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Developing 3D Automated Human Heart Model to Teach Abstract Concept of Biology

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Abstrak

Model adalah replika langsung, gambar atau salinan dari benda atau angka nyata yang dibuat sesuai dengan objek aslinya dan karenanya digunakan seperti objek aslinya. Ketidakmampuan untuk mengakses organ dalam mamalia merupakan salah satu tantangan dalam mengajarkan beberapa konsep dalam mata pelajaran Biologi. Oleh karena itu, perlu dikembangkan model jantung manusia otomatis 3 dimensi (3-DAMHH) untuk mengajarkan konsep Biologi. Dalam hal ini ini peneliti mengambil konteks di Ilorin, Nigeria. Penelitian ini merupakan penelitian pengembangan menggunakan model ADDIE. Temuan penelitian ini mengungkapkan bahwa: model jantung manusia otomasi 3 dimensi berhasil dikembangkan dengan permen karet silikon, pop, cat minyak, selang, perangkat pompa, transformator, dan dioda. Temuan lain juga mengungkapkan bahwa model otomatis 3 dimensi jantung manusia hemat biaya. Studi ini merekomendasikan agar para guru Biologi menggunakan 3-DAMHH untuk mengajar konsep abstrak dalam biologi dalam pembelajaran mereka.

Abstract

Models are direct replica, image or copy of real objects or figures. They are made in place of the original object and therefore used as such in place of the original. Inability to have access to mammalian internal organs is one of the challenges in teaching some concepts in Biology. Hence, the need to develop 3-dimensional automated model of human heart (3-DAMHH) to teach Biology concept in Ilorin, Nigeria. The study was a developmental research design model. ADDIE model was adopted. Findings of this study revealed that 3-dimensional (3D) automated model of human heart was successfully developed with silicon gum, pop, oil paint, hosepipe, pumping devices, transformer, and diode. Findings also revealed that 3-dimensional automated model of human heart was cost effective. This study recommends the biology teachers to use 3-DAMHH for teaching abstracts concepts in biology.

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INTRODUCTION

Biology has an essential role in controlling environmental contamination and attractive sense of art and magnificence. High yielding varieties of crop plants like rice, wheat, salt, sugar cane among others are currently reared experimentally. Ailment safe grain verbalized seeds are made (Biotechnology) and Fossils are significant in finding underground oil and natural gas resources. The significance of biology have make it a course or subject of impact in the life of individuals and the nation world in general; in this way prompts the learned to make it a mandatory course of study in every level of instruction primary, secondary, and tertiary institutions (Akinfe, Olofinniyi, & Fashiku, 2012).

Biology being a natural science can be studied both indoor and outdoor as most biological specimen is plants and animals which possess large amounts of nature. However, some laboratory facilities may not be found outside the laboratories such as reagents, henceforth the need to have a well-stocked laboratory with accessible and sufficient facilities. For science teachers to play their roles in teaching science, laboratory facilities ought to be available and utilized properly to improve the performance of students. Students' poor performance in Biology particularly at Senior School Certificate Examinations (SSCE) level has turned into a wellspring of worry to all stakeholders in education in the country (Musah & Umar, 2017).

Students come to the science classroom with many misconceptions which need to be corrected for proper scientific learning to progress. Schools must base instructional materials on fundamental scientific concepts and principles, which serve to support students' understanding with current knowledge and teach them to monitor and control their own thought processes to facilitate learning (Christine, 2014). Students are more likely to list the internal organs such as brain, lungs, liver, bladder, kidneys, stomach, intestines and the heart but may not fully understand the functions or the interconnected nature of these organs. For instance, students at this level may realise that the brain helps the body parts but not aware that the body helps the brain or may realise that the heart is a pump but not realise that the blood returns to the heart. Building students' understanding of internal body organs, how these are linked and why they work together as systems is a complex process. Hence, the need for the integration of automated instructional medial to concretise the abstract concept in Biology.

