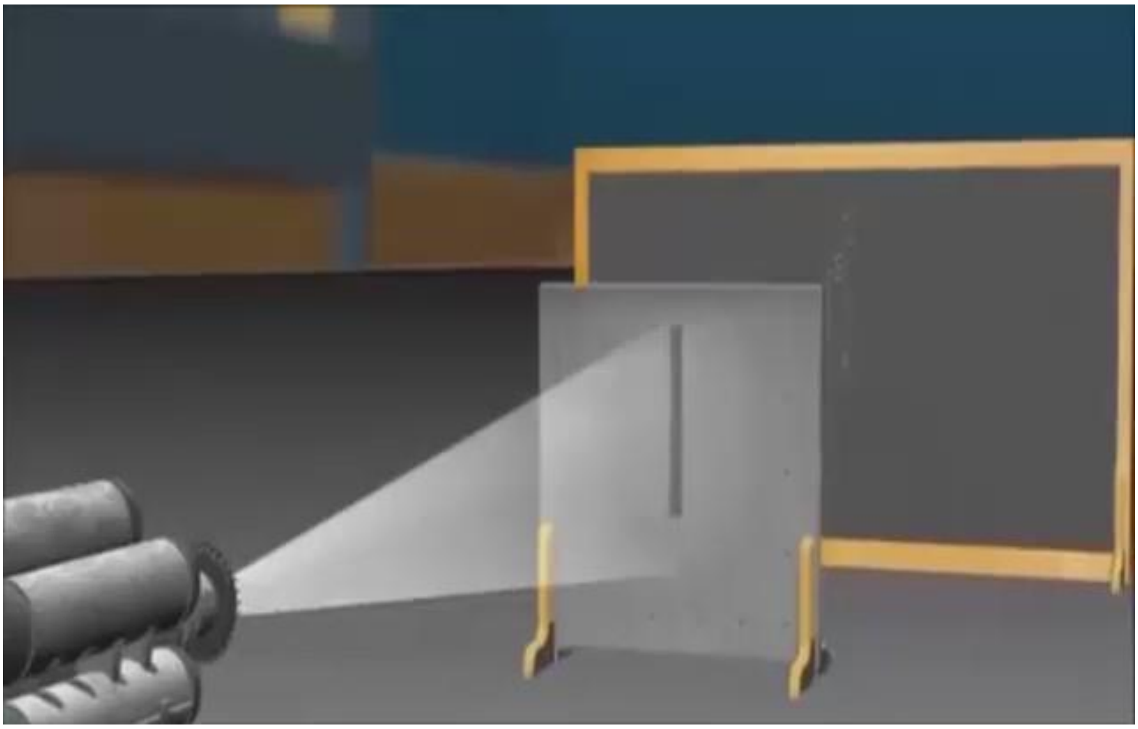

Question1:
Explain why light can behave like a particle and also like wave



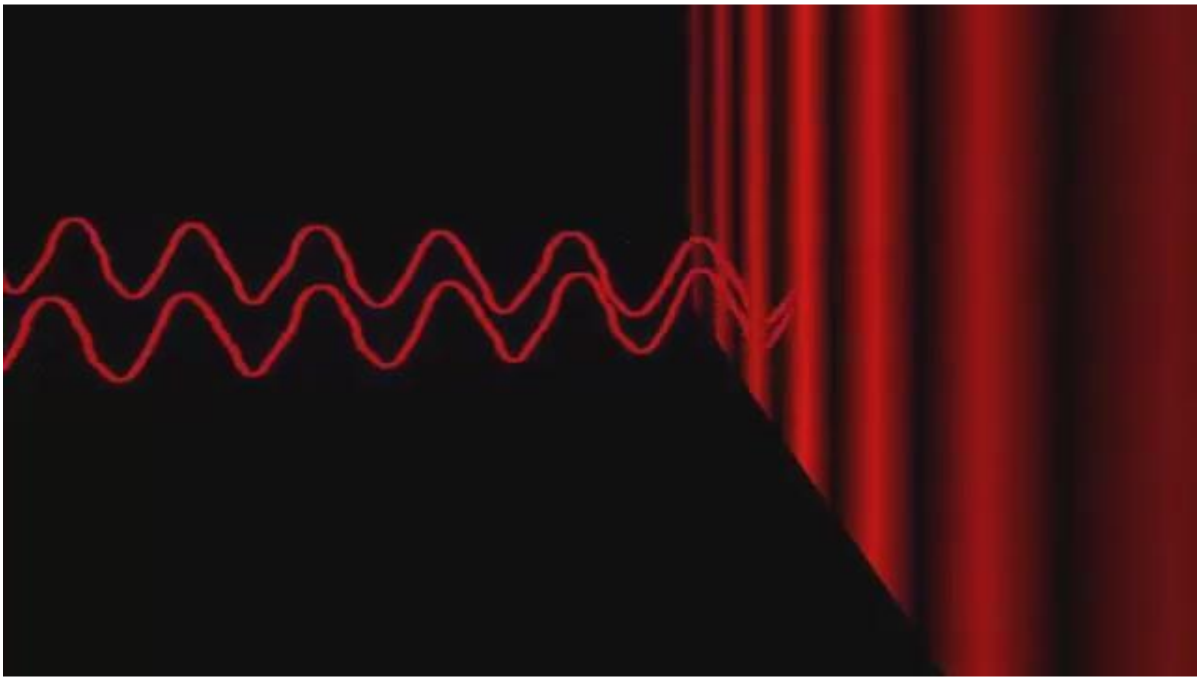
QUESTION TIME

