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Design and Development of Human Excretory System Model to Teach A Biology Concept in Ilorin, Nigeria

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ABSTRACTS

Meaningful instruction takes place only with the appropriate use of instructional materials, especially in their real form. Inability to have access to mammalian internal organs is one of the challenges in teaching some concepts in Biology. Lack of practical experience in the teaching and learning of Biology that leads to poor mastery of important scientific skills and concepts could be among those factors responsible for students' poor performance in Biology. Hence, the need to design and develop the Model of Human Excretory System (MHES) to teach Biology concepts in secondary schools. The study was a developmental research design, ADDIE instructional system design model was adopted in the production and evaluation of the model. The development involved four out of the five stages of the ADDIE model. The adapted phases include ADDE; these are Analysis, Design, Development, and Evaluation. Findings of this study revealed that: The model of the human excretory system was successfully developed using four (ADDE) out of the five stages of the ADDIE model as a guide and the cost of developing the model of the human excretory system was determined and found to be cheaper through the use of locally sourced materials.

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1. INTRODUCTION

Science is a great enterprise that nations depend on that to advance technology. Science, therefore, is receiving much emphasis in education because of its significance and relevance to life and society. Biology as a branch of science and the prerequisite subject for many fields of learning contributes immensely to the technological growth of the nation. This includes medicine, forestry, agriculture, biotechnology, and nursing. The study of Biology in senior secondary school can equip students with useful concepts, principles, and theories that will enable them to face the challenges before and after graduation (Akinwumi & Falemu, 2020). Biology is one of the significant scientific subjects taught in secondary schools. It is structured in the educational plan to instruct individuals regardless of their future aspirations.

Biology is one of the required subjects for many fields of learning such as botany, anatomy and physiology, microbiology, medicine, agriculture, pharmacy, biotechnology, and others. Science and biology education contributes immensely to the technological intensification and development of any nation if they carry out simultaneously with the assistance of satisfactory instructional resources and facilities (Ahmad *et al*., 2018). Biology Education is the study that combines knowledge of biology with pedagogy to equip the learners with relevant skills in the production of manpower for teaching biology. The main target of the program is to produce competent biology teachers. Biology education is a typical education that aims at training and marketability essential skills for the well-being of man. The knowledge of plants and animals, their use, and their management represent one of the few opportunities for the nation's state of well-being, development, and of course, productivity.

Adegboye *et al*. (2017) defined biology as a unique branch of science that seeks an in-depth understanding of natural phenomena and events. Biology is the science that manages the investigation of varieties of living organisms including ourselves (plants and animals). It likewise examines how our environment advanced from the triple organism and this is personally part of our environment. Medicinal progression demonstrates the significance of biology in our day-by-day lives. The investigation of feared infections, their causative agents, fix just as the activity of medications are a method for Biological enlightenment that strives at limiting human suffering, its attempts to discover the solution for inherited variations from the norm like hemophilia, Down's syndrome, and so on.

The existence of misconceptions about the nature of biology in the cognitive structures of the biology teachers could significantly contribute to the lack of meaningful understanding of biology concepts among biology students (Adegboye *et al*., 2017). Students are more likely to list the internal organs but may not fully understand the functions or the interconnected nature of these organs. The excretory system consists of organs that remove metabolic wastes and toxins from the body. In humans, this includes the removal of urea from the bloodstream and other wastes produced by the body. The removal of urea happens in the kidneys, while solid wastes are expelled from the large intestine. The excretory system in humans consists mainly of the kidneys and bladder. The kidneys filter urea and other waste products from the blood, which are then added to the urine within the bladder. Other organs, such as the liver, process toxins but put their wastes back into the blood. It is up to the kidneys to filter the blood so that toxic substances do not accumulate.

Biology is a unique science discipline with peculiar philosophical principles and methodology that do not apply to other science disciplines. Understanding the unique structure of knowledge, principles, and methodology for providing explanations in biology is sine-qua-non for effective and efficient teaching of biology by teachers, and meaningful learning by the students (Adegboye *et al*., 2017). Instructional resources guarantee maximum

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value and effectiveness in the 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.

