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Development of Electronic Design Cognition during Undergraduate Electronic Engineering Education: Issues and Perspectives

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ABSTRACT

Electronic design cognition ranks among the top qualitative competencies of electronic engineers and technologists. Electronic design cognition accounts for the creative ideas and innovations that have resulted in the inventions and innovations of all scales of electronic devices and systems that have revolutionized modern society. This study examines the factors that affect the development of electronic design cognition in undergraduates during their structured engineering education, and the nexus between curriculum design in electrical and electronic engineering technology and the development of electronic design cognition using a qualitative survey approach in a Nigerian Polytechnic setting. Findings suggest a non-adaptive and lagging-content curriculum design, misalignment to the evolution of electronic engineering education in the 21st Century, poor cultivation of electronic engineering education sub-ecosystem, and dogmatic constraints as factors that distinguished the learners in the study setting from those in other climes where electronic design cognition systematically blossoms into one of the core competencies developed through education. For a paradigm shift, a future-ready curriculum is advocated. At the same time, an improved electronic engineering education sub-ecosystem should be cultivated to target a new generation of learners (putting new wine in a new bottle), with a vigorous emphasis on enhancing and diffusing science, technology, engineering, and mathematics education through sustainable educational policies and quality assurance in the procurement of learning and teaching facilities.

Keywords: *Cognition, curriculum, electronic design cognition, electronic engineering, engineering education*

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INTRODUCTION

Engineering is generally understood as the practical application of scientific knowledge to create solutions to societal needs. Engineering has transformed the world into a haven of technological development, from medieval and middle-age outlooks to modernistic ones through the unprecedented technological feats of infrastructure development, information and communication advancement, and the taming of nature of its disasters (Aslaksen, 2017). Engineering development sets countries apart, and the distinction between first and third-world nations is profoundly based on technological self-reliance. The evolution of engineering has resulted in the unbundling of traditional engineering disciplines like electrical, mechanical, and civil engineering into several sub-disciplines and specializations, which have continued to diversify as knowledge evolves. Electrical engineering focuses on the design of systems that utilize electricity, while electronic engineering focuses on using electron dynamics to design and produce electronic devices, systems, and equipment. The major distinction between electrical and electronic engineering relates to current utilization. Electrical engineering utilizes “high current” in the development of its subfields of power system engineering equipment and control system engineering, while electronic engineering utilizes “light current” in the processes involved in its various subfields of telecommunications, electronics, computer systems, microelectronics, and a host of others.

Electronic engineering plays a crucial role in creating communication systems, consumer electronics, automobile electronics, computing systems, biomedical systems, and mechatronic systems. Countries without strong creative and functional electronic engineering backgrounds are worst hit by the dumping of electronic waste (Garlapati, 2016; Odeyingbo et al., 2019). Electronic engineering education is in a state of continuous flux, constantly evolving at the pace of the industrial and technological revolution. These changes respond linearly to the volatility of knowledge generated by the complexity of societal technological needs, which is mirrored qualitatively through dynamic school curricula that lay the foundation for creating novel ideas that result in innovations and inventions of electronic systems.

Design as a concept and an activity

Design is a ubiquitous but complex problem-solving activity engaged by individuals in various fields and across diverse disciplines. Common and distinct cognitive processes associated with the design cut across disciplines, and their distinctions reflect diverse disciplinary foci and perspectives (Barrett, 2020). As an inherently creative process, design is integral to several disciplines, such as the arts and architecture, and it reflects the core values of these disciplines' expressions. What is in engineering that is not design underscores the criticality of design activity to engineering (Atman et al., 2015).

Engineering design is a critical component of engineering education and a crucial competency that prospective engineering students must acquire. Engineering design is paramount to engineers because it integrates engineering knowledge, skills, and vision in the pursuit of innovations to solve problems (Atman et al., 2015). In recent years, it has become a global trend to include engineering design in the learning packages of pre-secondary and secondary school curricula for learners in the STEM fields (Chien et al., 2023). This enables the early development of cognition and competencies for engineering careers in young schoolchildren, which can lead to an increase in enrolment and more interest in engineering careers.

Electronic design is a problem-solving activity that conceptualizes and develops electronic circuits, devices, and systems. Electronic circuit design involves the selection and interconnection of physical devices in a variety of topologies to meet performance specifications, environmental requirements, power and cost budgets, operating life requirements, and other design constraints in agreement with an overall schedule (Gard, 2015). Electronic design types include digital, analogue, mixed-signal, and microelectronic system design.

