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The Impact of Computer Aided Architectural Design Tools on Architectural Design Education. The Case of KNUST

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Abstract

Computer Aided Architectural Design (CAAD) tools have been available to the architect in practically useful form for a close to a century. It has evolved from being a complicated simulation tool available to mainframe computers and used exclusively by experts working on special "CAAD projects" to being accessible to any interested individual on a personal computer. CAAD plays a vital role on the profession and academia of architecture in recent years. The aim of this study is to provide a reflective perspective of the current architecture education on CAAD in the Department of Architecture in Kwame Nkrumah University of Science and Technology (KNUST). It compares the method of architecture design education in the department of architecture in KNUST to other methods architecture design education of other universities. It examines the various benefits of incorporating CAAD into the curriculum and looks at the various shortfalls limiting the full exploitation of CAAD into the design curriculum of architecture education also the role CAAD the design process from conceptual to final product is examined. Survey questionnaires were distributed to students in the Department of Architecture and CAAD tutors interviewed to ascertain the level of impact of CAAD in the department. It was realized that the level of integration of CAAD with the design studio is low and transition from traditional drafting methods to the modern methods of using computers in design is not clearly established, thus recommendations were made to rectify the situation.

Keywords: Computer Aided Architectural Design; Architecture education; Curriculum; Design process

Introduction

CAAD was introduced into the department of Architecture for more than a decade; however its full potentials have not been realized, therefore the benefits of employing CAAD tools in the design process is not enjoyed by students of architecture in the department. This situation can be linked to a plethora of problems such as: inadequate logistics for the teaching and practicing of CAAD, absences of CAAD training experts, complexities in the user interface of CAAD tools and on the frail creativity of the development work in CAAD. The current concept of architecture design education is a blend of both the traditional methods of drafting with the drawing board andT-square and the use of CAAD tools in the design process.

Students are restricted from using CAAD tools in the first and second years of their architecture training. They are taught the basic hand drafting and graphic communications skills and other forms of conventional architectural design education. They are expected to apply such skills into their designs. However in the third to sixth years of their architectural education, they are encouraged to use both traditional methods and computer aided drafting and design methods. Sadly, the transition from tradition methods to computer aided drafting design methods are not clearly defined, thus some students are left at a disadvantage when tasked to use CAAD in their design thus deprived of the tremendous advantages of using CAAD. A major advantage of this method is that, students are introduced to both methods of architecture design education and are able to implement either or both methods when needed. CAAD is the solution. CAAD offers the means of evolving design ideas in a three Dimension (3D) space that addresses all design issues that would have otherwise been ignored in two Dimension (2D) drawings on the sheet. CAAD tools enable the architect to better understand the various components of the project, its structural integrity, Heating, Ventilation and Air Conditioning, analyzing the environmental performance of the building and performing real life simulations in virtual reality systems.

By virtue of the changes now affecting architecture as a profession, there is the need for the Department of Architecture in KNUST to expose her students to the emerging technology of computer aided design. Mere acquisition of appropriate hardware and software for the teaching and learning of CAAD and recruiting faculty knowledgeable in CAAD is not enough. Students should be encouraged to implement learned skills in CAAD to "special design projects" in a practical manner and be examined on how effectively skills learned are applied in real life situations. The purpose of this paper is to study the current curriculum of architecture design education in the department and how it is been implemented in the department and examine the role of CAAD in the design process from conceptual to final product as used in the department of architecture in KNUST.

In this era of rapid technological growth and fierce competition, there is the need for architects in the developing world to keep pace with the latest advancements of technology and computing used in the design of the built environment. The use of Computer aided architectural design (CAAD) tools by architects' dates back to the early 1960s. CAAD tools are used by architectural firms and they greatly help in the production of drawings from inception to completion [1]. Computing in architecture has posed new challenges since its early beginning; it has changed the working methods in the architectural profession and study [2], it has reduced the need for draftsmen in offices thus reducing the number of human labor, resulting in an increase in productivity. However majority of architects in the developing

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countries may not be fully aware of the applications of computers in architecture except for the applications of computer aided drafting, modeling and visualization [3]. CAAD has a notable impact on the profession and academia of architecture. Some professionals in the architectural field have predicted that in the coming years drafting board and sketchpads would be replaced by computers in offices and gradually in schools [2], thus there is the need for architecturecurricula to be modified to integrate CAAD education.

