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ADVANCEMENTS IN COMPUTER-AIDED DESIGN AND THE CHALLENGES FOR ARCHITECTURAL EDUCATION IN NIGERIA – FEEDBACK FROM THE STUDENTS' INDUSTRIAL WORK EXPERIENCE SCHEME

Sunday A. Bobadoye[1], Dorcas A. Ayeni[2], Saidat D. Olanrewaju[3] and Ajenifujah-Aminat O. Ajenifujah-Abubakar[4]
[1,2,3,4]*Department of Architecture, Federal University of Technology Akure, Nigeria*

The paper examines the challenges that revolutionary advancements in Computer-Aided Design (CAD) pose to architectural education against the background of widespread applications of computers to architectural practice in twenty-first Century Nigeria. Architectural education as universities in Nigeria are offering it has not adequately responded to the challenge of equipping students to cope with computer applications to architecture and construction. On the other hand, design and modelling operations in architecture and construction establishments are mostly done in CAD. Using a structured questionnaire as research instrument, this paper seeks to answer some questions: 1. What CAD knowledge does the architecture school provide? 2. What CAD competency do students possess, and how were they acquired? 3. Was CAD competency required to secure internship placements? Feedback from the mandatory Student's Industrial Work Experience (SIWES) program undertaken by fourth-year students of the Department of Architecture, Federal University of Technology Akure, Nigeria (FUTA), was used to gauge students' preparation and expectations from architecture and construction establishments. The questionnaire administered on sixty randomly selected students was used in eliciting data and serves as feedback on which this study was anchored. Content analysis was used to analyse the data obtained. Results from the survey revealed that the current curriculum does not provide the students with adequate CAD competency to meet architectural workplaces' challenges. However, CAD competency was significant in securing SIWES placements, and self-help measures were the primary means to acquire CAD competency. The study suggests the collaborative design of a Twenty-first Century relevant CAD curriculum, establishment and maintenance of functional CAD laboratories, re-skilling and up-skilling of educators to equip architecture students for the profession's CAD realities.

Keywords: architectural education, CAD, curriculum, students 'industrial work experience scheme

[1] sabobadoye@futa.edu.ng; adebobadoye@gmail.com
[2] daayeni@futa.edu.ng
[3] olanrewajuso@futa.edu.ng
[4] aoajenifujah-abubakar@futa.edu.ng

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INTRODUCTION

In the last three decades of the twentieth century, advancements in computer technology brought about sweeping changes in the way modern society learn, work and play. Further developments in the early years of the twenty-first century in Information and Communication Technology (ICT) have effectively transformed the world into a global information space causing revolutionary changes in workplaces. In contemporary Nigeria, the architectural profession has been inextricably drawn into the vortex of Information technology. The demand and realities of the local and global workplace have made it inevitable for practicing architects, architectural educators and students in Nigeria to seek proficiency in computing (Ogunsote and Prucnal-Ogunsote, 1987; Ogunsote, 2001; Bobadoye, 2002; Ogunsote and Prucnal-Ogunsote, 2006; World Economic Forum, 2016).

In line with global trends, architecture practitioners and construction establishments in Nigeria have embraced ICT; they are continually investing in new machines and software. Most reputable architecture firms and establishments in the country have been computerized, and the use of Computer-Aided Design (CAD) to accomplish tasks in the design process for conception, drafting, presentation, documentation and project management is now widespread. However, there seems to be a mismatch in what architecture establishments require and what architecture schools in Nigeria offer in terms of interns or graduates' CAD competency. As it is being taught in Nigeria Universities, architecture has not adequately responded to the challenges posed by dynamic advancements in Computer Technology and the increased deployment of CAD in architectural practice. In the 1980s and 1990's most Schools of architecture in the country lacked the wherewithal to produce CAD proficient architects, and so most architects learnt CAD outside of school. How much has the situation changed in the post year 2000 era? What are the challenges and prospects of producing CAD proficient architects by architecture schools in Nigeria? Ogunsote et al. (2006) provided insights into the other posers. First, the significant production of CAD proficient graduates by Nigeria's architecture schools will require a comprehensive review of the curriculum to make CAD an integral part of the training programme. Second, if resources are carefully planned and utilized, CAD proficient graduates' production is possible because global trends and improvements in computer technology have led to lower costs of hard and software.

