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DIGITAL TRANSFORMATION EDUCATION: CHALLENGES, EFFECTIVENESS, AND PERCEPTIONS OF COMPUTER-ASSISTED INSTRUCTION APPLICATION IN PHYSICS CLASSROOM

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Abstract:
Digital Transformation Education has received greater attention in teaching and learning, however, there is a scarcity of studies on the challenges, effectiveness, and perceptions of Computer-Assisted Instruction (CAI), especially in the Colleges of Education (CoE). In addressing these, the study used the mixed method research design using 12 Physics tutors and 254 Physics students from 3 CoE purposively selected from the Sekyere South District and the Mampong Municipality. Interviews and questionnaires were used for data collection and data analysis was done using Statistical Package for Social Sciences (IBM SPSS), version 26.1, employing descriptive statistics and thematic analysis. The results indicated that Physics tutors generally face a high level of challenges, with inadequate technological resources and limited financial support posing the greatest hindrances. In response, tutors employed various strategies including personal investment in internet bundles and advocacy for institutional intervention. It was again found that both quantitative and qualitative findings converged after merging and that the qualitative findings agreed with the quantitative findings. It was concluded that tutors of Physics in the CoE in the Mampong Municipality and the Sekyere South District encounter challenges during their integration of CAI in their Physics lessons. However, since students of Physics in the CoE perceive the use of CAI as very positive to their

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academic lives, it was recommended that using CAI for teaching and learning Physics in the colleges of education should be fortified.

Keywords: college of education, academic performance, tutors, students, technology, physics education

1. Introduction

The field of education has been profoundly impacted by the advent of digital technology, and this transformation has led to the emergence of digital transformation in education. Digital transformation in education, characterized by the integration of digital tools and technologies to enhance teaching and learning processes, with the ultimate goal of improving educational outcomes, has gained significant attention. Among these, Computer-Assisted Instruction (CAI) has proven to be an effective and advantageous instructional strategy for increasing interest, uplifting mindset, enhancing students' capacity for retention, and improving students' performance (Dwivide *et al*., 2022; Park *&* Son, 2022; Ezeh *et al*., 2021; Nwanne & Agommuoh, 2017; Suleman *et al*., 2017), and with significant impact to facilitate and augment traditional classroom teaching, especially in STEM subjects like physics (Barakabitze *et al*., 2019; Kaputa *et al*., 2022; Ghavifekr & Rosdy, 2015).

The utilization and exploration of Physics play a crucial role in driving the progress and development of societies and nations in the realms of science, industry, technology, and social evolution (Nwanne *&* Agommuoh). Therefore, Physics Education should aim at developing the skills required for a proper understanding of Physics principles governing the behaviours of natural phenomena and their applications. Despite formal instruction, there is still a gap between what has been taught and what is learned in the classroom. Other researchers ascribe the problem to the use of conventional direct instruction instead of active learning (Fraser *et al*., 2014; Rotgans & Schmidt, 2011). Therefore, it is worth investigating alternative teaching methods and approaches, such as the incorporation of technology into classroom teaching, to determine their capacity to promote active and self-directed learning (Rosali, 2020).

CAI is activity-focused and student-centered though its optimization has been a serious challenge (Byusa *et al*., 2022). CAI in teaching in the colleges of education in Ghana became prominent when the Ministry of Education, backed by the Act of Parliament (ACT 847, 2012), upgraded teacher training colleges to colleges of education status and with the accreditation for degree programmes in 2019. Since then, instructors have integrated various pedagogical modules involving CAI strategies such as the use of laptops, projectors, and smart boards in their teachings. Students, on the other hand, are allowed to use smartphones and laptops during instructional hours where the instructor can share videos, YouTube links, power points, and other electronic content packages. However, over the past five years, CAI integration in teaching in the Colleges of Education in Ghana has not been fully assessed with reference to its effectiveness,

challenges, and students' perceptions associated with its implementation. Therefore, this study examined the challenges, effectiveness, and perceptions of students regarding computer-assisted instruction in CoE physics classrooms in the context of digital transformation education.

2. Literature Review

This study draws on several theoretical perspectives, including the cognitive load theory, the social learning theory, and the technology acceptance model.

The Cognitive Load Theory (CLT) focuses on how the cognitive load imposed by instructional materials can affect the learning process. According to the CLT, learners have a limited working memory capacity, and when instructional materials exceed this capacity, learning can be impaired. The theory posits that instructional materials should be designed to minimize Extraneous cognitive load and maximize Germane cognitive load. Extraneous cognitive load refers to the cognitive load imposed by irrelevant information or poorly designed instructional materials. In contrast, Germane cognitive load refers to the cognitive load imposed by instructional materials that are directly relevant to the learning goal (Plass & Kalyuga, 2019). The CLT is relevant to this study because it highlights the importance of designing CAI materials that minimize Extraneous cognitive load and maximize Germane cognitive load. The study can investigate how the design of CAI materials in colleges of Education Physics' classrooms can affect the cognitive load of learners and influence their learning outcomes.

The Social Learning Theory (SLT) emphasizes the role of social interactions and observational learning in the learning process. According to SLT, learners can acquire knowledge and skills by observing the behaviour of others and the consequences of their actions (Pinho *et al*., 2020). The theory posits that learning is influenced by the cognitive processes of attention, retention, reproduction, and motivation. The SLT is relevant because it highlights the importance of social interactions and observational learning in the use of CAI. This makes it suitable for this study which investigates how the use of CAI can facilitate social interactions and observational learning in Physics Education in the colleges of education in Ghana.

The Technology Acceptance Model (TAM) is a theoretical framework that explains how users perceive and adopt new technologies. According to the TAM, users' attitudes towards technology are influenced by two main factors: perceived usefulness and perceived ease of use (Cai *et al*., 2019). Perceived usefulness refers to the extent to which users perceive that technology can enhance their performance and achieve their goals. Perceived ease of use refers to the extent to which users perceive that a technology is easy to use and learn.

3. Conceptual Framework

The conceptual framework in Figure 1 illustrates the relationships between the variables of the study. It suggests that the implementation of CAI in colleges of education Physics' classrooms can lead to increased effectiveness (improved learning outcomes) and positive student perception (Bizimana *et al*., 2022). However, these outcomes may be influenced by mediating variables, such as the challenges faced by teachers and the strategies to address them. Additionally, moderating variables, such as technological infrastructure and teacher competence can either facilitate or hinder the effectiveness and challenges associated with CAI implementation (Major *et al*., 2021).

This conceptual framework provides a visual representation of the interconnections among the variables guiding the investigation of the study's research questions and hypotheses. It helps to identify key factors and their potential impacts on the effectiveness and challenges of implementing CAI in colleges of education Physics' classrooms.