Cognition and design cognition

Cognition describes various mental processes that enable humans to reason, acquire, manipulate, store, and retrieve information in their environment and world (Bayne et al., 2019). Different terms have been used in the literature to distinguish cognitive functions. Among the types of cognition is basic cognition (Gahrn-Andersen, 2022), social cognition (Frith, 2008), emotional cognition (Reisenzein, 2020), spatial cognition (Pule and Attard, 2021), high-order cognition (Levine, 2009), creative cognition (Pinkow, 2023), and executive cognition (Cristofori et al., 2019), Cognitive performance results from the different domains of functions listed above, and are hierarchical, and interdependent in developmental processes (Harvey, 2019). Basic cognitive processes include learning, remembering, sensing, perceiving, planning, and thinking.

Design cognition is the mental processes and representations involved in designing (Hay et al., 2020). Design cognition is a core attribute of practitioners in disciplines that embody high-level thinking to create, recreate, innovate, design, and develop, like the arts (Zhao and Li, 2024), architecture (Higuera-Trujillo et al., 2021), and electronics engineering (Ball et al., 1994). Although the act of thinking is a fundamental psychological process in man, it has hierarchical structures when related to applied sciences and engineering. The design cognition landscape has widened in recent years to encompass cognitive processes, design artifacts, design processes, research methods, users, and designers, amongst others (Hay et al., 2020).

The emergence of artificial intelligence (AI) has opened a new frontier for the study of design cognition. Whether from the explorative or exploitative perspectives, the integration of AI holds promises for mental process enhancement, idea, and concept generation (Han et al., 2024), crystallization, and simulation in engineering design. The enhancement role of AI can be seen in its ability to assist designers in processing and mining data that could provide insights into design activities (Han et al., 2024).

Electronic design cognition

Electronic design cognition (EDC) is a distinct cognitive process and thinking style employed by designers (engineers, hobbyists) to create electronic circuits, devices, and systems. EDC encompasses a broad set of understanding of circuit architecture, circuit design cognition, signal flow economics, subsystem interconnectivity, and circuit specifications as depicted in (Figure 1).

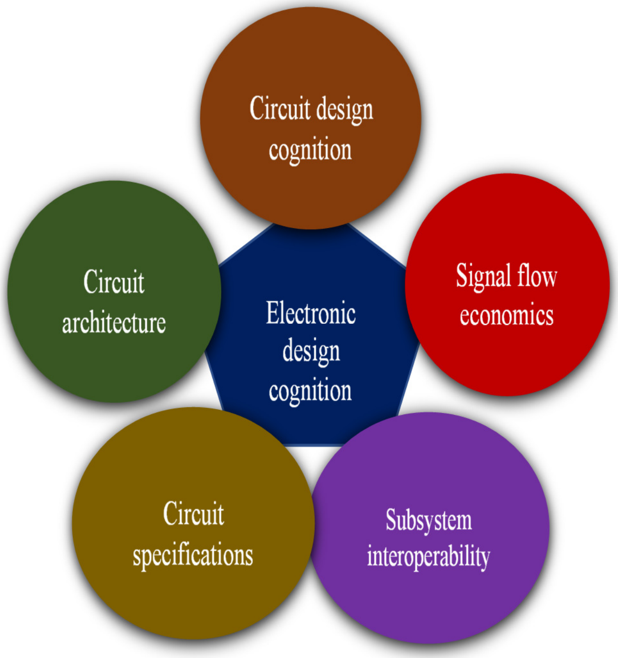

Figure 1: Subset of electronic design cognition

EDC contributes to bridging the knowledge-design skill deficiency in learners. This absence has been detrimental to the training and production of practical engineers, who are the bedrock of technological self-reliance. Research on EDC is gaining attention among engineering educators due to its relevance to the development of electronic devices and systems. The innovations and inventions that have transformed our world into a technologically advanced world are products of EDC. EDC has played a major role in their production, from simple electronic circuits found in radio receivers to intricate circuits embedded in microelectronic systems. Thus, learning electronic engineering is incomplete without the development of electronic design cognition in learners (Chien, et. al, 2023). Two types of cognition that stand out during the electronic design activity are high-order cognition and creative cognition. High-order cognition has been defined as a multifaceted and complex area of thinking that refers to the mental processes of reasoning, decision-making, and creativity. It involves the ability to understand and implement the steps necessary to solve problems, attack new ideas of learning, and think creatively (Akella, 2019), Creative cognition is understood as the set of cognitive processes that supports the generation of novel and useful ideas and underlies creative performances (Pinkow, 2023; Yu, 2024). Engineering education creates opportunities for people to design and build technologies that reduce their over-reliance on external forces for technological development. Inherent in technological development are indigenous innovations and inventions that promote technological self-reliance, foster infrastructural growth, and pedestal the image of sovereignties in the comity of nations (Umoh and Lugard, 2014). The foundation for generating engineering ideas and innovations is laid during engineering education. As a result, a pertinent question arises: Why are students of electronic engineering education in countries of the Global North producing graduates imbued with EDC capabilities that have yielded inventions and innovations, in contrast to those domiciled in the Global South, including Nigeria?