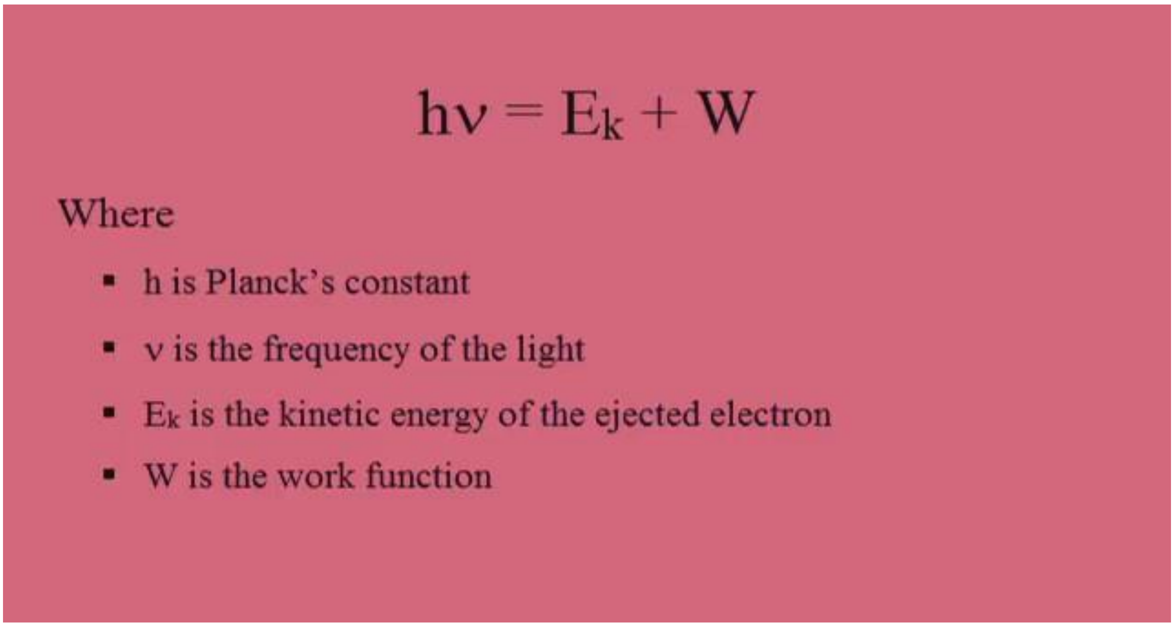


8. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION



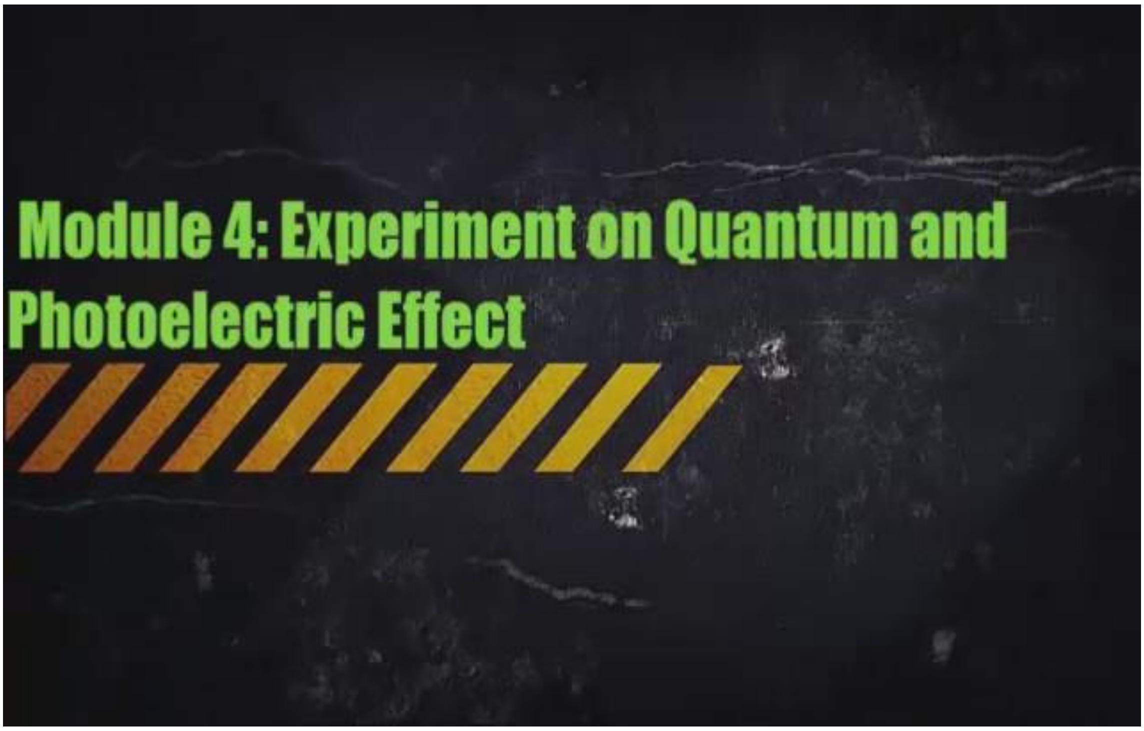
9. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION

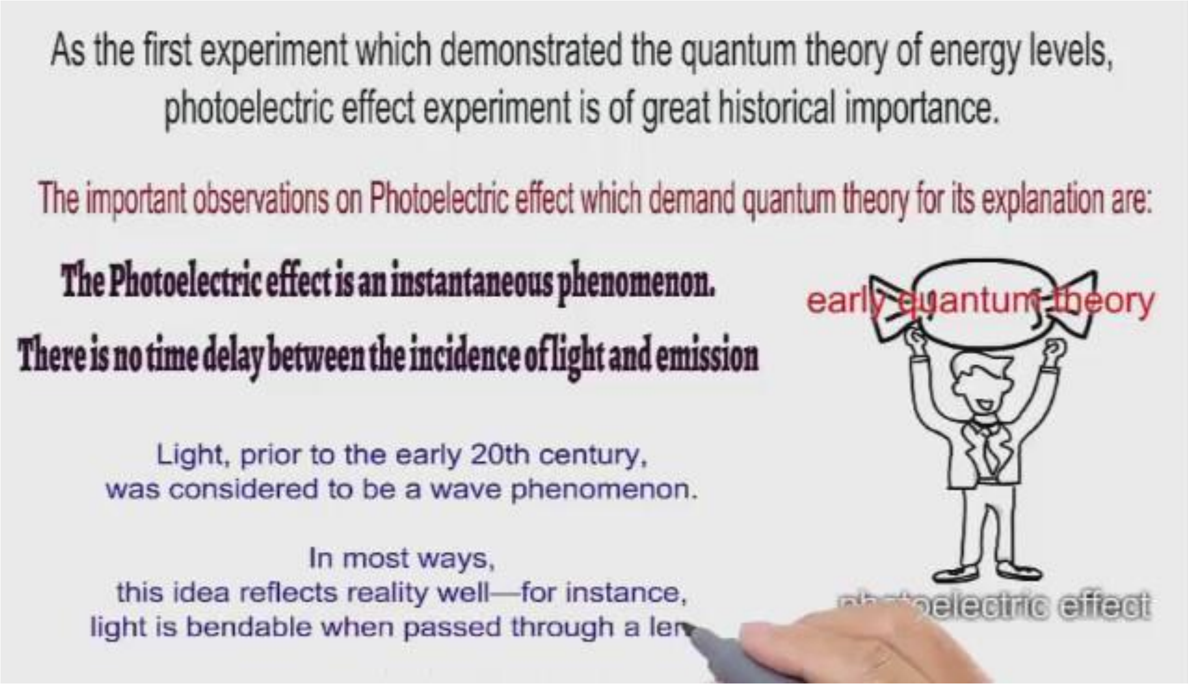


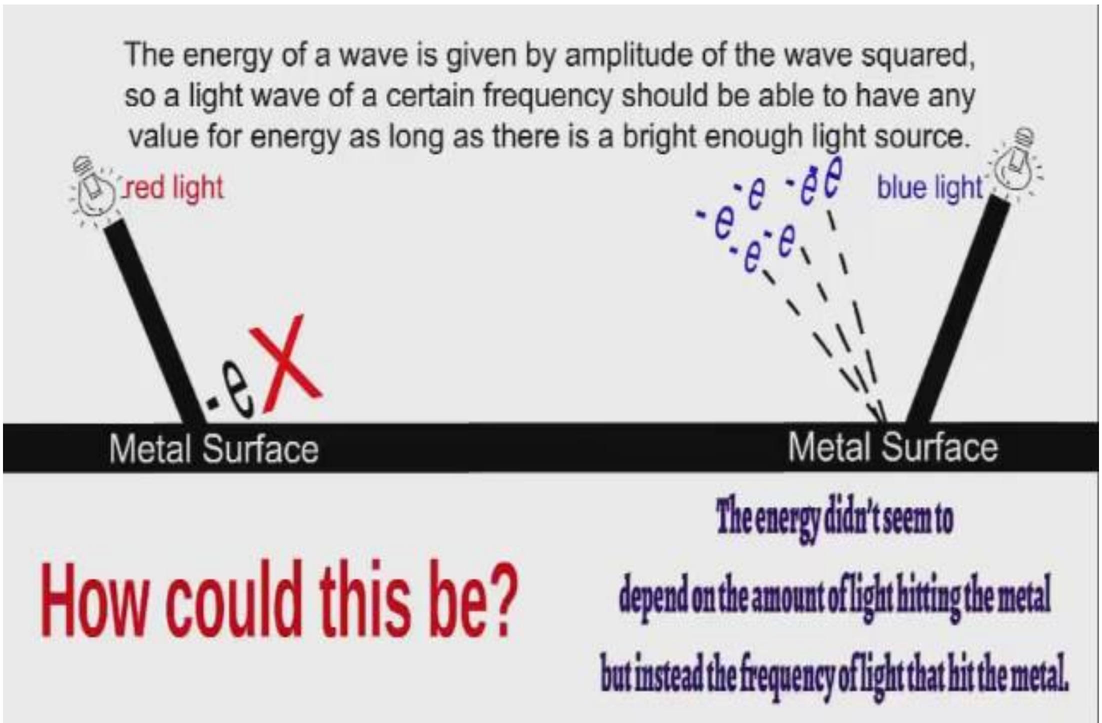


10. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION

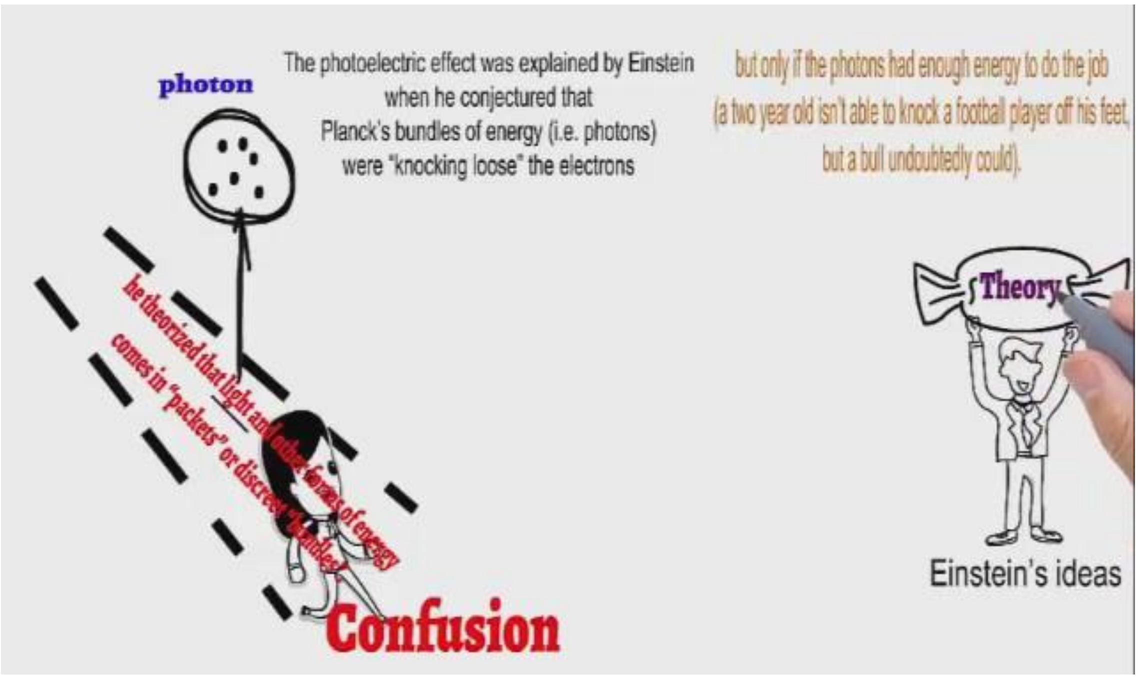

Question
Explain De Broglie conclusion on matter?

