Arkoh and Marful, J Archit Eng Tech 2023, 12:5

Architectural Engineering Technology

Research Article Open Access

Strategies for Introducing Robotics and Automation in Architectural Pedagogy in Ghana: The Case of KNUST

Benjamin Papa Arkoh* **and Alexander Boakye Marful**

Departments of Electronics and Communication, University of Ghana, Accra, Ghana

Abstract

The 20th century, characterized by initial developments in computers, robotics and automation marked the start of the computer age. The heightened quest to reduce limitations of human resource, coupled with further exploration saw significant advancements in technological developments in later years. Robotics and automation is an aspect of engineering encompassing the design, development and application of automated robots. Research shows robotics and automation is becoming an imperative part of architectural pedagogy and practice. However, in the case of Ghana, there have been minimal attempts at exploring robotics and automation in architecture pedagogy and practice. Concentrating on architecture pedagogy, specifically, the department of architecture KNUST, the research reviewed existing literature on the state of robotics and automation in architecture education in Ghana. Information gained was analyzed in conjunction with data collected by means of observations, questionnaires addressed to students and interviews directed at faculty staff to assess the existing inputted strategies as well as the limitations hindering the holistic pairing of both disciplines. Findings showed that although a majority of students and faculty staff were enthused about robotics and automation in architecture education, the absence of structured courses, the lack of robotic equipment in the department and the unwillingness of some students and faculty staff to adopt robotics and automation due to certain conceptions the have caused a gap between both disciplines. The paper proposed that, establishing structured courses, seminars and workshops with experts, making available robotics and automation tools for practical experimenting and encouraging students venturing robotics and automation through organized in person and online exhibitions can help effectively introduce robotics and automation in architecture pedagogy.

Keywords: Robotics and Automation (RA); Robots; Architecture pedagogy; Architecture practice; Ghana

Introduction

Advancement in Information Communication and Technology (ICT) yielded robotics and automation as a branch of engineering that employs software automated robots in completing specific tasks [1]. Projecting a promising prospect in human's attempt to achieve effectiveness and precision, healthcare and industry at large quickly saw a progressive fusion of robotics and automation. Unfortunately, the built environment manifests a contrast in similar progression [2-4].

Although architecture is renowned for its innovation and adaptability as architects strive to inculcate contemporary technologies in their field of work, incorporating robotics and automation as an intrinsic part of architecture has seen minimal advancement, especially in Africa [5].

Taking precedence from the progress of other disciplines due to robotics and automation sprouts the need to discuss the development of schemes by which robotics and automation and its potential meriting impact can be fused with architecture in Ghana.

Background

Robotics and automation: Robotics and Automation (RA) dates to the brink of the 20th century where pioneer George C. Devol in the 1950's developed the first model of a robot. However, the concept of robots will only start gaining ground in 1960 upon gradual realization of its limitless quality and accuracy [6-8].

The start of the 21st century saw further advancement with robotics and automation heavily involved in industry and healthcare. In architecture, Computer Aided Design (CAD) software, a basic element in automation, was gradually integrated. However, advanced software which links practical aspects of robotics and automation with architecture was initially tagged as futuristic [9]. The futuristic vision would come earlier than expected as demands of complexity, speed, accuracy in architecture heightened. Merging both disciplines would prove challenging, resulting in the need to identify effective strategies to ensure stakeholders in architecture welcomed robotics and automation. Works on experimenting in Europe and North America commenced in architectural universities and firms to determine the best way of merging both disciplines. Feedback from students and architects indicated the need and readiness to accept robotics and automation.

***Corresponding author:** Benjamin Papa Arkoh, Departments of Electronics and Communication, University of Ghana, Accra, Ghana, Tel: 233881717; E-mail: benjiarkoh@gmail.com

Received: 31-August-2023, Manuscript No. JAET-23-93761; **Editor assigned:** 04-Sep-2023, PreQC No. JAET-23-93761 (PQ); **Reviewed:** 18-Sep-2023, QC No. JAET-23-93761; **Revised:** 23-Sep-2023, Manuscript No. JAET-23-93761 (R); **Published:** 30-Sep-2023, DOI: 10.4172/2168-9717.1000353

Citation: Arkoh BP, Marful AB (2023) Strategies for Introducing Robotics and Automation in Architectural Pedagogy in Ghana. The Case of KNUST. J Archit Eng Tech 12: 353.

Copyright: © 2023 Arkoh BP, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

In Ghana, minimal work on transitioning robotics and automation into architecture has been done. Research indicates that only the very basics automation, mainly CAD software, is used in architecture pedagogy.

A survey spanning June 2014 to June 2015 assessing the use of ICT in construction in selected tertiary institutions showed lecturers and students rarely used CAD programs.

Another survey assessing the acceptance of Building Information Modelling (BIM) in 2017 established that, misconceptions towards and the lack of regard for the use of BIM software hindered a blend of robotics and automation and architectural construction. However, results revealed a positive change in attitude of participants towards BIM when the approach applied successfully eased misconceptions and their perceived usefulness of BIM.

Architecture in Ghana

Situated along the Gulf Guinea, Ghana, a West-African country, Ghana's architecture is characterized by an architectural time lapse showcasing a blend of vernacular earth constructions to contemporary glass and concrete buildings, the landscape is marked by the country's cultural and architectural dynamism.

Pedagogy: Architecture education is spearheaded by the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The department runs four years Bachelor of Science in architecture program and a two years master in architecture program.

In 2008, Central university, a private university located in Accra also established a school of architecture and science, running a five year masters of architecture program.

Practice: Architecture practice and pedagogy is regulated by the Ghana Institute of Architects (GIA) while the Architecture Registration Council (ARC) of Ghana is responsible for the registration of architects and architectural firms. As of 2016, the ARC had registered 977 architects, 218 architecture firms and 2 schools of architecture.

Hypothesis

It cannot be said that robotics and automation has had no involvement with architecture in Ghana as CAD and BIM software steadily transform aspects of the discipline. However, the stagnant progression in adopting advanced robotics and automation as a core of Ghana's built environment industry highlights the gap between both disciplines. Research in other countries showing architects and students exhibiting a desire for robotics and automation after experimenting with robotics and automation tools draws the question; what strategies should be established to effectively introduce robotics and automation in architectural pedagogy Ghana?