State of CAAD Education in KNUST

In the Department of Architecture, at the Kwame Nkrumah University of Science and Technology (KNUST), CAAD has been introduced into the curriculum of architectural design education since the year 2000, unfortunately its level of penetration in design education is restricted. The use of CAAD tools in design by the first and second year students of architecture is restricted. Students are taught basic hand drafting and graphic communication skills and are encourage to use such skills learnt in their designs.

Design drawings are made entirely with freehand. On the contrary architectural students in the third year to sixth year are allowed to use CAAD tools but are to use freehand sketches at the conceptual stage. In the 4th year students are encouraged to use CAAD in the design process except at the conceptual stage. There is strong link between CAAD and other electives subjects taught during the 4th year. At the time of the incorporation of CAAD into thecurriculum of design education in the department of Architecture in, the common CAAD softwaresin architectural practice, were AutoCAD developed by Autodesk and ArchiCAD developed by Graphisoft. AutoCAD was the dominate tool hence its adoption by the department. AutoCAD Release 3 was initially taught by the department, it was later upgrade to release 12. Currently AutoCAD architecture 2008 is taught in the department though the latest version is AutoCAD architecture 2014.

The computer (major CAAD tool) is seen as a mere electronic drawing board for worksheet drawing. This assertion clearly undermines the vast potentials the computer has to offer in the design process. Until this barrier is broken, the adoption of CAAD as a relevant tool in the design process would not be realized. With the availability of the Personal Computer (PC), the department set up a computer laboratory for the teaching and learning of CAAD, the laboratory was stocked with approximately fifty (50) computers. Currently, plans are in the pipeline in constructing a new modern computer laboratory to supplement the existing laboratory. AutoCAD is taught at the department as part of the design studio at the second year during the first and second semesters.

However the course is not examined at the end of the semester, marks accrued through quizzes are added to the overall studio marks of that year. This has resulted in little to no interest in CAD taught by the department. In Ghana presently, employment into any certified architectural firm requires CAAD proficiency in at least one of the many CAAD tools, thus there is the need for CAAD to be incorporated in to the design education of Architectural universities in the country, so as to make their graduates viable for employment into the design industry.

CAAD in the Design Process

Springer [4] defined Designing has an "activity which incorporates both physical and conceptual tools. In an architectural design process, besides the physical tools such as all the drawing and drafting instruments, several conceptual tools such as the shape grammar and library are used. These conceptual tools are the ones that designers use to abstract and comprehend the design problem, mentally reconstruct, figure out and resolve it thus generate the design idea and the physical tools are the ones to visualize and realize the design.

From the above, physical tools like computers, contribute significantly to the realization of thefinal design scheme. Pioneers of CAAD designed the software to mimic the hardware tools such as: pencils, paper, and paint brush. Designing requires the designer to think visually and be creative, thus visual elements created during the design process influence the designers thinking. CAAD may act as a visual aid through 3D modeling and sketches. According to Asut [5], "Design is not a linear process which focuses on the target, but a netlike path which includes instantaneous feedbacks and coincidental decisions". Benton [6] argues that the architectural designers must look beyond the complexities of the interface of CAAD tools as that leads to the development of predictive outcomes in design but rather view CAAD tools as "toys" that operate as speculative machines.

A designer should be solution- led but not problem led; use of physical tools of design helps in the evaluation of the solution through the BIM capability of physical tools such as Revit Architecture. The question at hand, is at what stage CAAD should be incorporated into the design process. One may argue that CAAD used in the design process becomes effective when the all the possible ideas of the task have been analyzed down to the smallest detail and the best solution arrived at; a view that results in the way CAAD is taught in the department, in this case the computer is reduced to a mere electronic board. However, recent advancement in CAAD tools makes it possible to incorporate CAAD-Systems at the conceptual stage of the design to the final stage of the design process.

