The Effect of Computer Software Interaction on Students Cognitive Abilities Enhancement

The Case of Engineering Educators' Perspective

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Abstract—In this digital age, the deployment of modern technology in the workplace to mitigate global challenges has become paramount. Therefore, the academic program, as accredited by the regulatory and accreditation bodies, is to ensure the production of quality industry-ready engineering graduates. These products are expected to be technology savvy and proficiently skilled in using computer software (CS) for productivity towards engineering activities. Unfortunately, there exists a gap in the quality of the graduates produced by tertiary engineering institutions in the developing world. This gap can be associated with the lack of computational thinking (CT) skills to meet the industry needs in this age of IR 4.0. Therefore, the paper reports the engineering educators' perceived contributions and gains achieved while employing computer software in the course of instruction towards the cognitive ability enhancement of the engineering students. It provides an in-depth exploratory inquiry into the deployment of CT and its impacts in engineering education while focusing on its integration at what level in the course of study. The research follows a phenomenographic research approach explored the experiences of engineering educators from different engineering disciplines in the higher education institutions, namely chemical, civil, electrical, and mechanical engineering, to gain valuable insights. Data collected through a semi-structured, in-depth interview was coded using NVivo 12 CAQDAS and analysed for relevant themes. The findings indicate a significant potential benefit of enhanced cognitive abilities leading to the development of special knowledge, generic intellectual abilities, and personal attributes. In addition, the integration of CS should be the focus of instruction at the most appropriate level of study to allow for considerable exposure to CS to achieve the desired learning outcome. These findings have direct implications on the engineering educators and students, engineering faculties, and other stakeholders.

Keywords—Computational thinking, cognitive skills acquisition, Computer Software Interaction, Phenomenographic Research

1 Introduction

According to the US Department of Labour report, career opportunities in the twenty-first-century economy are already being 'powered by technology, fueled by information, and driven by knowledge' [1]. In the same vein, an analytical report from Education: Future Frontiers stated the reality 'as technology reduces the need for workers to complete routine, manual tasks because they will spend more time focusing on people, solving more strategic problems and thinking creatively' [2]. This way of thinking has affected people's views despite being well-grounded in knowledge in key disciplines in engineering. To fit in the future world comfortably, students of technology and engineering would need various skills and capabilities. This situation implies that only individuals who have equipped themselves with relevant skillsets would be open to such opportunities in the workplace. Therefore, it becomes imperative that attention should be given to those issues manifesting as challenges to the employability situation and the economy in general [3]. These challenges often reshape the workplaces and, by extension, the nature of work in unprecedented ways. This brings about demands for new and different skillsets required. In order to succeed, therefore, a great responsibility is placed on the educators to re-orientate the students towards meeting future workplace requirements [3], [4]. More so, impactful skills are usually acquired through training and hands-on learning-based techniques relative to a well-mapped-out technology framework on specific goals. These authors [5], [6], [7] argued that twenty-first-century learning skills are critical for accomplishing the necessary transformation fit for purpose. So, they advocated that educators willingly 'embrace the 21st-century learning paradigm shift towards digital skills to ensure that students are adequately prepared for the global workforce' [5].

The importance of educators adapting instructions to the new educational technology platforms infused with the new skillsets is emphasized for success. A good example is the case where an educator has been involved in a distance education course using WEB 2.0 with instructions incorporated at developing new skillsets for the workplace and economy. It is noteworthy that information communication technology (ICT) is central and fundamental to skills development, especially those relevant to the workplace in the 21st century. Studies by [8], [9] posit that besides ICT being the platform for meeting critical societal needs, educational institutions remain the right environment for implementing such frameworks. Similarly, Partnership for twenty-first Century Learning (P21), and Educational Testing Services (ETS), expressed the same opinion [10], [11]. These positions attest to the significance of cognitive enhancement tendencies for skills, competencies, and knowledge acquisitions. In this regard, the National Research Council [12] identifies five skills: complex communication skills, adaptability, self-management or self-development, non-routine problem solving, and system thinking, as becoming valued increasingly. These skills are, however, embedded in the significant components of computational thinking (CT). Wing introduced the term computational thinking in a seminal paper [13]. Since then, CT is increasingly being acknowledged 'as a fundamental skill, similar to arithmetic, reading and writing necessary to navigate in an information society' [14] for the contemporary world.