LITERATURE REVIEW

Different perspectives on the cognitive development of engineers have been studied. Some researchers have focused on the effectiveness of mental strategies for design (Carroll, 2002), cognitive psychology of engineering (Wei et al., 2023), cognitive development resources such as course contents, teaching methods, networking, and school infrastructure (Mingaleva and Vukovic, 2020). Spatial cognitive processes are involved in the design of electronic circuits (Pule and Attard, 2021). Protocol analysis has been applied to study design cognition in engineering design (Hay et al., 2017), and the understanding of electronic design (Neill et al., 1998). The effect of design education on the design cognition of students of mechanical engineering was studied by Williams et al. (2011). Creative design cognition difference was examined among high school students with and without design education (Gero et al., 2018). Their study suggested that teaching engineering design to novice high school students can hasten the development of creative design cognition and a capacity for design thinking. Studies have been undertaken on how AI and design thinking may synergize to advanced design processes, encourage innovation, and proffer solutions (Sreenivasan and Suresh, 2024). Popescu examined how AI can impact a designer’s divergent and convergent thinking and accentuate cognitive biases during the ideation stage of the design process (Popescu, 2023). Studies on electronic design cognition in Nigeria's engineering education context are scarce. Most of the expository literature deals with engineering education in the Global North. However, (Umoh, 2000) examined the impact of breadboarding on the creative orientation of National Diploma students in Nigerian polytechnics and found that breadboarding has a marginal influence on the cognitive skill development of students at the lower-level certification in the Nigerian polytechnic system.

METHODOLOGY OF THE STUDY

The study is in two parts. Part One examined the curriculum factors by reviewing the existing curriculum in

Electronic Engineering Technology to relate its contents, specifications, and relevance to the development of electronic design cognition. Part Two examined the behavioural factors in the development of EDC by aggregating targeted respondents' opinions through the administration of questionnaires.

The curriculum

The curriculum has been defined as the totality of the experience offered to students in a school system. It has also been described by (Oliver, 1977), as the "educational program of a school, which has four basic elements; program of study (structured curriculum and academic focus), a programme of experience (which brings real-world scenarios to the learning experience through practical application of skills and knowledge and community service in the form of social responsibility, community services, and volunteering), programme of service (connecting engineering to community services) and hidden curriculum". The database of curriculum for Electrical and Electronic Engineering Technology (EEET), domiciled at the National Board for Technical Education (NBTE) (National Board for Technical Education, 2001), has provided both qualitative and quantitative information on the courses, course contents, and history of the contents. The curriculum data was analyzed in light of current advances in knowledge of electronic engineering.

Table 1: Number of subjects and associated courses.

Subject	Number of modules
General Studies	2
Mathematics	4
Computers	5
Electrical	8
Electronics	6
Electrical Power Systems	5
Electrical/Electronic Instrumentation and Measurement	7
Control Systems Engineering	2
Electrical Machines	3

Source: (National Board for Technical Education, 2001).

The use of the curriculum and course specifications for EEET commenced around 2001, after a collaboration between the NBTE and the United Nations Educational, Scientific and Cultural Organization (National Board for Technical Education, 2001; Yakubu and Mumah, 2003). During the intervening years, there had been several meaningful strategic efforts aimed at keeping the curriculum in a state of flux in tune with the changing dynamics of Nigerian society and response to the labour market in Nigeria including the Science and Technology Education Post–Basic Programme (STEP-B) project (Adikwu et al., 2017). The courses in the curriculum can be grouped into general studies, mathematics, computers, electrical and electronics, electrical power systems, electrical/electronic instrumentation and measurement, control system engineering, and electrical machines. The number of modules covered under the respective subjects is given in (Table 1), while the percentage distribution of subjects under the broad areas of electrical and electronics subjects, mathematics, computers, and general studies is depicted in (Figure 2).