The quintessence of qualitative education is to equip students for future tasks adequately and perform societal building roles effectively. This study is important because it sought to identify if there is gap between the CAD knowledge the formal architecture school exposes the students to and the level of competency expected from interns by architecture establishments and how such gaps are been bridged if they exists. It is indeed essential for stakeholders in architectural education to identify and fashion out means of bridging the gap between school and practice in the area of computer applications to architecture, especially Computer-Aided Design (CAD). In the light of the foregoing, this paper seeks to answer some questions: 1. What CAD knowledge does the architecture school provide? 2. What CAD competency do students possess, and how were they acquired? 3. Was CAD competency required to secure internship placements in architecture and construction establishments?

ADVANCEMENT IN CAD AND ARCHITECTURAL PRACTICE

Over the years, the use of computers in architecture has been dynamic. According to Rabee (2006), "it was first envisioned as a sophisticated simulation machine and then a repository of accurate and comprehensive records of buildings." On their part, Akin and Anadol (1993) opined that the computer was not seen as a replacement for other things such as draftsmen, hard copy documents and organizations. They instead considered it a "medium," no more no less, and then as a collaborator in the design process in which the computer and the humans complement each other's weaknesses.

In exploring the integration of digital design and architecture during the past three decades, Andia, (2001) revealed that architectural firms adapted their CAD skills in three distinctive eras: first, the CAD on Mainframe Era; second, the CAD Operator Era; and third, the High Computer Literacy era. This third wave ushered in introducing the personal computer and PC CAD to architectural firms in the developed world. This later spread to other developing countries in the late 1980s. By the 1990s, computers had advanced to the stage where debates could be held about whether it was possible to create spatial architecture in the virtual rather than in the real world (Dare-Abel, Igwe, and Ayo, 2014).

From a few years back, there has been rapid development of CAD in the field of engineering and architecture (World Economic Forum, 2016). CAD systems are used at various stages in the building design process and are integrated with analysis tools (Gero, 2002). It can be used to design 2D floor plans and visualize space within 3D in the field of architecture (Jayathilake and Shantha, 2015). This brought about a gradual end to the manual drafting and tracing era in architectural firms.

Since the 1980s, architectural firms in Nigeria have accepted computer technologies for operations. Since then, there has been incremental growth in the adoption of CAD in the practice of Architecture in Nigeria (Dare Abel, 2013). However, an article by Dare-Abel, Igwe, and Ayo (2014) revealed challenges encountered by architectural firms in adopting CAD. This includes high initial cost of hardware and software, high cost of maintenance, upgrades and training of staff; and health and safety implications. Other challenges are software compatibility problems and system crashes.

As buildings become more complicated due to the introduction of innovative technologies and increased awareness of social and communal needs, the design process requires significant modifications of previous practices to respond to newly emerging requirements (Aksamija & Ali, 2008). It is difficult to imagine how all these would be possible without CAD. CAD helps to bring several factors that affect design and construction, such as environmental sensitivity, energy efficiency, integrated building systems, life safety and security measures. As Aksamija and Ali (2008) observed, these factors might not result in the development of new building types, but instead, they change the nature of architectural discourse and practice and impact the design process. Using Building Information Modeling (BIM) software, architects can now better manage every aspect of a project as a shared database with other professionals whose inputs are needed for efficient job delivery through simulations and collaborations.

Such is the advancement of CAD in architectural practice. It has revolutionised how architects work positively, helping architects make the best design decisions. These gains of CAD in architecture do not appear to be waning as several kinds of research and improvements to existing technologies are underway in various institutions around the globe.

COMPUTER AIDED DESIGN IN NIGERIA'S ARCHITECTURE SCHOOL CURRICULUM

According to MacGregor (2009), education is the fundamental factor in developing human capital, the most influential form of capital, and a central societal development factor. In architectural education, future professional architects' training is based primarily around the design studio, which serves as the pivot and gathering point of all knowledge and skill acquired throughout the curriculum (Mostafa & Mostafa, 2010).