CT is a problem-solving strategy based on abstraction, analysis, automation, modeling, and other principles and practices to formulate problems and solutions with data processing devices [15]. This concept is central to computing and has emerged as an essential component of 21st-century education [16], [17]. In addition to other skills that are connected to CT, coding, in other words, programming is a component of CT [18], [19], in that it makes CT concepts more concrete. And can thus be used as a tool for teaching and learning, as it is a medium for exploring other domains, including digital storytelling and videogames). However, there exists a consensus that CT involves much more than the activities of coding. An example of such is problem analysis and problem decomposition, which are integral components of CT that precede the act of coding.

Several other studies and reports [20], [21], [22] also identified the critical skills needed to succeed in the 21st- century globalised world. These are creativity and innovation, critical thinking, communication, collaboration, information literacy, technology usage, career/ life skills, and personal/social responsibility. Therefore, P21 and North Central Regional Education Laboratory (NCREL), strongly recommend implementing the twenty-first-century initiatives. These include the provision of programs and workshops on 21st-century skills instruction for teacher professional development, the integration of 21st skills training into teacher preparation and certification programs, and teachers' online professional learning communities. Others are investing in ICT and professional development opportunities for both ICT staff and teachers, and finally, integrating 21st-century skills into teacher and student standards.

Learning inherently occurs in tandem with one becoming a member of a community (educators, students, and systems) of practice and is an evolving form of membership". Inside these communities, members are made to engage in communal learning in a shared domain and share resources from a typical common pool. These interactions within the community influence the way members of the community perceive and value the operational mandate and relationships among them. Hemmendinger [23] argued that the objective of CT is not meant for everyone to think like a computer scientist, but instead, for all professionals to understand how to use computation to create, and fruitfully resolve all challenges of their fields. Recent studies reveal that the university-industry (horizontal) mismatch is evidenced, where most engineers are not working in engineering jobs [24]. Unfortunately, the engineering institutions are presently not producing engineering graduates grounded in computational thinking skills to meet the industry needs. This paper hopes to bring reports on two fundamental questions of interest:

- RQ1: Does CT enhance cognitive skills acquisition in engineering students?
- RQ2: If it does, then at what level of study should the institution integrate CT?

To answer these questions, we have carried out a qualitative study to highlight the perception of engineering educators on the interactive role computer software plays in cognitive abilities enhancement towards engineering skills acquisition. While the paragraphs above present the problem background and the theoretical background of this work, the remainder of this paper can be summarised as follows: Section 2 describes the adopted methodology. The results and findings are presented in section 3, and finally, section 4 presents the implications and conclusions.

1.1 Theoretical Background

In this study, the concept of computational thinking is anchored on the situated learning theory to contextualise students' interaction with computer software as a complementary strategy toward problem-solving. Jean Lave and Etienne Wenger, in the early 1990s developed is an instructional strategy known as situated learning. It was inspired by the works of Dewey, Vygotsky, and others [25], [26] who assert that by actively participating, students have more tendencies to learn in the learning experience. Based on situated learning theory, this article deliberates on identity and membership in communities of practice. It provides them the ambience to relate to the contexts of cognitive abilities enhancement and computer software interaction to establish conceptual parameters for impactful work, world, and future-ready graduates. This viewpoint adopted here is that the course lecturers who intend to consolidate their delivery of certain concepts would introduce the students to a particular software that would enable them to solve both simple and complex engineering problems in a collaborative setting. This theory [26] focuses on relationships between the three components: learning, identity, and membership in communities of practice. According to the theory of situated learning, students' learning is at its best by doing what experts are doing (authentic tasks) in that field, and their knowledge gain is socially, physically and culturally situated [26], [27]. This theory further explains an individual's acquiring a form of professional skills and includes research on apprenticeship into how an individual can obtain membership in a community of practice through legitimate peripheral participation. Furthermore, situated learning theory suggests that knowledge is material to competence related to an esteemed enterprise and that knowledge is a matter of partaking in the quest for such an enterprise [28]. Ultimately, providing such learning environments, like classrooms, field trips, laboratories, and others, are designed interactions for this situated knowledge acquisition. In our quest to navigate and apply the necessary framework, there should be a deliberate plan and procedure for achieving our goal

