Integration of Robotics in Science Education: a catalyst for enhanced performance among Nigerian Biology students.

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Abstract

This paper proposes the integration of robotics into science education. Students encountered today are being prepared for next decades. The scope of knowledge should be unlimited. Inculcation of robotic modeling to the study of biological concepts as part of student's activities should be of great concern to curriculum planners. It requires the exploration of biological concept, design, and construction of its robotic model. Involving students in this process helps to develop mental representation; better understanding which enhances learning outcomes. Already, ***,*** *some organizations have keyed into this technology. However, current effort gears towards students' preparation for international robotic tournaments. Other opportunities offered by this technology were unexplored. The paper highlighted the steps for developing robotic model, prototype models, and the benefits of inculcating robotic modeling into teaching and leaning.*

Keywords: Integrative teaching model; Robotics; Biological system; Modeling; LEGO mindstorm kit.

Introduction

The advancement in science and technology has brought rapid changes in the society and created serious influence in methods of teaching and learning. It has offered new ways to represent knowledge, new educational practices, and new global communities of learners. Yet the contribution of these changes to formal education is largely unexplored (Goodyear & Retails, 2010). The future of learning is such that will incorporate digital technologies in innovative and transformative ways. Lewis (2006), advocates for a new interdisciplinary pedagogies ''that are integrative in approach, showing fluidity between engineering and science''. In other words, the teaching and learning of sciences should be integrative; harnessing the learning opportunities across different disciplines through applied learning experiences (Wan, 2007 in Dan & Igor, 2013).

The integrative model, developed by teacher educators Don Kauchak and Paul Eggen (Shutterstock, 2013), builds on the important work of Hilda Taba who authored the "Taba curriculum development project". It is a purpose-driven instructional model that supports students as they work to develop the ability to learn independently using various thinking skills. It is designed to help them construct a deep and thorough understanding of organized bodies of knowledge while simultaneously developing critical thinking abilities (Eggen, and Kauchak, 2006 in Mitchell, 2011). To effectively apply the integrative learning theory four major steps are involved. First, the students describe, compare, and search for patterns in an instructional content that represents an organized body of knowledge. Secondly, they explain the identified similarities and differences by examining the content more closely. They form hypotheses based on their examination of the content. And finally, they make broad generalizations about the content which stand as a basis for consideration in a larger context. Technology educators recommend this type of learning theory as a way to consolidate knowledge of concepts from different disciplines through applied learning experiences (Wan, 2007 in Dan and Igor, 2013).

How to integrate computers into the constructivist practice and philosophy is already widespread in all aspects of educational endavour. Lewis (2006) supported this interdisciplinary pedagogical approach. Robotics modeling of biological concepts is another aspect of this new approach. Bers, et al (2002) asserted that this approach is capable of engaging students and teachers in the active design and development of meaningful artifacts. It will not only equip them with basic engineering skill (design and building of robot), but endow them with computational skill such as programming of robot and the effective use of computer assisted instructional packages. In the light of this, the integration of Robotics into the senior secondary school biology curriculum in Nigeria should be a welcome innovation.

Merriam-webstar dictionary defines robotics as a technology dealing with the design, construction, and operation of robots by automation. The term was coined by an American scientist and writer Isaac Asimov. A robot on other hand is a machine that resembles a living creature in being capable of moving independently (by walking or rolling on wheels) and performing complex actions (such as grasping and moving objects). As a machine, it is built to resemble a human being, animal, or other objects in appearance and/or behavior. It is a device that can perform complicated tasks automatically and repeatedly. It is usually guided by computer or electronic programming. A model is a replica of an object in three-dimensional form, created to answer a certain need (International Technology Education Association, 2000). There are many "ready-made-models" commonly used in Biology education. They include: model of human skeleton, brain, eye, ear, nose, teeth, nervous system, skin, to mention but a few. Most of these models, if not all, are designed and produced without involving the teachers and the students. Thus, the creative idea, the hands-on and engagement aspect of modeling is completely lost among these important stakeholders.