The research aims at developing a blueprint to merge robotics, automation and architecture to help elevate the state of architectural education and practice in Ghana by investigating:

- The concept of robotics and automation, history, theories and the role robotics and automation play in architecture.
- Obstacles hindering the introduction of robotics and automation to architecture pedagogy in Ghana to propose counter policies.

Theoretical framework

Robotics: Moravec defines robotics as a subset of engineering which deals with designing, constructing, operating and application of robots while employing computers as processing and manipulation tools to control robots.

Robots: The term "robot" fails to lend itself to a straightforward definition. Various articles show explanations influenced by particular time settings and new findings in robotics.

Robots and the time factor: You may have fallen victim to the imagery of a metallic electric man or a humanoid of silver or gold that speaks with a frightening machine voice. In contemporary settings, such a description may be considered a statement of 'robotic comedy'. However, travel back to the very beginning of robots and a metallic artificial human was the norm for defining robots.

In modern times, robots break away from the symbolic representation of human forms as they exhibit diversity in design, size and capabilities. This makes it difficult to ascertain a common definition to robots. Some robots mimic human figures while others have a single limb or more than four limbs small as a coin to those bigger than a saloon car. Regardless of the divide in defining robots due to changing time settings, both agree that using robots reduce or replace human effort.

Robots and advancing robotics technology

Roboticist Anca Dragan defines robots as: I would say that a robot is a physically embodied artificially intelligent agent that can take actions that have effects on the physical world.

Simon on the other hand, argues that a robot should be a self-thinking device capable of interacting with its environment. Roboticist Kate Darling concords by saying.

My definition of a robot, given that there is no very good universal definition, would probably be a physical machine that's usually programmable by a computer that can execute tasks autonomously or automatically by itself.

The example below explains both views; consider two drones, both designed with intelligence responsible for navigation. One of the two requires a pilot to feed in commands and the other takes flight, moves, evades obstacles and lands automatically. With the initial example reflecting the view of Roboticist Anca Dragan while the latter cements that of Simon and Roboticist Kate Darling, can both be considered as robots?

Roboticist Rodney Brooks, in agreement with the latter example, perpetuates that robot should be autonomous. As a creator on the Roomba robotic vacuum project, he said:

Think of the Roomba robotic vacuum. It uses sensors to autonomously drive around a room, going around furniture and avoiding stairs; it carries out computations to make sure it covers the entire room and when deciding if a spot needs a more thorough cleaning and it performs an action by "sucking dirt".

Historical development of robotics

Mythical developments of robotics: It is difficult to imagine robotics as non-scientific. However, research indicates that the beginnings of present day robotics are believed to have mythical origins from ancient Africa, Europe and Asia.

- **Ancient Africa:** Egyptian lore states that in the new kingdom of Egypt, religious statues made from stone, metal or wood responded to consultations of worshippers with movement of the head.
- **European Christian legend:** Albertus Magnus' android which would have handled domestic tasks was destroyed by his student Thomas Aquinas for interrupting his meditations.
- **Ancient India:** Lokapannatti, a set of Indian cycles and lore produced in the 11th or 12th centuries AD, describes stories of automated soldiers called "spirit movement machines" which were developed to safeguard the relics of Buddha in a hidden stupa. It is believed that the Indians stole the plans for developing these humanoids from the kingdom of Rome.
- **Ancient China:** In chapter 5 of the Daoist text, King Mu of Zhou on his Western tour had the craftsman master Yan performs for him. Master Yan presented the court with automated human forms that performed diverse stunts for the king and his court's subjects.
- **Ancient Greece:** The legend Cadmus sewed dragon teeth which transformed into soldiers, also Hephaestus also created self-controlled three legged tables and a man made of bronze called Talos, the defender of Crete.

Scientific developments of robotics

Through the centuries, robotics has seen numerous scientific developmental phases (Figures 1 and 2). Predominant of these are:

- **Nineteenth century:** Nikola Tesla's electrical boat invention which had the radio remote control feature was used in World War. Tesla's invention was first unveiled with his submersible boat model at the Madison Square Garden in the year 1898.
- **Twentieth century:** The word "robot" was first used in 1921 in a drama published by the Czech Karel Capek. The satire, Rossum's universal robot, in which robots were described as biological beings responsible for manual work. Simons makes us understand that the word robot comes from the Czech "forced labor".

Figure 1: Silver arm.

Figure 2: The rancho arm.

In 1942 the word "robotics" was formed. Isaac Asimov, the Russian-born American science-fiction writer, initially used the term in his literary piece called "Runabout". Asimov held a contrary view to that of Capek by depicting robots as a better, neater race that are helpful to humans. Asimov suggested three laws of robotics that his robots followed:

- **First law:** A robot may not injure a human being or through inaction, allow a human being to come to harm.
- **Second law:** A robot must obey the orders given it by human beings except where such orders would conflict with the first law.
- **Third law:** A robot must protect its own existence as long as such protection does not conflict with the first or second law.

Twenty first century: In April 2001, Canadarm2 joined theinternational space station after it was launched into space.

In 2002, IRobot company debuted Roomba, the first robotic vacuum cleaner. The following year, on the 3rd and 24th of January, the Mars rovers spirit and opportunity arrived on mars; both robots covered much travel distance as anticipated such that Opportunity still functioned as of mid-2018 although dust storms cut-off communication with the robot (National Aeronautics and Space Administration (NASA).

Self-driving cars made an introduction in 2005 but the designs were hugely unadvanced. In 2006, Cornell university presented the "Starfish robot"; a four legged self-assembling robot which could learn to walk after it has been disassembled. The controversial female robot, Sophia was granted Saudi Arabian citizenship at the future investment summit Riyadh (Figures 3-6).

Figure 3: Roomba robot (national museum of American history, 2021).

Figure 4: Spirit robot (national museum of American history, 2021).

Figure 5: Starfish robot (Cornell chronicle-Cornell university, 2021).

Figure 6: Sophia (roboticstomorrow.com, 2021).

Automation

The International Society of Automation (ISA) defines automation as created technology capable of monitoring and managing the production and delivery of goods and services. However, Groover argues that mechanization adds that automation is achieved when integrated machines form a self-governing system.

Early developments of automation: The science of automation takes root from the discipline of mechanization which characterized the industrial revolution of the eighteenth century. Mechanization replaced the work input of humans and animals with some form of mechanical energy or power.