2 Method

The study followed a qualitative theoretical framework called phenomenography as proposed by Marton [29]. Phenomenography is defined as the empirical study of the different ways in which a group of people think of the world around them. As initially conceived, it has been designed to provide the answer for inquiries about instruction, particularly in educational research. Furthermore, phenomenography adopts an approach that is non-dualist and of the second-order perspective where the non-dualist aspect is viewed as the outcome of an interaction between humans and the world around them. Phenomenographers do not identify their results as being "true" or judge the conceptions they have identified in their studies as being "correct" or "incorrect." They do, however, claim that the results of phenomenographic studies are helpful in and of themselves. Marton [30],[31], taking a view through an educational lens, claims that "a careful account of the different ways people think about phenomena may help uncover conditions that facilitate the transition from one way of thinking to a qualitatively 'better' perception of reality". Thus, phenomenographic information about the different conceptions that students hold for a particular phenomenon may be helpful to teachers developing ways of helping their students experience or understand a phenomenon from a given perspective. The operational framework of this work is laid out as illustrated in Figure 1. In other words, the phenomenographic study aims to 'realise qualitatively the different ways' in which engineering educators 'experience, conceptualise, realise and understand' several aspects of the outcome when the students are made to learn new relevant concepts and skills interacting with computer software [32].

Purposive sampling has been employed for this research. According to [33], it is also known as selective, judgmental, or subjective sampling. As a non-probability sampling method, the researchers rely on their judgment to choose members to participate in their study from the population. Applying this sampling method requires that researchers have prior knowledge about the purpose of their studies to select and approach eligible participants correctly. We have used purposive sampling because we want to access a particular subset of all engineering educators, as all participants of a study are selected. After all, they fit a specific profile required of the participants. According to Orgill, phenomenography is empirical research; the researcher is studying the subjects' awareness and reflection and not his or her reflection and awareness. [31]. This is known as "bracketing". In other words, bracketing means that in approaching both the interview and the data to be analysed, the researchers must keep an open mind without any contribution from their perceptions.

At this point, the demographics of the participants for this study are carefully selected as their experience and understanding of the phenomenon being studied and the nature of the data is of great importance. Campbell [34] asserted that for the researcher to understand the 'general' nature of the experience and define it appropriately, the anticipated will be better if the participants are more demographically similar. Participants were made up of engineering educators selected through purposive sampling [33], [35] sourced from different engineering disciplines like chemical, civil, electrical and mechanical engineering departments in a university located in the South-South geo-political zone of Nigeria. As we considered them, the researchers interviewed eight (8) engineering educators, the most relevant for the sample set to explore the problem. Interviews are undertaken to have the participants reflect on their experiences and then relate those experiences to the interviewer so that the two come to a mutual understanding about the meanings of the experiences (or of the account of the experiences). This process is usually an inquiring discourse between the interviewer and participants. According to Marton [32], "the experiences and understanding are jointly established by interviewer and participants. These experiences and understandings are neither known prior to the execution of the interview process, ready to be "read off," nor are they only situational social constructions. They are aspects of the subject's awareness that change from being unreflected to being reflected”. Based on literature sources like [36], [37], the number of participants was determined when the data became saturated. No new data would have a remarkable additional effect on the phenomenon being studied. The study was designed to explore the educators' perception of the cognitive ability enhancement of their students through computer software interaction. Data was collected through in-depth semi-structured interviews, which consisted of several key questions that helped define the areas to be explored.

