Abstract

Recent advancements in Information and Communication Technology (ICT) have rendered the infrastructure evaluation criteria emphasised by the National Universities Commission (NUC) and the Architects Registration Council of Nigeria (ARCON) during accreditation of architecture programmes obsolete. This is because the NUC and ARCON model of architectural education is based on teacher-centric synchronous learning, a model that has proven inappropriate for the challenges of the 21st century information society. Effective learning must necessarily be student-centric and asynchronous. The emphasis today is on collaboration, teamwork and acquisition of social skills that necessarily require interconnectivity. It is within this new context that the provision of certain physical infrastructure has become unnecessary and retrogressive. Meanwhile infrastructure critical to effective architectural education such as computer and communication hardware and software, reliable power infrastructure, environmental controls and software tools for social networking is not evaluated by the NUC and ARCON. Virtual infrastructure is gradually gaining prominence over physical infrastructure, with e-learning replacing teaching and conventional universities struggling to compete with virtual universities. This paper argues that virtual infrastructure and reliable interconnectivity are necessary for sustainable education. Based on case studies of leading architecture schools around the world, the paper specifies the virtual infrastructure required for sustainable architectural education including current computer equipment and peripherals, ubiquitous networking, shared printing and plotting, digital projection, digital architecture laboratories, reliable power infrastructure; CAD, graphics, networking and communication software; adequate lighting, regulated ventilation and air-conditioning. It also identifies critical areas requiring interconnectivity including e-library, 3-D modelling, shared printing, plotting, rendering and animation. It discusses the advantages and disadvantages of virtualization and interconnectivity and it proposes a proactive strategy for managing the transition to this future.

Keywords: architectural education, e-learning, interconnectivity, sustainable education, virtual infrastructure.

1. INTRODUCTION

Adequacy and quality of physical infrastructure is a prerequisite for accreditation of architecture programmes by the National Universities Commission (NUC) and the Architects...
Registration Council of Nigeria (ARCON). Infrastructure here refers to the basic physical and organisational structures such as buildings, equipment and power supply needed for operation of a school of architecture. While the regulatory bodies emphasise physical facilities including laboratories, studios, classrooms, lecture theatres, offices and the equipment and furnishing of these spaces, recent advancements in Information and Communication Technology (ICT) have made these evaluation criteria obsolete. The NUC/ARCON model of architectural education is based on teacher-centric synchronous learning where the lecturer teaches students in a defined space using face-to-face interaction and equipment such as black boards, drawing boards and books or handouts. This model has however proven inappropriate for the challenges of the 21st century information society. Effective learning in this century must necessarily be student-centric, with students learning from each other and the teacher only guiding students in their learning. The emphasis today is rather on collaboration, teamwork and acquisition of social skills. Synchronous learning is being replaced by asynchronous learning where students can learn at any time, at any place and at any pace. Face-to-face interaction is being replaced by blended learning. Black boards and books are being replaced by e-books, multimedia, hypermedia, screencasts and podcasts while the drawing board is being replaced by computer hardware and software. It is within this new context that the provision of a drawing board per student, lecture theatres that can accommodate a whole class and even the availability of most laboratory equipment has become not only unnecessary but also retrogressive.

2. **NUC AND ARCON STANDARDS FOR PHYSICAL FACILITIES IN SCHOOLS OF ARCHITECTURE**

The certification of architects in Nigeria is done in both Polytechnics and Universities, but registration by the Architects Registration Council of Nigeria (ARCON) requires completion of a Master’s degree in a university, or a combination of a Bachelor’s degree, working experience and additional examinations. Holders of diplomas from Polytechnics are required to have even wider experience, and to pass even more examinations. The minimum physical facilities required in Universities that award Bachelor’s degrees in architecture are established by the National Universities Commission (NUC) and ARCON.

The National Universities Commission bases its assessment of physical facilities needed on the NUC Minimum Academic Standards, which specify the type of spaces required, the minimum floor area of these spaces and the equipment required (National Universities Commission, 2010). These physical facilities are divided into six categories, viz.

- Laboratory and studio spaces
- Equipment of laboratories and studios
- Classrooms and lecture theatres
- Equipment of classrooms and lecture theatres
- Office accommodation
- Safety and environmental sanitation of teaching facilities.

The requirements for a school of architecture are specified below.

2.1. **Laboratory and studio spaces**

Spaces used for training must be “adequate in size, be well equipped with suitable machinery, tools and equipment; be safe, well maintained and suitably laid out”. Over the years assessors have tended to place emphasis on availability of studio spaces (one for each level or year) and departmental library. The studios are expected to accommodate all students in each level or year with enough space for a standard drawing table per student. Less emphasis is placed on laboratories and workshops, and the assumption is often that these facilities are available for engineering and building programmes within the same institution and can therefore be accessed when needed.
2.2. **Equipment of laboratories and studios**

While the specific equipment required for laboratories and studios is not specified, assessors often base their standard on current technology. Currently, studio spaces are expected to be large enough to accommodate all students in the level, with a standard drawing board and stool for each student.

2.3. **Classrooms and lecture theatres**

The NUC requirement is that there should be separate lecture rooms big enough to hold the largest class.

2.4. **Equipment of classrooms and lecture theatres**

Lecture rooms should be equipped with chairs and maybe writing ledges. The requirement for blackboards is being replaced by whiteboards.

2.5. **Office accommodation**

Every staff is expected to have a large office although sharing of offices by two junior staff is allowed. The space should be adequate for counselling students, preparing materials for teaching and marking students' work. Academic staff offices should be equipped with basic items of furniture and storage such as a desk, chairs, drawing board and bookshelf and the office should be carpeted. Offices of senior staff should be air-conditioned.