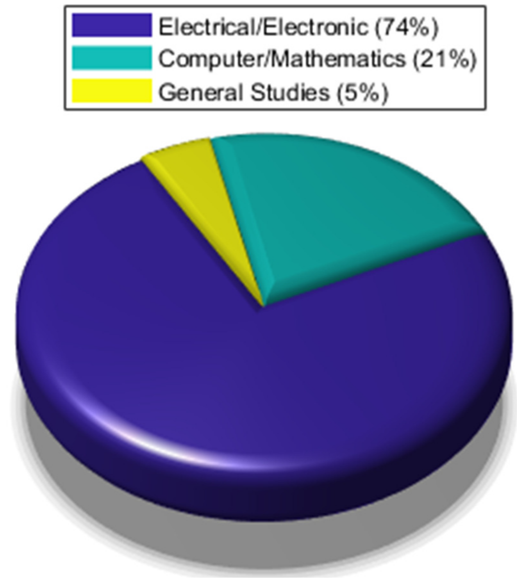

Figure 2: Percentage Distribution of subjects according to broad areas.

A close look at the curriculum

The study examined the components of some core electronic courses listed in (Table 2) in light of recent advances in areas like embedded systems, microcontrollers, and digital systems, from 2001 to date. A substantial number of the expected learning outcomes are historical and foundational.

The survey

The second part of the study was conducted to understand the impact or otherwise of some multifaceted factors on the development of electronic design cognition during electronic engineering education.

Data collection

The data collection method used in this study was an Electronic Design Cognition Survey Questionnaire (EDCSQ) administered to students of the Department of Electrical and Electronic Engineering Technology of a Polytechnic. The questionnaire contained both a dichotomous response structure and a textual response

Table 2: Review of contents of core electronics courses.

Course title	Relevance of course contents to the development of EDC	Implications of the course contents for EDC
Analogue Electronics	Foundational	Lagging
Digital Electronics	Foundational	Lagging
Electrical Circuit Theory	Basic/fundamental	Lagging
Electronic Design and Drafting	The course contents relate to drafting, not electronic circuit design	Lagging
Microprocessor Applications	Fundamental	Lagging

and consisted of six (6) sections namely demographic data, questions on the factors that influenced the respondents' choice of engineering career, design experience using software and hardware, the impact of open-source electronic circuits on electronic design cognition, dogmatic belief and cognitive bias related to engineering creativity and innovation, and the impact of educational ecosystem on the development of EDC.

Population

The survey targeted seventy-one (71) lower and upper-level students who constituted the population of the Department at the time of the study.

Research questions

The study adopted a non-hypothetical approach to our data analysis to help the contextual understanding of the study and the peculiarity of the research setting. The research questions that underpinned the study are:

1. What factors influenced respondents' choice of engineering career?
2. What are the factors that constrain the development of EDC?
3. What type of educational ecosystem can enhance the development of EDC?
4. Do dogmatic beliefs and cognitive bias affect the development of EDC?
5. What pedagogical paradigms can entrench a culture of EDC?

Sample characteristics

Fifty-one filled questionnaires were returned, with a response rate of 72%, consisting of 50 male respondents (98%), 1 female (2%).

Data analysis

The responses of the population were aggregated under seven (7) questions. The frequency of the responses were subsequently computed to ascertain the leading factors under each response. The results are presented in (Table 3).

RESULTS

In this section, we aggregated and quantified the population's responses from the filled questionnaires.

Factors that influenced the choice of engineering career

The factors that influenced respondents' choice of engineering as a career were grouped under two influences – personal interest and peer pressure. Personal interest relates to an intrinsic interest in engineering as a career. Peer pressure attributed their choices to the influence of group dynamics. 88% (n=45) of the respondents attributed their choice to intrinsic interest, 4% (n=2) of the respondents attributed their choice to peer pressure, and 8% (n=4) of respondents did not indicate any influence. Respondents were asked to pick subjects or combinations that influenced their interests in engineering careers. Among these subjects are Physics (PHY), Basic Electricity (BE), Mathematics (MTH), Electrical Installation Works (EIW), and subject combinations including Physics and Mathematics (PHY and MTH). Some respondents did not indicate any subject (NI). Figures 3 and 4 show the ranking of the subjects.

Design experience with software and hardware

Design experience related to a respondent's prior access to software (electronic circuit capture and computer simulation of circuits like PSPICE®, MultiSim®, Proteus®, etc.) and hardware (hands-on experience in the use of discrete electronic components for practical implementation of circuits on breadboard or PCB). 61% (n=31) of the respondents affirmed prior design experience, while 39% (n=20) negated. 45% (n=23) sourced their circuits from the internet (open-source electronics), 1 (2%) from engineering textbooks, 14% (n=7) designed the circuits, and 39% (n=20) did not indicate sources.