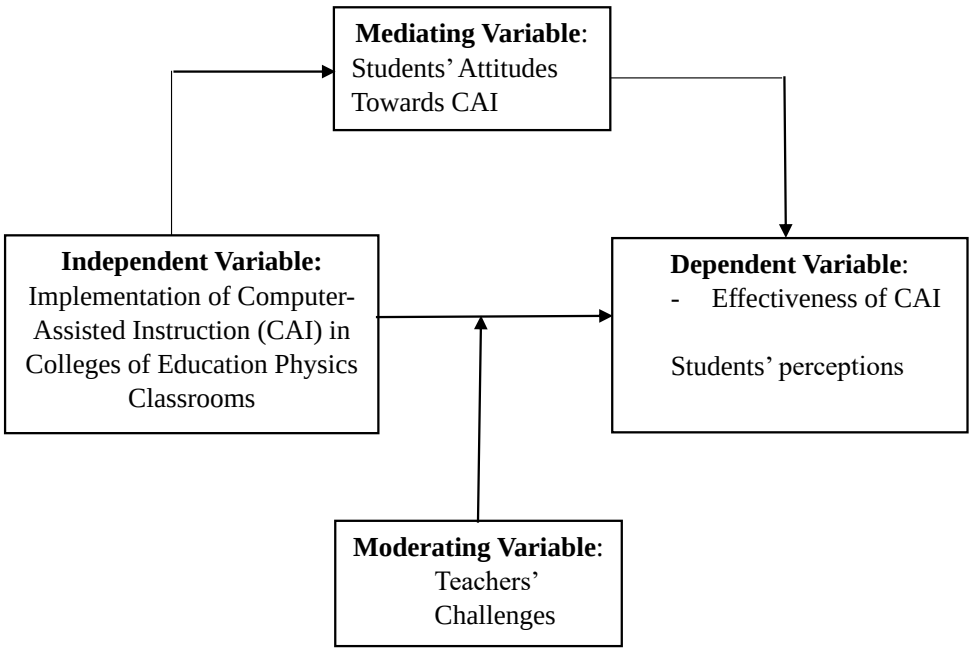

Figure 1: Conceptual Framework for CAI in Colleges of Education Physics' Classrooms

4. Research Purpose and Questions

Despite the challenges and variations in needs, the use of CAI in colleges of education Physics' classrooms represents a promising approach to enhancing student learning outcomes and contributing to the advancement of Physics Education (Cai *et al*., 2017). Several studies have reported positive results such as improved conceptual understanding, increased motivation and enhanced problem-solving skills on the use of CAI in Physics Education (Prahani *et al*., 2022). By examining the impact of CAI on student-centered learning, students' participation and motivation as well as

comprehension of concepts, this study will contribute to the existing body of knowledge on educational technology in the Ghanaian context. It will provide empirical data to validate the perceived advantages of CAI and shed light on the extent to which it facilitates the understanding of complex scientific concepts.

Additionally, this research aims to identify the challenges faced in the implementation of CAI strategies. Understanding the barriers encountered by CoE Physics tutors' and students is crucial for developing targeted interventions and support systems. Therefore, the findings of this study would contribute to the improvement of instructional practices and the successful integration of CAI in Physics Education within the colleges of education in Ghana.

Consequently, the study sought to address the following research questions:

1) What challenges do Physics tutors face when integrating Computer-Assisted Instruction (CAI) in Physics classrooms in colleges of education, and how do they address these challenges?
2) How do students perceive the effectiveness of Computer-Assisted Instruction in Physics classrooms in colleges of education, and what factors contribute to their perceptions?
3) To what extent do the quantitative findings on CoE Physics tutors' challenges in integrating CAI and CoE Physics students' perceptions on the effectiveness of CAI corroborate with the qualitative findings on CoE Physics tutors' challenges in integrating CAI and CoE Physics students' perceptions on the effectiveness of CAI?

5. Research Methodology

The study was conducted in three selected colleges of education; Seventh-day Adventist College of Education, Agona, St. Monica's College of Education and Mampong Technical College of Education. This study was designed to operate in the realm of pragmatism perspective, which uses a methodologically diverse and pluralistic approach to study, which was the foundation of this study. The concurrent embedded design in mixed method was employed, characterized by the simultaneous collection of both quantitative and qualitative data in a single data collection phase.

A total of four-hundred and five (405) Physics students, consisting of two hundred and ninety-nine (299) males and one hundred and six (106) females were used for the study. However, employing multi-stage sample selection approach, a sample of two hundred and fifty-four (254) students of Physics and twelve (12) Physics tutors were randomly selected for the study. Table 1 provides the detailed multi-stage sampling approach used, while Figure 1 presents diagrammatic flow-chart of the overall study design.

Table 1: Details of Multi-stage Sampling Procedure Used in the Study

Stage	Sampling procedure	Activity	Sample Size (N)
Stage 1	Purposive sampling	Selection of second year Physics students and tutors in all three CoE.	405
Stage 2	Simple random sampling	Selection of CoE Physics students to participate in the study.	254
Stage 3	Total purposive sampling	Selection of experienced and willing Physics tutors, who use CAI in all three CoE.	12