CAAD programs are designed to have the capabilities of performing multiple complex design task with little human effort in a short time which otherwise would require intensive human effort and a lengthy period of time to accomplish with traditional methods of design, that is, manual drafting.

In the traditional method of drafting, any errors that needs to be corrected leads to a complete redrafting/retracing of the project. For instance, a spill of ink on the sheet or a change in the spatial arrangement of spaces on the floor plan requires redrafting of the project. In contrast designing with CAAD allows for the affected portion to be corrected without the need to redraw the entire project. CAAD programs are time-saver tools that allows for similar features in the design project to be repetitively drawn at their desired points. For instance, in a multi-storey building with typical floor plan, successive floor plans can be drawn by copying the initial plan and pasting at desired points. However, manual drafting requires redrawing each floor plan.

CAAD versus Creativity

According to Proctor [7], "Design educators attempt to train the eyes and minds of students to see and comprehend the world around them with the intention of preparing those students to become good designers, critical thinkers and ultimately responsible architects". Accordingly students are expected to be creative in their pursuit of becoming architects. Students of Architecture strive to attain a level of professional competence. The ability to think visually is a skill that distinguishes architects from other professionals [7].

CAAD tutors have the responsibility of encouraging students to think how CAAD tools can be used in creative way. CAAD tools can be used as an extension of our creative possibilities. Creativity can be enhanced through the use of CAAD in the development of architectural

forms and the subsequent visualization of the form through 3d modeling, renderings, animations and virtual reality. Presently, the mode of teaching CAAD in the department does not encourage the use of CAAD at the conceptual stage. CAAD is merely taught as a digital representation of 2D works done through traditional designs methods. Students are expected to memorize all AutoCAD commands they are then given 2D drawings on a sheet to replicate on the computer with the AutoCAD program.

Furthermore, CAD is taught in isolation of other design courses in the department. This does not only limit the creativity of students but it does not motivate the students to learn the tool. Negroponte [4] cautioned designers to be weary of the computer because it could affect their creative thinking, he suggested that designers should consciouslydistinguish between "heuristic of form" and heuristic of method". According to Negroponte, this would create a symbiotic relationship between the architect and the tool. However, [8] disagrees with Negroponte assertions, she calls for the need for ideas and concepts to be less ambiguous so has to transfer them into digital tool.

Materials and Methods

A quantitative approach was used to sample the opinions of students. Through the use of structured questionnaires, the opinions of one hundred students on the current curriculum on CAAD in the department and its impact on the decisions they make, regarding their pursuits of architecture as a profession were ascertained. Also through unstructured interviews, the opinions of CAAD tutors in the department, regarding the state of CAAD in the department and the way forward were collected. The data collected were categorized under primary and secondary source.

Description of Department of Architecture, KNUST

The study was conducted at the Department of Architecture at KNUST. The department is the pioneer school of architecture in the country and one of the best in West Africa.

Findings and Discussions

A total of 110 (one hundred and ten) questionnaires were distributed to students in the department of architecture from second (2^{nd}) year to the sixth (6^{th}) year. A total of one hundred (100) questionnaires representing ninety one percent (91%) of the total questionnaires administered were returned. Students from the second (2^{nd}) year to the sixth (6^{th}) year were the focus of this study, because the above mentioned years are allowed to use CAAD in the studio programs but in varying extent. CAAD restrictions lessens from the second year to the sixth year (Figure 1).

Students awareness on CAAD curriculum in the department is generally high, ninety five (95) percent of students questioned, confirmed the existence of CAAD courses in the department. However when asked to rate the effectiveness of this CAAD courses to the knowledge of any CAAD tool, fifty one percent (51%) of students gave the CAAD courses taught in the department the lowest rank, whilst forty one percent (41%) and eight percent (8%) gave a rank of two(2) and three(3) respectively. Interestingly, no student ranked the CAAD curriculum in the department above three (3) (Figure 2).