Understanding of electronic circuit design

Comprehension and understanding of electronic circuit design are integral to electronic design cognition. Learning about electronic circuits progresses from interpreting components, visualizing their interconnections, and decoding signal flows to understanding the underlying principles of operations and convergence of all signals to desired outputs. 43% (n=22) of respondents expressed difficulty in understanding electronic circuits, while 53% (n=27) suggested an understanding of electronic circuits.

Table 3: Data analysis.

Question	Response structure	Frequency/ Percentage (f)
Factors that influenced the choice of electrical and electronic engineering as a career	▪ Personal interest	45 (88%)
	▪ Peer pressure	02 (4%)
	▪ N/A	04 (8%
Design experience with software and hardware	▪ Yes	31 (61%)
	▪ No	20 (39%)
Sources of electronic circuits used during the experience in (2)	▪ Internet	(45%)
	▪ Textbooks	01 (2%)
	▪ Self	07 (14%)
	▪ N/A	20 (39%)
Understanding of electronic circuit design	▪ Yes	22 (43%)
	▪ No	27 (53%)
	▪ N/A	02 (4%)
Impact of the school ecosystem on EDC	▪ Yes	29 (57%)
	▪ No	18 (35%)
	▪ N/A	04 (8%)
Impact of unavailability and inaccessibility of learning resources on EDC	▪ Yes	40 (78%)
	▪ No	09 (18%)
	▪ N/A	02 (4%)
Effects of Dogmatic and cognitive bias on engineering creativity and innovation	▪ Yes	11 (22%)
	▪ No	38 (75%)
	▪ N/A	02 (3%)

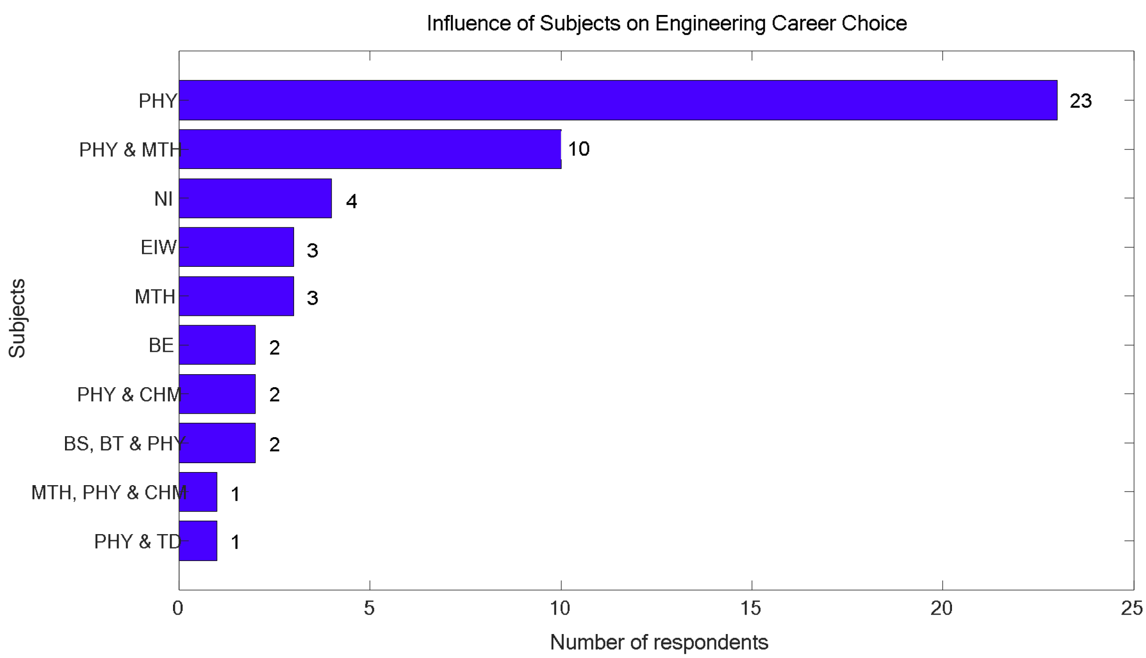

Figure 3: Ranking of the influence of subjects on the choice of engineering career

Impact of the school ecosystem

The impact of the school ecosystem pertains to the institutional ecosystem, which comprises the learning and teaching infrastructure, stakeholders' dynamism, physical infrastructure, and locational and internal security of the environment. 57% (n=29) of the respondents indicated that the school's ecosystem constrained their cognitive abilities, while 35% (n=18) suggested no consequences.

Impact of unavailability and inaccessibility of learning resources

Learning resources include computers, software, hardware, libraries, and the internet. 78% (n=40) suggested that non-accessibility to learning resources affected their cognitive abilities, 18% (n=9) reported no effect, while 4% (n=2) did not indicate.