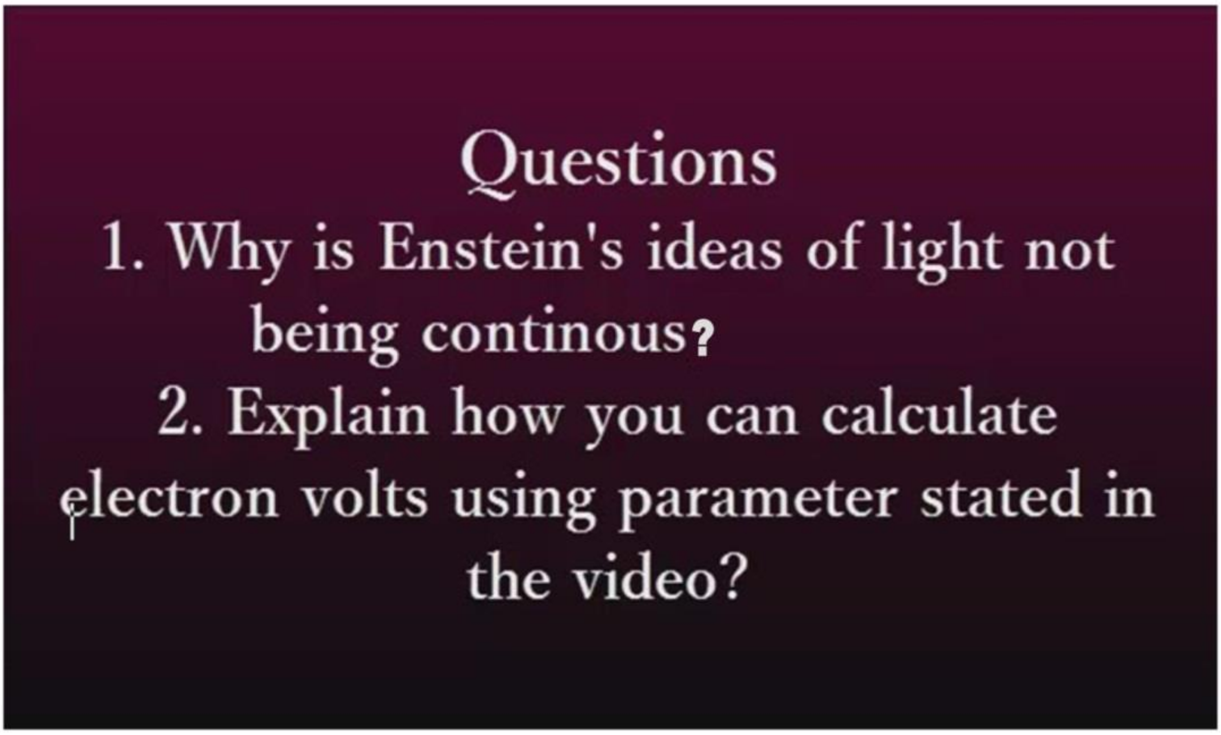

Module 4: Experiment on Quantum and Photoelectric Effect





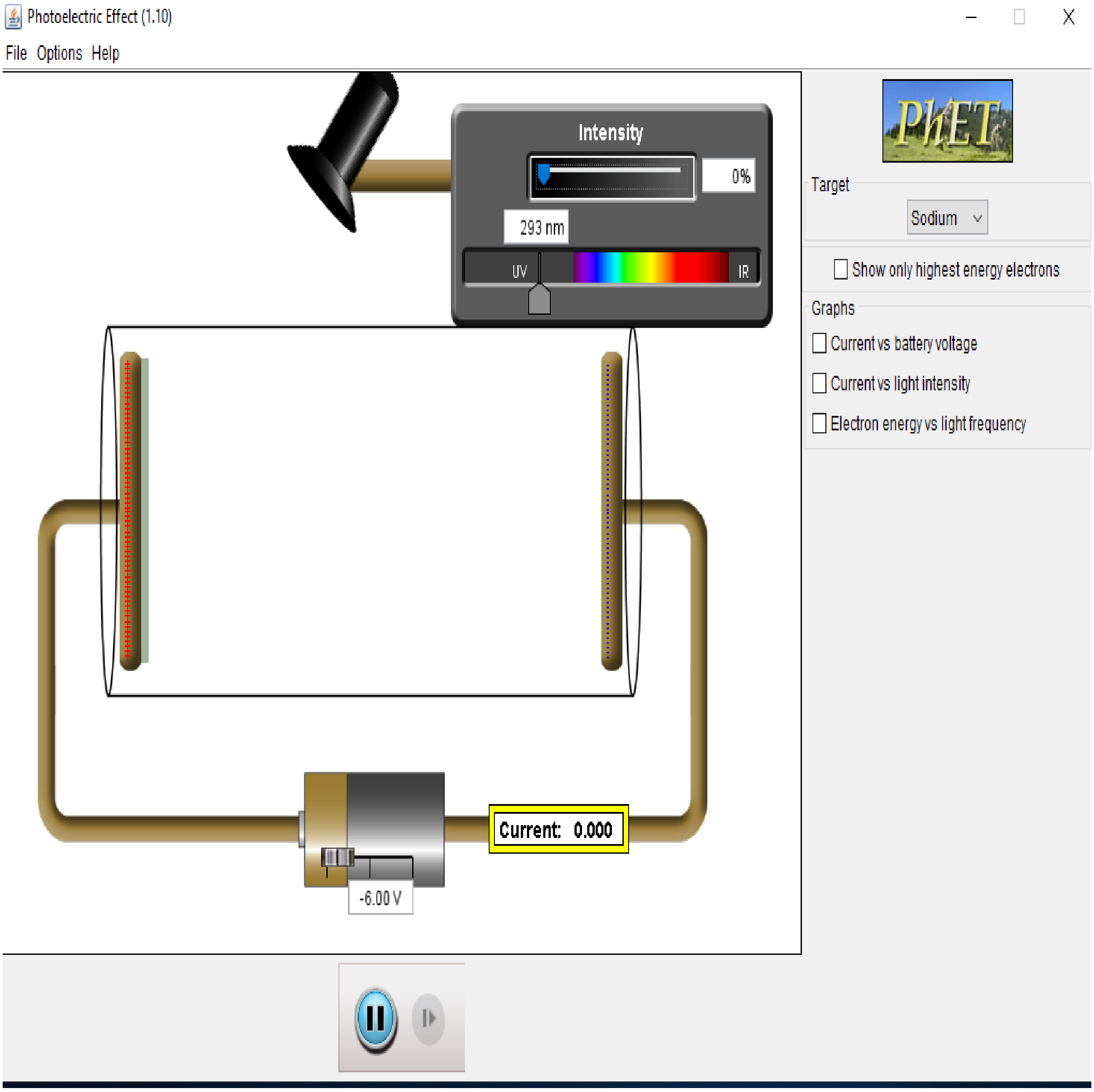
11. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION



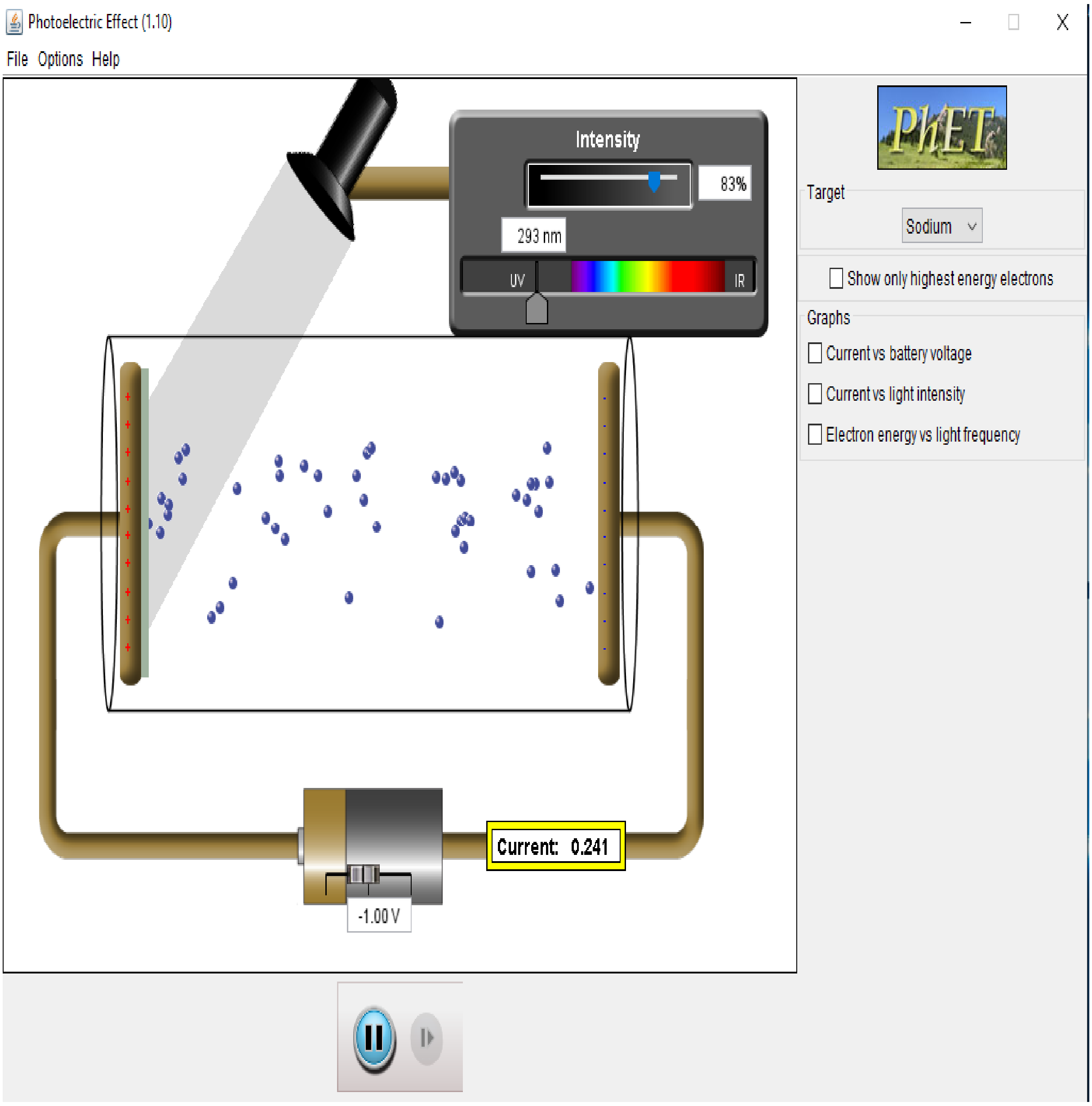


12. CROSS-SECTION OF THE SIMULATED – VIDEO CLASSROOM INSTRUCTION