Based on the following parameters, students' views were solicited on the current CAAD curriculum; the CAAD course should be restructured, the CAAD course should be maintained as it is, the CAAD course should be removed from courses taught in the department (Figure 3). Ninety seven percent (97%) of students called for the restructuring of the current departmental course on CAAD, one percent (1%) of students called for the CAAD course to be maintained as it is, whilst two percent (2%) called for the elimination of CAAD from the courses taught by the department. Interestingly, forty (40) respondents who ranked the current curriculum on CAAD the lowest called for the restructuring of the CAAD course, whilst the two (2) respondents who ranked the current curriculum the lowest called for the elimination of CAAD from the architectural design curriculum. Though seven (7) respondents gave a rank of 3 for the effectiveness of CAAD curriculum, six (6) respondents called for its restructure whilst

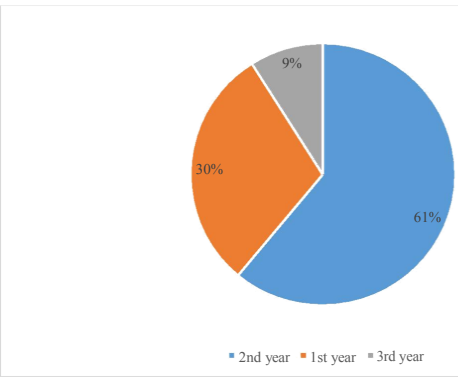

Figure 1: Year of learning CAAD.

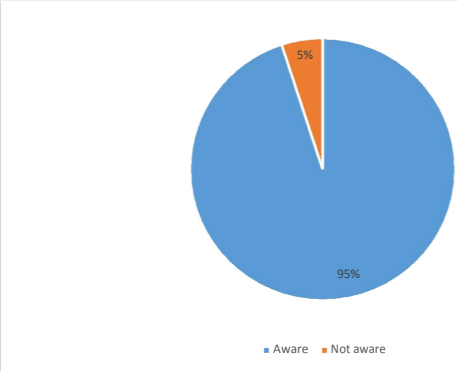

Figure 2: Students' awareness of CAAD in the Department of Architecture.

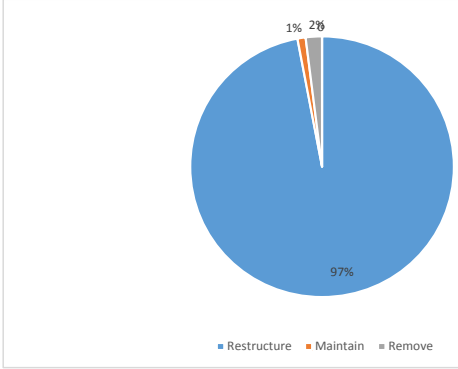

Figure 3: Views on the current curriculum.

a respondent said it should be maintained as it is (Figures 4 and 5).

Table 1 students were questioned on the CAAD softwares the employ in the design projects. Though ninety five percent (95%) of students use CAAD softwares in their design projects, they all did not use the same CAAD software. Thirty five percent (35%) of students use AutoCAD architecture, though it is the software taught by the department. The dominate software used by the respondents was Revit Architecture though it is not taught by the department. Fifty three percent (53%) of students used Revit Architecture in their design projects in design studio. Other softwares used by respondents are Google Sketchup and Autodesk ArchiCAD representing 5.3% and 4.2% respectively. Students employ various methods to gain proficiency in CAAD softwares. They were asked to state means by which they gained proficiency in the CAAD software of their choice based on the following parameters: Departmental courses on CAAD, self-teaching of CAAD software and organized private classes on CAAD.

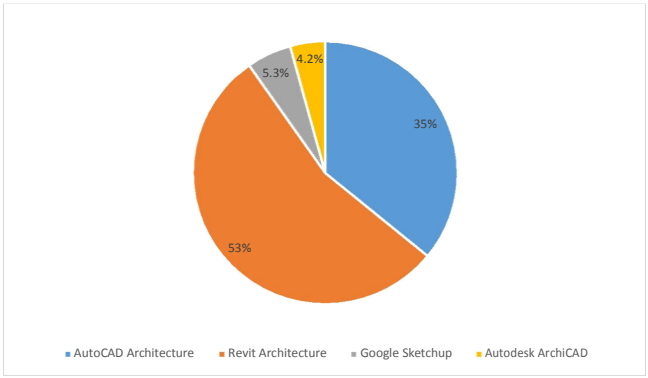

Figure 4: Type of CAAD software used by students.