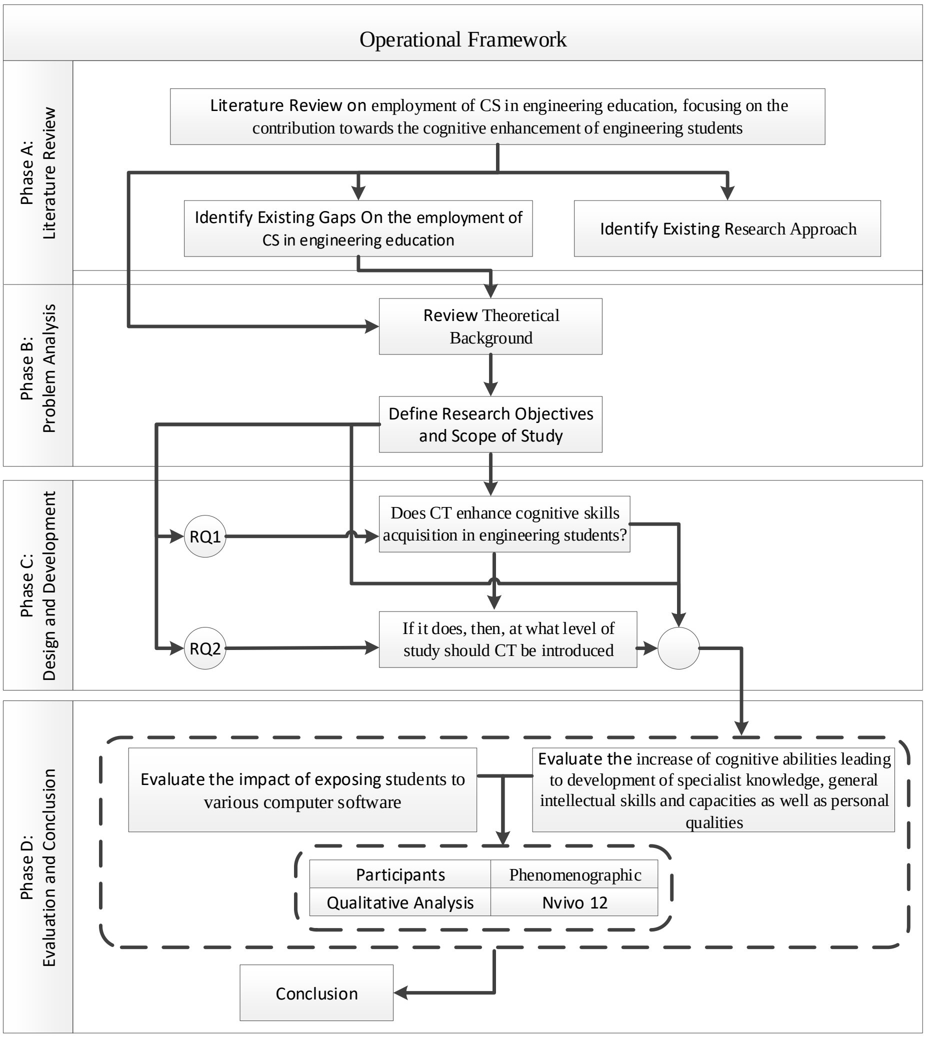

Fig. 1. The operational framework

This type of interview allowed the researcher to diverge in order to explore some other ideas in details [38]. This interview format also provided much flexibility for the discovery and elaboration of information that are important to participants and provided the opportunities to revisit thoughts that were not addressed previously [38]. Ethical considerations in the process of undertaking this study were strictly observed throughout all stages of the qualitative research [39]. The reason is to maintain the balance between the potential risks and the likely benefits of the study. To protect the identity of participants, the researchers used pseudo names.

In the qualitative analysis, the researcher adopted the following steps [40]: familiarized with data through listening to the recorded materials, reading; transcribed recordings; organized and indexed data for easy retrieval and identification. Also, some sensitive data were anonymized. Others steps employed were coding, identified themes, and re-coding; then developed categories. Relationships were established between these categories, refining previous themes, and categories for final global themes. Finally, the theory was tested against the data using NVIVO 12, a computer-based qualitative analysis software.