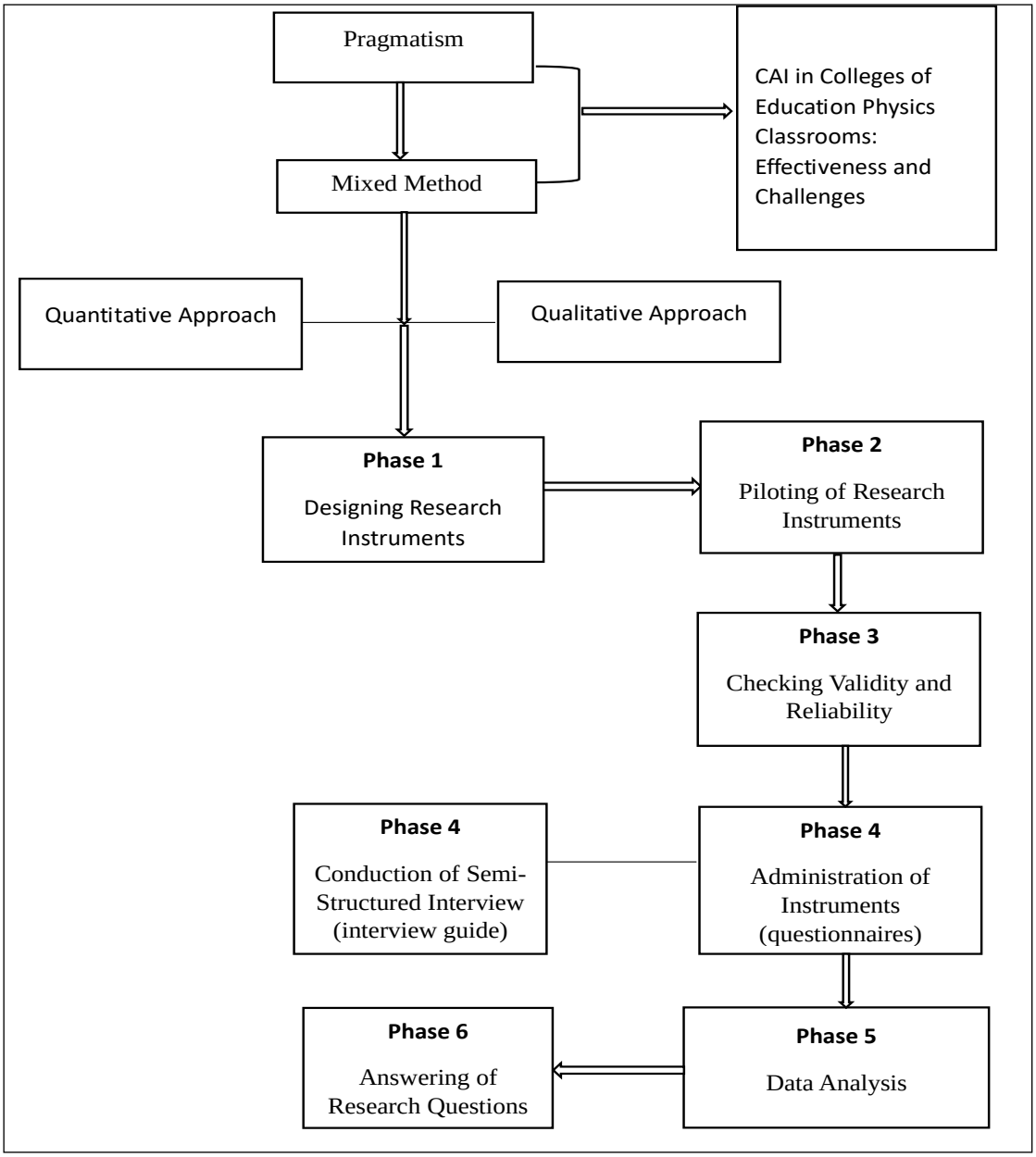

Figure 1: A Flowchart of the Study's Design

In this study, qualitative data was collected with a semi-structured interview using an interview guide, however, quantitative data was collected using questionnaires. The questionnaires were in two folds; Teacher Challenges and Solutions Questionnaire and

Students' Perceptions and Factors Questionnaire. The "Teacher Challenges and Solutions Questionnaire" (Appendix A) was designed to assess the challenges CoE Physics tutors encounter in the integration of CAI in their Physics lessons, and the solutions they employ to address the challenges. This instrument consisted of two sections. The first section (Part A) sought for the background information of respondents, while the section (Part B) of this instrument was adapted from Bariham *et al.* (2019) and consisted of fourteen (14) items which were grouped into two domains. The first domain consisted of nine (9) items which assessed the challenges CoE Physics tutors encounter in the integration of CAI, while the second domain consisted of five (5) items and assessed the solutions CoE Physics tutors employ to address the challenges.

The "Students' Perceptions and Factors Questionnaire" (Appendix B) was used to measure CoE Physics students' perceptions towards the effectiveness of CAI in their learning of Physics, and the factors which contribute to their perceptions. This instrument was adapted from Gambari & Shuaibu (2013) and Arthur-Baidoo *et al*. (2022), and consisted of three sections. The first section, "Part A" sought for the background information of respondents, while the second section, "Part B", which consisted of thirteen (13) item statements, characterised by closed-ended response options, sought to determine CoE Physics students' perceptions towards the effectiveness of CAI in their learning of Physics. The third section, "Part C", which consisted of five (5) "perception factors" also sought to determine the factors which contributed to CoE Physics students' perceptions towards the effectiveness of CAI. Responses to the individual items lie on a four-point scale: "strongly agree", "agree", "disagree" and "strongly disagree". Respondents were asked to state their levels of agreement to the statements by choosing one response from a selected number from the following four responses given for each statement in the instrument. The instruments (Appendix A and B) were given to six (6) experts in the field of science education who determined whether each item on each instrument was "essential", or "not essential".

Afterwards Lawshe's (1975) criteria was used to determine the content validity of the instruments, using Lawshe's Content Validity Ratio (CVR). According to Almanasreh *et al*. (2018), CVR varies between 1 and −1, where high values of CVR indicate the agreement of panelists on the relevance of an item in the instrument. The CVR of the "Teacher Challenges and Solutions Questionnaire" and "Students' Perceptions and Factors Questionnaire was 0.928 and 0.949 respectively, which according to Almanasreh *et al.* (2018), indicate a valid instrument.

The instruments were piloted in order to determine the reliability of the scores of the instruments using fifty-three (53) students who shared similar characteristics with the research participants, but did not take part in the main study (Hertzog, 2008; Johanson & Brooks, 2010). The method of internal consistency reliability, namely Cronbach's alpha, was employed and reliability of "Teacher Challenges Questionnaire" and "Students' Challenges Questionnaire" were found to be 0.831 and 0.782 respectively. These values indicate a "good and high" internal consistency of the scores according to Mohajan (2017).

After administration of the questionnaire, twelve (12) students who were willing, and participated in the completion of the questionnaire, were randomly selected for the interview in order to determine qualitatively, their perceptions on the effectiveness of CAI in the Physics classrooms. Additionally, twelve (12) tutors were as well interviewed on the challenges during CAI integration in Physics lessons. Two main statistical approaches, descriptive statistics and thematic analysis, were employed to answer the research questions. Statistical analysis was carried out using Statistical Package for Social Science (IBM SPSS), version 26.0 for Windows.

6. Results and Discussions

6.1 Research Question 1

In order to ascertain the challenges Physics tutors encounter in using CAI for Physics instructions, tutors' views were sought using a four-point Likert-type questionnaire, as well as transcribed data of teachers' views from a semi-structured interview. Accordingly, the results were answered quantitatively and qualitatively, thereby triangulating the findings. Quantitatively, descriptive statistics, specifically means, standard deviations, overall mean scores, and mean ranks of the responses from the "Teacher Challenges and Solutions Questionnaire" were determined. To interpret the results, Pimentel (2019) interpretation for a four-point Likert scale questionnaire was adapted (Table 1).

Table 1: Adapted Scale of Interpretation for a Four-Point Likert-type Scale Questionnaire

Point	Scale Range	Level of Agreement	Interpretation
1	1.00 – 1.75	Strongly Disagree	Least
2	1.76 – 2.51	Disagree	Low
3	2.52 – 3.27	Agree	High
4	3.28 – 4.00	Strongly Agree	Highest

Source: Pimentel (2019).