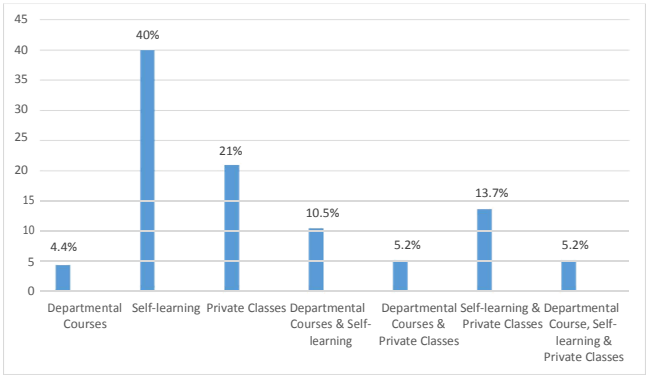

Figure 5: CAAD Learning Methodology by Students.

Learning	Designation	Percentage (%)
Approach		
Departmental Course	A	4.4
Self-learning	B	40
Private Classes	C	21
Departmental Course and Self-learning	A and B	10.5
Departmental and Private Classes	A and C	5.2
Self-learning and Private Classes	B and C	13.7
Departmental Course, Self-learning and Private Classes	A and B and C	5.2

Table 1: CAAD Learning Methodology.

The Table 1 below shows students means of learning CAAD softwares of their choice. Each method is assigned a given letter; Departmental courses on CAAD=A, Self-teaching of CAAD software= B, Private classes on CAAD=C

Total sample size is 95 students because 5 students do not use CAAD. Unsurprisingly, out of ninety nine students sampled, sixty one percent (61%) of students learnt the CAAD software in the second year of their study of Architecture, mainly because they were introduced to CAAD softwares in that year, however thirty percent (30%) learnt the CAAD software in the first year. The remaining percentage learnt the software in the third year. Student's proficiency level in CAAD softwares varies. Forty one (41%) of students had moderate proficiency in CAAD softwares whilst six percent (6%) of students had the lowest proficiency in CAAD softwares, interestingly, students that learnt the CAAD software by themselves had moderate to high proficiency in CAAD software.

The stages of the design process are listed: conceptuals, schematic design, design development, construction drawings and detailing and specification. Based on the stages of the design process, students were asked to state the stage/stages of the design process the employ the use of CAAD softwares. Out of a total of hundred students, thirty five percent (35%) of students use CAAD throughout the design process, whilst, no respondent use CAAD software for only conceptuals, this can be attributed to the fact that respondents do not see the CAAD software has a mere digital replacement of the traditional methods of manual drafting designs on the drawing board, but has an extension of drafting designs with vast potentials of evolving varied design ideals thatpreviously were impossible with traditional methods of drafting on the drawing board, also because 43.2% of students learn the CAAD software through their own effort, they have come to appreciate the vast potentials of CAAD softwares and they strive to incorporate skills learnt into their design projects. Interestingly, no student use CAAD at the conceptual stage only (Figure 6).

When students were asked to state some of the challenges the encounter when using the CAAD software, thirty six percent (36%) of students out of the ninety nine (99) student said the intensive training required to be proficient in the CAAD software was the major drawback in learning CAAD softwares. Twenty one percent (21%) said the hardware requirements of the CAAD software was their major drawback and twenty seven percent (27) of students attributed the

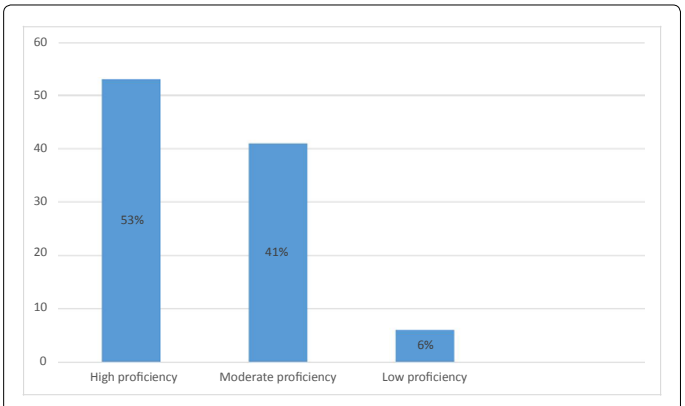

Figure 6: Proficiency Level in CAAD Software Application.