2.6. **Safety and environmental sanitation of teaching facilities**

The environment should be generally clean and the buildings should be safe and comply with Federal, State and Local Government Laws relating to safety and fire hazards. All buildings should have functional fire extinguishers and fire buckets with sand and water.

3. **WHY THE NUC STANDARDS ARE OUTDATED**

The Minimum Academic Standards used by the NUC in accreditation of programmes was arrived at by working closely with schools of architecture and professionals who recommended these standards to the NUC. These recommendations undergo some review and fine-tuning, and are eventually adopted for accreditation purposes. In effect, these Minimum Academic Standards are not set by NUC but by schools of architecture and professionals. While these standards are expected to be regularly reviewed, the NUC has failed in its duty as arbiter in this process and our standards are very outdated. Accreditation panel members often have to resort to their discretion and amend these standards to fit a more modern society. This failure of the NUC can be accredited to the following:

- The expanding portfolio of the NUC with the emergence of numerous state and private universities, which overstretch the capacity of the NUC.
- The rapid growth of the information society and technological advancements that are not adequately reflected in the NUC bureaucracy, personnel profile and infrastructure.
- Lack of sufficient pressure from the stakeholders especially schools of architecture and professionals. This is not helped by the dearth of professorial cadre lecturers in the schools of architecture and Pritzker prize quality architects in practice.

The most obvious indication that the standards used by the NUC for accreditation are obsolete is that most schools granted full accreditation by the NUC fail to obtain accreditation from international regulators such as the Commonwealth Association of Architects (CAA). These schools with so-called full accreditation cannot compete with other architecture schools on a global scale.
4. WHAT IS WRONG WITH THE NUC STANDARDS FOR PHYSICAL FACILITIES?

All stakeholders agree to one extent or the other that the NUC standards for physical facilities require review. Faculty members are always running helterskelter before and during accreditation, operating from offices, studios and workshops rented on “short-time” basis, often masking facts and pretending that all is well with architectural education in Nigeria. The administration is often blackmailed into making promises it lacks the wherewithal to fulfil, and students dare not say that they desire more modern teaching facilities. Probably the most comfortable are the practising architects who are members of the accreditation team. They complain that the quality of graduates is low, but they do not say what the professional body is contributing to improving the teaching facilities.

The picture painted above may make it seem that the standards for architectural education in Nigeria are the worst in the world, but this is simply untrue. Even the most advanced countries and the best schools of architecture are faced with the challenge of reviewing their standards to meet the requirements of the 21st century. Simply put, current standards are not necessarily bad; they are simply outdated and fall short of the requirements of the information society. One of the reasons is that they are based on an outdated model of education (Noon, 2005; Sirat & Ling, 2013). The modern model of education differs from the traditional in many ways including the following:

- The traditional model emphasizes teacher-centric learning while the modern model encourages student-centric learning.
- The traditional model is structured for different types of education and various "school ages" while life-long education is now in vogue.
- The traditional model uses traditional methods for learning while e-learning is becoming more popular.
- The traditional model is based on synchronous learning in which teaching and learning take place at the same time while there is rising demand for asynchronous learning.
- The traditional model is classroom based but mobile learning has become a necessity.
- Face-to-face interaction is required in the traditional model but blended learning has proven more effective.
- There is emphasis on collaboration and social networking in the modern society and this is undermining the teacher-knows-all and books-contain-all-facts mentality of the traditional model.
- The traditional model requires schools complete with a street address, buildings and laboratory equipment (physical infrastructure) but more and more learning is taking place without a street address, without buildings and without laboratory equipment (virtual infrastructure).
- Conventional universities are being replaced by virtual universities.

4.1. Teacher-centric and student-centric learning

Teacher centric learning is based on a model in which a knowledgeable teacher dispenses knowledge to less knowledgeable students. The teacher is superior to the students and he determines how much they have learnt using various examination techniques. In student centric learning, students and the teacher pool their knowledge, they learn from each other and are all involved in the assessment of the knowledge gained. The teacher is not necessarily a superior, but an experienced guide.

4.2. School-age education and life-long education

The traditional approach is to provide education at primary, secondary and tertiary levels. These graduates are then released into the labour market with the assumption that they have acquired all necessary skills during their education and will pursue the same career all their life. The current reality is that workers are expected to possess skills they did not acquire while in school, technological advances are creating new “hot” jobs while old jobs are dying and most
high-paying jobs require a mix of experience and knowledge. The professor emeritus must undergo computer training to be effective.

4.3. **Learning and e-learning**

Traditional education emphasises the skills of the teacher but the emphasis is shifting to greater reliance on technology. Electronic learning or e-learning is computer-enhanced learning and it is commonly associated with **advanced learning technologies** (ALT), which deal with both the technologies and associated methodologies in learning using networked and/or multimedia technologies. E-learning makes it possible for the teacher to teach a class from a distance and also for students in various geographical locations as well as teachers to meet in a virtual classroom. Some of the 'technologies' used in e-learning are **screencasts**, **podcasts**, **web-based teaching materials**, **collaborative software**, **learning management software**, **virtual classrooms**, **computer aided assessment**, **educational animation**, **discussion boards**, **blogs**, **wikis**, **hypermedia**, **multimedia**, **email** and **e-portfolios** (Wikipedia, 2013c).

4.4. **Synchronous and asynchronous learning**

In the traditional model, a student learns at the same time a teacher is teaching. Both teacher and student must thus be present in the same place at the same time. This is becoming ineffective with large populations of working students, especially professionals wishing to acquire new skills or senior executives requiring training in new procedures and techniques. These students work full time and can only learn after office hours when the teachers would have also closed from work. Asynchronous learning enables the student to learn at any time, and not necessarily while the teacher is teaching. This is achieved through e-learning technologies.