Inventions of prehistoric men signaled early attempts of humans using intelligence to channel their physical strength into tools made of stones, wood and bones. The abilities of humans were magnified with the development of simple machines such as levers, wheels and pulleys. The next phase of machines, including simple steam driven, waterwheels and windmills did not require human effort in their operations (Table 1).

S. no.	Regional context	Time range	Contribution to automation
1	Asia (specifically China)	202 BC-220 AD	Trip-hammers powered by flowing water and waterwheels.
2	Europe	1335	The development of the complex mechanical clock, with a built-in power source (a weight).
3	Middle East and Europe	Middle ages	Windmills, with automated turning sails.
4	Europe (specifically England)	Age of industrial revolution	Watt steam engine.

Table 1: Historical contributions to automation.

Contemporary developments: Developments significant to modern day automation occurred during the twentieth century. The digital computer and computer software programs, advancements in technologies for data storage and the development of the mathematical control theory immensely contributed to present day automation. Modern automation has seen development from 1946 till date in the areas of:

- **Electronic digital computer:** Integrated circuits.
- **Computer programming languages:** C+ and Java script.
- **Data storage technology:** Flash drive and cloud storage.
- **Sensor technology control:** Systems Complementary Metal Oxide Semiconductor sensor (CMOS).
- **Control systems:** Artificial intelligence.

Robotics meets automation

The terms robotics and automation are usually used hand in hand, with the two words used interchangeably. Though there are shingling scenarios where robotics and automation overlap, they differ. To understand the intersection between robotics and automation, both their differences and similarities must be highlighted.

Robotics as a concerned with the design, development, manipulation and the use of robots use sensors and actuators to communicate and navigate its surroundings (hills electrical group, 2020) while automation primarily concerned with replacing human effort by utilizing computer software, physical machines and other technologies to complete task.

The above definitions reveal robotics and automation have similar aims by seeking to make tasks easier and safer, increase efficiency of productivity and ensure better standards (hills electrical group, 2020): However, practically, they bear distinct differences which are explained with the following examples:

- **Automation without robotics:** A customer sends a report to the support team of his/her bank. A chatbot responds to the customer, requests any additional information and directs the customer to send feedback at the end.
- **Automation without robotics:** A customer sends a report to the support team of his/her.
- **Automation using robotics:** In a car factory, a robot on an assembly line assembles parts to form a car.
- **Robotics without automation:** In a retirement home, lonely elderly people are provided with robotic dogs to keep them company.

Scope of architecture (Ghana)

Harris defines architecture as an art and science directed at designing and constructing structures, communities or open spaces that reflect the environment, history, climate, weather, people and culture it is situated in:

Architecture practice: The Architecture Registration Council (ARC) of Ghana, established in 1969 is the statutory body responsible for the regulation and promotion of architectural practice in Ghana (ARC, 2021). Acknowledges 722 Architects, 132 probational architects and 118 architecture firms.

Architecture pedagogy: Certified architecture education is offered in two university in the country; KNUST, Kumasi and Central University in Accra accredited by the commonwealth association of architects and royal institute of British architects with certification from GIA and Ghana Institute of Construction (GIOC) (Kwame Nkrumah University of Science and Technology (KNUST).

The case of KNUST, Kumasi; a study on an aspect of automation (Computer Aided Architectural Design (CAAD) in 2015.

Research conducted in 2015 on the impact of Computer Aided Architectural Design (CAAD) tools on architectural design education the case of KNUST, shows that the level of integration of CAAD with pedagogy is low and the jump from conventional drafting methods to the contemporary methods of using computers in design is not clearly entrentched.

Botchway, Abanyie, Afram explain that, the situation can be attributed to a number of challenges such as: Inadequate arrangement for the teaching and practicing of CAAD, lack of CAAD training experts, unfriendly user interface of CAAD tools and on the weak creativity of the development work in CAAD. The concept of architecture design pedagogy is a mixture of both the conventional approach of drafting with the drawing board and T-square and the application of CAAD tools in the design process.

The department of architecture at the Kwame Nkrumah University of Science and Technology (KNUST) runs a four year bachelors in architecture program and a two years master's degree architecture program. Although CAAD has been in the curriculum since the year 2000, its level of use has been restricted. First and second year students are trained to use solely conventional methods of drawing boards and T-square. However, the third to sixth year design studios are permitted to use CAAD except when conceptualizing where students are expected to sketch. There is a strong link between CAAD and other elective subjects taught during the 4th year. At the time of the introduction of CAAD into the curriculum in the department of architecture, the dominant CAAD software in architectural practice were AutoCAD, developed by Autodesk and ArchiCAD developed by Graphisoft. In 2015, AutoCAD architecture 2008 was being taught in the department though the latest version is AutoCAD architecture

2014. AutoCAD is taught at the department as part of the design studio in the second year during the first and second semesters. The computer (major CAAD tool) is perceived as a mere electronic drawing board for worksheet drawing, thus undermining 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. Plans were made to develop a new modern computer laboratory to supplement the existing laboratory.

The findings revealed a low level of integration of CAAD in architectural pedagogy in KNUST as compared to other prominent departments of architecture. In the maiden year in the department of architecture in KNUST, CAAD is not taught. Students are trained to use conventional methods of design education in their studio projects. However, during the first semester of second year where CAAD education is supposedly administered, they are prohibited from using the skills learnt in CAAD in their studio programs, until the third year.

Unfortunately, a greater percentage of students forget the lessons taught in the second year. Students do not rely solely on the departmental courses on CAAD but rather private tuition conducted by students who are well vested 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. Also, the transition from the conventional methods of drawing boards to modern methods of computer design is not clearly outlined. Students are not effectively guided in transitioning from skills learnt through the traditional methods of design to the more complicated method of design education with the computer and other CAAD tools.

Botchway EA, Abanyie SA, Afram SO recommended that the bridge between the traditional and modern methods of architecture pedagogy in the department can be strengthened by encouraging research into CAAD through CAAD tutors, improving upon current curriculum teaching of CAAD and the development of CAAD systems in the department. Emphasizing the need to the sustain student's interest in CAAD recommendations of introducing electives courses in CAAD accompanied by video tutorials and electric handbooks as an intrinsic part of studio and the creation of development of a well-stocked high end software computer laboratory in the department were made to encourage CAAD use in the department.