Freehand design, sketching, and manual drafting have always served as useful tools in the crucial stages of ideation and creative development of Architectural design. However, the development of digital technology in architecture has opened up a new vista in the architects' profession and education. As observed by Dare-Abel, Igwe, and Ayo, (2014), a significant revolution in architectural practice occurred on a global scale from the 1980s through 1990s when drawing boards were replaced with the newly developed system called CAD (Computer Aided Drafting). CAD applications are now generally recognized as a vital aspect of computers' utility in the architects' workplace and design industry at large (Suleiman, 2006).

As a result of all these developments, the profession is continuously compelling architecture schools to enhance CAD teaching in their curricula (Pektas & Erkip, 2006). Consequently, Ogunsote, Prucnal-Ogunsote and Umaru, (2006) sought to identify computer courses taught to architecture students in selected universities. The study showed that the Schools of Architecture are making concerted efforts to make CAD an integral part of the training programme. Computer-aided design into the architectural school curriculum has been lengthily debated among scholars (Iwuagwu, Azubuine, & Eme-Anele, 2015). However, it has not yielded the desired fruits as CAD still occupies the background in the architecture schools (Uwakonye, Alagbe, Oluwatayo, Alagbe, & Alalade, 2015). Towards entrenching CAD in the architecture school curriculum, Ogunsote, Prucnal-Ogunsote and Umaru (2006) proposed a CAD curriculum for Nigerian architecture schools cutting across all undergraduate learning levels. They opined that CAD proficiency should cover basic computer literacy, CAD concepts and theory, graphics software, 2D CAD and 3D CAD and visualization.

Notable challenges are affecting the integration of CAD into the architectural curriculum. These include placement of additional work-load on the already overloaded curriculum, lack of sufficiently qualified resource persons, poor power supply and inadequate funding for necessary infrastructure, hardware and software (Iwuagwu, Azubuine, & Eme-Anele, 2015). Added to this is the lack of curriculum specialization by Architectural schools, which has limited the schools in several aspects of their operations, including CAD's successful teaching (Balah & Damen, n. d.). As a result of these bottlenecks, a piecemeal approach has been used to

teach CAD in the curricula of schools of architecture in Nigeria, which is due to the already overloaded curricula. In entrenching CAD training, care must be taken to ensure that students are well-prepared to use the tool by first being adequately trained in manual design and presentation techniques. This will aid the avoidance of 'garbage-in-garbage-out' kind of design endeavour (Al-Qawasmi, 2005; Alagbe, Aderonmu, Opoko, Oluwatayo, & Dare-Abel, 2014).

CAD CURRICULUM IN FUTA

As at the time of conducting this study, an old curriculum is being phased out while a new curriculum takes effect with the 2016/2017 session intake of The Department of Architecture, Federal University of Technology Akure. The old curriculum still applies to the students who participated in this study. In the old curriculum, students could use the computer as a conception tool, while detailed drawings are presented using manual drafting. In the newly revised curriculum of the FUTA architecture school, CAD education was introduced at 300 and 400 undergraduate programs. The CAD courses are compulsory for all architecture students. It is offered in the first semester of the third year as Computer-Aided Design I (ARC 303) and the fourth year as Computer-Aided Design II (ARC 415). It was expected that, at this level of study, students had reached an acceptable design maturity that would enable them to experiment and deal with the advanced design issues explored in the CAD. In ARC 303, students learn computer basics, computer in architecture, operating systems and introduction to hardware and different software. Furthermore, they explore the use of Microsoft office and documentation tools and get an introduction to AutoCAD software. Students are expected to produce 2D drawings of a simple structure using AutoCAD at the end of the semester. In ARC 415, students learn how to use other significant CAD software focusing on their rendering facilities such as Archi-Cad, Revit architecture, Goggle sketch-up and 3D Max (Department of Architecture, FUTA, 2018). However, at the postgraduate level, usually, the initial drafting and modelling are done manually when most design rationalisation occurs, and computer drawing and rendering are mostly used for final presentations and project documentation.