4.5. **Classroom based and mobile learning**

We can all remember our classrooms and classmates having passed through the traditional education system. Today more and more education is taking place on the go; a welcome relief to social nomads. M-learning or mobile learning is **learning that happens across locations, or that takes advantage of learning opportunities offered by portable technologies**. In other words, mobile learning decreases limitation of learning location with the mobility of general portable devices (Wikipedia, 2013e). Mobile learning covers:

- **learning with portable technologies**, where the focus is on the technology (which could be in a fixed location, such as a classroom);
- **learning across contexts**, where the focus is on the mobility of the learner, interacting with portable or fixed technology; and
- **learning in a mobile society**, with a focus on how society and its institutions can accommodate and support the learning of an increasingly mobile population that is not satisfied with existing learning methodologies (**nomadic education**).

4.6. **Face-to-face (F2F) and blended learning**

Face-to-face learning depends on physical interaction between teacher and students, often with blackboards and notebooks in attendance. Blended learning on the other hand is the combination of multiple approaches to learning with 'blended' virtual and physical resources. It is a blending of different learning methods, techniques and resources and the application of these in an interactively meaningful learning environment. A typical example of this would be a combination of technology-based materials and face-to-face sessions used together to deliver instruction. (Wikipedia, 2013a). In the strictest sense, blended learning is the combination of two or more methods of delivery of instruction. However, this term most often applies to the use of technology for instruction. A good example of blended learning would be to give a well-structured introductory lesson in the classroom, and then to provide follow-up materials online. With today's prevalence of high technology in many countries, blended learning often refers
specifically to the provision or use of resources which combine e-learning (electronic) or m-learning (mobile) with other educational resources.

4.7. Emphasis on collaboration and social networking

Formal learning is incapable of providing all the information needs of the modern society and research has shown that students learn more out of school than in school. The current tendency is to encourage students to learn from each other and from the larger society and to become members of many communities. Some of these communities are virtual communities using social software, which are systems used outside the workplace, for example, online dating services and social networks like Facebook and Twitter. Students thereby contribute to knowledge in the process of learning. Popular tools used for collaboration and social networking include discussion boards, blogs and wikis.

Facebook (facebook.com)

Facebook is a social networking website that allows users to add friends, send them messages, and update their personal profiles to notify friends about themselves. Additionally, users can join networks organized by city, workplace, school, and region (Wikipedia, 2009d).

Twitter (twitter.com)

Twitter is a free social networking and micro-blogging service that enables its users to send and read messages known as tweets (Wikipedia, 2013f). Tweets are text-based posts of up to 140 characters displayed on the author’s profile page and delivered to the author's subscribers who are known as followers. Senders can restrict delivery to those in their circle of friends or, by default, allow open access. Users can send and receive tweets via the Twitter website, Short Message Service (SMS) or external applications.

Discussion board (Internet Forum)

This is a web application for holding discussions and posting user-generated content. Internet forums are also commonly referred to as Web forums, newsgroups, message boards, discussion boards, electronic discussion groups, discussion forums, bulletin boards, fora or simply forums (Cooperative Educational Service Agency, 2009; Wikipedia, 2013b). Messages are displayed either in chronological order or as threaded discussions. Such forums perform a function similar to that of dial-up bulletin board systems. A sense of virtual community often develops around forums that have regular users. Technology, computer games and/or video games, sports, fashion, religion, and politics are popular areas for forum themes, but there are forums for a huge number of topics. Popular forums patronised by architects include Autodesk Forum, Revit Forum, and Autodesk Education Community.

Blogs

A blog (an abridgment of the term web log) is a website, usually maintained by an individual, with regular entries of commentary, descriptions of events, or other material such as graphics or video. Entries are commonly displayed in reverse chronological order. Many blogs provide commentary or news on a particular subject; others function as more personal online diaries. A typical blog combines text, images, and links to other blogs, web pages, and other media related to its topic. The ability for readers to leave comments in an interactive format is an important part of many blogs. Most blogs are primarily textual, although some focus on art (artlog), photographs (photoblog), sketches (sketchblog), videos (vlog), music (MP3 blog), audio (podcasting) and are part of a wider network of social media. Micro-blogging is another type of blogging that consists of blogs with very short posts. With the advent of video blogging, the word blog has taken on an even looser meaning of any bit of media wherein the subject expresses his opinion or simply talks about something. YouTube, a Google subsidiary, has become very popular for video blogging.
**Wikis**

A wiki is a collection of web pages designed to enable anyone who accesses it to contribute or modify content, although commonly with some form of censorship. Wikis are often used to create collaborative websites and to power community websites. The collaborative multilingual encyclopaedia, *Wikipedia*, is one of the best-known wikis. Other wikis run by the Wikimedia Foundation include *Wiktionary* (a dictionary project), *Wikiquote* (a collection of quotations), *Wikibooks* (a collection of collaboratively written free books), *Wikiversity* (a project for the creation of free learning materials) and *Wikimedia Commons* (a repository of free electronic media).

### 4.8. Physical and virtual infrastructure

Large student populations and rising cost of education is making the provision of adequate physical infrastructure more difficult, and more and more learning is taking place in virtual classrooms. A virtual classroom is a classroom where virtual education takes place. Virtual education refers to instruction in a learning environment where teacher and student are separated by time or space, or both, and the teacher provides course contents through course management applications, multimedia resources, the Internet, videoconferencing, etc. Students receive the contents and communicate with the teacher via the same technologies. This term is primarily used in higher education where so-called Virtual Universities have been established.