Robotics and automation meets architecture

- Building Information Modelling (BIM) gradually shaped various parts of architecture over the years. Liucci states that contemporary software such as AutoCAD architecture have helped improve the architectural design processes; however, there are other fields where modern technologies transform the construction area.
- Architects and student architects utilize robotics and automation technologies like 3D printing to generate detailed physical design models. With these models, architects can evaluate various materials to determine strength and weaknesses before construction begins (Figure 7).

Figure 7: 3D print product of the Yale school of architecture.

- A collaboration between robot manufacturer KUKA and rhinocerous (a Non-Uniform Rational B-Splines (NURBS) modeling program and Grasshopper (a rhinocerous plugin) allows architects to manipulate robots to simulate digital fabrication design and processes.
- At the university of Stuttgart, researchers programmed a robot to create 196,850 feet of carbon and glass fiber filament into a lobster exoskeleton inspired pavilion.

Construction (practice):

- Custom building parts are milled with detailed precision by robots. For example, KUKA developed the KR100 L80AH 6-axis robot capable of milling pieces as large as 50 feet wide and 12 feet high as well as smaller detailed pieces. The robot is capable of milling diverse materials, ranging from foam, wood, fiberglass and the like.
- Drones are replacing tall scaffolds in brickwork by transporting and laying bricks. Long robotic arms replace traditional cranes for material transportation on building sites.
- Iconbuild is a Texas based company involved in 3D-printed houses across the United States and Mexico.
- At the university of Stuttgart, researchers programmed a robot to create 196,850 feet of carbon and glass fiber filament into a lobster exoskeleton inspired pavilion (Figure 8).

Figure 8: Lobster skeleton inspired pavilion.

Branches of robotics and automation

Robotics: Robotics comprises numerous branches, most relevant to architecture pedagogy and practice these are:

- **5RERWLF PDSSLQJ** The branch of robotics that deals with autonomous robots constructing and localizing maps and/or floor plans.
- **5DSLG SURWRW\SLQJ** Automated construction of tactile objects by additive manufacturing from virtual models CAD software, creating them into thin horizontal sections and printing successive layers until the model is complete.
- **6LPXOWDQHRXV /RFDOL]DWLRQ DQG 0DSSLQJ 6/$0** The science of using autonomous robotic vehicles to create maps within unknown surroundings or to update a map within a known environment simultaneously keeping track of their current location.
- **Artificial intelligence:** The science that studies the simulation of human intelligence making computer systems act with human cognition.

- **Automation:** Generally, there are two main branches of automation; industrial automation and software automation.

- **Industrial automation:** Industrial automation employs control devices thus eliminating human labor to manage industrial processes and machinery. Advances in technology have resulted in a gradual transition from mechanization which required human interventions to industrial automation which utilizes physical machines and control systems to automate tasks. There are two types of Industrial automation; process plant automation and manufacturing automation system (Figure 9).

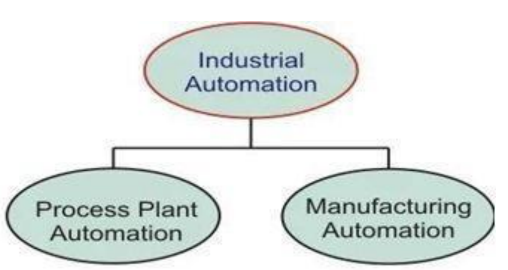

Figure 9: What is industrial automation.

- **Software automation:** Software automation refers to computer based tools designed to undertake repetitive tasks which comply with a particular logic. There are three sub-categories of software automation: Business Process Automation (BPA), Robotic Process Automation (RPA), and Intelligent Process Automation (IPA).

Merits of robotics and automation in architecture

- **Promoting sustainability:** Automated devices help ensure energy efficiency. The use of “edge monkeys” regulates energy use by signaling internal occupants upon detection of energy wastage, regulating facade treatments to allow daylight into internal spaces.
- **Safer work environments:** Robotics and automation technologies are utilized in dangerous site work such as demolishing process, building stages at high heights, drilling and below grade activities; drones, for example are capable of fire safety inspection, tracking work progress and alarming potential dangers at initial stages.
- **Curbs skilled labor shortage:** Effective in precision while simultaneously reducing labor cost and improving overall work productivity and quality.
- Speed and accuracy.

The limitations and remedies

- **Limitation 1: The complexities of architecture to robotics and automation:** The volatile nature of the architecture design and construction process makes it challenging for robots and automated devices to function effectively; robots and automated devices are built based on predictable sequential patterns and collated past.

  Remedy: Standardization of architecture and improved robotics and automation technologies standardization of architecture design processes and construction and site work. Thomson goes further to cite Building Information Modelling (BIM) as a key player in establishing a systematic change with the introduction of digital plans that automated robots can easily understand. Also, the multi-tasking abilities of robots can be improved with advanced machine learning technologies and artificial intelligence.
- **Limitation 2: Cost of robotics and automation technology:** Procuring automated robots can be extremely costly even for large architecture firms and schools. The upfront investment required to purchase automated devices are quite high though they are steadily dropping.

  Remedy: Renting to replace purchasing. Automated robot manufacturers can run a system of renting robots rather than have architectural firms and schools purchase them outright allowing for a quicker and more effective transitioning of robotics and automation into architecture.
- **Limitation 3: Establishing human robot collaboration:** Effective interaction between architects and robots is still a major challenge. Also, robots pose a potential threat to humans; for example, an automated robot while lifting a heavy object work is unable to detect the close presence of human personnel beneath and with the slightest miscalculation drops the object on the human.

  Remedy: Currently, Cobots a type of robot with improved abilities to understand human emotions, language and behavior is being developing to increase cohesion between automate robots and humans; cobots are to possess advanced Natural Language Processing (NLP), Natural Language Understanding (NLU) and Natural Language Generation (NLG) and behavior recognition technologies.
- **Limitation 4: Misconceptions:** Construction workers and artisans are concerned that automated robots stand to take their jobs. Most architects tend to see robotics as something very far in the future. Do you think that this is causing them to be left out of the conversation?