3 Results and Discussion

3.1 Descriptive Statistics on Demography

The descriptive statistics on demography for this study reveal that 90% of the participants have over 15 years of teaching work experience in the university, with 85% having not less than postgraduate degrees. Also, over 55% have in the last 10years managed the ICT unit of their respective departments. This makes their responses relevant to this study.

3.2 Does computational thinking enhance cognitive skills acquisition?

Computational thinking is open to all, not only to students of engineering and technology. It is a strategic way involving some mental processes through problems and processing the stepwise manner, which can lead to a solution, helping to develop the capacity and limits of computing. With the constant evolution of technology, engineering educators must empower their students to become digital citizens and encourage them to take ownership of their learning. Students may have been exposed to some form of technology at a tender age, but they must be guided to know how to apply it appropriately. The first problem this work seeks to address is cognitive skills acquisition through computational thinking to enhance learning in engineering students. Hence, results of the perceptions from the participants on the impact of computational thinking concerning cognitive skills acquisition is shown in Figure 2.

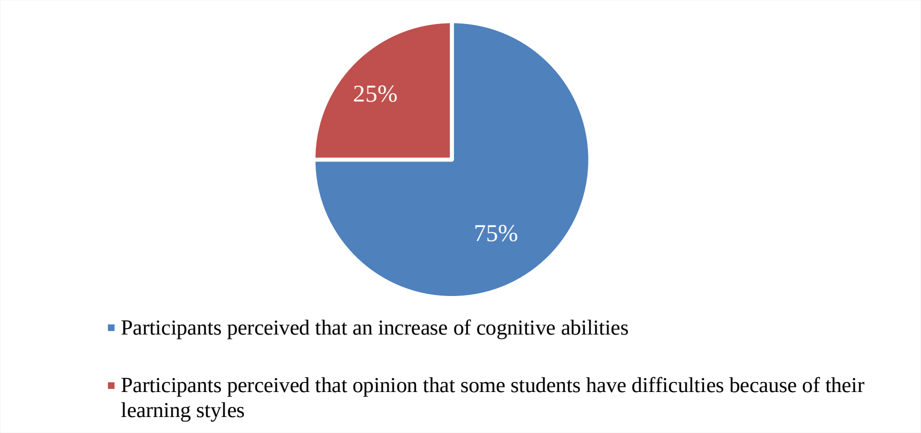

Fig. 2. The impact of computational thinking on cognitive skills acquisition

The findings on the interview were carried out to determine if computational thinking enhances cognitive skills acquisition; almost all of the participants expressed their perception that an increase of cognitive abilities leads to the development of special knowledge, generic intellectual capacities, and personal attributes. In the quest to finding answers to RQ1, three sub-questions were asked. These are as follows:

- What other abilities could the students gain while learning to be proficient in any specific computer software toward job placement or self-employment?
- What kind of improvement will an engineering student derive from interaction with computer software?
- What type of satisfaction would an engineering student acquire from interacting with computer software?

Figure 3 shows an illustration of the thematic network that emerged in analysing the data collected for the study.

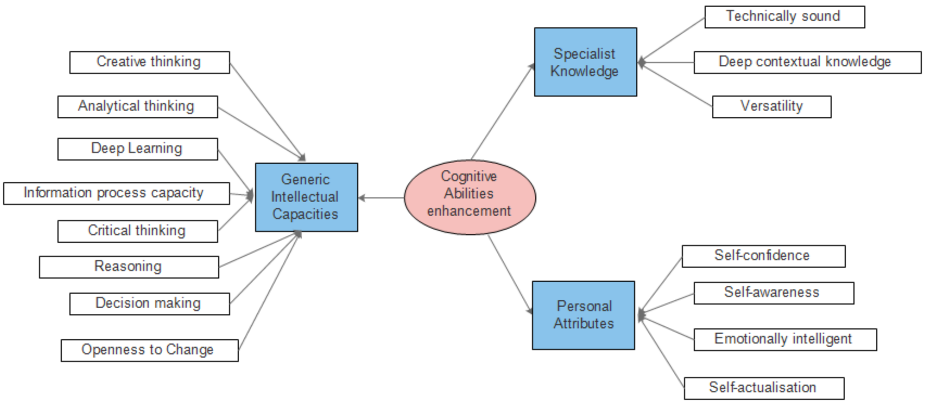

Fig. 3. Thematic network showing interrelationship between themes and the global themes (categories).