Instructional Materials in its most straightforward term are those materials that help the Teachers to teach easily and the students to learn without pressure. Instructional Materials incorporate projected, non-projected, printed and others, such as object, 3-dimentional objects that are created through nearby source materials, program instruction, instructional package and so on (Olumorin, Yusuf, Ajidagba, & Jekayinfa, 2010). Instructional materials are resources for transmitting information, ideas and notes that can help in facilitating learning. They help in making students comprehend, retain and recall concepts, principles or theories and acquire professional skills (Ogunlade & Amosa, 2015). The role of instructional materials if thoroughly considered cannot be completely detached from teaching and learning process. For any meaningful educational program to be accomplished in terms of its implementation, the part of instructional materials must be given genuine need (Bisiriyu, 2016).

Instructional materials perform such work as the expansion of the range of experience accessible to students, enhancement and complement the instructor's verbal explanations therefore making learning experience richer and giving the teacher enthusiasm into a wide collection of learning exercises. To help the attainment of objectives of teaching a subject matter, it acts on teacher to help his teaching with suitable instructional material that will empower him to accomplish his objectives, and this improves academic achievement of the students taught (Awolaju, 2016). Instructional materials are those materials that are purposely used to attain improvement in instruction. They are those materials and equipment utilized by the teacher during teaching to improve student's learning, capacity, and skills, in order to monitor their assimilation of information and to add to their general advancement and upbringing (Onasanya, 2016).

A key component of successful teaching is the choice of instructional materials that address the issues of students and fit the limitations of the teaching and learning condition. A common statement that is obviously true in teaching is that, if you have not learnt, I have not instructed. A sensible end at that point is that the significance of instructional materials in educating and learning science is most successfully outlined

through student accomplishment results (Christine, 2014). The teacher and student interactions in numerous science studies are not beneficial on account of adequate resources. Inquiry focused science teaching showing requests a ton of exercises with respect to the student that require scientific materials and equipment (Omorogbe & Ewansiha, 2013). Availability of textbooks, laboratory apparatus and other learning resources contribute significantly to the performance of students in science subjects.

The heart is a muscular organ about the size of a fist, located behind and a bit left of the breastbone. The heart pumps blood through the system arteries and veins called the cardiovascular system. The heart has four chambers: The right atrium receives blood from the veins and pumps it to the right ventricle; The right ventricle receives blood from the right atrium and pumps it to the lungs, where it is loaded with oxygen; The left atrium receives oxygenated blood from the lungs and pumps it to the left ventricle and The left ventricle (the strongest chamber) pumps oxygen-rich blood to the rest of the body. The left ventricle's vigorous contractions create blood pressure (Matthew, 2014). The human heart has four chambers: two upper chambers (the atria) and two lower ones (the ventricles), according to the National Institutes of Health. The right atrium and right ventricle together make up the right heart, and the left atrium and left ventricle make up the left heart. A wall of muscle called the septum separates the two sides of the heart (Lewis, 2016). One of the challenges in teaching some concept in biology is inability to have the in-depth study of internal organs in the body which is probably because these organs are not visible and accessible. Instructional model can bridge this gap if carefully designed, developed, and validated.

Models are direct imitation, image or duplicate of real, original, or natural objects or figures. They are made in place of the original figure or object for obvious reasons, and they are therefore used as such in place of the original objects or figures. Meaningful instruction takes place only with appropriate use of instructional materials especially in their real form. Models come in form of 3-dimentional forms; it includes instructional material that has length, breadth, and depth (Olumorin, 2016). A model is a representation of an actual object. It may be longer or smaller or of the same size as the original.

Development of 3-dimensional model can be done comfortably with the aid of instructional design model to guide the developer to effectively carry out the task to meet the needs of the learners. Instructional design models provide framework to facilitate gaining new knowledge, skills or attitudes. Instructional designers use these models to guide the creation of engaging learning activities based on the science of how people learn (Culatta & Richard, 2019). Models for developing and evaluating instructional materials include ADDIE model, Dick & Carey, Kemp ISD models, Smith and Ragan model, Gerlach-Ely model, Stufflebeam's Content Input Process and Product (CIPP) Evaluation model (decision-making); Tyler's Evaluation Model (goal-based); Scriven's Goal-Free Evaluation Model (goal-free); Kirkpatrick's Evaluation Model (system-analysis); Bates ACTIONS Model and ETIMI Model.