Therefore, using Pimentel's scale of interpretation, the items were ranked according to the level of challenges based on their mean scores, as presented in Table 2. Table 2 summarises the mean scores and standard deviations of the 14 items of the "Teacher Challenges and Solutions Questionnaire" (Appendix A). The mean scores of the items of the challenge dimension of the "Teacher Challenges and Solutions Questionnaire" ranged from 1.50 to 4.00, while standard deviations ranged between 0.00 and 0.522. The overall mean score of the challenge dimension was 3.10 (SD = 0.390), suggesting that CoE Physics tutors generally "agreed" that the challenges they encounter during the integration of CAI in their Physics classrooms is at a "high" level, per Pimentel's scale of interpretation. Specifically, as presented in Table 2, per Pimentel's scale of interpretation, items 1, 2, 3, 4, 6 and 9 were reported by CoE Physics to pose the "highest" level of challenge during their integration of CAI in their Physics lessons; item 7 was reported to be at a "high" level of challenge encountered by CoE Physics tutors, while items 5 and 8

were reported to pose the "least" level of challenge. Moreover, from Table 2, CoE Physics tutors' responses from the "Teacher Challenges and Solutions Questionnaire" revealed that, the highest ranked challenge encountered by CoE Physics tutors in integrating CAI into their Physics lessons is item 2 (lack of internet in the school), while the least ranked challenge is item 8 (unstable electricity supply).

Table 2: Descriptive Analysis of Scores from Teacher Challenges Questionnaire

Domain	Item	N	Mean	Std. Dev.	Interpretation	Mean Rank
Challenges						
	1	12	3.67	.492	Highest	4
	2	12	4.00	.000	Highest	1
	3	12	3.99	.000	Highest	2
	4	12	3.33	.492	Highest	6
	5	12	1.58	.515	Least	8
	6	12	3.52	.522	Highest	5
	7	12	2.58	.515	High	7
	8	12	1.50	.522	Least	9
	9	12	3.75	.452	Highest	3
Overall Mean/Std. Dev.		12	**3.10**	**0.390**	**Highest**	
Solutions						
	10	12	3.21	.421	Highest	2
	11	12	1.99	.505	Low	3
	12	12	1.02	.523	Least	5
	13	12	1.23	.554	Least	4
	14	12	3.78	.010	Highest	1
Overall Mean/Std Dev.		**12**	**2.248**	**.421**	**High**	

As revealed in Table 2, in the "solutions dimension", which measures how CoE Physics tutors address the challenges they encounter, the mean item scores ranged from 1.02 to 3.78, standard deviations also ranged from 0.010 and 0.554. The overall mean score of the "solution" dimension was 2.248 (SD = 0.421), suggesting that CoE Physics tutors "agreed" that they address the challenges they encounter during the integration of CAI in their Physics classrooms at a "high" level, per Pimentel's scale of interpretation. Specifically, per Pimentel's scale of interpretation, items 10 and 14 were reported by CoE Physics to be the "highest" level of solution employed to address the challenge they encounter during their integration of CAI in their Physics lessons; item 11 was rated to be at a "low" level of solution employed by CoE Physics tutors, while items 12 and 13 were reported to be at the "least" level of solution employed. Moreover, the highest ranked solution employed by CoE Physics tutors in addressing the challenges they encounter in integrating CAI into their Physics lessons is item 14 (I purchase internet bundle with my personal money), while the least ranked solution employed is item 12 (I purchase my personal technological tools like projector, laptop, etc).

To validate this finding, CoE Physics tutors were interviewed in a semi-structured interview and the findings from the interview were thematically analysed, where the

themes are presented in Table 3, with some representative statements stated below, where all names are pseudonyms.

Table 3: Thematic Analysis of Challenges CoE Physics Tutors Encounter in Implementing CAI

Theme	Challenge	Solution
1	Lack of internet access for instructional purposes	Purchase of personal internet bundles
2	Insufficient and faulty technological equipment	Drawing attention of school authorities
3	Limited time to complete course work	Organising extra classes after normal school sessions
4	Lack of technological skills	Seeking help from well-versed colleagues and students

6.1.1 Theme 1: Lack of internet access for instructional purposes

As presented in Table 3, CoE Physics tutors suggested that tutors saw a lack of technological resources as a major obstacle to using CAI in their Physics classes. Despite a few instructors acknowledging that they have access to computers and internet in their schools, the majority of them admitted they do not. Therefore, CoE Physics tutors articulated that in their attempt to implement CAI into their Physics lessons, access to internet has become one of the limiting factors.

For instance, Mr. Nyarko, a Physics tutor who had taught Physics for eight years in a college of education said:

> "*I have been teaching Physics in this institution for eight years, but neither the government nor the authorities have made any effort to set up active internet services in the school that tutors and students may use to enhance teaching and learning in the classroom*."

Mr. Nyarko further voiced out:

> "*Sometimes I would want to show video demonstrations in the course of instruction to help students understand and conceptualise some complex and abstract Physics concepts. Nevertheless, due to lack of internet access in the school, I find it difficult to do so. As a result, I always hear students complaining about the abstract nature of some Physics concepts we learn in the classroom*."

Also, Mr. Ntiamoah, a CoE tutor who had taught Physics at the CoE for seven years added:

> "*…my brother, you agree with me that we are in days where the computer is assisting man to ease the complexities in life. But for academic purposes, it (the computer) can only be useful when we can access the internet. However, as we talk now, we do not have internet access in our college here.*"

Mr. Ntiamoah continued that:

"*One thing is that Physics is always abstract. Sometimes you can draw a diagram or make an illustration to represent a Physics phenomenon, however, most of the concepts we learn in Physics are not always seen in real life by students and they may need to view an image or video for better understanding. But in this advanced technological world, those resources can only be acquired online. And here we are where we cannot even access those images online.*"

Mr. Opoku, a Physics tutor who had been in service at the CoE for six years equally added that:

"*…I always try to let students download video demonstrations and some tutorials relevant to the Physics concepts we learn in the classroom. However, students always complain they have limited amounts of money to purchase internet bundles all the time, which makes the integration of CAI very challenging. This is because no provision has been made to improve internet connectivity in the school for enhanced educational activities.*"

6.1.1.1 Solution

In an attempt to provide a solution to this challenge, CoE Physics tutors asserted that they only try to purchase their own internet bundles which will enable them access the internet.

For example, in his own words, Mr. Nyarko stated that:

"*Sometimes, what I do to solve this challenge is to use my personal money to buy internet bundles, so that I will be able to access the internet in search for content which will help me deliver lessons to students successfully. But will I always get money to buy internet bundles for my lessons?"* Mr. Nyarko rhetorically asked.

In support of Mr. Nyarko's initiative, Mr. Opoku also added that:

"*The only way I could help is to purchase internet bundle for myself so as a professional who loves his job, I will have to purchase internet bundle with my own money before I can look for appropriate videos and tutorials to help students understand difficult and abstract Physics concepts. And even if I buy, I do not think I can buy also for students."*

6.1.2 Theme 2: Insufficient and Faulty Technological Equipment

Another major challenge which hampered the integration of CAI by CoE Physics tutors into their Physics lessons was insufficient and faulty technological equipment which will help them integrate CAI successfully.