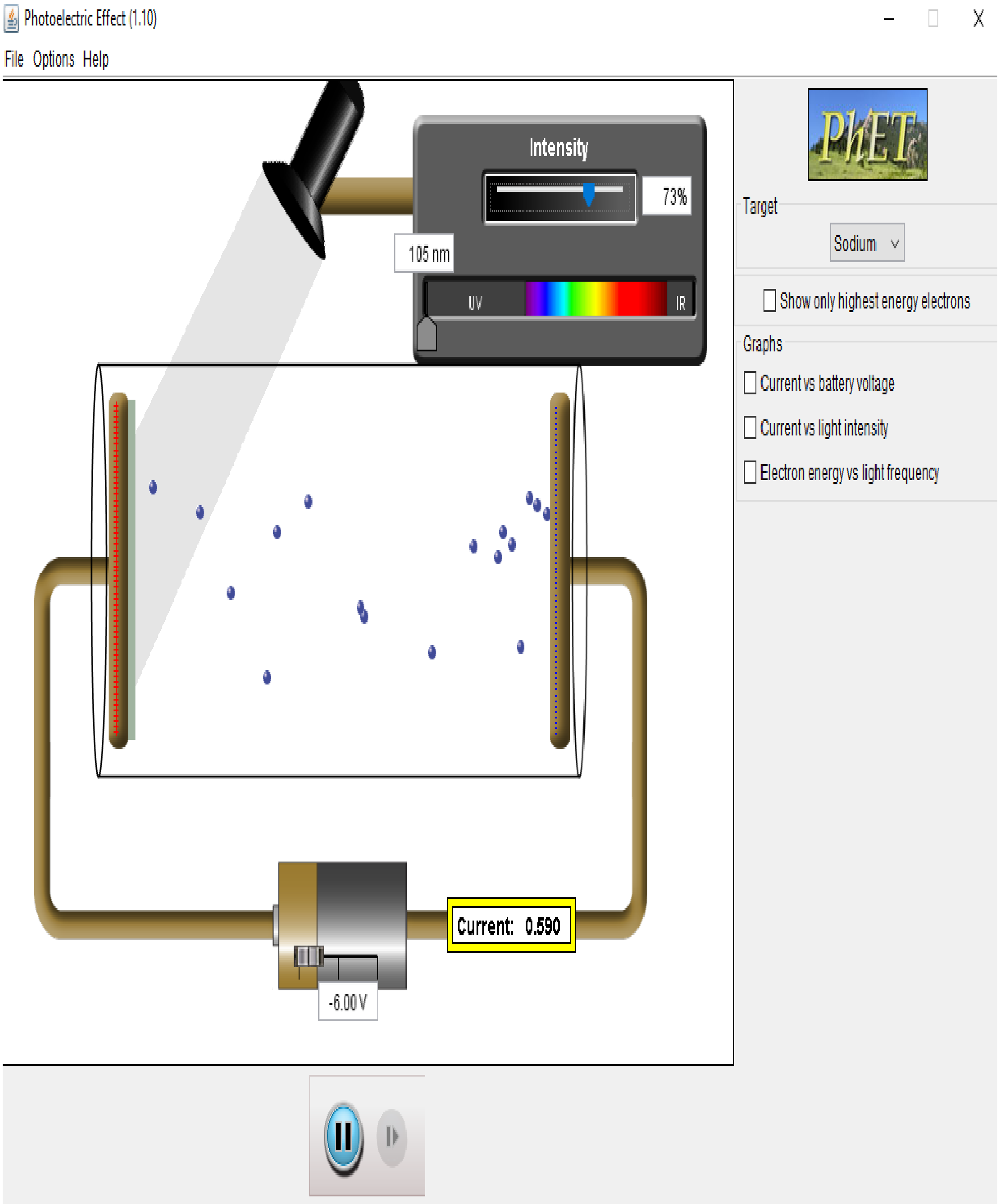
APPENDIX 11
Cross-Section of Virtual Laboratory Based Inverted Classroom Strategy