### 4.9. Conventional and virtual universities

Correspondence colleges have always had a place in education and they have proved useful in providing education for special classes of people many of who are disadvantaged by location and are unable to register for full-time regular courses being working students. These correspondence colleges are metamorphosing into virtual universities. They offer virtual degree programmes using virtual courses and sometimes, virtual teachers. Virtual degree programmes (virtual courses of study) are study programmes offered by virtual universities in which all courses, or at least a significant portion of the courses, are virtual courses. Virtual courses popularly known as online courses are courses delivered on the Internet. Virtual is used here to characterize the fact that the course is not taught in a classroom face-to-face but through some substitute mode that can be associated with classroom teaching.

### 5. ADVANTAGES OF VIRTUAL INFRASTRUCTURE AND UBIQUITOUS INTERCONNECTIVITY

There are numerous advantages of using virtual infrastructure to complement or replace physical infrastructure.

#### 5.1. Inadequate physical facilities

Probably the most significant advantage of using virtual infrastructure is the ability to remedy inadequacy of existing physical facilities. Lecture theatres can be decongested if lectures are broadcast live and recorded and studio space will accommodate more students if drawing boards are replaced with laptop computers. Software can be used to carry out studies that would have required expensive specialist laboratories such as lighting and wind load studies. For example, 3D Studio Max Design can be used for detailed day-lighting. Current versions of CAD and BIM software, including Revit, now offer detailed day-lighting studies as well as sun shading, thermal comfort, and energy usage and optimization modelling out of the box.

#### 5.2. Learning in remote regions with small populations

It is possible to teach specialised courses in remote regions with small populations using virtual infrastructure. In the traditional model, students would have had to travel to far-away universities at great cost.
5.3. **Specially suitable for working students**

Working students do not have the time to make use of the physical facilities provided by conventional universities but are able to access online resources during breaks or even at night.

5.4. **Large student populations and small tutor to student ratios**

The carrying capacity of a university is determined among others by the physical facilities available for teaching. Many universities exceed their carrying capacity resulting in students standing during lectures and in small teacher to student ratios. The use of virtual infrastructure can increase the carrying capacity of universities in multiple folds.

5.5. **Acquisition of new skills by elderly students**

Many of today's students are either retired or elderly and cannot learn at the same rate as young students. The use of virtual infrastructure makes it possible for these elderly students to learn at their own pace, and without having to sit in the same class with their grandchildren.

5.6. **Mobile students**

Most students study in universities in towns and cities other than that in which their parents live. Many also live off-campus. They therefore have no access to physical university infrastructure while they are off-campus or at home. The use of virtual infrastructure makes it possible to study practically at home or off campus.

6. **CHALLENGES OF VIRTUAL INFRASTRUCTURE AND UBQUITOUS INTERCONNECTIVITY**

There are however many challenges facing the widespread adoption of virtual infrastructure for architectural education in Nigeria.

6.1. **Cost**

The initial cost of virtual infrastructure is higher than that of physical infrastructure but it is lower in the end due to low running and maintenance costs.

6.2. **Staffing**

The use of virtual infrastructure and especially the use of modern teaching techniques requires knowledgeable, skilled and multi-disciplinary staff with the proper attitude. It is difficult to get such staff and training them requires time and significant financial outlay.

6.3. **Technology**

The technology for virtual infrastructure is largely imported and maintenance is often expensive.

6.4. **Transmission of large graphics and video files**

The use of virtual infrastructure for architectural education involves the transmission of large graphics and video files requiring expensive Information and Communication Technology (ICT), hardware and software.

6.5. **Computer-based assessment limitations**

While the technology for computer-based assessment is improving, it is still very difficult to rule out impersonation, plagiarism and fraud.

6.6. **Need for personal mentoring**

Architecture has traditionally been taught in master-apprentice and teacher-student relationships that are based on personal mentoring. Current technology makes it difficult for a teacher to personally mentor students taking a virtual course, and where it is possible to do so
the stress on the teacher is more than in the traditional model. Teachers lose their privacy and receive calls for assistance at any time of the day or night and even during public holidays.

7. VIRTUAL INFRASTRUCTURE AND INTERCONNECTIVITY PROVISIONS IN NIGERIAN SCHOOLS OF ARCHITECTURE

Most schools of architecture rely mainly on physical infrastructure and they have very limited virtual infrastructure and interconnectivity. The following physical infrastructures, which were documented largely during accreditation visits to schools of architecture, are representative of Nigerian schools of architecture.

7.1. Provision and Equipment of Laboratory and Studio Spaces

Studios are currently equipped with little more than drawing boards and stools, often with two or more students sharing a drawing table (Plates 1 - 6). Less emphasis is placed on laboratories and workshops; however, several schools have carpentry workshops and access to building and materials workshops (Plates 7 and 8).

7.2. Provision and Equipment of Classrooms and Lecture Theatres

Most schools of architecture use their studios as classrooms and lecture rooms despite the fact that these spaces are not well suited for lectures. Most lecture rooms are equipped with chairs and maybe writing ledges. Blackboards are being replaced by whiteboards. When projectors are available, they are not permanently installed, but brought into the lecture rooms and placed on a table or stool. Permanently installed projection screens are practically non-existent, with improvised whiteboards or walls being used instead. When digital projection boards are available, they are used as glorified white boards, since the complementary ultra-short throw projectors are never installed, and data and network connectivity are lacking.

Plate 1. Exhibition of student projects in a studio at the Abubakar Tafawa Balewa University, Bauchi. Note the design of the drawing tables. Source: Photograph by the authors, 2006.