For example, in his voice, Mr. Agyemang, who had also taught Physics in the CoE for six years articulated that:

"*My friend, I have a laptop, and I am ready to sacrifice part of my salary to purchase internet bundle in order to access the internet for some tutorials and demonstrations to be implemented in my lessons, yet there are limited projectors in our department which could assist me to project videos and tutorials for students to understand the Physics concepts better.*"

In agreement with Mr. Agyemang, Mr. Ofosu added that:

"*Personally, I do not have a laptop, however, I always prefer to send students to the computer laboratory for some simulations on certain abstract concepts. Yet, I observe that, majority of our computer systems are faulty, and the good ones are also outdated which makes it difficult to run modern-day software for instructional purposes.*"

6.1.2.1 Solution

To address this challenge, views of CoE Physics tutors were sought to determine how best they fix this challenge. In their attempt, tutors reported that they only try to forward their concerns to the appropriate authorities for their immediate intervention.

For instance, in his voice, Mr. Agyemang stated that:

"*I think for this challenge, it will only request appropriate authorities to intervene. This is because, when equipment like projectors is insufficient, it is only the institution which can provide or make arrangements for sufficiency. What I can only do is to borrow from other colleagues from different institution/department, but that obviously will be difficult.*"

Not only Mr. Agyeman, but Mr. Ofosu, also suggested that:

"*When computers and accessories are faulty, I think it is the responsibility of the institution to fix them. That is beyond the tutor. Therefore, what I do is to forward the challenge to the appropriate authority for their intervention.*"

6.1.3 Theme 3: Limited Time to Complete Course Work

Additionally, CoE Physics tutors reported that time was another limiting factor which interfered the use CAI in class. Physics tutors must dedicate time to lesson planning, choosing the right software or digital resources, and becoming technological savvy in order to successfully integrate CAI.

For instance, Mr. Asiedu stated:

"*I would love to integrate CAI into my Physics lessons, however, looking at the workload and time schedule, with the added responsibility of completing the course in time for students to get ready for their external examinations, I am always restrained to limit the usage of CAI*". Mr. Asiedu went further to say that "*mostly, when I plan using CAI, I will have to spend inordinate amount of time to gather resources, as well as finding the*

appropriate software to use. Due to this I mostly use the marker board for my Physics lessons."

Also Mr. Owusu, a CoE tutor who had taught Physics at CoE for nine years said that:

"*…the topics we are treating per semester are many, which we have to be diligent to complete them within few weeks in a semester, which can also be packed with numerous co-curricular activities for students, and other official responsibilities for tutors. Though in spite of all these, I integrate CAI in my lessons, but at a very minimal rate. Sometimes I download video demonstrations and tutorials for students to watch before face-to-face classroom activities. But I always see that additional information in the face-to-face classroom lessons may require further demonstrations, but due to time coupled with other official duties, I am not able to employ these videos and demonstrations at the maximum*."

6.1.3.1 Solution

To provide a solution to this challenge, CoE Physics tutors voiced that they sometimes organise extra classes outside the normal school sessions so that they can complete their lessons within the semester if they are to integrate CAI into their lessons.

For example, Mr. Owusu stated that:

"*Oh, sometimes I try to organise extra classes (evenings/weekends/early mornings) apart from the usual school curriculum sessions, but that is not comfortable for students since they also need time to do other activities in addition to their personal studies. And because the extra classes are not organised by the college with students being comfortable, I have decided to stop.*"

Mr. Asiedu further added that:

"*… in this situation, the only solution is to organise extra classes for students, and these are also against the school's regulations, so that means I do that in secret*."

6.1.4 Theme 4: Lack of technological skills

According to Boadu *et al.* (2014), initial time commitment can be significant, especially for tutors who are not accustomed to integrating technology into their lessons.

For example, Mr. Nkansah, who had taught Physics in the CoE for over five years said that:

"*I prefer using CAI and would be happy and willing to use it all the time since we are in an age where the use of computer has become the norm in every aspect of life. However, frankly speaking, I am not well versed in computing and we have few tutors who are ready to come to my aid when I encounter challenges. As a result, my usage of CAI is limited*."

In the same way, Mr. Aboagye, a CoE Physics tutor who had also taught Physics in the college for nine years said:

> "*There are skills and techniques which I think I must be acquainted with to be able to use CAI effectively in my Physics lessons; however, I lack some of those basic skills. Also, rarely do we get trained to acquire those basic skills needed to effectively use the computer to improve teaching and learning of Physics, since there are new and modern advancements in the use of the computer. Though I have colleague tutors who can come to my aid when I need them, they are very few in number. This makes it very difficult and stressful to integrate CAI fully in my lessons.*"

6.1.4.1 Solution

To address this challenge, CoE Physics tutors stated that they only try to seek help from knowledgeable colleagues.

For instance, Mr. Nkansah said:

> "*There are few young modern tutors who are more technologically inclined than I do, so I try to sometimes reach out to them for their assistance if the need be. I sometimes do not mind whether they are in my department or not.*"

To add to Mr. Nkansah's solution, Mr. Aboagye also said that:

> "*Some of the students are more knowledgeable in operating these technological equipment and resources. Anytime I want to integrate CAI and I feel like lacking the required knowledge to use it, I call on them to assist me so that I can successfully integrate it.*"

These finding agreed with that of Boadu *et al*. (2014) and Bariham *et al*. (2019), who also reported unavailability of technology resources, such as computers and projectors as a great challenge to their use of technology in teaching. Bonsu *et a*l. (2020) also reported lack of funding, training of teachers, inadequate number of computers in schools; lack of internet in schools; insufficient number of projectors; lack of technical support for teachers; limited ICT skills among teachers and students; and lack of funds to purchase and maintain ICT resources in schools as the biggest challenges teachers encounter when using CAI in teaching and learning. But according to Bariham *et al*. (2019) if teachers are required to utilize CAI in a meaningful way, then unfettered access to training would constitute effective computer use. In this regard, effective leadership is essential for CAI implementation in general in teaching and learning.

However, many administrators and executives, particularly in Africa, lack computer literacy despite having minimal experience or education, limiting their usage of computers to the most fundamental tasks like word processing and PowerPoint presentations (Bello, 2023). Also, according to Bello, the majority of emerging nations, particularly those in Africa, are severely constrained by a lack of resources. Even in cases

where CAI's importance is explicitly endorsed, insufficient funding is frequently provided for the growth of ICT infrastructure in schools. For modern teachers who want to incorporate CAI into their lessons, this always presents many difficulties.

6.2 Research Question 2

This research question sought to determine how Physics students in the CoE perceive the effectiveness of the implementation of CAI during Physics lessons, and the factors that contribute to their perceptions. This research question was also answered using both quantitative and qualitative data, thereby triangulating the findings. Thus, quantitatively, the perceptions and factors contributing to the perceptions of CoE Physics students towards the effectiveness of CAI were sought using means, standard deviations, overall mean scores, and mean rank, from a four-point Likert-type "Students' Perceptions and Factors Questionnaire" (Appendix B). The results are presented in Table 4 and the qualitative analysis was done using transcribed quotes of students' views from a semi-structured interview.