STUDENTS' INDUSTRIAL WORK EXPERIENCE SCHEME (SIWES)

The Students' Industrial Work Experience Scheme (SIWES) is an initiative of the Federal Government of Nigeria. Its implementation is through the Industrial Training Fund (ITF) in collaboration with Universities, Polytechnics and Monotechnics offering science and technology-related courses in Nigeria. It is funded and managed by the national government through the Federal Ministry of Education (Balah & Damen, n. d.). SIWES is fashioned to provide practical opportunities to undergraduates outside of their institutions. The core objective of SIWES is to expose students to industrial practices via attachments to firms and establishments that are engaged in endeavours related to their field of study. Attachments are for a period of up to six months under supervision, after which they are answerable to their respective institutions for assessment. During the internship, the students are expected to have accrued to themselves, tangible work experience, sense of devotion and responsibility, innovativeness, the right attitude to work, and requisite skills. As outlined above, these gains are expected to increase

the students' knowledge in their field of study and fire up their zeal, aspirations, and readiness to be introduced into the work community upon graduation. It also gives the students the opportunity to develop employability skills (Oladimeji et al., 2017)

In the Students' Industrial Work Experience Scheme, architecture students secure attachments to architectural, construction and other related firms and establishments with a view to making them develop more skills in the field of architecture. It exposes them to workplace realities and provides an additional opportunity for students to learn to write field reports.

METHODOLOGY

A structured questionnaire was used to obtain data. Questions were drawn based on the objectives of the study. Questions that sought to identify students' CAD competency before SIWES, facilitators of CAD training and the CAD competencies required by SIWES employers were included in the questionnaire. Population for the study comprised of fourth-year students of the Department of Architecture, Federal University of Technology Akure, Nigeria (FUTA), who completed the mandatory Students Industrial Work Experience Scheme (SIWES) in the 2015/2016 academic session. Sixty (60) questionnaires were administered, out of which fifty-six (56) were found suitable for analysis. Our study is, therefore, based on the content analysis of fifty-six (56) questionnaires. Descriptive statistics in the form of frequencies and percentages were used to present the responses on the various questions raised. Findings from the study are presented below.

FINDINGS

Table 1 presents the number of students who had knowledge of CAD before proceeding on SIWES. From the analysis, 96.4% of respondents had acquired knowledge of CAD before going on SIWES. This infers that the level of awareness and readiness to learn CAD is quite high among the students.

Table 1: Knowledge of CAD before SIWES

Responses	Frequency	Percentage
Yes	54	96.4
No	2	3.6
Total	56	100.0

Source: Field Work, 2017

With respect to the level or period at which the students began learning the use of CAD, the results showed that the 200 Level was most occurring with 48.2% of respondents, closely followed by the 100 Level with 21.4% (Table 2). Other scenarios that included learning CAD before coming to FUTA; and no prior knowledge of CAD were each represented by 5.4% of respondents. Furthermore, 17.9% of the population indicated 300 Level as their point of learning CAD. However, the higher levels, that is the 400 and 500 Levels, presented 5.4% and 1.8% respectively, an indication that the students' quest for the knowledge of CAD started at the earlier stages of their learning in Architecture.

Table 2: Level at which respondents begun learning CAD

Level	Frequency	Percentage
100	12	21.4
200	27	48.2
300	10	17.9
400	3	5.4
500	1	1.8
Others	3	5.4
Total	56	100.0

Source: Field Work, 2017

In response to the enquiry on the level of CAD knowledge acquired before SIWES, most respondents reported that they had acquired the intermediate-level proficiency in CAD with 60.7% occurrence; basic level proficiency was next with 19.6%, closely followed by advanced-level proficiency at 17.9%. Only one person indicated no level of knowledge, which suggests that one of the respondents who had earlier indicated no knowledge of CAD probably had a level of knowledge that may be classified as rudimentary (see Table 1). Therefore, this indicates that the majority (98.2%) of the respondents have at least a basic knowledge of CAD before SIWES (Table 3).

Table 3: Level of CAD knowledge acquired before SIWES

Responses	Frequency	Percentage
Basic (2D only)	11	19.6
Intermediate (2D and 3D)	34	60.7
Advanced (2D, 3D, Advanced rendering and animation)	10	17.9
None	1	1.8
Total	56	100.0

Source: Field Work, 2017

With respect to CAD being a part of the curriculum, students' responses showed that 57.1% of respondents believe that CAD training was not included in their Architecture curriculum, while 41.1% opined contrariwise. Contradiction arose from respondents during the survey; CAD was only taught as a small component of 300 and 400 Level design studios and not as a stand-alone course in the curriculum.