While there a lot of instructional design models, ADDIE model is still the most widely used model, which includes the generic phases found in most of the subsequent models. The ADDIE model is the generic process traditionally used by instructional designers and training developers. ADDIE model aims for a learner-centered rather than the traditional teacher-centered approach to instruction, so that effective learning can take place. This means that every component of the instruction is governed by the learning outcomes, which have been determined after a thorough analysis of the learners' needs. The five phases: Analysis, Design, Development, Implementation, and Evaluation. This sequence, however, does not impose a strict linear progression through the steps (Serhat, 2017). This represents a dynamic, flexible guideline for building effective training and performance support tools. The five stages of ADDIE model will be adopted in the production process of the replica of the human heart. Cost analysis is associated with the first stage of ADDIE, which includes the analysis of the materials and tools to compare with the expected gain to see if it worth it.

Cost analysis is an evaluation tool that is designed to assist in choosing among alternative courses of action when resources are limited. According to Merriam-Webster dictionary cost analysis is the act of breaking down a cost summary into its constituents and studying and reporting on each factor. Cost analysis methods in design and production of instructional materials help instructional designer to choose from the alternative such as sourcing for available local materials within the environment so as to reach

the desired outcomes while spending the least amount of money (NCC, 2010). With cost analyses, educators can systematically estimate cost items for production of instructional materials and compare with outcome to see if it worth it (Engida, 2012).

The status and political power of any nation rely on its level of scientific activities. National security, high standard of living, good health care and general prosperity of a nation including Nigeria can be achieved through proper appreciation of science and technology. The current development in science and technology has greatly affected the lives of every human being such that, to be ignorant of the basic knowledge of this development is to live an empty, meaningless, and probably unrealistic life. Science and technology are closely related but not synonymous. Science tries to elucidate the natural world while technology dwells on the human-made world. Technology is a method of skilful utilization of ideas for the benefit of humanity. It is widely used in this current society, most especially for the purpose of teaching and learning (Bingimlas, 2017).

In teaching and learning, educational technology incorporates all forms of technologies to address educational needs and problems with emphasis on the application of the most applicable and present-day devices. Educational technology is a subset of the field of education which is concerned with useful communication and instruction. It refers to different types of technology, which can be used to facilitate teaching and learning process (Daramola, 2016). Educational technology is described in terms of audiovisual aids, educational media, communications and in terms of instructional technology. It is all about the application of human and non-human resources to facilitate and augment teaching and learning for meaningful and productive learning to be achieved (EIT, 2015). Educational technology facilitates the individualized instruction since it is the means by which instruction is paced to the individual level of learners understanding (Daramola, 2016).

The concept of educational technology has its root from innovation which is viewed as equipment and combination of both hardware and information to influence a positive change in circumstance. Educational technology goes further than gathering of educational materials; however, it incorporates the utilization of media, instructional technology, communication theory and systematic approach to solve educational problems in the course of utilization of knowledge. Learning is progressively pleasurable and the result increasingly changeless when educational technology is utilized (Kareem & Olafare, 2017).

The infusion and integration of technology in the instruction procedure have introduced new avenues by which instructors can enrich and enhance teaching and learning exercises. Teachers respond to their use in the classroom setting in several ways. First, there are those teachers who fear using any form of technology apart from those with which they are very comfortable with. Secondly, others make use of some form of technology even if they do so infrequently for example overhead projector and videotapes during class presentations. Thirdly, some teachers maximize the use of different technologies sometimes to the point of overuse during classroom activities. The various manners by which educators react to the need to incorporate innovation in classroom activities may be predicated on their pre-service preparing and additional encouragement provided in the different educational environments (Duhaney & Devon, 2010).