Table 4: Descriptive Analysis of Scores from Students' Perceptions Questionnaire

Item	N	Mean	Std. Deviation	Mean Rank	Interpretation
1	254	3.35	.615	9	Highest
2	254	3.41	.513	7	Highest
3	254	3.31	.671	12	Highest
4	254	3.44	.624	4	Highest
5	254	3.46	.634	3	Highest
6	254	3.66	.632	1	Highest
7	254	3.42	.563	6	Highest
8	254	3.34	.582	10	Highest
9	254	3.33	.587	11	Highest
10	254	3.62	.554	2	Highest
11	254	3.43	.554	5	Highest
12	254	3.30	.630	13	Highest
13	254	3.40	.545	8	Highest
Overall Mean Score	**254**	**3.42**	**.593**		**Highest**

The analysis of responses from "Students' Perceptions Questionnaire", as presented in Table 4, shows that for all the 13 items, the mean scores of the items from the "Students' Perceptions and Factors Questionnaire" ranged from 3.30 to 3.66, while standard deviations ranged from 0.513 and 0.671. The overall mean score of the items from the "Students' Perceptions and Factors Questionnaire" was 3.42 (SD = 0.593), suggesting that CoE Physics students' general perception towards CAI is at the highest level according to Pimentel's scale of interpretation. Specifically, all the items from the "Students' Perceptions Questionnaire", which measured the perceptions of CoE Physics students' perceptions towards the implementation of CAI were interpreted as highest level of perception. It was also revealed from Table 9 that the highest ranked item was item 6 (CAI provides me with better understanding of complex issues in Physics), while the least

ranked item was item 12 (I like learning with CAI because it can accommodate different learning styles).

The second part of research question 2, which sought to determine the factors that contribute to students' perceptions towards CAI was also answered using "Part C" of "Students' Perceptions and Factors Questionnaire" (Appendix B). The scores of the responses from CoE Physics students were analysed using mean, standard deviations, and mean rank from the four-point Likert-type "Students' Perceptions and Factors Questionnaire". As revealed in Table 4, using Pimentel's scale of interpretation, students strongly agreed that all the factors contributed to their highest level of perception as indicated in Table 4. However, according to their ranks based on individual item means, perceived learning outcomes was the highest ranked factor which contributed to students' highest level of perception towards CAI, while interactivity was the least ranked factor which contributed to students' highest level of perception towards CAI.

Table 5: Descriptive Statistics of Students' Responses of Perception Factors from "Students' Perceptions and Factors Questionnaire"

Factor	Mean	Std. Dev.	Mean Rank
Teacher's Pedagogical Approach	3.69	.525	4
Learning Style	3.67	.543	3
Interactivity	3.30	.571	5
Relevance of Content	3.52	.550	2
Perceived Learning Outcomes	3.79	.505	1

To confirm the findings in research question 2, the perceptions of CoE Physics students were sought qualitatively through a face-to-face semi-structured interview and the replies from CoE Physics students suggested that students had positive perceptions concerning the effectiveness of CAI in the Physics classrooms. Students' perceptions were analysed in themes which are presented in Table 6. Some of the views of CoE Physics students (all names are pseudonyms) from the interview are also presented.

Table 6: Thematic Analysis of CoE Physics Students' Perceptions Towards the Effectiveness of CAI

Theme	Perception	Contributory Factor
1	Understanding of Physics concepts	Better academic performances
2	Adoption of CAI in their professional careers	Tailoring instructions to students' need through real world applications
3	Recommendation of the continuous use of CAI by Physics tutors in the Physics classrooms	Guidance and support from tutors and active participation

6.2.1 Theme 1: Understanding of Physics concepts

As presented in Table 6, CoE Physics students voiced that, one of their perceptions towards the implementation of CAI was understanding of Physics concepts. Students perceived that being exposed to CAI raised their understanding of Physics concepts to another level.

Owusuaa, a 23-year-old female CoE Physics student said:

"*…personally, I am so happy and very much comfortable with how my Physics tutor takes advantage of the computer to improve our understanding of Physics concepts. My Physics tutor most of the time gives us videos and tutorials before and after the lesson, especially when he perceives that particular topic was going to be difficult for us to understand. In this way, after watching the video demonstrations and the tutorials, in addition to my Physics teacher's explanation of concepts in the classroom, I understand Physics concepts much better*".

Alex, a 22-year-old male Physics student also said:

"*My Physics tutor does a great job by taking advantage of the social media. Sometimes before he comes to class, he sends us videos in addition to assignments from what we learnt from the video, concerning the topic he is yet to teach. Since my tutor adopted this teaching strategy, I have observed that my understanding of Physics concepts has moved to another level. I now enjoy Physics more than anyone in the class*".

In the words of a 21-year-old female Physics student, Felicia remarked that:

"*…it is only in this school that I have experienced that Physics teachers make good use of the computer sometimes. In our Physics classroom, my Physics tutor always presents to us video demonstrations and tutorials when we find it difficult to understand the ideas which he wants us to grasp. Since then, I prefer not to learn from the textbook anymore. I have been a student who learns all the time using the computer, because my understanding level has improved*".

Mohammed, who is a 23-year-old Physics student in the CoE also added that:

"*In fact, prior to my coming to the CoE, all that I was hearing in the house concerning Physics were not encouraging but I was determined to study Physics in the college. Some were saying it is too abstract, others were saying it is the most difficult subject among the sciences, and many more. But Sir, frankly speaking, since I came here, I have seen it to be absolutely opposite. In fact, I think my Physics tutor also acknowledges the fact that the subject is very difficult and sometimes abstract, he uses the computer and internet to make sure that the concept is turned from abstract to concrete. This has really helped me in my learning of Physics in the college*".

6.2.1.1 Contributory Factor: Better Academic Performances

CoE Physics students expressed that what caused them to have the perception of understanding Physics concepts much better was how those understandings were reflected in their quizzes and assignments.

For instance, Owusuaa added that:

"…This is evident in my performances during assessments. I always find out that, anytime my Physics tutor uses CAI to teach, my performance in quizzes is much better than when he only comes to the class to lecture".

Also, Alex stated that:

"*…I see my performance in class quizzes and assignments is always improved*".

In addition, Mohammed remarked that:

"*…My second semester result in Physics was better than my first semester's. I think in the second semester, my Physics teacher used technology more than the first semester. So I was able to learn according to my characteristic*".

6.2.2 Theme 2: Adoption of CAI in Their Professional Careers

Also, CoE Physics students responded that if they are given opportunities and support from their prospective educational authorities, they would in no doubt use CAI in their professional careers. This is because student-teachers believed they have greatly benefited from the use of CAI in their training by their CoE Physics tutors and could equally transfer such benefit to their learners when posted to their field of practice.

For instance, Ibrahim, a 24-year-old CoE Physics student acknowledged that:

"*I think it is better to begin the introduction of learning with the computer in our basic schools, as well as the Senior High Schools. At least starting with the basic concepts which are required at their levels. This is because, how the introduction of the computer in our Physics lessons has benefited me is another world to me. For example, the way my Physics tutor uses CAI has really motivated me to use it when I get the opportunity to teach. I will therefore definitely apply it in my professional career if only I get the support and backing from the school's authorities*".