Plate 2. 300 level studio at the Ambrose Alli University, Ekpoma. Note the locally constructed drawing tables. Source: Photograph by the authors, 2005.
Plate 3. Exhibition of student projects in a studio at the Olabisi Onabanjo University, Ago Iwoye. Note the design of the locally constructed drawing tables. Source: Photograph by the authors, 2005.

Plate 4. Exhibition gallery at the University of Jos, Jos. Source: Photograph by the authors, 2008.

Plate 5. 500 Level studio at the Federal University of Technology, Akure. Source: Photograph by the authors, 2012.

Plate 6. A lecture room at the Federal University of Technology, Akure. Source: Photograph by the authors, 2012.
8. VIRTUAL INFRASTRUCTURE AND INTERCONNECTIVITY PROVISIONS IN LEADING SCHOOLS OF ARCHITECTURE

Given the challenges faced in Nigerian schools of architecture, and the on-going debate about if, when and how to migrate from manual drafting to digital technologies, the authors were curious about how leading schools of architecture in the world were responding to the various challenges. Dozens of universities and schools of architecture were visited worldwide, including the ones listed in table 1.

Table 1. 2012 and 2013 World Ranking of Selected Universities Visited.

<table>
<thead>
<tr>
<th>University</th>
<th>Country</th>
<th>Year of visit</th>
<th>2011-2012 World Ranking</th>
<th>2012-2013 World Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvard University, Boston</td>
<td>USA</td>
<td>2005</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>University of California, Los Angeles</td>
<td>USA</td>
<td>2010</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>University of Tokyo, Tokyo</td>
<td>Japan</td>
<td>2011</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>Kyoto University, Kyoto</td>
<td>Japan</td>
<td>2011</td>
<td>52</td>
<td>54</td>
</tr>
<tr>
<td>University of Sydney, Kyoto</td>
<td>Australia</td>
<td>2010</td>
<td>58</td>
<td>62</td>
</tr>
<tr>
<td>University of Queensland, Brisbane</td>
<td>Australia</td>
<td>2010</td>
<td>74</td>
<td>65</td>
</tr>
<tr>
<td>Tokyo Institute of Technology, Tokyo</td>
<td>Japan</td>
<td>2011</td>
<td>108</td>
<td>128</td>
</tr>
<tr>
<td>Illinois Institute of Technology at Chicago</td>
<td>USA</td>
<td>2005</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td>University of Tennessee, Knoxville</td>
<td>USA</td>
<td>2009</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Addis Ababa University, Addis Ababa</td>
<td>Ethiopia</td>
<td>2007</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>University of Science and Technology, Kumasi</td>
<td>Ghana</td>
<td>2000, 2008</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Indian Institute of Technology, New Delhi</td>
<td>India</td>
<td>2011</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Universiti Teknologi Malaysia, Kuala Lumpur</td>
<td>Malaysia</td>
<td>2011</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>The Bauhaus, Dessau</td>
<td>Germany</td>
<td>2007</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Source: Adapted from Times Higher Education (2013) and Internet searches.
8.1. **Department of Architecture and Architectural Engineering, Graduate School of Engineering, Kyoto University, Katsura Campus, Kyoto**

The Katsura Campus of the Kyoto University is at the outskirts of the city. The campus is very modern, extensive and was still under construction. The Department of Architecture and Architectural Engineering is in the Graduate School of Engineering Zone. The multi-storey building was specifically designed to house the department, and the spaces and facilities were customised for this purpose (Plate 9).

8.2. **Department of Architecture, Kyoto University, Yoshida Main Campus, Kyoto**

Undergraduate architecture students are trained at the Yoshida Main Campus of the Kyoto University. The year 1 studio has simple drawing boards with retractable power points for powering laptops suspended from the ceiling. There are lockers provided and students can regulate the ventilation and air-conditioning systems in each studio. The year 2 and 3 studios are similar, with ample desk space for design and modelling (Plate 10). Every desk has sockets for power and networking. The provision of writing and display boards in these studios encourages collaboration. There are several lecture rooms and an exhibition gallery for presentations and exhibitions. The computer laboratory is very spacious and it has a suspended widescreen LCD monitor and a suspended digital projector for demonstrations.

Plate 9. A seminar room in the Department of Architecture and Architectural Engineering, Kyoto University, Katsura Campus. Source: Photograph by the authors, 2011.

Plate 10. Year 2 studio in the Department of Architecture, Kyoto University, Yoshida Main Campus. Source: Photograph by the authors, 2011.

8.3. **Department of Architecture and Urban Design, School of Arts and Architecture, University of California, Los Angeles**

Housed in the popular Perloff Hall, this leading school has well-lit studios, electronic studios, lecture halls, library, exhibition gallery, faculty offices, multipurpose rooms, photographic studio; networked, distributed computing environment; leading edge technology centre for visualization and fabrication and a very serene environment (University of California, Los Angeles, 2013). See Plate 11.

8.4. **Department of Architecture, Illinois Institute of Technology, Chicago, USA**

Famously known as Crown Hall, this building is considered Mies van der Rohe's masterpiece, and is one of the most architecturally significant buildings of the 20th Century Modernist movement (Plate 12). The two level building is configured as a pure rectangular form, enclosing a column free interior space on the upper level sitting above a sunken lower level. The suspended roof, steel frame, and single, open-plan, glass-enclosed architecture studio space characterize this building.
8.5. **Department of Architecture, Tokyo Institute of Technology, Tokyo**

The Department of Architecture and Building is situated in the Graduate School of Science and Engineering, in the Faculty of Engineering. It is a well-lit, externally braced building with spacious studios (Plate 13), study rooms and detached lecture halls.