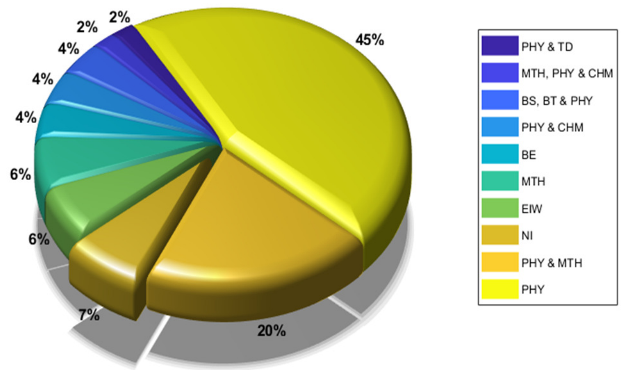

Figure 4: Percentage ranking of subjects/subject combinations that influenced the choice of engineering career.

Dogmatic belief and cognitive bias about engineering innovation and creativity

Dogmatic beliefs are tenacious beliefs that can shape worldviews on engineering practices, inventions, and innovations, leading to unyielding views about the evolution of technologies. A cognitive bias is a systematic error in thinking that occurs when people process and interpret information in their surroundings, influencing their decisions and judgments (Tversky and Kahneman, 1974). Cognitive bias can affect critical thinking and scientific reasoning in students and teachers. Dogmatic beliefs and cognitive bias are caused by a lack of exposure to the history of technology, cultural influence, and religious bigotry (Daws and Hampshire, 2017). One of the beliefs widely held by a cohort of electronic engineering students is that white people (people of the Global North) and Asians are creatively superior to black people of the Global South due to the technological developments attributed to them. Dogmatic beliefs can have implications for the outcomes of learning experiences. In this study, 11 (22%) of the respondents believed in the creative superiority of the white race, 38 (75%) suggested otherwise, while 2 (3%) abstained from suggesting. Another disturbing belief is the association of the advances in technology with supernatural forces, rather than a result of research and development. For example, some students ascribe the advances in microelectronics, like miniaturization and encapsulation of billions of transistors on a wafer, to transcendental illuminations and spiritual powers inhabiting the waters.

DISCUSSION

This section discusses the implications of the curriculum for electronic design cognition and inferences from the results.

Curriculum design

A close look at the components of the core electrical and electronic courses listed in (Table 2) suggests a wide gap between the expected learning outcomes and their real-world application to the electronic manufacturing industry, and the advances trending in electrical and electronic engineering. Although relevant, they are foundational and essential for knowledge accumulation, but bring only fragmented changes to the dynamics of electronic engineering education. The curriculum is based on the Curriculum 2.0/Education 2.0 model. In retrospect, it is safe to say that there had not been definitive curriculum designs that aligned with the successive periods of the evolution of education, like Curriculum 2.0/Education 2.0 (Tîrziu and Vrabie, 2015), Curriculum 3.0/Education 3.0 (Songkram et al., 2021), and Curriculum 4.0/Education 4.0 (Bonfield et al., 2020), respectively. Consequently, the curriculum lags behind its era in applicability and knowledge translation. The curriculum constrains the incubation of EDC. Based on these scenarios, machinery should be put in place to fashion out a new curriculum that will embody new learning outcomes that are consistent and in step with advances in technology.

Factors that influenced the choice of engineering career

Factors that influence career choices in engineering could be educational, social, or psychological. However, prior learning experiences play a crucial role in career choices. As shown in (Figure 2), STEM subjects accounted for all choices, with Physics influencing 45% (n=23). This factor suggests the respondents were intrinsically motivated to choose engineering careers.

Prevocational subjects such as Electrical Installation Works (EIW), 6% (n=3), Basic Technology (BT), 4% (n=2), and Technical Drawing (TD), 2% (n=1) had less influence. This contrasts with a study by (Umoh, 2002) where prevocational subjects accounted for students' preferences for engineering careers. The cumulative percentage rankings in (Figures 3 and 4) corroborate and underscore the importance of a strong foundation in STEM subjects as a precondition for choosing engineering as a future career.

Design experience with software and hardware

Polytechnic education in Nigeria is a two-level system in which students graduate from a 2-year lower-level learning experience (National Diploma), before reapplying for admission into a 2-year high-level learning experience (Higher National Diploma). During the low-level learning period, students of Electrical and Electrical Engineering Technology typically get exposed to simulation-based learning with software like ORCAD® PSPICE®, MULTISIM®, and PROTEUS®, and hands-on experiments using breadboards and PCBs. However, design experience does not imply internalization of the principles of operation of circuits, thus, some students have challenges with electronic design, which affects their comprehension of electronic circuits (Pule and Attard, 2021).