In her view, Diana, a 23-year-old female Physics student added that:

"*Sir, you know we are in the computer world where I think everything, including learning should be done with the computer. Therefore, personally, I will be happy to integrate the computer in the teaching and learning process in my professional career. I think this will draw young learners' attention to the importance and benefits of mobile phones, tablets and modern technological devices and equipment in their academic lives, rather than using it for entertainment. I have actually learnt a lot through the way my teacher uses CAI, where he wants all students to be actively involved in the lesson."*

By adding to the views of Frimpong and Ibrahim, Cecilia also expresses her delight and anticipation on the use of CAI in her professional career since it would be of immense benefit to learners under her care.

In her own words, Cecilia stated that:

> "*I will make no mistake to let this knowledge and benefit I have received here in the college be in vain. I will make sure that the younger ones whom I will also get the opportunity to train in the future will also benefit greatly from using the computer to learn, maybe beginning with the simple aspects. So that by the time they grow and advance to the higher levels in their academic careers, they would have understood the benefits of the computer in teaching and learning. This is because, the use of computer in the classroom and outside the classroom has transformed me as a student*".

6.2.3 Contributory Factor: Tailoring Instructions to Students' Needs Through Real World Applications

CoE Physics student-teachers further explained that the contributory factor to them utilising CAI in their professional careers was as a result of how their Physics tutors integrated CAI in their Physics lessons.

For instance, Cecilia, in her expression continued that:

> "*… my Physics tutor can connect CAI activities to real-world applications and scenarios. This helps me to see the practical value of what we always learn in Physics. And we are told that, students learn better when information is presented from concrete to abstract. So, I have witnessed this for myself, and I think it will be very good to also implement it with the younger students who even need to learn in more concrete ways*".

Ibrahim also added to Cecilia's voice that:

> "*…I think my Physics tutor can use CAI to modify instruction to individual student needs. I can now see that CAI adapts to my level and speed at which I understand some Physics topics. It is because of this reason that I personally believe what we are taught that, adapting instructions to students' level and pace of learning helps students to do well. Because of this I think it will be very good to also use it when I begin my service*".

6.2.3 Theme 3: Recommendation of the Continuous Use of CAI by Physics Tutors in the Physics Classrooms

Lastly, Physics students in the CoE endorsed that they would like Physics tutors to continue and increase the use of CAI in Physics lessons. Students acknowledged that though the benefits they enjoyed and the importance CAI had on their academic lives cannot be overlooked, however this benefit was the results of the minimal usage of CAI in the Physics classrooms.

For example, Anthony, a 22-year-old Physics student-teacher in the CoE expressed that:

"*…it is so exciting what I see the computer brings to me as a Physics student, however, this is only done less times. It is not always used by my tutor, but whenever he uses it, the way he uses it to suit my learning style makes me have a good experience. I do not know why he does not frequently use it, but I think they should not discontinue the use and integration of computer in the teaching and learning of Physics*".

Paulina, a 22-year-old female Physics student-teacher similarly said:

"*… perhaps for genuine reasons, I do not see my Physics tutor use it regularly, but even my tutor knows that his lessons become interesting to almost all students whenever he uses or integrates the computer into the Physics lessons. I will therefore recommend that, my Physics tutor should continue the use of computer during the instruction*".

Similarly, Angela, a 23-year-old female Physics student-teacher in the CoE said:

"*In my class, some of my colleagues have this attitude that, whenever our Physics tutor comes to the class to lecture without using any aspect of the computer to facilitate instruction, they (students) feel bored and doze off while the tutor is teaching. I think it is because, students are not really engaged and also do not understand the concept being taught that day. But anytime, my tutor engages us through the integration of CAI, we become active. Therefore, I will recommend that my Physics tutor should use the computer often in the teaching and learning of Physics*".

Lydia, a 23-year-old female Physics student-teacher in the CoE also added that:

"*… I have observed that, in any semester, topics which my tutor integrates the computer in the teaching and learning process, our grades are exciting to see, but in semesters where the computer and its other aspects are not used, we struggle in the exams. So, I hope that the computer and its other aspects are often used, even if it can be used every day in the teaching and learning of Physics*".

6.2.3.1 Contributory Factor: Guidance and Support from Tutors and Active Participation

CoE Physics student-teachers also recommended the continuous use of CAI by Physics tutors in the Physics classrooms due to the pedagogical approach by their tutors when they use CAI.

For instance, Lydia expressed that:

"*…my Physics tutor can offer guidance and support as we use CAI, especially when we encounter difficulties. Because this assistance always boost our confidence to use CAI*".

Angela also explained that:

"*…my Physics tutor can plan activities that require active participation rather than sitting down and listening to him. When we interact with what learn and solve problems through CAI, we find it more engaging and effective, that is why I think it is better to use it always*".

These finding was in accordance with that of Gambari & Shuaibu (2013), Belal (2014) and Arthur-Baidoo *et al*. (2022), who all reported that students had positive perceptions about the integration of CAI. This finding is possible because according to Qaiser *et al*. (2017) the integration of CAI offers equal educational opportunities for students by using the same programme. It also helps to enable learners to focus on the physical meaning of the abstract concepts, subsequently, to get a detailed understanding of the theory, while providing flexibility to learners. This will inevitably result in students becoming more engaged in the course and more motivated to study, which will improve their academic results (Ekundayo, 2022; Li *et al.*, 2023).

6.3 Research Question 3

This research question sought to determine how quantitative findings in this study validated with the qualitative findings. Table 7 showed that in merging quantitative and qualitative results, a merging-converging nature existed in Challenges CoE Physics tutors encounter in integrating CAI in their Physics lessons. According to Wang (2008) and Lubis & Fithriani (2023), addressing the challenges for effective and successful implementation of CAI does not involve only the tutor, but also authorities and major stakeholders of the educational system. This could account for the low level of solution employed by tutors as they are not solely responsible for addressing the challenges.

In addition, the factors which contribute to CoE Physics student-teachers' "highest" level of perception also merged with the qualitative findings as indicated by the themes. This finding was also consistent with Gambari & Shuaibu (2013) who stated that more than 50% of students who were exposed to CAI affirmed that CAI can help them learn some difficult concepts more easily, and also can accommodate different learning styles.