Plate 11. Typical studio in the Department of Architecture and Urban Design, School of Arts and Architecture, University of California, Los Angeles. Source: Photograph by the authors, 2010.


8.6. **Department of Architecture (Wilkinson Building), University of Sydney, Sydney**

The Wilkinson Building houses studios, offices, workshops, laboratories and library for both undergraduate and postgraduate students on five levels (University of Sydney, 2013). The building has a central courtyard that provides natural lighting and visual connection to the studios and facilities built around it. Most laboratories and workshops are in the basement. The equipment, variety and number of laboratories and workshops are exemplary. See Plate 14.

Plate 13: A studio in the Department of Architecture and Building Engineering, Tokyo Institute of Technology. Source: Photograph by the authors, 2011.

Plate 14. Department of Architecture, University of Sydney, Sydney showing the central courtyard. Source: Photograph by the authors, 2010.

8.7. **Graduate School of Design, Architecture and Urban Planning Boston, USA**

Housed in the famous Gund Hall, the School has studio and office space for about 500 students and more than 100 academic and administrative staff. There are also lecture and seminar
rooms, workshops, audio-visual centre, cafeteria, project room, auditorium and library. The yard area is used for basketball, volleyball, picnics, exhibition area for class projects and ceremonies. The central studio space extends through five levels under a stepped, clear-span roof that admits natural light and provides views toward the city. See Plate 15.

8.8. College of Architecture and Design, University of Tennessee, Knoxville, USA

The College of Architecture and Design offers both undergraduate and postgraduate degrees, with specializations in landscape architecture and interior design (Plate 16). The College provides a fully equipped wood technology workshop and state of the art digital technology, including laser cutters, 3-D digital modelling equipment, computer pools and an image centre for printing and digital reproduction needs (University of Tennessee, 2013).

Plate 15. Graduate School of Design, Architecture and Urban Planning (Gund Hall), Harvard University, Boston showing the stepped levels. Source: Google images.

Plate 16. Exhibition gallery in the College of Architecture and Design, University of Tennessee, Knoxville, USA. Source: Photograph by the authors, 2009.

8.9. Department of Architecture, University of Tokyo, Tokyo

The Department of Architecture, University of Tokyo is housed in a brick building abutting an expansive square. The studios are notable for the use of window walls, retractable power points, freestanding ventilators, and suspended platforms with lighting and networking routers. See Plate 17.

8.10. The Bauhaus, Dessau, Germany

Founded by Walter Gropius in Weimar, the Bauhaus, or “School of Building” combined crafts and the fine arts, and is famous for its approach to design. Although the school was closed in 1933 while under the leadership of Mies van der Rohe, the Bauhaus Dessau Foundation was founded in 1994, and it uses the school buildings as a research centre and museum. See Plate 18. The school is now a World Heritage Site.
9. VIRTUAL INFRASTRUCTURE REQUIREMENTS IN MODERN ARCHITECTURE SCHOOLS

The on-going transition from traditional studio techniques to e-learning and the adoption of modern teaching methods requires fundamental changes in the way we design our architecture schools. Many of the new requirements concern integration of ICT into the building fabric. Others emphasize accepted standards of good functional layout, adequate natural lighting and ventilation, and creation of a generally conducive environment for long hours of creative work.

9.1. Computer equipment and peripherals

Possession of a powerful laptop computer capable of running the latest CAD software should be a fundamental requirement for fresh students. These should be supplemented by computers provided by the school for demonstrations during lectures, and a rendering farm for rendering visualizations and animations. Where possible, provision should be made for both Microsoft Windows and Apple OS computers. It is necessary to provide large format scanners and plotters, large guillotines, colour inkjet and LaserJet printers, and other imaging devices. Technical specifications of computer equipment must be compatible with the software minimum requirements.

9.2. Wired and Wireless Networking

The advantages of collaboration make communication between students, teachers and administrators over a network an important requirement. This can be in form of a Local Area Network (LAN) or Intranet. This will include cabled and wireless networking hardware, routers, switches and wireless access points. The speed and reliability of the network is very significant, and particular attention must be paid to cabling and equipment specifications. Currently, wired networks and equipment used in Local Area Networks must be capable of gigabit speeds (one billion bits per second) using category 6 cabling, or even the upcoming 10 gigabit and 100
gigabit speeds using category 6a or 7 cabling. Modern wireless routers can run at speeds up to 450 megabits per second (Mbps), but speeds around 54 Mbps are more common. See Plates 19 and 20. Internet connectivity can be achieved by connecting to central university Internet resources, but providing a Very Small Aperture Terminal (VSAT) or broadband modems has proven more reliable.

Plate 19. Wired networking of a standard student workstation in the Year 3 studio in the Department of Architecture, Kyoto University, Yoshida Main Campus. Source: Photograph by the authors, 2011.

Plate 20. Wireless access point in the ceiling of a studio in the Department of Architecture, University of Tokyo. Source: Photograph by the authors, 2011.

9.3. Shared printing and plotting

This is a fundamental resource in a school of architecture. Although many students own A4 inkjet or LaserJet printers, posters and presentations are usually on A2 paper size or larger, and printing these require large-format printers and special paper, which are not economical for students to own. Furthermore, printing is often done in school, and it is unrealistic to expect students and staff to carry their printers around. Colour large-format Deskjet and LaserJet printers with network access should be provided in the school. For large format plotters, the proposed minimum size is 24 inches (A1+), however a 36-inch (A0+) plotter is recommended to ensure versatility (Prucnal-Ogunsote, Ogunsote and Ogunsote, 2012). Students should pay a small printing fee, usually on a per-page basis. See Plates 21 and 22.