Therefore, instructional resources guarantee maximum value and effectiveness in teaching and learning process. The instrument of instruction is communication which must be skillfully designed and developed if the objective of the instruction is to be accomplished. This requires the utilization of explicitly produced material used to make the process of instruction to be more pleasant and enjoyable. Materials which are utilized during the process of instruction to make instruction more meaningful and pleasurable are called instructional materials (Onasanya, 2016). Hence, if students' knowledge in Biology will be grounded there is a need to Develop 3-dimensional automated model of human heart (3-DAMHH) to teach Biology concept in Ilorin, Nigeria. Meaningful instruction takes place only with appropriate use of instructional materials especially in their real form. As a result of lack of enough number of certain real objects, non-availability in the immediate environment and in situation where such object or figure is not accessible or too large to be brought to the class for use as instructional material, model is used in place of such. Model helps to introduce to the class, objects that cannot be physically brought to the class.

Empirical evidence such as Samikwo (2017) and Awolaju (2016) reveals those factors

that could be responsible for poor performance in biology as lack of practical experience in the teaching and learning of biology that led to poor mastery of important scientific skills and concepts. Among other factors that could be responsible for this failure, is unavailability of instructional materials coupled with teachers' attitude towards the utilization during classroom teaching and learning situations, instructional materials which must have a significant role to play in teaching and learning processes. Nneamaka (2018) also concluded that Nigerian schools at all levels are lacking the essential materials for teaching, especially for science practical classes. This, no doubt, affects the learning process. Most secondary schools lack science materials, and those that claim to have been managing the old ones. Hence, the students only cram theoretical steps rather than carrying out the practical.

Therefore, this study developed an automated model of human heart to help students have direct access to what they have learnt or heard in the classroom, enhance the teaching of the topic Structure of Human Heart, and thereby develop the skills of observing, investigating, thinking and provide in-depth understanding of the concept of human heart among the students.

METHOD

This study adopted a design and development research (Richey, Klein & Nelson, 2004) which dealt with the design, development, validation and use of models. This study was a design and development research which deals with the design, and development of new product in Ilorin Nigeria. The data collection and development of the 3-dimensional automated model was designed and developed in university of Ilorin in 2019/2020 section to teach Biology concept in Nigeria secondary school. Three experts were purposively selected for the purpose of validation of the 3-dimensional automated model. The 3-dimensional automated model were validated and adjudge to be valid to teach Biology concept in Nigeria.The development involved the five stages of ADDIE. These are: Analysis, Design, Development, Implementation and Evaluation.

The 3-dimensional automated model was designed and developed by the researchers. Materials sourced from the environment were used to produce the model. Such materials include silicon gum, cement, pop, paint, hosepipe of different sizes, leather material, clay and pumping device. The production involved the five stages of ADDIE instructional system design model. These are: Analysis, Design, Development, Implementation and Evaluation.

The Development of 3-Dimensional Automated Model undergoes the following procedural step.

First, analysis. At this stage researcher decided the learning outcome for which the model of human heart is needed (the meaning of human heart; the structure of the heart; arteries and veins; process of transportation of blood in human). Information regarding the learners such as the learning environment, preferences, age, and existing knowledge and skills were identified in this phase. The instructional goals and overall objectives were also established. The model was analyzed so as to gain understanding, the tasks associated with each part of the model were outlined (Pumping, returning, contraction and relaxation of the heart) and those tasks that students need to learn through the model were selected and stated in behavioral term: students should be able to (explain the meaning of human heart; identify arteries and veins and describe the process of transportation of blood in human). This stage also allows the researcher to analyze the cost of the materials and tools needed for production. Analysis of the cost of production of the 3-dimensional automated model helps the researcher to reach the desired outcome with lesser amount of money. The available materials in the natural environment as well as scraps from commercial and domestic were sourced and used to produce the model.

Second, design. The design stage of the 3-dimensional automated model of human heart stated the learning objectives, instructional method and actions, storyboards, content, subject matter knowledge and lesson outlines. Blueprint for the construction of the model of human heart were drafted by the researcher. This stage developed the objectives to involve the entry and summative objectives for the teaching for which the model is required. Different source such as textbooks, Google and science laboratory were consulted by the researcher before the conclusion on the shape and form of the model of human heart. All the needed materials and tools, trial construction, production of miniature of the model were also established in this stage.