As indicated in some literature (Talaiver & Bowen, 2010; Williams, & Prejean, 2010), when robotics are used as educational tool, they help students develop the knowledge and skills required in order to survive in the ever-changing, interconnected information society era of the 21st century. In addition, it will inspire them to develop interest in science based courses, promote creativity, team spirit, collaborative learning, and enhance academic performance. Judging from the West African Examination Council (WAEC) result of May/June 2013/2014, the performance of the students was relatively low. The result showed that only 31.28% of the over 1.7million candidates had credits in five subjects including English and Mathematics compared to 36.57% in 2013 and 38.81% in 2012 (Idowu, 2014). This dwindling performance has almost become a recurring decimal. It is rather more worrisome when one recalls that the school is supposedly the "factory" where skilled manpower needed for the development of all the sectors of the economy is produced. Claims and counter claims have been advanced for the cause of this anomaly, ranging from curriculum issues, unstable educational policies, dearth of adequate infrastructures/instructional materials, poor funding, to lack of innovative teaching, lackadaisical attitude of teachers, learners, and parents. In his study on the availability and utilization of instructional materials for the implementation of the new biology curriculum in senior secondary schools in Lagos, Nigeria, Arum, (2015) found that almost complete absence of technology; over reliance on obsolete instructional materials, and poor method of teaching were major obstacles. Doing the same thing over and over can never give a different result. Therefore, the integration of digital technologies to the teaching and learning of biology, in the opinion of the researcher will go a long way in enhancing knowledge and promoting performance.

The purpose of this paper is therefore to propose the integration of Robotics into the biology education curriculum. The intention of the researcher is to advocate the inculcation of robotic modeling of some biological concepts as part of student's activities during a biology lesson.

Robotic modeling will require a student to explore a biological concept that involves a model for its effective study; the design, and construction of its model using appropriate robotic kits. Involving students in the whole process of designing, construction, and programming of the robotic model of any biological process helps them to develop a mental representation of the related biological concept and inspires them to build more sophisticated artifacts in a self-reinforcing circle (Lego education, 2010). Unlike the "ready-made-models" mainly used as visual aids (Lipson 2007), robotic model, is a dynamic physical object which facilitates learning through hands-on activities of its construction and operation.

In 2009 through seminars/workshops, and press conference, Dr. Ndubuisi Ekekwe, made an initial attempt towards creating awareness about robotics in Nigeria. A robotics engineer based in the United States, his moves suffered some set backs. By then, nobody in the country could readily operate or do anything in robotics engineering. He noted that if a graduate of robotics anywhere came back to Nigeria to practice he would not have a lot of career opportunities (Nkpuhe, 2010). Three years later, Obinna Okwodu founded *the Exposure Robotics Academy* in Nigeria in 2012. This was against the backdrop that Nigeria educators took students through cycles of cramming and regurgitation of information, without placing enough emphasis on how to apply what they learn to solve real life problems (Diasporan Wazobia, 2013). Since then, over 80 students from all over Nigeria were exposed to robotics education with amazing result. In November 2013, for example, students from Troika School, Lekki; Zamani College, Kaduna; Alofos Foundation, Surulere; and Ilado Community Junior High School, Ikoyi represented Nigeria at the World Robot Olympiad (WRO) held in Jakarta, Indonesia (Campus portal, 2013). As a build up to this international engagement, a pre-competition training workshop and selection of National representatives was organized for students. Participants from Anambra, Bayelsa, Cross-river, Delta, Ekiti, Lagos, Kano, Niger and Osun states assembled at the African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E), Obafemi Awolowo University (OAU), Ile Ife. The researcher presented participants in this national competition and was amazed at the type of skills in building and programming of the robots exhibited by all the participating students. He was more impressed by the fact that the skills were acquired after a short period of training, drill and practice.

If students' interest could be aroused with this technological innovation to the extent of acquiring relevant skills within a short period of time, it is therefore not out of place to advocate for its integration into the teaching and learning of biology. It was against this background that the purpose of this opinion paper was based. This is paramount because students need to master new skills in order to participate productively in the 21st century society and workplace. The 3Rs – reading, 'riting' and 'rithmetic'; deemed essentials in the 19th century industrial age where mass printing and machine-made paper and ink made books were available, are no longer enough. Like wise, the over-reliance on already-made models for biology instruction is long over due. Robotic modeling is rather dynamic and facilitates learning through hands-on activities of its construction and operation. Students of today need a fourth R: reading, 'riting', 'rithmetic' and 'rithms', as in algorithms, or basic computational skills (Davidson, 2011). Truschel (2011), emphasized that we must add the three Cs - computing, critical thinking and capacity for change. This is because the students we encounter in today's classrooms are being prepared to live a life in the next few decades. Therefore the scope of their knowledge and level of technological involvement should not be limited.