  Remedy: Creating awareness: Organizing workshops and seminars to create awareness of the state of robotics and automation in architecture can help eliminate the misconceptions.
- **Limitation 5: Minimal attempt at robotics and automation courses in architecture schools:** Unavailability of programs to introduce architecture students to robotics and automation makes the thought of robotics and automation in architecture distant.

  Remedy: Introduction of robotics and automation into architectural pedagogy.

Materials and Methods

The inductive research approach was used since the subject under study is a relatively new area, considering the scope of Ghana. Inductive approach is geared towards establishing a theory by data collection, data analysis and finally, proposal of a theory.

Citation: Arkoh BP, Marful AB (2023) Strategies for Introducing Robotics and Automation in Architectural Pedagogy in Ghana. The Case of KNUST. J Archit Eng Tech 12:353.

The research combined literature review, observation and the qualitative research techniques. Bhandari perpetuates that qualitative research brings a better understanding of experiences and opinions and enlists observation, interviews and questionnaire surveys.

Purposive sampling was used in this research because it was directed at a specific group that required selected participants to have an appreciable level of exposure to architecture and robotics and automation. Through the use of structured questionnaires, the views of 100 students on the impact of robotics and automation in architecture design education were ascertained. As a member of the student body. Observations made by the researcher against reviewed literature as a means of chronological study are also recorded.

Data obtained were presented in tables and charts and analyzed against recorded observation and reviewed literature through discussions.

Adhering to ethical conduct in research, the questionnaires were reviewed before distribution. Respondents were informed about the research's purpose and responses given by participants will be devoid of traceable identity tags.

Results and Discussions

A total of 120 questionnaires were administered to students of the department of architecture, KNUST, from the second year to the sixth year studio. A sum of 100 responses representing approximately eighty four (84%) of the questionnaires administered were returned. The research focused on students in the second to sixth year studios because all forms of robotics and automation are prohibited in the first year studio. From the data collected, approximately 8% were masters of architecture students and about 92% were undergraduate students (Figure 10).

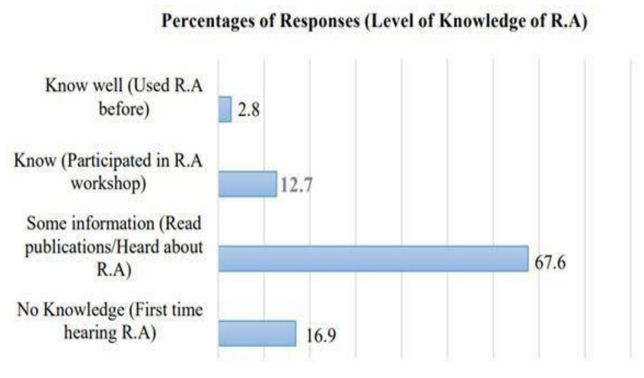

Figure 10: Percentages of the level of knowledge of respondents in robotics and automation.

Data collected shows that the majority of respondents represented by an approximation of 67.6% have had minimal exposure to robotics and automation. Respondents with a relatively higher exposure to robotics and automation by means of workshops stand at 12.7%. Though the majority have some knowledge about robotics and automation, the data collected shows a drastically dwindled 2,8% of respondents who are well vested and have used robotics and automation in areas architectural pedagogy with 16.9% of respondents having no prior exposure to robotics and automation (Figure 11).

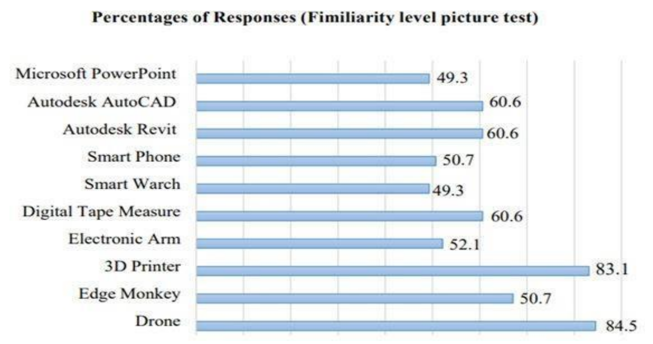

Figure 11: Percentages of respondents' familiarity level with robotics and automation.

The highlight of the results is centered around Autodesk software and Microsoft Powerpoint; approximately 60% of respondents correctly identified the former and 49.3% the latter as automations though this software is already actively being used by students of the department. Drone and 3D printer recorded high percentages of 84.5% and 83.1% (Figure 12).

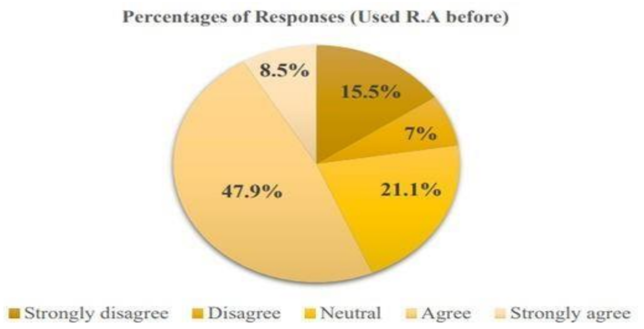

Figure 12: Percentages of respondents that have used robotics and automation before.

8.5% of the respondents were very certain they had applied robotics and automation before. At 47.9%, a large number of the respondents agreed to an appreciable level of exposure to robotics and automation. A total of about 22.5% of the respondents disagreed, claiming no level of involvement with robotics and automation (Figure 13).

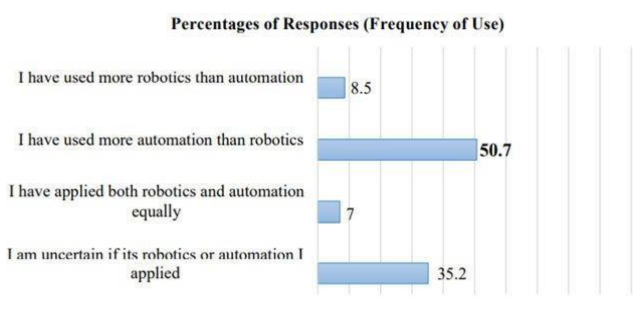

Figure 13: Percentages of respondents' frequency of use between robotics and automation.