Plate 21. Network printers and plotters in the Department of Architecture and Urban Design, School of Arts and Architecture, University of California, Los Angeles. Source: Photograph by the authors, 2010.

Plate 22. Network plotter in the Department of Architecture and Building Engineering, Tokyo Institute of Technology, Tokyo. Source: Photograph by the authors, 2011.
9.4. **Digital projection**

The use of digital boards and digital projectors is now common in lecture rooms and computer laboratories. There is need to provide digital projectors permanently suspended from the ceiling and conduits between the computer and the projector. A better but more expensive solution is to mount ultra-short-throw projectors on the wall above digital boards. Both the computer and projector should have uninterruptible power supply. Retractable projector screens can be installed above white boards. Short-throw projectors are especially useful with digital boards. While large format touch-screen monitors are being replaced by digital boards, suspending wide computer monitors or digital TV screens from the ceiling of computer laboratories is useful for large student populations (Ogunsote and Prucnal-Ogunsote, 2012). See Plates 23-24.

![Plate 23. Detail digital projection in the computer laboratory of the Department of Architecture, Kyoto University, Yoshida Main Campus. Source: Photograph by the authors, 2011.](image)

![Plate 24. Multifunctional space in the Department of Architecture and Urban Design, School of Arts and Architecture, University of California, Los Angeles. Source: Photograph by the authors, 2010.](image)

9.5. **Computer Laboratories**

Despite the pervasiveness of laptop use, computer laboratories continue to feature significantly in modern architecture schools. These computer laboratories are however not used for regular design work by students, but for printing, plotting, rendering, animation and for training using networked licensed software. The computers in these laboratories are usually workstations and not desktop computers, and they are therefore optimised for parallel, high-speed processing using multi-core and multi-processor technology. Digital projectors and High-Definition Multimedia Interface (HDMI) capable screens suspended from the ceiling and projection screens are often provided when these laboratories are used for training. Networking is usually wired using high-speed cabling and gigabit routers and switches, with networking and power cabling commonly concealed in raised floors. Very large monitors are common, and these laboratories are usually open 24/7 to accommodate time-consuming processing. It is usually possible to submit jobs over the Internet. The ideal is to grant students 24/7 access to computer laboratories and printer rooms by swipe card. See Plates 26 and 27.
Modelling has become very central to architectural design at all levels. Laser cutters, Computer Numerical Control (CNC) routers, and 3-D rapid prototyping systems simplify model making and they are becoming standard equipment in architecture schools. They employ Computer Aided Manufacturing (CAM) technology to produce models from CAD models. Laser cutters are used for etching patterns or cutting virtually any 2-dimensional shape from a wide variety of thin materials such as acrylic, chipboard, wood veneer, and thin plywood for model making and prototyping. CNC routers are used in automated production and manufacturing of diverse products, including building components, and they allow extremely accurate and complex shapes to be made in a relatively streamlined manner from 2-D and 3-D shapes drawn in digital design environments. 3-D rapid prototyping systems print 3-D models from computer files and they employ ink-jet technology to apply binder to thin layers of gypsum-based powder. See Plates 28-30.
9.7. **3-D Hologram Printing**

3-D hologram printers produce film based prints that display true 3-D holograms of 3-D digital models when viewed with a simple halogen or LED light source and without wearing special glasses. They are extremely realistic, and look like actual 3-D objects trapped on film. They can be viewed from any angle (360 degrees), and they can combine up to four images in a single holographic print (Zebra Imaging, 2013). These prints can be monochromatic or in full colour; they are portable and durable, and multiple copies can easily be produced. They can be stored flat like sheets of paper. They are currently very expensive and available only from a few commercial enterprises.

9.8. **Lighting, ventilation and air-conditioning**

Although the case studies were in temperate zones and in highly industrialized countries with constant power supply, all the studios had very good natural lighting. Artificial lighting was adjustable, and although the buildings used sealed envelopes, natural ventilation would have been adequate had the windows been openable. Air conditioning in our tropical climate will significantly improve productivity. See Plates 31 and 32.
9.9. **Power infrastructure**

Power infrastructure should include backup power generators, inverters and uninterruptible power supplies. Critical computer and networking equipment, as well as printers and plotters should have constant power supply provided by inverters or uninterruptible power supplies. Power cabling should provide power to individual student laptops during lectures and workshops, in addition to all teaching, multimedia, and computer equipment and peripherals.

**Power supply to laptops and communication devices**

One of the greatest challenges faced in making existing studios ICT-compliant is provision of power to individual desks. New designs make provisions in walls, floors and ceilings, but for existing studios, the best solution is using a raised floor. These standardised solutions use a metal framework about 10 cm thick, with removable framed floor tiles. The space provided is sufficient for both power and network cabling, and it is easy to customise and make modifications because the floor tiles, just like suspended ceiling tiles, are removable. This can be combined with retractable power points in the floor. A cheaper but less aesthetically pleasing solution is to drop retractable power and data points from a (suspended) ceiling. See Plates 33-36.
9.10. CAD and graphics software

Current and versatile software is essential for productivity and efficiency. The use of free software is encouraged because of the exorbitant cost of especially CAD and graphics software. Autodesk has recently upgraded its education programme to provide free three-year licenses for fully functional software to students and educators, including their most famous AutoCAD, AutoCAD Architecture, 3DS Max Design and Revit Architecture. The programme has been extended to schools outside the United States and the authors currently benefit from many such educational licenses. The software recommended for architecture schools is shown in table 2.