Table 4: CAD training as part of school curriculum

Responses	Frequency	Percentage
Yes	23	41.1
No	32	57.1
Unsure	01	1.8
Total	56	100.0

Source: Field Work, 2017

Table 5 shows information about the various facilitators of CAD training. Influences of the academic environment are higher at a combined 72.8% occurrence as against private tutors and self-tutoring at an occurrence of 27. 2%.

Table 5: Facilitators of CAD training

Facilitators	Frequency	Percentage
Design tutors	5	9.1
Level mates	26	47.3
Senior Architecture students	9	16.4
Private tutors (individual)	5	9.1
Private tutors (training centres)	2	3.6
Self-training	7	12.7
Others	1	1.8
Total	55	100.0

Source: Field Work, 2017

A crucial question which the study sought to answer was if CAD knowledge was a condition for securing the SIWES internship. Table 6 below shows that for 75.0% of the students, CAD knowledge was a condition for securing the SIWES internship. However, CAD knowledge was not a condition for securing the SIWES internship for the remaining 25.0%.

Table 6: CAD knowledge was condition for securing SIWES internship placement

Responses	Frequency	Percentage
Yes	42	75.0
No	14	25.0
Total	56	100.0

Source: Field Work, 2017

Furthermore, the study examined the level of CAD knowledge that architectural firms require interns at the entry point. The survey showed that 21.4% required Basic CAD knowledge (2D only); 50.0% required Intermediate knowledge (2D and 3D) while for 21.4% of students, Advanced CAD knowledge (2D, 3D, rendering and animation) was required at the point of seeking SIWES placement.

Table 7: Level of CAD knowledge which the employer required at the point of seeking SIWES placement

Responses	Frequency	Percentage
Basic (2D only)	12	21.4
Intermediate (2D and 3D)	28	50.0
Advanced (2D, 3D, Advanced rendering and animation)	12	21.4
None	4	7.2
Total	56	100.0

Source: Field Work, 2017

In Table 8 below, a list of CAD software is presented, and the number of proficient respondents before IT is given. Note that a student may be proficient in more than one software; hence, the total figures may not add up to each category's sample size.

Table 8: CAD software in which respondents were proficient before SIWES

Software	Frequency
Autodesk AutoCAD	46
Graphisoft ArchiCAD	26
Autodesk Revit Architecture	36
Google SketchUp	9
Artlantis Studio	15
Rhinoceros	2
Autodesk 3D Max	6
Lumion	6
Others	14

Source: Field Work, 2017

Table 9: Additional CAD training by SIWES establishment to help fit into the workplace

Responses	Frequency	Percentage
Yes	25	44.64
No	31	55.36
Total	56	100.0

Source: Field Work, 2017

From Table 9, the study sought to know whether or not architectural establishments have CAD training programmes for their new interns. A little over half (55.36%) of the establishments do not have additional CAD training to help their employees fit into the workplace.

Table 10 reveals the types of software training on offer to interns who got additional training at the entry point. Almost half (48.0%) of the architectural establishments gave Autodesk AutoCAD training to interns, while 28.0% gave Autodesk Revit Architecture training. Furthermore, 12.0% of the architectural establishments gave Graphisoft ArchiCAD training, while 8.0% gave Autodesk 3D Max training. Rhinoceros software was the least on offer at 4.0%.

Table 10: Type of CAD software training that was received by students during SIWES internship

Responses	Frequency	Percentage
Autodesk AutoCAD	12	48.0
Graphisoft ArchiCAD	3	12.0
Autodesk Revit Architecture	7	28.0
Rhinoceros	1	4.0
Autodesk 3D Max	2	8.0
Total	25	100.0

Source: Field Work, 2017

Finally, Table 11 shows that occurrence of acquisition of higher CAD knowledge after SIWES was in the majority (66.1%), while 25.0% did not acquire a higher level of CAD competency after SIWES.