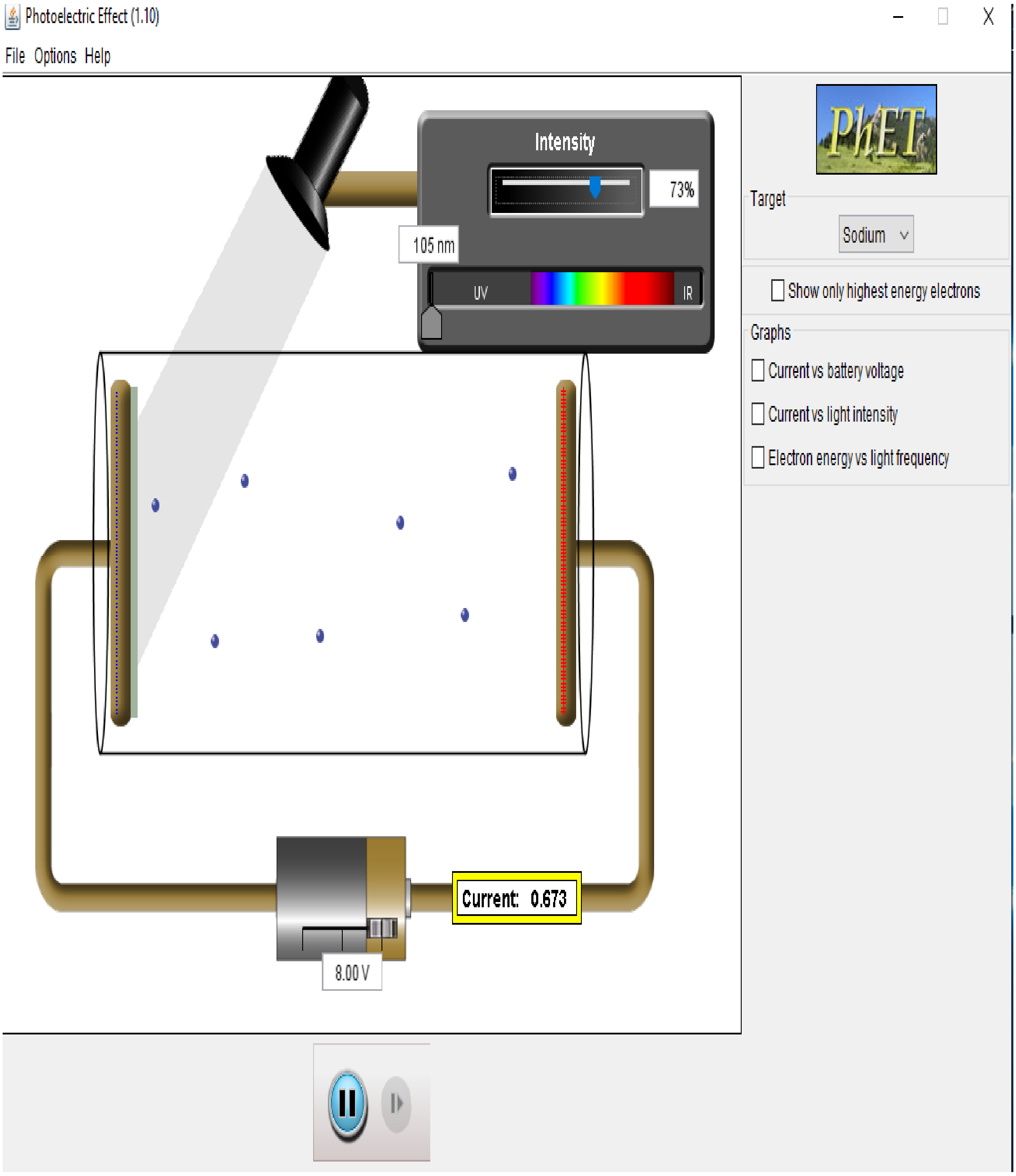
1. CROSS-SECTION OF VIRTUAL LABORATORY CLASSROOM INSTRUCTION



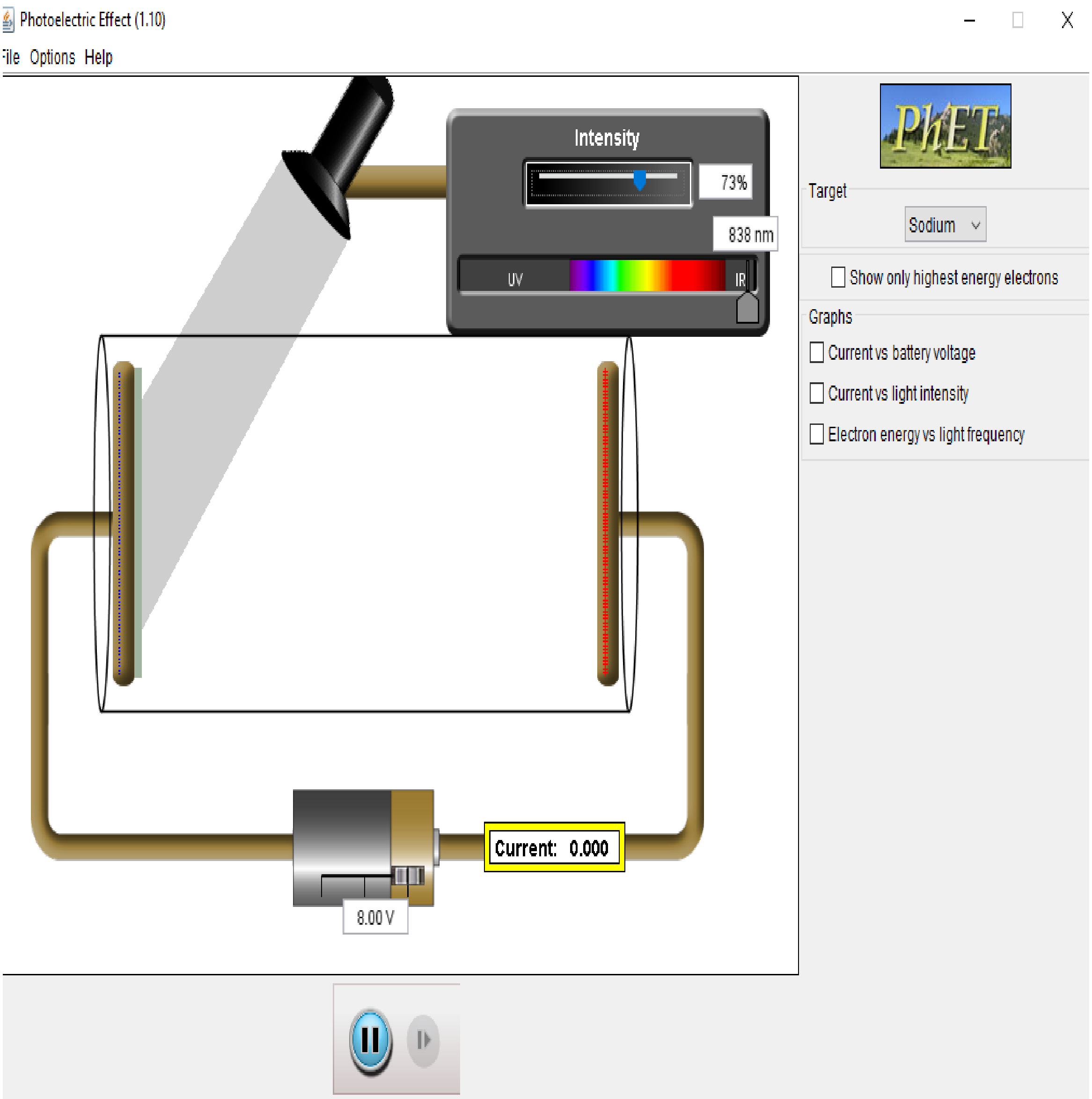
2. CROSS-SECTION OF VIRTUAL LABORATORY CLASSROOM INSTRUCTION



3. CROSS-SECTION OF VIRTUAL LABORATORY CLASSROOM INSTRUCTION



4. CROSS-SECTION OF VIRTUAL LABORATORY CLASSROOM INSTRUCTION



5. CROSS-SECTION OF VIRTUAL LABORATORY CLASSROOM INSTRUCTION

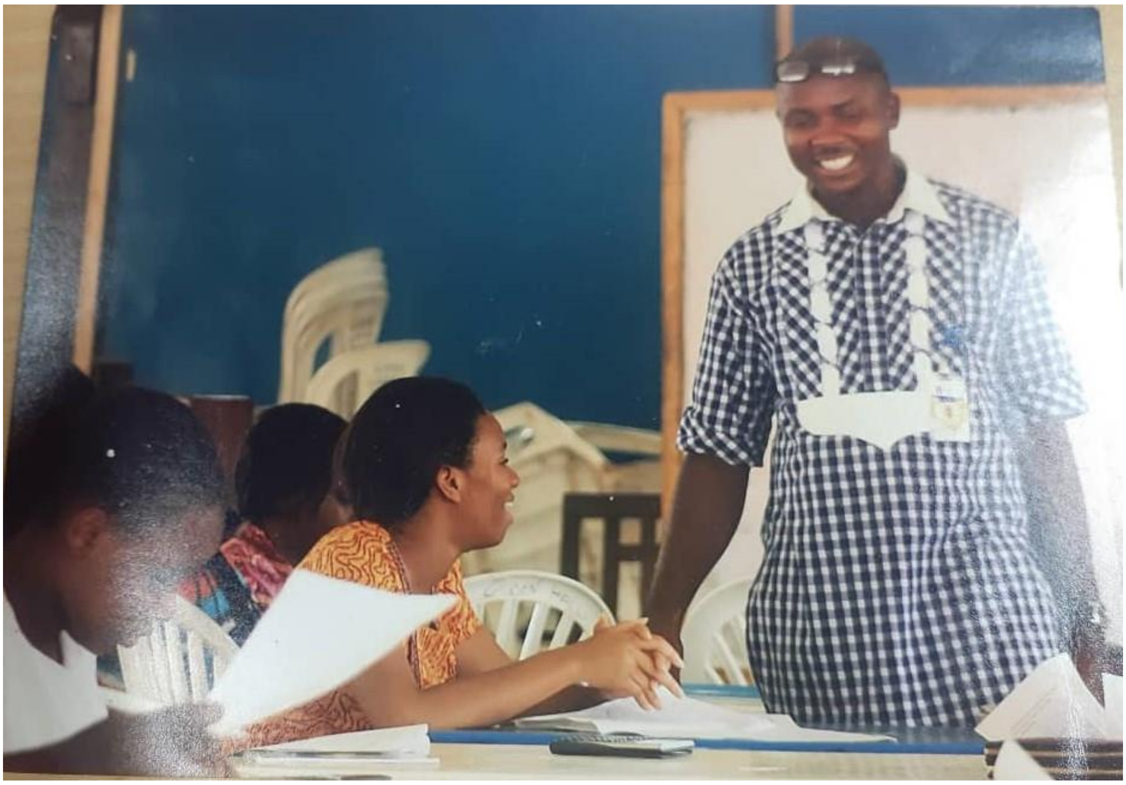
APPENDIX 12
PICTURES OF PREDEGREE STUDENTS IN VARIOUS PRIVATE UNIVERSITIES

CROSS SECTION OF BABCOCK UNIVERSITY PRE-DEGREE STUDENTS

CROSS SECTION OF CALEB UNIVERSITY PRE-DEGREE STUDENTS

CROSS SECTION OF ADELEKE UNIVERSITY PRE-DEGREE STUDENTS

CROSS SECTION OF LEAD CITY UNIVERSITY PRE-DEGREE STUDENTS



CROSS SECTION OF ACHIEVERS UNIVERSITY PRE-DEGREE STUDENTS

CROSS SECTION OF AFE BABALOLA UNIVERSITY PRE-DEGREE STUDENTS