9.11. Networking and communication software

Networking and communication software are often free, and it is important to install the most current versions of the best software on computers and applications on mobile devices. Recommended networking and communication software is shown in table 2.
<table>
<thead>
<tr>
<th>Required Category of Software</th>
<th>Sample Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating systems</td>
<td>Microsoft <em>Windows</em>, Apple OS</td>
</tr>
<tr>
<td>Internet browsers</td>
<td>Google Chrome, Mozilla FireFox, Opera, Safari</td>
</tr>
<tr>
<td>Miscellaneous application packages</td>
<td>Microsoft Office (Word, Excel, PowerPoint, Publisher, Access), OpenOffice</td>
</tr>
<tr>
<td>Computer Aided Design (CAD) and Building Information Modelling (BIM)</td>
<td>AutoCAD, AutoCAD Architecture, Revit Architecture, ArchiCAD, Google SketchUp, Google SketchUp Pro, Maya, Rhino, Navisworks</td>
</tr>
<tr>
<td>3-D modelling, rendering and animation software</td>
<td>AutoCAD, AutoCAD Architecture, Revit Architecture, ArchiCAD, 3DS Max Design, Atlantis</td>
</tr>
<tr>
<td>Networking and communication software</td>
<td>Skype, Gmail, download accelerators, communication and social networking apps for mobile devices, FTP clients (FileZilla)</td>
</tr>
<tr>
<td>Specialised software</td>
<td>Google Earth, media players (VLC), media converters (Freemake Video Converter, Any Video Converter, Any Audio Converter), media burning software (Ashampoo Burning Studio), file explorers (FreeCommander), anti-virus software (Avira Antivir Personal, AVG Antivirus), Autodesk Design Review</td>
</tr>
</tbody>
</table>


10. INTERCONNECTIVITY REQUIREMENTS IN MODERN ARCHITECTURE SCHOOLS

The primary requirement for interconnectivity in modern architecture studios is networking using ICT. This is necessary for accessing educational resources; printing and plotting; and 3-D modelling, rendering and animation. Some schools however also provide spatial connectivity, making it possible for students in various studios to visually connect with other students for social interaction and mentoring, as in Gund Hall, Harvard University.

10.1. Intranet and Internet Connectivity

An Intranet is required to link ICT resources within the school or university while Internet connectivity is required for connecting to the World Wide Web. In low-technology environments such as Nigeria, emphasising excellent Intranet resources and connectivity is important, since most network traffic is within the Intranet, and even when Internet resources are accessed, the same resources are often repeated accessed, making it reasonable to cache or mirror such resources on the Intranet. See Plate 37.
10.2. Educational Resources (Learning Management Systems, E-library)

One of the most important reasons why architecture schools must have network connectivity is to gain access to educational resources. Many schools offer online courses, and submission of assignments and assessment can be done online. Access to design data and past projects in the school e-library is also very important.

10.3. 3-D Modelling, Rendering and Animation

The use of CAM equipment and render farms for network rendering and animation requires a computer network. Although CAM equipment requires supervision, modelling jobs can be submitted online. Render farms are several (sometimes dozens) of networked workstations with multiple fast multicore processors that can share a single job to speed up its processing. See Plates 38 and 39.

10.4. Printing and Plotting

Printing and plotting to networked printers, plotters and devices require network connectivity. This connectivity is usually wired because of the large volumes of data transfers required, and thus must be designed into the fabric of the building.
11. SUMMARY AND CONCLUSIONS

A comparison of the infrastructure available in the leading schools of architecture with those in Nigerian schools of architecture, and a further comparison of the quality of projects produced by students on both sides of the divide, suggests that improving the infrastructure available in Nigerian schools of architecture may lead to enhancement of the quality of training.

11.1. Integration of Digital Media into the Architecture Curriculum

All the schools visited used CAD at all levels, even when new students were required to do manual drafting. The use of models and 3-D model making technology (CAM) was pervasive. Computer laboratories, dedicated large format printers, Local Area Networks and provision of power and data connectivity at every table were observed.

11.2. Customised Studio and Learning Spaces

All the newly designed architecture schools had customised studio spaces that enabled students to draw and model at their own desks. Older schools were adapted to fit the new demands. Storage space for drawings and personal effects was provided. Good natural lighting, good artificial lighting, ventilation and air conditioning (often within suspended ceiling space) were always provided. Power for laptops was designed either into the building, or provided via retractable drop-down or pop-up power points, or through raised floors. Wireless networking was pervasive.

12. RECOMMENDATIONS

It is recommended that the physical infrastructure and network resources in Nigerian schools of architecture be enhanced to bring them closer to international standards.

12.1. Recommended Physical Infrastructure

1. Studios should be custom designed and should have adequate furniture and environmental controls. Good ventilation and adequate natural lighting should be provided.
2. Lecture rooms (as distinct from studios) should be provided and they should be equipped with necessary multimedia equipment.
3. Workshops and laboratories should be provided in close proximity to design studios.
4. Uninterruptible power supply using inverters should be provided for critical equipment.

12.2. Recommended network resources

Based on our level of technological advancement and our societal demands the following networked resources are recommended for schools of architecture in Nigeria (Ogunsote, Prucnal-Ogunsote and Umaru, 2007; Ogunsote, Adebayo and Prucnal-Ogunsote, 2007).

- Internet connectivity, preferably using a Very Small Aperture Terminal (VSAT) or enterprise grade broadband routers.
- LAN (wired and wireless). The wired LAN should cover all staff offices, studios, lecture rooms and administrative offices while the wireless network should be pervasive.
- File servers with software, backup and library. The file servers should contain model libraries and be used to backup staff and student files. Installation of licensed software on personal computers should be performed using files resident on this server.
- Network printers and plotters for printing to any printer or plotter for a minimal fee.
- Windows versions of licensed software for staff and student usage.
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14. REFERENCES


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