Materials that are utilized during the process of instruction to make instruction more meaningful and pleasurable are called instructional materials. The role of instructional materials if thoroughly considered cannot be either partially or isolated from the teaching and learning process. For any meaningful educational program to be achieved in terms of its implementation, the aspect of instructional materials must be given serious priority. Instructional materials perform such functions as the extension of the range of experience available to learners, supplementing and complementing the teacher's verbal explanations thereby making the learning experience richer and providing the teacher with interest in a wide variety of learning activities. To boost the attainment of objectives of teaching a subject matter, it behaves on Biology teacher to assist his teaching with appropriate instructional material that will enable him/her to achieve his/her objectives and this improves the 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. The key feature of effective teaching is the selection of instructional materials that meet the needs of students and fit the constraints of the teaching and learning. A truism often heard in teaching is that if you have not learned, but a teacher has not taught. A reasonable conclusion then is that the importance of instructional materials in teaching and learning integrated science is most effectively illustrated through student achievement results. Generally, the position of biology in the education of secondary school students is to allow the students to manipulate and experiment with suitable equipment and materials. This will prepare them for acquiring adequate laboratory and field skills in biology. For an instructional designer to successfully design effective instructional material to be used in the teaching and learning process, an instructional system design model need to be adopted as a guide to be able to achieve the stated objectives.

Instructional design theory is a design-oriented process to attain the goals of learning. It attempts to identify ways, methods, or means that will support and facilitate learning and monitor the learning environment or situation. Instructional system design will enable the teacher to select, plan, develop and implement instructional activities that can lead the learners to learn in the most conducive environment. Instructional design models help instructional designers to make a good judgment of abstract learning theory and enable the real-world application. It provides structure and meaning to an instructional design problem. Many of them have common instructional design principles and patterns. While there are a lot of instructional design models, the 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 strictly linear progression through the steps (see

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https://educationaltechnology.net/the-addie-model-instructional-design/). For this study, four out of the five stages of the ADDIE instructional system design model were adopted for the effective production of the human excretory system. The stages include ADDE, Analysis, Design, Development, and Evaluation. To ascertain the accuracy and usability of the instructional model, it must be verified by a professional or expert in the area of the subject content. Before an instructional model can be used to teach a concept of Biology, it has to be inspected and verified by a qualified biology education expert to ascertain its accuracy while the usability has to be verified by an educational technology expert (Olumorin *et al*., 2021). 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 is worth it.

Cost analysis is a systematic approach to estimating the strengths and weaknesses of alternatives used to determine options that provide the best approach to achieving benefits while preserving savings. Educators can systematically estimate cost items for the production of instructional materials and compare them with the outcome to see if it is worth it. Cost analysis methods in the design and production of instructional materials help instructional designers choose from alternatives such as sourcing available local materials within the environment to reach the desired outcomes while spending the least amount of money.

Biology is a fundamental subject in sciences offered in senior secondary schools, it is an integral science subject that centers on the understanding of living things. It is a primary requirement that needs to be passed by students who want to study Biology related courses such as science, medicine, anatomy, agricultural science, microbiology, medicine, nursing, pharmacy, forestry, and fisheries in higher institutions of learning (Hassan, 2019). Lack of practical experience in the teaching and learning of Biology that leads to poor mastery of important scientific skills and concepts could be among those factors responsible for poor performance in Biology. The failure rate in Biology at senior certificate examinations could be attributed to many factors; one of such factors is the lack or total absence of instructional materials. In teaching and learning, instructional materials play a key role in concretizing learning.

Instructional materials make learning meaningful and help to improve students' academic achievement. However, these advantages of instructional materials have not been reflected in the education system because of the dearth of these instructional materials in our schools. Hence, the need for alternative instructional materials called improvisation. Biology is resource-intensive, and in an era of poor funding or scarcity of resources, it may be very difficult to find some of the original materials and equipment for the teaching of Biology in schools adequately and most importantly, their inability to have access to mammalian internal organs is one of the challenges in teaching some concepts in Biology. Improvisation becomes the next option. A 3-dimensional model is a step forward in this direction, it enables students to have direct access to what they have learned (Olumorin *et al*., 2021).

Therefore, this study develops the model of the human excretory system to help students have direct access to what they have learned or heard in the classroom, enhance the teaching of the topic human excretory system and thereby develop the skills of observing, investigating, and thinking and provide an in-depth understanding of the concept of human excretory system among the senior secondary school Biology students.

Based on our previous studies (Olumorin *et al*., 2021) the following research questions were raised to guide the conduct of this study. (i) What are the steps involved in the development of the human excretory system? (ii) What is the cost of developing the model of the human excretory system?