Data collected shows that automation is applied more frequently as 50.7% of respondents agreed to applying more automation than robotics. Considering robotics, 8.5% of respondents agreed to use more robotics than automation while 7% agreed to apply both equally. At 35.2%, a relatively large number of respondents were unsure as to which they had applied. Figure 14 reveals a trend indicating that automation is more available to students as compared to robotics with a little over fifty percent being certain they applied automation technology more than robotics. Furthermore, the lack of knowledge in robotics and automation surfaced as an appreciable number of respondents expressed uncertainty to using robotics or automation.

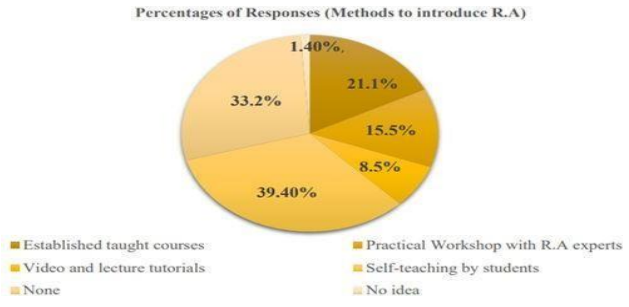

Figure 14: Percentages of respondents' perspective on methods used.

Results revealed 39.4% of respondents identify with self-teaching by students as the most used method. 21.1% of the respondents felt the department has made efforts with the established taught courses, 15.5% selected practical workshops with robotics and automation experts and 8.5% selected video and lecture tutorials (Table 2).

Method	Percentage	Rank
Self-teaching by students	52.1	1st
Practical workshop with R.A experts	19.7	2nd
Video and lecture tutorials	15.5	3rd
Established taught courses	15.5	4th
None	8.5	
No idea	1.4	

Table 2: Ranking methods of introducing robotics and automation.

Results revealed 39.4% of respondents identify with self-teaching by students as the most used method. 21.1% of the respondents felt the department has made efforts with the established taught courses, 15.5% selected practical workshops with robotics and automation experts and 8.5% selected video and lecture tutorials (Figure 15).

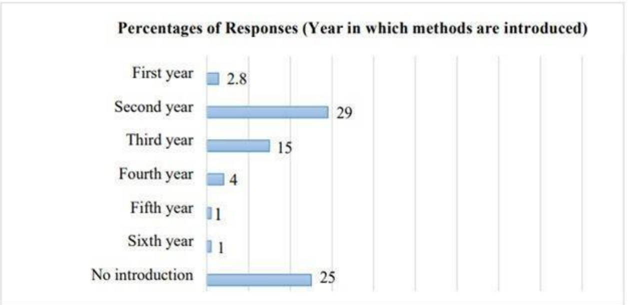

Figure 15: Perspective of respondents' year in which methods are introduced.

Data collected shows 29% of respondents believed the said methods are introduced in the second year of architecture school. Followed by 15% holding the view that introductions are made in the third year, an alarming 25% of respondents believed no attempts of introduction are made throughout the six year architecture program (Figure 16).

Citation: Arkoh BP, Marful AB (2023) Strategies for Introducing Robotics and Automation in Architectural Pedagogy in Ghana. The Case of KNUST. J Archit Eng Tech 12:353.

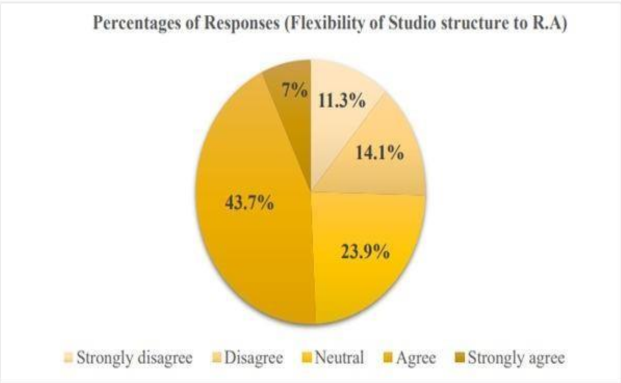

Figure 16: Perspective of respondents on studio structure.

The results indicate 43.7% of respondents agreed that their current studio set-up allows for the use of robotics and automation technologies in studio assignments. With 23.9% of the respondents holding a neutral stance, a sum of 25.4%, however, disagreed that studio structures permit the use of robotics and automation technologies in studio sessions.

The survey enquired views of respondents in relation to whether studio staff encourages students to use robotics and automation technologies (Figure 17).

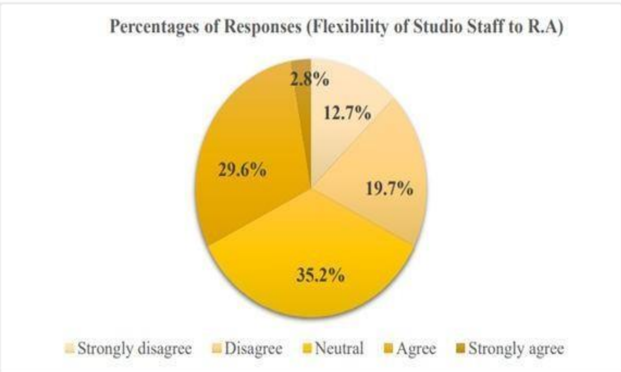

Figure 17: Perspective of respondents on studio staff to robotics and automation.

The responses reflect a largely neutral stance with 35.2% of respondents hoarding an unobjectionable view. Results also showed equally split views with a sum of 32.4% of the respondents agreeing and disagreeing with the question.

The questionnaire survey compared the prior methods applied before the introduction of robotics and automation (Figure 18).

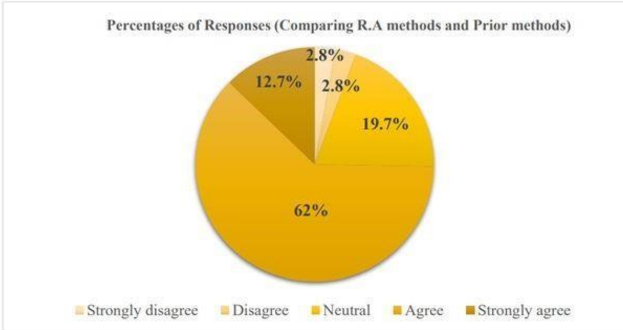

Figure 18: Percentages of responses; comparing robotics and automation methods and prior methods.