Robotics modeling of some biological concepts

Gilbert, Boulter, & Elmer, (2000), considered learning with models as a promising approach to bridge science and technology. To create a robotic model of a biological system requires serious biological inquiry and technological design. While inquiry involves making observations, posing questions, surfing the net, and other sources of information to see what is already known; design includes identifying the need, generating ideas, exploring possible solutions, building and testing prototypes, and refining the solution. Engaging students in robotic modeling helps them to create a mental representation of the concept under study. In this way, the teacher does not only capture the interest of the students, but sustains such interest as long as he/she desires.

Steps to be taken to develop a robotic model

In the words of Dan & Igor (2013), a number of steps are to be taken to design and develop a robotic model of any biological systems.

i. Acquiring technological knowledge

The first step is to acquaint the student with the technological content knowledge (TCK) essential for using the construction kit (Lego NXT mindstorm) to build simple robot. He is introduced to the components of a robot such as, sensors, control, simple mechanisms, motors, bricks, etc and how to assemble them to develop an artifact. When learning about the sensors, the broader aspect of sensing and sense organs in the animal kingdom is highlighted.

ii. Selecting a biological process

The student is guided to select a specific biological process within a topic that requires a model for its effective instruction. He takes into account the technological opportunities that can be provided by the construction kit.

iii. Inquiry into the biological system

The student (as an individual or a team member) conducts a self-regulated inquiry on the biological process. This is aimed at finding out the clear principles guiding the process as well as the biological process he wants his robotic model to imitate.

iv. Building the model

Haven acquired the technological and scientific background and getting insight into the natural phenomenon, the next step is to design and build the robotic model using the appropriate construction kit. This may involve a number of trials until the model prototype resembles that of the biological process he intends to imitate.

v. Assessing differences and similarities

The last step is to systematically compare and contrast the model with the biological process. A record of the technical and operational guidelines is kept for future references. With technical content knowledge already acquired, the student can move to step two to design and develop a robotic model for another biological or any other science process. The steps are summarized in figure 1.

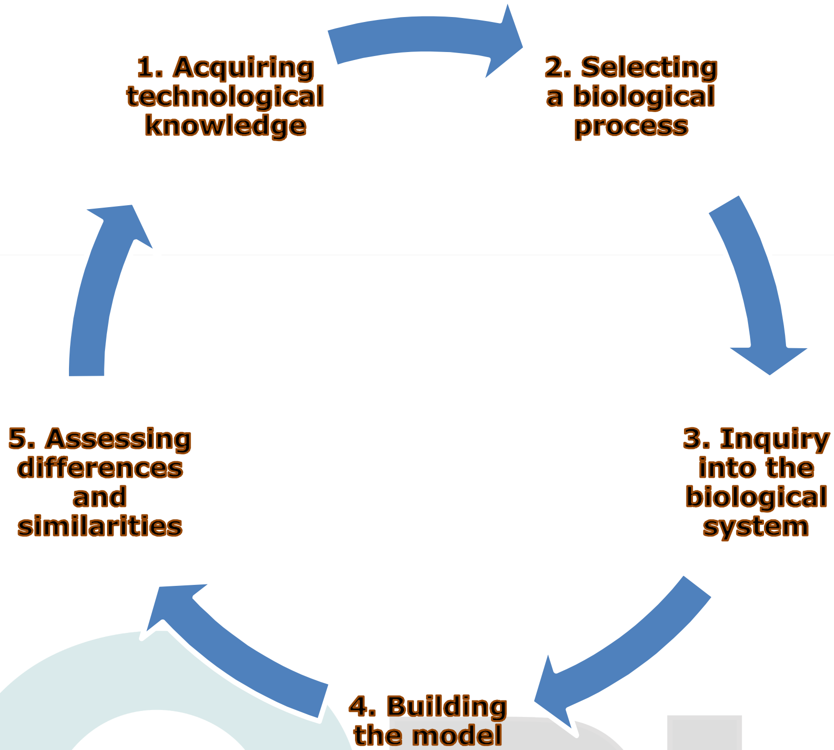


Figure 1: Steps for developing a robotic model

Prototype model of some biological concepts.