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2. METHODS

This study adopted a design and development research that dealt with the design, development, validation, and use of models. Research and development were used in this study because we developed and validated a model of the human excretory system to teach a Biology Concept in Nigeria. Three educational technology experts and three Biology education experts were purposively selected for validation of the model of the human excretory system. The model was validated and adjudged to be valid to teach the Biology concept in Nigeria. The development involved four out of the five stages of the ADDIE instructional system design model. The adapted phases include ADDE; these are Analysis, Design, Development, and Evaluation.

The 3-dimensional model of human excretory which will be used as instructional material to teach the topic "Human Excretory System" in Senior Secondary School two Biology classes were designed and developed using an adapted ADDIE instructional system design model as a guide. Materials sourced from the environment were used to produce the model. Such materials include Plaster of Paris (POP), Resin, Accelerator, Catalyst, Fiber (Mat), Top Bond, Car Paint, Acrylic Paint (Red and Blue), Sandpaper, Painting Brush, and Paraffin Wax. Research question one gave detailed information on the processes of designing and developing the Human Excretory System. Table showing the cost of the items used for the production of the model of the Human Excretory System was used to provide an answer to research question two.

3. RESULTS AND DISCUSSION

3.1. Procedure for the Development of the Model of Human Excretory System

These sections deal with the process and the procedure for the development and validation of the model of the human excretory system. Thus, the cost-effectiveness of the model of the human excretory system was analyzed.

3.2. Research Question One: What are the steps involved in the development of the model of the human excretory system?

The development of the model of a human excretory system to teach a Biology concept in Ilorin, Nigeria was carried out using four out of the five stages of the ADDIE instructional system design model as a guide, the adapted phases include Analysis, Design, Development, and Evaluation (ADDE). The procedure for the development of MHES is a process that evolved from the simple and familiar to the more complex. The steps followed as stated in the instructional system design model of ADDIE identified some stages involved in the development of the model.

(i) **Analysis**. This phase includes the analysis of the learners' needs, attitudes, culture, and interests, and deciding on instructional goals to be achieved such as the ability of the students to have an in-depth understanding of the human excretory system. In this study, we gathered all the necessary information regarding Senior Secondary School Two Biology students' characteristics, including their previous knowledge, and available facilities in the Biology laboratory to gain insight into the difficult concept of learning Biology. We started with an idea, a problem situation (poor academic performance in biology), and a need identified within an instructional design plan for a unit of the subject. The idea was translated into specific objectives for the planned teaching.

(ii) **Design.** The instructional designer writes learning objectives and determines the instructional strategies that were utilized to achieve the objectives of this research.

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Decisions are made about how the model of the human excretory system looks like, feels and be delivered to the learner. Storyboards and learning prototypes of the human excretory system are created. Therefore, described all the content areas covered in form of scriptwriting, storyboard, text, and sketches in preparation for the development of the model of the human excretory system. Thus, the outputs of this phase were the inputs for the development phase.

(iii) **Development.** We developed the model of a human excretory system according to the real form and features of the real human excretory system. Available materials which are easily accessible in the environment were used to produce the model. Those materials include Plaster of Paris (POP), Resin, Accelerator, Catalyst, Fiber (Mat), Top Bond, Car Paint, Acrylic Paint (Red and Blue), Sandpaper, Painting Brush, Paraffin Wax (Separator), Flex Banner, Spatula and Welding of the Stand. At this stage, we transmit those actions in the designing stage into concrete material by following a sequential order. A kit containing the resin, hardener (catalyst), fiber (cloth) for structural strength, and other tools were bought and assembled respectively. An armature was made as a framework around which the model of the human excretory system was built. The armature was made from heavy, dark aluminum wire which was twisted into the shape of the human excretory system. The pre-cast human excretory system was molded with clay. The artist begins fleshing out the sculpture by adding clay over the armature. Hence, clay is any of a group of malleable substances used in building and sculpting. Plaster of Paris (pop) was used in the casting of the mold. Paraffin wax was applied to the clay work with the aid of a painting brush to make the pop mold remove easily without stress. The mold was made from the molded clay model. The mold was divided into two pieces with aluminum slate and a shim with keys placed between the parts during construction so that the mold can be put back together accurately. Paraffin wax was applied with a brush on the mold for easy remover of the fiberglass. Hence, the resin will glue the work to the mold. The fiber mat was cut to suitable sizes to cover the form in preparation for fiber casting. An appropriate amount of resin was measured in a metallic container and a catalyst was added according to package instructions. After which fiber mat and resin mixture were spread on the mold coated with paraffin wax. **Figures 1** and **Figure 2** show the images of the process involved in the casting of the model of the human excretory system. Additional coats of resin were applied with the aid of a painting brush to build up the layer of fiberglass to a thickness of up to ½ inch (0.56 cm), the material was applied over the mat completely until it is covered uniformly. The application of mat and resin was repeated until the finished project is as thick as the desired shape. The fiberglass production was removed and joined together with a mixture of resin and pop to form the complete shape of the human excretory system in three-dimensional forms. To refinish the production, the surface was rough up using sandpaper. Then clean thoroughly and dry completely. The finished work was coated with car paint and fixed on a metallic stand. After which Acrylic paint (red, blue, and brown) was applied to the surface of the model to aid the actual resemblance of the real figure. **Figures 3, 4,** and **Figure 5** show the model after being coated with the car and acrylic paint.