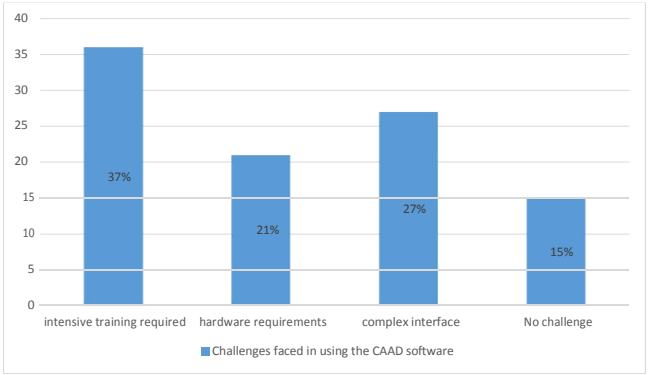

Figure 7: Challenges students encounter in using the CAAD tools.

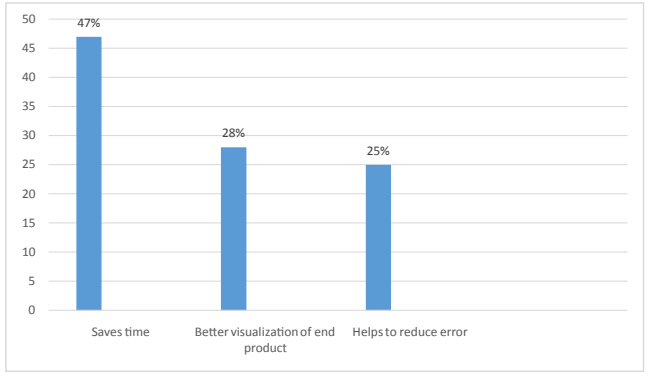

Figure 8: Advantages of Using CAAD Software.

complex interface of the CAAD software has their major headache, surprisingly, fifteen percent (15%) of students face no challenge in using the CAAD software, all fifteen percent learnt the CAAD software on their own (Figure 7).

In the same light, students were also asked to state the advantages they enjoy when using the CAAD software. Out of ninety nine (99) respondents, forty percent (40%) indicated that CAAD software helps them finish their works faster than manual drafting with the drawing board. Interestingly, all twenty one percent (21%) of students that said CAAD software helps them visualize end product better than manual drafting with the drawing board use CAAD software in all stages of the design process. Out of the eighteen percent (18%) of students that said, CAAD software helps reduce errors compared to manual drafting with the drawing board, twenty eight (28%) use CAAD in all stages whilst ten percent (10%) used CAAD software for design development and construction drawings and all eighteen percent (18%) respondents use Revit Architecture has their main CAAD software (Figure 8).

Summary of Findings

The primary focus of this research is to determine the impact CAAD tools have on architectural design education in the Department of Architecture, KNUST. In the department of Architecture in KNUST, the method of architectural design education involves the combination of traditional methods of design education involving the drawing board and the paper and the modern method of design education involving CAAD tools. Based on the research conducted, the following findings are summarized below.

1. It is realized that, the level of integration of CAAD in architectural design education is low compared to other internationally recognized departments of Architecture. In the first year in the Department of Architecture in KNUST, CAAD is not taught, students are taught to use traditional methods of design education in their studio projects. However, during the second year where they are supposedly taught CAAD during the first semester, they are prohibited from using the skills learnt in CAAD in their studio programs, but are expected to use the skills learnt in the first semester of the second year in their studio programs of the third year where CAAD courses are not taught by the department. Sadly, majority of students forget the skills learnt in the second year except students that do not rely solely on the departmental courses on CAAD but rather private Classes conducted by students with high proficiency in various CAAD tools. Some students also strive to learn the CAAD tools on their own and apply the skills learnt in their studio programs. This is evident by the fact that out of one hundred (100) respondents that have varied levels of proficiency in CAAD tools none relied solely on departmental courses on CAAD to gain proficiency in the CAAD tools but rather a combination of private classes and/or self-taught. Also though CAAD is encouraged in the design studio from the 2nd year to the 6th year, five percent(5%) of respondents do not use CAAD in the design studio.