Table 11: Acquisition of higher CAD knowledge at the completion of SIWES

Responses	Frequency	Percentage
Yes	37	66.1
No	14	25.0
Uncertain	5	8.9
Total	56	100.0

Source: Field Work, 2017

Implications of findings for academia and architectural practice

The findings shows that less than 10% of the sample gained CAD competency through the design tutors. Nonetheless, 88.6% of the students have knowledge of CAD which is good enough to enter most architecture firms (intermediate knowledge, 60.7%; advanced knowledge, 17.9%). However, employers require definite CAD competencies ranging from basic to advanced CAD competencies from over 90% of prospective SIWES interns. Most students acquired CAD knowledge from level mates and senior architecture students (47.3% & 16.4% respectively). The findings therefore implies the inadequacy of formal CAD pedagogy as offered through teaching staff to prospective SIWES interns. The need to overhaul CAD curriculum and pedagogy is further highlighted. The availability or otherwise of sufficient CAD savvy Tutors needs to be scrutinized. In the short term, it is likely that students will continue to rely on non-formal means of acquiring CAD competency to bridge the gap. Architectural practice will definitely seek more advanced CAD competencies from interns and staff while the architecture schools play catch up.

CHALLENGES FOR ARCHITECTURAL EDUCATION

Massive transformations in architecture and construction, aided by technological advancements in CAD and ICT, have made architectural education devoid of computing skills near obsolete. Over the past four decades, the steady and rapid growth of CAD applications to the field of architecture has been relentless. The emergence of 3-D printing, for example, holds enormous potential for revolutionising construction (World Economic Forum, 2016). Because recent advancements like 3-D printing rely on cutting-edge CAD and ICT to function, it becomes germane that the training of architects must consider contemporary advancements in CAD.

A combination of excellent traditional sketching and design skills with CAD proficiency is key to survival in the highly competitive architecture field. This is where the architecture school must excel. The School curriculum has to be responsive and even pro-active to accommodate the challenges that CAD realities have brought upon the architectural profession. How well this has been done in Nigeria is always in question and will remain so until a significant shake-up is made in the school curriculum. The dynamism that CAD has brought to architecture poses specific challenges that the architectural schools must respond to, being the training ground for future architects who are expected to shape society's physical fabric. In all these, the expectations of architectural establishments for the architectural graduate most be borne in mind. This is to ensure that whatever the processes adopted to combat the challenges of students' CAD proficiency; it must

be relevant to the work environment in which they are expected to function on completion of their studies.

Some challenges that are inhibiting the training of CAD proficient architects were identified first from the literature and second, from our survey and are highlighted and discussed below:

1. A near static curriculum in an era of rapid technological change: The architecture school curriculum in Nigeria has come under intense scrutiny over the last three decades (Olotuah, 2005; Uwakonye, Alagbe, Oluwatayo, Alagbe, & Alalade, 2015). One of its main shortcomings is CAD's poor presentation, making it seem almost absent (Ogunsote, Prucnal-Ogunsote, & Umaru, 2006; Uwakonye, Alagbe, Oluwatayo, Alagbe, & Alalade, 2015). Since the curriculum is the guide for the teaching of architecture, what the student learns is determined mainly by the curriculum's design and implementation. A curriculum that does not give due attention to CAD will result in students being trained in an environment that inhibits their growth in CAD applications. Furthermore, this is a significant challenge to the training of CAD competent architects in Nigeria. The continuous relevance of drawing board-based studios in this computer age is still unclear. The earlier the architectural educators and proprietors face the computer revolution reality, the better for architectural education and practice. The rate at which technology advances over the last few decades poses a critical challenge to architectural education and CAD competent students' training. The rate at which software is being developed and replaced is quite challenging. These changes leave architectural educators and architects almost no time to react, with new developments springing up every few months (Bobadoye, 2002). Computer technology is an indispensable tool for the accumulation and distribution of knowledge in today's information-driven world. Hence, architectural education must be flexible and dynamic enough to cope with rapid technological changes. Nevertheless, Field (2005) warns on the limitations of computer technology to both the practice and education of architecture if architecture is more than a direct problem-solving profession.
2. Funding: The availability and process of providing funds is a cardinal challenge to the training of CAD competent students. This challenge plays out in several ways. The first problem is that government, which is the main sponsor of architectural education in Nigeria, has demonstrated its inability to solely and adequately fund architecture schools. The problem is now made worse by the downturn in Nigeria's economy and the associated dwindling allocations to the education sector. The second problem is acquiring the full licensed software packages that are needed for academic instruction in the architectural school and utilising the funds efficiently to get the best deals. CAD software is expensive, and upgrades do not come cheap either. In addition to the cost of acquiring licensed CAD software, schools are required to set-up standard fully equipped CAD laboratories where CAD teaching can be comfortably done to the full benefit of students. Another way funding becomes a challenge is when we consider that students who use the self-help route to gain CAD competency usually pay significant amounts of money to acquire the training. Not every architecture student can bear the cost. Insufficient funding of architectural education poses a definite challenge to effective CAD pedagogy.