A convincing sum of 74.7% agreed that existent robotics and automation technologies introduced are better than prior conventional methods used in teaching and learning of architectural education. A sum of 5.6% of the respondents held a contrary view siding with prior methods being better than that of robotics and automation technologies (Figure 19).

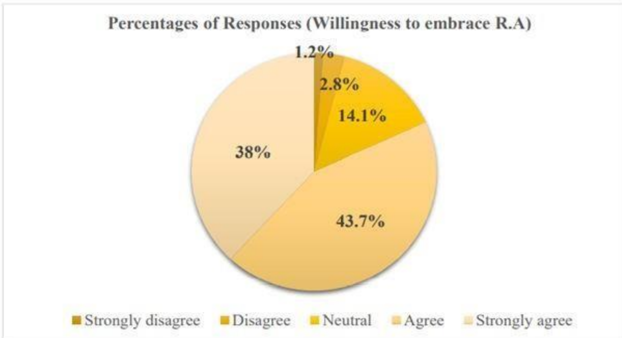

Figure 19: Percentages of responses; willingness to embrace robotics and automation.

Data collected shows an enthusiastic drive to welcome robotics and automation into architecture education as 38% agreed and 43.7% strongly agreed to readily partake in architecture inclined robotics and automation courses. Notable is the 1.2% and 2.8% of respondents that expressed reluctance in taking up courses in robotics and automation (Figure 20).

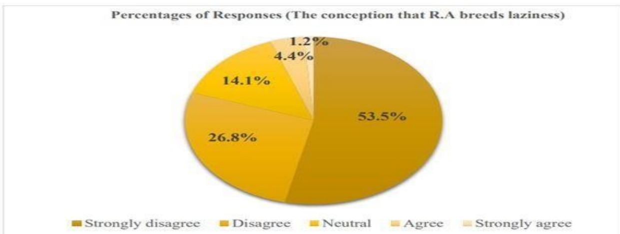

Figure 20: Percentages of responses; the conception that robotics and automation breeds laziness.

The results revealed many respondents expressed a contrary opinion to the statement in question. Out of the lot, 53.5% of respondents strongly disagreed and 26.8% disagreed that robotics and automation technologies will make students lazy. Though the majority disagreed, 14.1% maintained a neutral stance while a total of 5.6% agreed that robotics and automation tend to make students lazy.

Again, literature review revealed that the slow progress in merging robotics and automation and architecture stems from a conception that robotics and automation technologies if fused with architecture stands as a threat to the job securities of professionals in the field. The perspectives of respondents on the concept were captured by probing their stance on robotics and automation being the new future of the architecture industry (Figure 21).

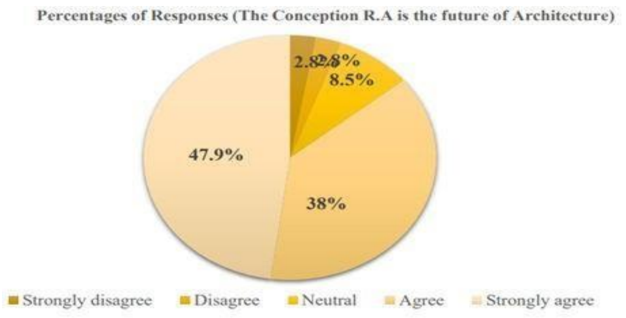

Figure 21: Percentages of responses; the conception robotics and automation is the future of architecture.

From Figure 21, the chart shows that 47.9% respondents strongly agreed and 38% agreed that robotics and automation is poised as the next phase of architectural development. Represented by a total percentage of 5.6 some respondents disagreed, while 8.5% expressed a neutral stance.

The survey probed if students will be more inclined to technology savvy architecture firms as they enter the world of architectural practice.

Data collected shows that the majority of students will readily join technology inclined firms as 36.6% strongly agreed and 39.4% agreed. 18.3% maintained a neutral position while a sum of 5.6% of respondents expressed unwillingness to join technology advanced firms after architecture school.

The survey enquired from respondents if more could be done to cement the bond between robotics and automation and architectural education (Figure 22).

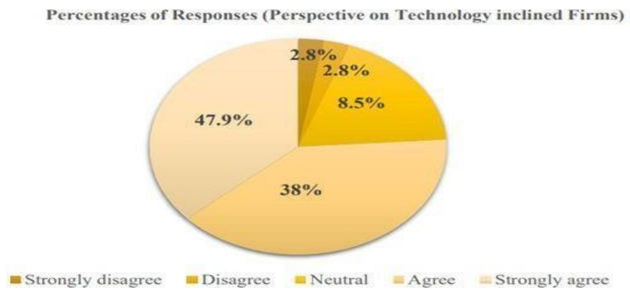

Figure 22: Percentages of responses; perspective on technology inclined firms.

Majority of respondents agreed with 39.4% strongly agreeing and 49.3% agreeing that more input could be made in merging robotics and automation and architecture education. 7% took a neutral stance and 4.3% respondents disagreed, implying current efforts made are sufficient (Figure 23).

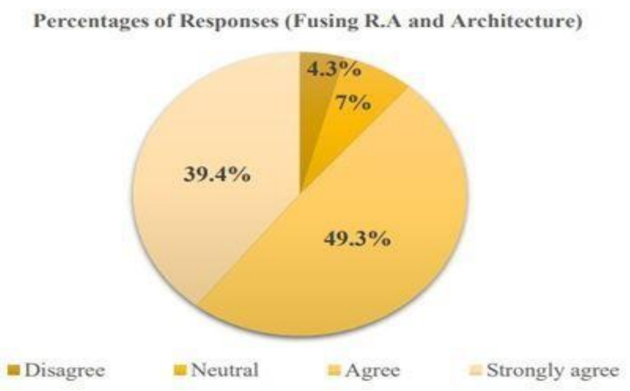

Figure 23: Percentages of responses; fusing robotics and automation and architecture.

Possible strategies to fuse robotics and automation and architecture pedagogy as suggested by respondents: Some respondents suggested various means by which they thought best robotics and automation can be merged with architecture. The suggested ideas are grouped into four main umbrellas; exposure to robotics and automation, introduction of robotics and automation related courses, sensitization of students and lectures to encourage the use of robotics and automation, interactions with professionals using robotics and automation (Table 3).