Third, development. The development stage of ADDIE model is where all the results of the designed stage were put into action. During this stage, the model of human heart was developed according to the real form and features of

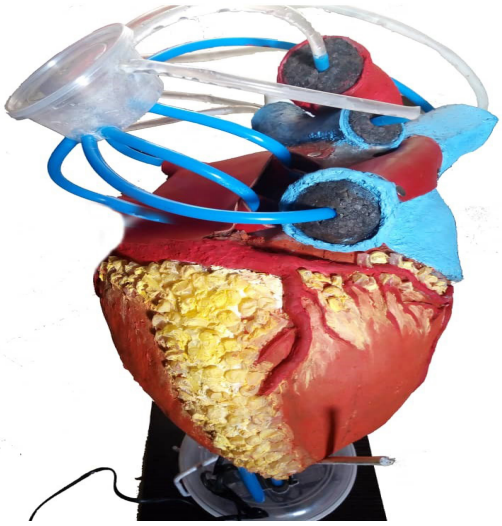
the original human heart after which the model was validated by experts to ensure it satisfy the set goals and objectives. Available materials which are easily accessible in the environment were used to produce the model. Such materials include silicon gum, cement, pop, and paint, hosepipe of different sizes, leather material, clay and pumping device. At this state, researcher transmits those actions in designing stage into concrete material by following a sequential order. Clay was used to mold the figure of human heart which requires reinforcement materials that includes iron rod and wire to make the model to stand solid on the based. Plaster of Paris (P.O.P) was used to pre-cast the mould while silicon gum was used to charge the mould so as to form the shape of human heart.

The automated aspect of the model involved two devices, pumping device to pump blood through the arteries and return blood to the heart through the veins. 12volt of aquarium pumping device were connected to transparent pipe from the bowl at the base of the model through the model to the upper part of the model to indicate blood circulation, similarly blue pipe of the same size were used to indicate veins so as to returned oxygenated blood back to the heart. 12volt DC motor device was constructed with iron to form the internal mechanism for the contraction and the relaxation of the heart. After which Winton oil colour (red, yellow, blue and orange) were applied on the surface of the model to aid actual resemblance of the real object.

Fourth, implementation. This is the delivery of lesson presentation in which the topic structure of human heart was taught with the aid of the developed automated model of human heart. Efficient and effective delivery of instruction using the automated model of human heart is among the purposes of this phase. After knowing that students have been taught the topic Structure of Human Heart, pre-test were administered to the students. With the help of biology teacher who acted as a research assistant, students were taught with the aids of the model. Students were permitted to move around the model and identify the arteries, veins while they also observed the model performing the task of contraction (systole) and relaxation (diastole). The exercise lasted for two weeks, two periods per week and 90 minutes per day.

Fifth, evaluation. During the evaluation stage, the researcher determined what success look like and how it was been measured. The evaluation consists of two phases: formative and summative. Formative takes place at every stage of the adopted instructional design model (ADDIE). Formative evaluation is a corrective stage whereby modifications, errors or corrections were made before the final production of the model. Summative evaluation is the determination of the usage of the developed model of human heart by Educational Technology experts rating score of (SA = 46.7%, A = 53.3%) and Biology education experts rating score of (SA = 78.6%, A = 21.4%). The summative assessments test contained the performance test adapted from WAEC past questions on the topic Structure of Human Heart that was administered.

Figure 1 3-Dimensional Automated Model of Human Heart



The heart has four chambers: two upper chambers (the atriums) and the two lower chambers (the ventricles). The right atrium and right ventricle together make up the right heart, and the left atrium and left ventricle make up the left heart. It is two pumps in one. The right side of the heart receives blood from the body and pumps it through the pulmonary circulation, which carries blood to the lungs and returns it to the left side of the heart. In the lungs carbon dioxide is exchanged for oxygen. Carbon dioxide diffuses from the blood into the lungs, and oxygen diffuses from the lungs into the blood. The left side of the heart pumps bloods through the systematic circulations which carries blood to all remaining tissues of the body and return it to the right side of the heart.