3. **The paucity of CAD specialists among teaching staff**: This critical challenge to the production of CAD competent architecture graduates focuses on the teaching staff in schools of architecture in Nigeria. Here, the challenge arises from the fact that compared to industry standards, most teaching staff possess little or near obsolete CAD skills and rarely have core specialisation in CAD. The shortcomings have rendered most teaching staff in architecture schools incompetent to handle the teaching of CAD to their current crop of students. The magnitude of this single challenge is quite enormous; it is at the core of the challenge of producing CAD proficient students. Without capable teaching staff, modifications to the curriculum and provision of more funds will be meaningless, and the expected result, which is the production of CAD competent graduates, will not be achieved.

Suggestions

The challenges associated with producing CAD competent students can be tackled reasonably if the following suggestions are implemented:

- **Designing a CAD curriculum minimum benchmark for architecture students**: This study suggests collaborations among Nigerian schools of architecture, Association of Architectural Educators (AARCHES), Architects Registration Council of Nigeria (ARCON) and Nigerian Universities Commission (NUC) to establish a 21st Century relevant national CAD curriculum benchmark for architecture students. In the interim, we suggest that CAD courses should be mounted in the third and fourth of year of undergraduate studies in architecture with additional courses at the Master's degree programmes. These study levels are suggested since students need to acquire basic knowledge in the design and related subjects upon which CAD pedagogy can be built.
- **Establishment and proper funding of CAD laboratories**: standard and functional CAD laboratories should be established in each architecture school. We suggest the sequential acquisition of computer hardware, software, and ancillary equipment to respond to funding limitations. In line with the foregoing, public-private partnership is advocated to assist the architecture schools with establishing truly functional CAD laboratories in light of the government's inability to bear the enterprise's financial burden alone. The enthralling global village that ICT has turned the world into makes it imperative for architectural firms to collaborate with the academic institutions to achieve desired results.
- **Re-skilling and up-skilling of architectural educators**: Architect educators should be supported to attain cutting edge competency in CAD (2D, 3D rendering, visualization and animation) and Building Information Modeling (BIM). Scholarships and grants will significantly help educators pursue a specialization in the challenging but exciting world of architectural computing. Reskilling and up-skilling of architect educators are critical to kick-starting a CAD pedagogy revolution. Educators must engage in continuous learning and should know enough to train industry-relevant graduates. This is in line with the global best practice where educators and students are encouraged to engage in lifetime training (World Economic Forum, 2016) This, in synergy with traditional training and design experience of lecturers, will go a long way in facilitating the effective teaching and learning of CAD in the schools. Regular collaborations that feature workshops on computer application in architecture

should be undertaken by stakeholders such as the Nigerian Institute of Architects (NIA) and Association of Architectural Educators in Nigeria (AARCHES) as forms of continuing education for practicing architects and architect-educators. This will also serve to bring educators and practitioners up to date with the latest CAD developments in architecture and construction.

CONCLUSIONS

The use of computing in architecture in Nigeria has only been on for about four decades. However, it has recorded phenomenal growth over the period. The deployment of CAD in architectural practice has increased tremendously in twenty-first century Nigeria. We hypothesize that all leading architectural firms have become computerized. It is rare for a non-computerized architectural practice to win decent commissions. It is also unlikely that a graduate of architecture will get an excellent job in an architecture firm without being CAD competent (Lawani, 2001; Bobadoye, 2002).

Advancements in Computer Technology and its robust application to architectural practice pose a definite challenge to architectural education, and the response has been painfully slow. Restructuring of the architecture curriculum, establishment and proper funding of CAD laboratories in schools of architecture, sequential acquisition of computers and associated equipment by the schools, public-private sector partnership, re-skilling and up-skilling of architectural educators are suggested as means of equipping students of architectural schools Nigeria to meet the challenges of the dynamic nature of the global architectural practice. Further research may consider how students 'dominant reliance on self-help as means to gain CAD competence impact on their understanding of basic architectural principles.

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