Suggestion	Peculiar points	Frequency	Positions
Introduction of R.A related courses	Establishing taught R.A courses spread over the course of the architecture program. Courses should be practical and not immensely theoretical.	16	1st

Interactions with professionals using R.A.	Workshops and trips to firms that incorporate R.A. practical workshop with R.A experts.	7	2nd
Exposure to R.A.	Experimenting with robotics to ascertain its productivity level. Introducing students to animation and virtual presentations.	3	3rd
Sensitization of students and lectures to encourage the use of R.A.	Encouraging students to R.A in studio sessions.	2	4th

Table 3: Suggestions of possible strategies.

The Table shows that the majority of respondents expressed interest in the introduction of courses that teach robotics and automation to the curriculum. The next most frequent suggestion was bridging the gap between robotics and automation inclined professionals and architecture students through workshops, seminars and field trips. A few respondents suggested the need for a conscious effort to permit students to experiment with available robotics and automation technologies. Finally, a couple of views captured the need for sensitization of students and lectures to encourage the use of robotics and automation.

Hankiewicz explains that, although robotics and automation have some differences, both disciplines usually move hand in hand. The article by Botchway, Abanyie and Afram evidently shows that over a period of fifteen years (2000-2015) CAAD, which is mainly a subset of automation, is the only element of technology relatively introduced into architecture pedagogy in the department of architecture KNUST.

As a student of the department of architecture, currently in the fifth year, after four years in undergraduate school between the years 2017 to 2021, followed by a year out of school and returning to the fifth year of architecture school, KNUST; my observation during my course in the department is, CAAD software remain the sole input of technology in architecture design education. The use of computer aided design software has diversified with students and tutors exploring various moderned and improved options as compared to the AutoCAD and Archicad of 2015. Unfortunately, the methods of effectively merging robotics and automation with architecture continue to be unclear. Findings from the survey, reveals that self-teaching by students remains as the most effective method. Students expressed that the department has made minimal input to advance the holistic intersection between robotics and automation and architecture pedagogy. Furthermore, it is evident that the application of automation is spearheaded more than robotics. This has encouraged the conception that, the need for physical robots in architecture is futuristic.

The 2015 challenge of unclear transitioning from conventional methods to technological methods continued to persist in 2021. Findings and observation revealed that, CAAD is not taught in first year but introduced in the second year. Students are trained to use conventional methods until the third year. However, in contrast to 2015, I observed that the third-year studio staff made a conscious effort to teach a wide range of CAD software in 2021.

The findings revealed that a majority of students expressed the willingness to use robotics and automation. Though there has been little exposure to robotics students expressed the need to venture into the fields of 3D printing, robotic arms and virtual reality tools.

Findings revealed the need to discuss ways to effectively establish robotics and automation in architecture pedagogy in the department.

Conclusion

The inclusion of robotic and automation technology in the profession of architecture in similarity to professions such as medicine is an inevitable future that is closer than we imagine. It cannot be said that absolutely no attempts to introduce robotics and automation in architectural pedagogy and practice in Ghana. However, the research shows that the efforts are very minimal and almost insignificant considering the entirety of robotics and automation.

Secondly, the merits robotics and automation presents to architecture immensely outweigh its disadvantages while providing key solutions to a number of challenges in the field of architecture. Some of these are contributing to sustainability in architectural education design and practice; with the heightened global advocacy for sustainability the introduction of robotics and automation technologies would help curb issues with waste and energy inefficient building designs.

It can be said that a majority of stakeholders in architecture in Ghana exhibit a positive attitude to welcoming robotics and automation in architecture. Majority of students of the department of architecture KNUST expressed the need to holistically include robotics and automation in the curricular as they regarded robotics and automation as the new future of architecture. In architectural practice, literature review revealed a gradual absorbance of robotics and automation in firms and construction sites over the years.

The most pressing challenges hindering the full realization of robotics and automation in architectural education and practice in Ghana are: An appreciable number of stakeholders know little about robotics, automation and architecture related robotics and automation developments. Misconceptions surrounding robotics and automation also breed reluctance in accepting robotics and automation. The cost of implementing, running and maintaining robotics and automation technologies in schools and firms is a deterrent to acquire robotics and automation.

Recommendations

Educating student architects and practicing architects in Ghana: The research revealed extremely limited knowledge is known about robotics and automation, therefore, a combined practical and theoretical course of robotics and automation, subsiding prohibitive cost of implementing and maintaining robotics and automation technologies in schools and practicing firms. High expenses of robotics and automation can be subsided by encouraging and patronizing local technology producers. Also, partnerships between firms to purchase robotics and automation technologies will reduce burden on an individual entity.

Creating an enabling environment an enabling environment is one that encourages students and lecturers involved with robotics and automation by exhibiting their works, thus, helping to reduce misconceptions.

References

1. Botchway EA, Abanyie SA, Afram SO (2015) The impact of computer aided architectural design tools on architectural design education. The case of KNUST. J Archit Eng Tech 4: 145.
2. Kilani MA, Kobziev V (2016) An overview of research methodology in Information System (IS). Open Access Libr J 3: 1-9.
3. Acquah R, Eyiah AK, Oteng D (2018) Acceptance of building information modelling: A survey of professionals in the construction industry in Ghana. J Inf Technol Constr 23: 75-91.
4. Godwin W (1876) Lives of the necromancers: Or, an account of the most eminent persons in successive ages who have claimed for themselves or to whom has been imputed by others, the exercise of magical power. Chatto Windus, Oxford university press, London, England.
5. Kapadia A, Walker I, Green KE, Manganelli J, Houayek H, et al. (2010) Architectural robotics: An interdisciplinary course rethinking the machines we live in. IEEE International Conference on Robotics and Automation 48-53.
6. Kheni N, Adamu M (2017) Assessment of Information and Communication Technology (ICT) use in construction education in Ghana. J Sci Res Rep 14: 1-11.
7. Krishnan A (2009) Killer robots: Legality and ethicality of autonomous weapons. 1st edition, Ashgate Publishing, Ltd. Farnham, United Kingdom.
8. Littlejohn R, Dippmann J (2012) Riding the wind with Liezi: New perspectives on the Daoist classic. State University of New York Press, New York, United States.
9. Maspero G (1985) Manual of Egyptian archaeology and guide to the study of antiquities in Egypt: For the use of students and travellers. H. Grevel and Company Publishing, Newyork, London.