Understanding of electronic circuit design

Generally, understanding of electronic circuit design encompasses fundamental concepts underlying electronic circuits, principles of operation of circuits, analysis and synthesis of circuits, and how electronic components are interconnected. The essence of developing design cognitive skills is to understand electronic circuits and their functionalities. While 53% (n=27) of respondents claimed to understand electronic circuits, 43% (n=22) expressed difficulty. A question arises: Does prior design experience with software or hardware enhance the understanding of electronic circuits? Inference from the study suggests prior design experience can influence the understanding of electronic circuits, but not necessarily enhance it if the depth of the design experience is shallow, and the software and hardware are not commensurate with the level of experience expected. Thus, comprehension and understanding begin at the primary education level. Poor presentation of STEM subjects at the primary and secondary school levels impacts the cognitive capabilities of learners at the tertiary education level. In the Nigerian primary and secondary school systems, subjects' related to basic electricity and technology have been incorporated into the curriculum, though with some limitations related to guides and assessment of outcomes. However, in many instances, as researchers corroborate, what is taught in classrooms is in dissonance with curriculum intentions, resulting in learners not acquiring knowledge of the subject content (Okanlawon et al., 2023). Some of the factors that override policy intentions are the lack of instructional materials, attitude, orientation, and professionalism of teachers (Edwards, 2011), and the lack of tools and equipment in laboratories and workshops.

Impact of school ecosystem

The concept of an ecosystem has been used metaphorically in various disciplines to attribute connectedness, equilibrium, resistance or resilience, diversity, and adaptability. First applied in the field of education by Lawrence Cremin (Cremin, 1976), it elucidated the concept of an ecosystem as a network of active (biotic actors) and passive (abiotic, non-living elements), essential for quality teaching and learning. The active components comprise learners, parents, family, peer groups, government agencies, institutional bodies, educational associations, and curriculum developers. The abiotic components are books, infrastructure, assessment tools, and learning-teaching materials (Bandyopadhyay et al., 2021). The interconnectedness and multidimensionality of the educational processes determine the balance of the educational system (Levina and Prokofieva, 2021). The study suggested that the school ecosystem plays a critical role in the incubation of electronic design cognition. Exposure to variegated learning experiences, such as participation in hackathons and project design competitions, and access to online educational videos via YouTube and courseware, is critical to this process.

Impact of unavailability and inaccessibility of learning resources

Incubation of electronic design cognition depends on the full complement of learning resources. The repertoire of skills necessary for electronic design cognition includes critical skills, problem-solving skills, high-level thinking skills, and creative skills which are all sharpened through learners' rigorous self-application to the learning process. As technology evolves with new knowledge and skills, some learning tools and equipment have been rendered obsolete, while others are outdated, requiring new or updated tools and facilities to prosecute learning. Thus, when this equipment and learning infrastructure are unavailable, learners' development is stunted. On the other hand, students may not have access to the learning and teaching materials on the internet and digital libraries due to transactional costs, unavailability of electricity, non-availability of internet facilities, or lack of self-commitment to maximize these resources. Open-source resources like electronic circuits, computer programs, inquiry-responding platforms, and freeware are an integral part of the learning ecosystem of a school, and when policies are not put in place to commit learners to leverage these resources for learning, their problem-solving and critical thinking skills are negatively affected.

Dogmatic beliefs and cognitive bias about engineering innovation and creativity

Studies have shown that cognitive bias can lead to the interpretation of information in ways that confirm our beliefs, whether the interpretations are accurate or inaccurate (Idiong et al., 2023). Dogmatic beliefs and cognitive bias can inhibit idea generation, and create skepticism in learners. As captured by (Ambrose and Sternberg, 2012) "In a world plagued by enormous, complex problems requiring long-range vision and interdisciplinary insights, the need to attend to the influence of dogmatic thinking on the development of high ability and creative intelligence is pressing". In contextualizing dogmatic belief and cognitive bias in this study, we did not observe ideological underpinnings in their responses. Rather, we inferred factors such as socialization and localization, lack of exposure to technological developments through media including television channels, and the lack of commitment to inquiry and exploration of technological development. Integrating these factors into academic programmes may help dogma subscribers to break free from their insularity.