A wall of muscle called the septum separates the two sides of the heart. Arteries carries blood away from the heart is thick, muscular, and elastic. Walls of the right ventricles are thinner than the left ventricle due to short distance

between the lungs and the heart. The contraction of the left ventricle must send the blood round the shorter pulmonary circulation. Thus, blood entering the aorta is at a very high pressure (about 105 mmHg), while that entering the pulmonary artery is at a much lower pressure (about 16 mmHg). The different between the auricle and ventricle is that the walls of the ventricles are more muscular than the auricles. Pulmonary veins return oxygenated blood from the lungs to left auricle of the heart.

RESULT AND DISCUSSION

These sections deal with the process and the procedure for the development and validation of the design 3-dimensional automated model of human heart. Thus, cost effect of the 3-dimensional automated model of human heart was analysed.

A. Research Question 1: What Procedures Are Involved in The Development of the 3-Dimensional Automated Model of Human Heart?

The development of the 3-dimensional automated model of human heart to teach a biology concept in Ilorin, Nigeria was carried out using the stages of ADDIE instructional system design model which are: Analysis, Design, Development, Implementation and Evaluation. The procedure for the development of 3-DAMHH is a process that evolved from the simple and familiar to the more complex. The steps followed as stated in instructional system design model of ADDIE which identified some stages involved in the development of the model. The stages involved by adapting ADDIE Model are as follows.

Analysis phase is the foundation of all other phases of instructional system design. This phase requires the instructional designer to identify the source of the problem, define it and determine possible solution for better instruction. At this stage, David (2015) suggested that instructional designers needs to identify the learning environment, the instructional objectives and the students' needs, existing knowledge and any other relevant characteristics. In this study, the researcher gathered all the necessary information regarding SSS2 Biology students' characteristics, including their entry behavior/previous knowledge, available facilities in Biology laboratory so as to gain insight to those difficult concept in learning Biology prior to the design process.

Design phase came after analysis, where researcher created an overall blueprint of how the instructional delivery was carried out. This phase deals with the outputs obtained from the analysis stage and planned a strategy for developing the 3-dimensional automated model of human heart. Cheung (2016) viewed this phase to involve selecting the optimal strategy of teaching and creating useful action-oriented learning objectives to guide the learning process. One need to outline how to achieve the instructional objectives determined during the analysis phase and expands the instructional foundation. The researcher in this stage planned what would be taught and what the students would be able to carry out at the end of the instruction. Therefore, described all the content areas that will be covered in form of script writing, storyboard, text, and sketches in preparation of the development of the 3-dimensional automated model of human heart. Thus, the outputs of this phase were the inputs for the development phase.

Development is a stage in production of automated model of human heart in which both analysis and design processes interact. The development phase is built on both analysis and design phases (David, 2015). It is the actual production of the instructional content and automated model of human heart based on the design phase. This is, after selecting the methods of instructional delivery and creating the learning objectives in the design phase, the development phase deals with creating and organizing the actual learning material that will be used during lesson presentation (Cheung, 2016). Therefore, the researcher produces the 3-dimensional automated model of human heart to be used in teaching the topic Structure of Human Heart. At this stage, researcher held the overview created in the design phase and thought thorough full on how to practically deliver each feature of the instruction step by step when it comes to actual implementation of the topic Structure of Human Heart.

Implementation came after a thoughtful analysis, design, and development, and then comes to execution of the topic Structure of Human Heart. This is the actual delivery of lesson presentation in which the topic structure of human heart would be taught with the aid of the developed automated model of human heart. Efficient and effective delivery of instruction using the automated model of human heart is among the purposes of this phase. After the delivery, the effectiveness of the developed model of human

Table 1 cost of items used for the production of the automated model of human heart

Unit	Items	Price (#)	Total
10	Silicon Gum	1,100	11,000
1	Silicon Gun	800	800
½	Bag of P.O.P	1,800	1,800
4	Oil Paints	1,200	4,800
2	Hosepipe (White and Blue)	1,900	3,800
1	Leather Material	1,000	1,000
2	12vt Pumping Devices	5,000	10,000
1	12vt DC Gear Motor	7,000	7,000
1	12vt Transformer	1,200	1,200
1	Diode	200	200
2	Bowl	500	1000
4	Supper Glue	50	200
	Iron Stand with base	2,000	2,000
	Painting Brush	800	800
	Clay	600	600
	Zip	200	200
	Transportation	1,400	1,400
	Flex Banner	2,500	2,500
	Total		#50,200

heart will be evaluated (Cheung, 2016). The efficiency and effectiveness of the program is measured at Evaluation, which happens throughout the instructional process whether within phases, between phases or after implementation of the instruction. Evaluation of the developed model would be in form of formative and summative. It assesses the overall effectiveness of the instruction; data from summative evaluation is often used to make a decision about the instruction, such as whether to adopt the developed model or not.