A. The Venus Fly Trap

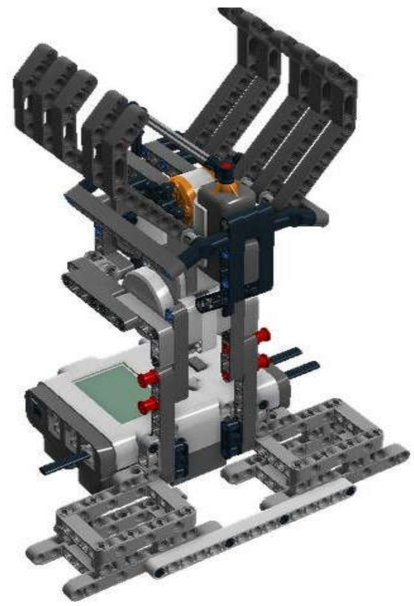
This is a carnivorous plant that has the ability to detect and trap insects and other small animals. They derive nitrogen from them, because the soil in which they grow is poor in this nutrient. To develop a robotic model for this mode of nutrition, two pre-service teachers were guided by some biological principles (Dan & Igor, 2013). They learned the following features of the flytrap mechanism:

- The trap consists of two lobes, which close together forming an enclosed pocket.
- The center of each lobe contains three mechano-sensitive trigger hairs.
- Two touches of a trigger hair by a prey are needed to activate the trap which snaps in a fraction of second.
- The closing process involves a change of the leaf's geometry. The upper leaf is convex in the open position and concave in its closed position.

Using the above principles as guide, the researcher fabricated a robotic model of the organism by:

a. Using two touch sensors for the trigger mechanism; to enhance open/close of the trap structure.
b. Using angular beams driven by a DC motor to represent the leaflets.
c. Using different bricks, axiles, and connectors he built a structure that represents the plant stem.

Figure 2a: Venus Fly trap crushing earthworm



2b: researcher-developed robotic model of Venus Fly trap

B. Pulse rate control: a heart functional model:

Three middle school students investigated the influence of external stimuli on the heartbeat rate (Dan & Igor, 2013). Searching through the internet, they identified certain features of the heartbeat mechanism. The volume of blood pumped by the heart is regulated through heart rate control. This control function is managed by the autonomic nervous system (sympathetic and parasympathetic nervous systems). Guyton & Hall (2006) added that the heart beat can increase due to strong sympathetic stimulation (stress state) or decrease due to strong parasympathetic stimulation (rest state). The above principles were used to depict the effect of visual stimulus (light intensity) on heartbeat (figure 3b).

- ❖ Light sensor was used for sensing the external environment.

- Lego angular beams covered with a transparent polythene bag with a heart-shape was used.
- The beams were driven by a DC motor.
- Both the beams and the sensor were connected to a programmable brick.

The rotatory movements of the angular beams caused the transparent polythene bag to contract and expand just like the typical human heart. At default, the model was programmed to rotate continuously but increase or decrease its speed with a change in the intensity of light exposed to the sensor. In this way, the robotic model of the heart mimicked the human heart in responding to external stimuli such as sudden loud sound like gun shot.