Table 7: Data Integration of Qualitative and Quantitative Findings

Aspect of focal point	Dimension	Quantitative finding	Qualitative finding	Nature of integration
CAI Implementation Challenge	Challenges	CoE Physics tutors challenges they encounter during the integration of CA I in their Physics classrooms is at a "high" level, with an overall mean score of the challenge dimension was 3.10 (SD = 0.390).	Tutors acknowledged that lack of internet access for instructional purposes, insufficient and faulty technological equipment, limited time to complete course work, and lack of technological skills hamper their integration of CAI.	Merging-converging
	Solutions	The overall mean score of the "solution" dimension was 2.248 (SD = 0.421), suggesting that CoE Physics tutors address the challenges they encounter during the integration of CAI in their Physics classrooms at a "low" level	CoE Physics tutors stated that they resort to purchase their personal internet bundles, drawing the attention of school authorities, organising extra classes after normal school sessions, and seeking help from well-versed colleagues and students.	Merging-converging
Students Perceptions Towards the Effectiveness of CAI	Perceptions	CoE Physics students generally had highest level of perception towards the effectiveness of CAI. The overall mean score of the items from the "Students' Perceptions Questionnaire" was 3.42 (SD = 0.593).	understanding of Physics concepts, adoption of CAI in their professional careers, and, recommendation of the continuous use of CAI by Physics tutors in the Physics classrooms were some of the perceptions CoE Physics students had towards the effectiveness of CAI.	Merging-converging
	Factors Influencing Perceptions	Using mean ranks, perceived learning outcomes was the highest ranked factor which contributed to students' highest level of perception towards CAI, while interactivity was the least ranked factor which contributed to students' highest level of perception towards CAI.	Students think their better academic performances in Physics assessments, Instructions tailored to students' need through real world applications, as well as guidance and support from tutors and active participation, were some contributory factors leading to their highest level of perceptions	Merging-converging

7. Conclusion

Based on the findings of this study it can be concluded that CoE Physics tutors in the Mampong Municipality and the Sekyere South District encounter challenges during their integration of CAI in their Physics lessons. However, the study revealed that students of Physics in the study areas perceived the integration of CAI in their Physics lessons as very positive to their academic and professional lives. Precisely, students perceive that the integration of CAI helps in understanding of Physics concepts. Therefore, they expressed their readiness and willingness to implement CAI in their professional careers after their college education.

Availability of Data and Materials
The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

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Authors declare there are no competing interests.

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Appendix A: Teacher Challenge and Solution Questionnaire

Part A: Demographic characteristics

This section contains tutors' demographic characteristics. Please provide the appropriate information in the boxes provide beside each characteristic.

- Number of years in service: ☐
- Gender:
  - Male
  - Female

Part B: The number of statements with their responses

This section consists of a number of statements with their responses, concerning CoE tutors' challenges encountered through the usage of CAI in Physics lessons. The responses range from Strongly Agree to Strongly Disagree. Please provide the appropriate response by ticking the corresponding response scale beside each statement.

Domain	Item	Statement	Response			
Challenge	1	Inadequate number of computers in the school	SA	A	D	SD
	2	Lack of internet in the school	SA	A	D	SD
	3	Insufficient number of projectors in the school	SA	A	D	SD
	4	Lack of technical support for teachers.	SA	A	D	SD
	5	Limited ICT skills among teachers and students.	SA	A	D	SD
	6	Lack of relevant digital content to support the integration of CAI	SA	A	D	SD
	7	Insufficient time for integration of CAI into teaching and learning process due to pressure to prepare students for exams	SA	A	D	SD
	8	Unstable electricity supply	SA	A	D	SD
	9	Lack of funds to purchase and maintain CAI resources in the school.	SA	A	D	SD
Solution	10	I always draw the attention of school authorities to seek for their intervention	SA	A	D	SD
	11	I attend online seminars for knowledge and skills update	SA	A	D	SD
	12	I purchase my personal technological tools like projector, laptop, etc.	SA	A	D	SD
	13	I create online blogs and websites for students to access important information relevant to the course	SA	A	D	SD
	14	I purchase internet bundle with my personal money	SA	A	D	SD

Appendix B: Students' Perceptions Questionnaire

Part A: Demographic characteristics

This section contains students' demographic characteristics. Please, provide the appropriate information in the boxes provide beside each characteristic.

- Age: ☐
- Year: ☐
- Programme: ☐
- Gender:
  - Male
  - Female

Part B: The number of perception statements

This section consists of a number of perception statements with their responses, concerning the effectiveness of CAI in Physics lessons in colleges of education. The responses range from Strongly Agree to Strongly Disagree. Please provide the appropriate response by ticking the corresponding response scale beside each statement.

Perception Statement	**Response**			
I enjoy using computer to solve Physics problems.	**SA**	**A**	**D**	**SD**
Using computer to solve Physics problems gives immediate feedback.	**SA**	**A**	**D**	**SD**
I learn faster when I use computer to solve Physics problems.	**SA**	**A**	**D**	**SD**
The usage of computer to solve Physics questions can be enjoyable and stimulating.	**SA**	**A**	**D**	**SD**
Knowing how to use computers is a worthwhile skill for Physics students.	**SA**	**A**	**D**	**SD**
CAI provides me with better understanding of complex issues in Physics.	**SA**	**A**	**D**	**SD**
CAI links the various topics together.	**SA**	**A**	**D**	**SD**
CAI brings out the meaning of the abstract concept better.	**SA**	**A**	**D**	**SD**
Computer can be exciting when used to solve Physics problems among the group members.	**SA**	**A**	**D**	**SD**
I can learn Physics using computer without the help of teacher	**SA**	**A**	**D**	**SD**
Using computer to learn Physics improves my understanding of Physics	**SA**	**A**	**D**	**SD**
I like learning with CAI because it can accommodate different learning styles.	**SA**	**A**	**D**	**SD**
I have a lot of self-confidence when it comes to working with computers.	**SA**	**A**	**D**	**SD**

Note: Response scale: *Strongly Agree (SA) *Agree (A) *Disagree (D) *Strongly Disagree (SD)

Part C: The five factors which contribute to perception

This section consists of five factors which contribute to your perception towards the effectiveness of CAI in Physics lessons in colleges of education, with their responses. The responses range from Strongly Agree to Strongly Disagree. Please, provide the appropriate response by ticking the corresponding response scale beside each statement.

Factor	**Response**			
Teacher's Pedagogical Approach	**SA**	**A**	**D**	**SD**
Learning Style	**SA**	**A**	**D**	**SD**
Interactivity	**SA**	**A**	**D**	**SD**
Relevance of Content	**SA**	**A**	**D**	**SD**
Perceived Learning Outcomes	**SA**	**A**	**D**	**SD**

Appendix C: Interview guide for CoE Physics tutors challenges they encounter in Integrating CAI

1) How often do you use CAI during the teaching and learning of Physics, and what motivates you?
2) What are some of the challenges that are within and beyond your control, which you encounter during the implementation of CAI?
3) How do you address these challenges when they are met?
4) How do other tutors come to your aid when those challenges are met?
5) What necessary arrangements has your school put in place to help tutors effectively implement CAI during Physics lessons?

Appendix D: Interview guide for Students' Perceptions Towards the Effectiveness of CAI

1) What aspects of CAI do you like best, and why?
2) How does CAI suit your style of learning?
3) Briefly describe the differences in your knowledge of Physics concepts when your Physics tutor uses CAI versus when he does not.
4) Why would you like your Physics tutor to use CAI more or less than they are currently using?
5) To what extent will you use CAI in the classroom when you become a professional teacher, and how do you intend to use it in your lessons?