(iv) **Evaluate.** We used various methods to determine whether the objective has been met. Evaluation happens throughout the instructional process whether within phases, between phases, or after implementation of the instruction material. Evaluation of the developed model was in form of formative and summative. The formative evaluation was done in between the phases of the adapted instructional system design model, from analysis to design and development respectively. The overall effectiveness of the instructional model was assessed in this stage. Data from the summative evaluation is

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often used to make a decision, such as whether to adopt the developed model or not. Thus, the data from both educational technology and biology education experts were used to determine the usability of the human excretory system.

Figure 1. Casted Mold (Right and Left Side).

Figure 2. Casting Stage (Mold Casting with P.O.P).

Figure 3. Coated with Car Paint.

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Figure 4. Painting with Acrylic paint (red, blue, and brown).

Figure 5. Finishing Stage.

3.3. Research Question Two: What is the cost of developing the model of the human excretory system?

Table 2 shows the list of materials, tools, price, and overall total of the items used for the production of the model of the human excretory system. The overall total was #28,900. Table 1 also revealed that analysis of the cost of production of the human excretory system model shows that researchers can reach the desired outcomes while spending a 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.

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Table 2. Cost of developing the model of human excretory system.

S/No	Materials and Tools	Price (#)
1.	Plaster of Paris (POP)	3000
2.	Resin	2500
3.	Accelerator	2800
4.	Catalyst	3000
5.	Fiber (Mat)	3200
6.	Top Bond	1000
7.	Car Paint	2000
8.	Acrylic Paint (Red and Blue)	2200
9.	Sandpaper	500
10.	Painting Brush	400
11.	Paraffin Wax (Separator)	900
12.	Flex Banner	1000
13.	Spatula	400
14.	Welding of the Stand	2000
15.	Artisan	4000
	Total	**28900**

3.4. Discussion

The development of a model of the human excretory system to teach biology concepts in secondary schools was successfully developed using four: Analysis, Design, Development, and Evaluation (ADDE) out of the five stages of the ADDIE instructional system design model. The Adapted ADDIE model was used as a guide for the pre-production, production, and post-production activities of the study purposely because it correlates with the designing, development, and evaluation of the model of the human excretory system, ADDIE instructional system design is a generic model of instructional system design which has stood the test of time. The finding of this study revealed the relevance of the instructional system design model as a guide in the production of instructional materials.

The cost of developing the model of the human excretory system was determined and found to be cheaper through the use of locally sourced materials. The production cost is 28,900. This finding is supported by NCC who reported that Cost analysis methods in the design and production of instructional materials help the instructional designer to choose from the alternative such as sourcing available local materials within the environment to reach the desired outcomes while spending the least amount of money.

4. CONCLUSION

This study concluded that if the instructional model could be developed for teaching and learning Biology, effective teaching and learning are assured and students' performance would be enhanced. Based on the result of the experts' validation, it is obvious that the developed model of the human excretory system will solve a lot of problems in the teaching and learning of Biology. It would allow learners to observe in detail the excretory system of human beings. Since the human excretory system is not visible, learners are more likely to retain and recall with ease a greater percentage of what they see and learn. 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. Students understand better when they involve themselves in the practical experiment, thus matching theory with practice. This is because as the students participate and manipulate equipment and materials, they apply their five senses and other skills more than when they would have learned in

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abstraction or remained less active in the class. Thus, teachers should use practical activities while teaching biology since students learn better when they are involved. It was recommended that developers of instructional resources should ensure that ADDIE instructional system design model or similar ISD model is implemented. This will serve as a guide towards developing quality instructional material and secondary school administrators should encourage their teachers to make use of available materials to produce instructional materials to encourage and promote indigenous technology.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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