B. Research Question 2: What is The Cost of the Developed 3-Dimensional Automated Model of Human Heart?

Table 1 shows the list, unit, price, and overall total of the items used for the production of the 3-dimensional automated model of human heart. The overall total was #50,200. Also, the table indicated that analysis of the cost of production of the 3-dimensional automated model shows that researcher can reach the desired outcomes while spending lesser amount of money. The available materials in the natural environment as well as scraps from commercial and domestic were freely and easily available for use in the production. Hence, this indicated that the benefits of the developed 3-dimensional automated model of human heart cannot be compared with the cost of producing it.

C. Discussion

This study developed 3-dimensional automated model of human heart to teach a concept of Biology in Ilorin, Nigeria. 3-dimensional automated model of human heart is a direct replica image or copy of human heart that includes mechanism to replicate the pumping and beating system of human heart. It is made in place of the original figure of human heart to be used for the purpose of instruction in the classroom. One of the important attributes of 3-dimensional model is making learning real, permanent, and most immediate. The results of the findings had indicated that students understand better when relevant and appropriate instructional materials are used for teaching.

ADDIE model was used as a guide from the pre-production, production and post production activities of the study purposely because it has correlation with the designing, development and evaluation of the model of human heart though the adoption of ADDIE model, the generic model of instructional system design which has stood the test of time. This view aligned with Pappas (2018), Hillen and Landis (2014) who concluded that ADDIE model is a set of interrelated and interacting parts that works towards a common objective. For lesson presentation, lesson note was developed in line with SS2 Biology syllabus and was also exposed to experts' validations to ensure it covered the required concept.

Analysis of the cost of production of the 3-dimensional automated model shows that researcher can reach the desired outcomes while spending lesser amount of money. The available materials in the natural environment as well as scraps from commercial and domestic were freely and easily available for use in the production. This conclusion is supported by Engida (2012) who made it clear that cost analysis allows instructional designer to go for best alternative materials. In the same vein, Sivakumar (2015) investigation revealed that low cost teaching aid prepared with simple materials cost very little by involving teacher and students. The results also agreed with earlier findings by Olumorin, et. al. (2010) who reported that inexpensive instructional materials could be prepared from local

resources to make learning effective, comprehensive and fascinating. This study contribute to the teaching of Biology in Nigeria secondary school by assisting teachers of Biology at all levels to simplify the abstract and complex concept in Biology. Hence, students' interest in biological concepts are aroused and they are stimulated to learn through the media.

CONCLUSION

This study concluded that the developed 3-DAMHH is cost effective, the benefit cannot be compared to cost of producing the 3-DAMHH. It was recommended among others that Biology teachers should employ the use of 3-diminsional automated model for teaching other abstracts and complex concepts in biology. Biology teachers should also employ the use of 3-diminsional automated model for teaching other abstracts and complex concepts in biology. Management of secondary schools should make provisions and encourage productions of instructional materials to be used in teaching and learning process. School management should organise training for their teachers on designing and production of instructional materials, this can be through conferences, seminars, and workshops attendance within and outside their educational district. Secondary school teachers should make use of those available materials in their environment to produce instructional materials.

Future research could also involve more teachers, not only from Banda Aceh, but widening the population to all districts in Aceh province. This attempt will give a more general and varied result when the population is bigger and hence the study is able to represent all XYZ Principals and teachers in Aceh. Besides that, involving Principals as other respondents of research will give a deeper understanding about Principals' role in managing curriculum and instructions. Two perspectives both from teachers and principals could open up the possibilities to employ qualitative and quantitative research design at the same time. By having survey for teachers and interview for principals, it is hope that more complex understandings would be obtained in future research.

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