2. The transition from the traditional methods of design to modern methods of design is not clearly established, students are not guided in transferring their skills learnt through the traditional methods of design to the more complicated method of design education with the computer and other CAAD tools. CAAD is an extension and an improvement of traditional methods of design education. Most skills learnt through traditional methods of design are applicable in CAAD.

CAAD tools were designed to mimic traditional methods of design with the drawing board and pencil. Principles of Shape grammar, basic drafting and lettering and color combinations among others are needed to become proficient in the CAAD programs. Students that are able to use principles learnt from traditional methods of design education in CAAD have higher proficiency than late bloomers. Also the varied level of transfer of skills from traditional methods of design education to the modern method of design education by students results in varying degree of CAAD integration in the design process. Student that are able to transfer skills learnt from traditional methods of design use CAAD effectively at all stages of the design process, thirty five percent (35%) of respondents use CAAD in all stages of the design process whilst remaining respondents apply their CAAD skills in varied combination in the design process.

This can also been in seen in the level of awareness of CAAD courses taught in the department respondents view of the current departmental courses and how respondents ranked the department courses on CAAD. Though eighty nine (89%) of respondents were aware of courses on CAAD taught by the department, ninety seven percent (97%) of respondents called for a complete restructuring of the current departmental courses on CAAD whilst fifty two percent (52%) of respondents gave the lowest rank for how effective the departmental course on CAAD influences their knowledge of CAAD tools. This situation can be attributed to the fact that the transition from the traditional methods of design to modern methods of design is not clearly established, by virtue of the weal linkage between the traditional and modern methods of architectural design education.

Conclusion

Findings revealed that the method of architecture design education

in the Department of Architecture in KNUST involves the combination of both traditional methods of design education to modern methods of design education, however the transition from traditional design education methods to modern methods of design education are not clearly established resulting in respondents not able to realize/derive the full benefits of combining both methods of architectural design education. Though CAAD is encouraged by the department, its level of integration into the design studio is low, this is due to the fact that students have little to no interest in the CAAD courses taught by the department.

Recommendation

As a means of strengthening the linkage between the traditional and modern methods of architecture design education in the department, there is the need to encourage research into CAAD by CAAD tutors, improving upon current curriculum teaching of CAAD and the development ofCAAD systems in the department. Adoption of Revit Architecture as the main CAAD tool for CAAD courses because fifty two percent (52%) of respondents use it in the design studio. Also users of Revit Architecture enjoy the BIM capabilities in the software.

In order to encourage interest in CAAD courses by students, CAAD should be made an elective course also the number of credit hours of CAAD courses should be increased, furthermore CAAD courses should only be taught at the 2nd year but rather it shouldbe an integral part of the design studio from the 2nd year to the 6th year. Finally, students should beexamined at the end of the semester rather than including marks of students accrued from quizzes into the overall marks of their design studio.

Various forms of interactive education systems such as video tutorials, electronic handbooks and so on should be adopted in the teaching of CAAD. The creation of a CAAD laboratory well stocked with high-end computers that should at least conform to the minimum specification for running CAAD softwares, thus enhancing the teaching and learning experience of CAAD teaching. Also, CAAD laboratory should be designed to create a conducive environment for the teaching and learning of CAAD.

Preference should be given to collaborative learning of the CAAD software using the work set sand work sharing capabilities of Revit where individuals that is groups of two students collaborate on a particular project using the work sets. This would create team work and evoke parallel processing of CAAD application to arrive at an end product. Preliminary investigation on the strength of students in the CAAD applications should be undertaken and less proficient students should be paired with students of high proficiency, Care should be taken so that students of equal proficiency in the CAAD application would not be paired together.

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