A need analysis

The challenges facing electronic engineering education in Nigeria are multifaceted. Cultivating the electronic engineering education sub-ecosystem into a functional system that trains and equips learners to respond to the innovative and creative needs of society will require a need analysis. Among these needs are the following:

Future-ready curriculum design and alignment

The relevance of the curriculum in Nigeria's Polytechnic system has been called into question. The Nigerian university system has set the machinery to revise and produce new responsive curricula for engineering education through the core curriculum minimum academic standards (CCMAS) which guides universities to autonomously develop their engineering curricula in line with their visions and mission (National Universities Commission, 2023), such a plan is not in place for the polytechnic system at the time of this study. A thin line separates the engineering curricula of both systems due to unaddressed overlapping of designs despite their existential differences. However, the polytechnic system must develop curricula that can engender a holistic, rather than fragmented change in the teaching and learning of electronic engineering. A future-ready curriculum for electronic engineering should be adaptive, integrative, and flexible to absorb the changing dynamics of the field, and societal needs and should equally align with the evolution of education (Wijngaards-de Meij and Merx, 2018). Essentially, a future-ready polytechnic curriculum can be fashioned out based on the framework of Curriculum 3.0/Education 3.0 paradigms, and also be adaptive to Curriculum 4.0/Education 4.0.

Cultivation and enhancement of electronic engineering education sub-ecosystem

Subsisting electronic engineering educational ecosystems in the polytechnic can be further cultivated and enhanced to develop learners with high-level thinking skills essential for innovation and invention. The list of components of such an ecosystem includes collaboration with other institutions on knowledge and skill development and resource sharing, hackathons, endowment funds for awards of prizes at different levels of undergraduate studies, industry-institution partnerships for level-specific hands-on training, and electronic design competitions. These components can potentially enhance cognitive development processes in electronic engineering education (Bostrom and Sandberg, 2009).

Transition to new paradigms of pedagogy and learning approaches

Despite the advances in the technology of teaching and learning infrastructures, the polytechnic classroom is largely fixated on the old traditional model of active-teacher, passive-student paradigms with fragments of digital delivery tools like digital projectors, educational videos, and laboratory exercises, which has continued to reproduce what researchers have called "outdated ways of knowing" (Luksha and Kinsner, 2020). It is, therefore, imperative that new pedagogical paradigms supersede outdated ones. The complexity of incubating electronic design cognitions calls for paradigms that enhance and blend students' different cognitive capabilities in tune with developments in the electronic engineering field. New pedagogical paradigms will entail an amalgamation of different approaches and the refinement of existing approaches. Of the different learning approaches, three are critical to EDC. These are project-based learning, problem-solving learning, and flipped classroom approaches. These approaches are already integral to the teaching approaches in the system. However, the outcome of applying them has not yielded the expected returns in the cognitive development of learners.

Adoption of best practices in the procurement and learning and teaching facilities

One of the factors that has constrained functional electronic engineering education is the mismatch between available training facilities and the specifications of practical exercises in the curriculum, which is caused by the lack of stakeholder involvement in the procurement processes. When electronic engineering laboratories and workshops are stocked with obsolete measuring instruments, diagnostic and troubleshooting tools, monolithic training modules, and test equipment, it causes a disconnect between what is taught in the classroom and what is practiced in the laboratory. Best practices begin with a needs assessment of the specifications of the equipment, alignment of equipment and facilities with the curriculum, and involvement of stakeholders like project managers and teachers in developing procurement processes.

CONCLUSION

The attainment of the aim and objectives of electronic engineering education is generally measured by the quality of skills acquired and the competencies developed by learners. Functional electronic engineering education is expected to imbue learners with competencies that will solve emerging challenges related to innovation and invention to sustain society. In this study, we have studied the processes of incubating electronic design cognitive skill, and the factors that have constrained its blossoming among students of electrical and electronic engineering technology at a polytechnic in Nigeria. Factors such as outdated curriculum, comprehension and understanding of electronic circuits and theory, the impact of the school ecosystem, and unavailability and inaccessibility of learning resources contributed to the slow development of EDC. To chart a new pathway, stakeholders must fashion out a future-ready curriculum, cultivate and enhance a new electronic engineering education ecosystem, adopt new approaches to pedagogy, and re-orient students with cognitive and dogmatic biases to adopt alternative viewpoints pivoted on critical thinking, and also entrench global best practices during the procurement of learning and teaching facilities for schools. This has the potential to effectively match procured facilities with curriculum expectations. In conclusion, this study has exposed the gap in the development of electronic design cognition that is missing in the learning of electronic engineering in Nigerian schools. The study can be serve to open a new vista in the study of dynamic strategies to enhance cognitive learning outcomes in electronic engineering students.

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Conflict of Interest Declarations

The authors declare that there is no conflict of interest concerning this article

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