Regarding the category "special knowledge", for any individual to have possessed the level of expertise in any acquired skills, that individual would have become proficient in that area. Therefore, in response to the first sub-question, Participant P3 said 'Most of the students having had their hands-on training on the computer software, are more motivated because they understand better…' P4 responded that "...concepts are better understood". P5 said "…know so much about the fundamentals of the skills being trained for…. Similarly, P6 answered "-…well-grounded in the nitty-gritty of the subject matter…." While the remaining participants believe that some students have difficulties because of their learning styles, P1, in his assertion, contributed that specialist knowledge acquisition can be hampered due to the learning ability of the student "…some are slow learners partly because of learner styles". Under this category, it could be said that the individual would have taken ownership of the subject matter, including technical issues relating to the operations, the merits and shortfalls of the software. Such an individual could even proffer innovative ideas and suggestions leading to the upgrading of such software.

In a related study [41], though an experimental research with a qualitative component incorporated, the participants' opinions were sought after learning HTML under certain conditions. The results show that the participants experienced a greater degree of knowledge transfer at the end of the experiment. This is an indication that computer software interaction is highly beneficial to the learner. Concerning the other two attributes, participants expressed similar divergent opinions to varying degrees.

Now concerning the category "generic intellectual capacities", the second sub-question seeking to know the opinions of the engineering lecturers, the kind of cognitive improvement this interaction would yield in the student. Participants indicated that when students are exposed to computer software, they are more likely to gain more significant insights into the subject matter to which the software is connected. The responses reveal that the thinking and learning skills are greatly enhanced. Participant P3 said with emphasis that "… the students engage in asking the 'why' and the 'cause-and-effect' questions of each principle and stage of the interaction". P4 contributed that "…reasoning on what to do and to think out of the box is likely…". Others participants like P6, P1 and P2 responded accordingly "…sometimes in a scenario they are involved in making crucial decisions while designing a project…", "…they could interpret situation more critically…" and "… master the idea of evaluating and comparing ideas and solutions." respectively. Therefore, it is evident that themes generated from the data like critical thinking, creativity, decision making, openness to change, and ability to solve problems are associated with intellectual capabilities [42], [43]. These are likely to improve after interacting with the computer software.

The "personal attributes" category is centred around the third sub-question, 'what type of satisfaction will the engineering student acquire from the interaction with the computer software to be proficient?'. This category could be the underlying basis for fulfillment in every human endeavour and under this category is the term 'motivation'. Most of the participants asserted that motivation is the driving force for any achievement. For example, P2 said that … "the first and foremost factor for satisfaction to be considered is that the student should be someone with great motivation to drive him". P5 stated that "...-having become proficient in his chosen career, he will be self-confident while being engaged in communication". P5 also added that "… he knows his worth…". P8 commented that for such a person "It shows some resilience towards a better livelihood". For P1 and P6. it was seen as a platform for "sharing knowledge", and "duplicating himself in knowledge" and closely related is the opinion of P8, who said his "… willingness to share his knowledge…". P7 mentioned that "…the student will see himself to have attained his immediate target or goal". Finally, most of the participants added that it was "a well-taken step taken towards financial independence". According to Stenberg [42], motivation is thought to be the driving force behind meta-cognitive skills, which in turn triggers learning and thinking skills, which then provides feedback to the metacognitive skills, enabling one's level of proficiency towards that desired goal to increase. Conclusively, by incorporating the concepts of CT in various disciplines, the engineering students will learn skillsets related to computational thinking, having the opportunity to apply their skills within the context of a different subject matter.