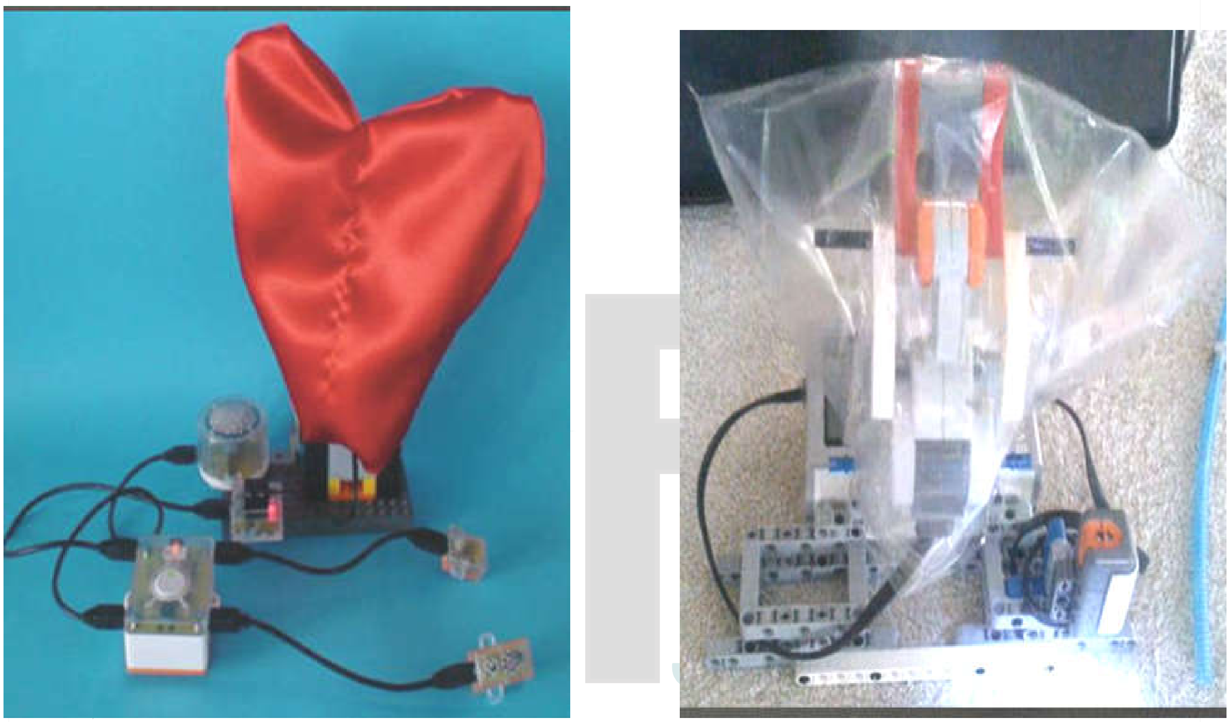


Figure 3a: heart beat model (Dan & Igor, 2013) **3b: researcher-developed robotic model of heart beat**

Benefits of integrating robotics into teaching and learning.

The inculcation of robotics to teaching and learning has been advocated in several fora, symposia, conferences, and workshops all over the world. This is as a result of the diverse opportunities it has created within the short time of its evolution. Vital among them include:

1. **Promoting critical thinking for problem solving:** inculcating robotics into the classroom has the potential to make computer programming a less abstract endeavor especially at this part of

the world. It is capable of engaging the youths who would otherwise not be interested in technology or engineering, and brings high-technology down to the practical, everyday level (Fears, 2012). It provides a computational environment to help students learn by doing, by active inquiry, and by playing with the (computational) materials around them to design and develop meaningful projects. Studying theoretical concepts along with constructing their tangible models help them to understand the subject matter more deeply. Regardless of the fields they end up in, they remain problem-solvers.

2. **Promoting team spirit:** students can work in teams throughout the robotic program. Every member of each team is assigned a specific role. The recorder reads out the procedure, the type, and number of robotic components from the robotic kit; the resource managers sort out and pick up the robotic components from the kit; the constructors assemble the components following an operational manual; while the time keeper ensures that the group works according to the stipulated time. This pattern of grouping encourages team work and collaboration needed by students to actively participate in today's society and work place. It also promotes specialization and efficiency.

3. **Motivating learners:** After exposing a girl who wanted to be a medical doctor, to two weeks LEGO robotics programming, she started wandering how possible it was for robots to play a role in the field of medicine. This is thinking outside the box, one of the major objectives of robotics in education. Students are dissatisfied with their surroundings and tend to question everything that goes on around them. It is only when this happens that we begin to see concrete change in our society. Working with the robotic kit is attractive and interesting. The desire to build a robotic model typically triggers students' curiosity to the biological phenomenon and drives the inquiry.

4. **Hands-On Learning & Engagement:** students love a chance to show their peers what they have learned and what they can do. The different steps involved in the building and setting a robot into motion expose the students to chances of finding something that suits their particular interests (Fears, 2012)

5. **Fosters the spirit of imagination:** students have read and seen robots in films but have never manipulated it for any meaningful task before. Exposing them to robotics, especially when they progress successfully in accomplishing their tasks, their curiosity is greatly energized. The best learning experiences happen when people are encouraged to explore their own thinking process.

Conclusion

The whole idea of this paper was to advocate the incorporation digital technologies in innovative and transformative ways. This is because the students we encounter in today's classrooms are digital natives. They are being prepared to live a life in the next few decades. Therefore the scope of knowledge and level of technological involvement should not be limited. A learning environment which will prompt and inspire practical design and active engagement of the students should be embraced. It is hoped that the educators and curriculum planners in Nigeria will key into this innovation as a way of bridging the gap between abstract and concrete exploration biological concepts.

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