3.3 At what level do you think the institution should introduce computational thinking in the course of study?

Computational thinking is the prerequisite skill for understanding the technologies of the future. It is a thought process rather than a specific body of knowledge about a device or language. For that reason, computational thinking can be a part of any classroom environment, and this should include the classrooms of our youngest learners in the primary grades. From the results (Figure 4) on the appropriate level of study at which computer software interaction toward digital skills could be introduced to foster computational thinking in the engineering programme of the university, 90% of the participants believe that student should be exposed to such computer software right from the onset of their engineering programme.

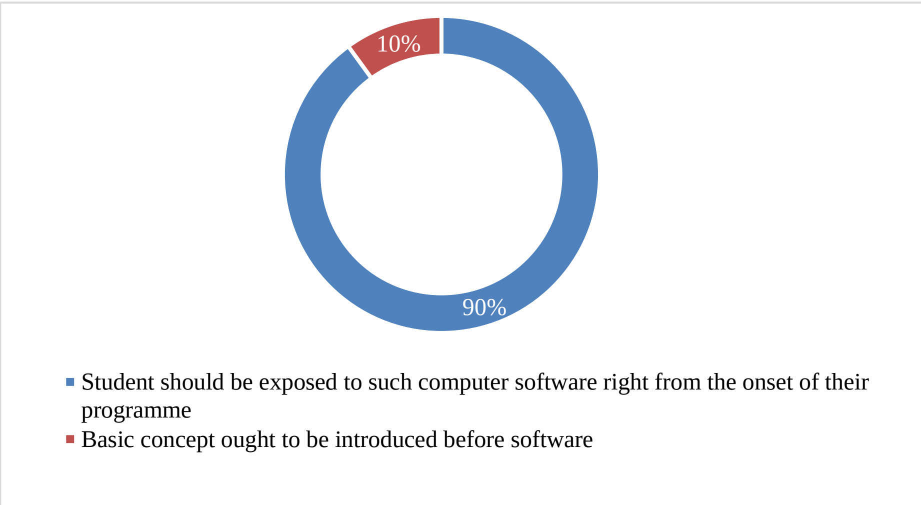

Fig. 4. Results on the level of study to introduce computational thinking

P3 and P5, in particular, are of the view that early exposure to such software enables flexibility that would be of great benefit to the students in their academic performance. Below are some of the responses; P3 responded Thus ‘we are in a digital era; therefore, the earlier the students are exposed to the software, the better…’; P3 answered ‘…preferably, at the start of the programme considering the benefits it brings along…’ and P5 said ‘I believe it should be from the onset as long as the software is available for learning….’

In contrast, P7 believes that basic concepts ought to be understood before introducing the software. P7 responded accordingly ‘I would think that the basic concepts should be taught first, that is, applying the first principle…’ And, in my opinion, I would arguably assert that CT is fast becoming a foundational skill set necessary for engineering students. By explicitly teaching and allowing space for the development of computational thinking, engineering educators can ensure that their students are exposed to and learning to think in such a way that would enable them to access and understand their digital world. In short, future professional successes for the students are greatly dependent upon the curriculum and instructions integrating computational thinking. From the results obtained from analyzing the participants' opinions, CT should be introduced from the on-set of the programme to achieve its full potential.

4 Conclusion

In this digital age, enhancing skills acquisition through computer software interface has proven to increase the employability of the individuals for improved well-being and a nation’s economy. Two fundamental questions of interest were considered in this research. Firstly, does CT enhance cognitive skills acquisition in engineering students? Secondly, if it does, then at what level of study should it be introduced or integrated? Results from this study show that there exists a positive benefit in exposing our students to modern technology. It also reveals that the practical efforts have an impact directly on engineering educators and students. Therefore, the university's engineering faculty where this study was undertaken and other stakeholders alike should be encouraged to ensure that the ICT infrastructure is regularly updated to meet the industry standards and demands. In particular, engineering educators should be exposed to regular training (capacity building) to enable them **to** keep abreast of developments as they unfold in practice. Now that some insights into this study's issues have been gained, a quantitative methodology could be looked into for a generalization consequence.

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