3D Printing Applications in STEM Education

Norman Gwangwava
Botswana International University of Science and Technology, Botswana

Catherine Hlahla
National University of Science and Technology, Zimbabwe

INTRODUCTION

The chapter focuses on the design of educational toys for early school aged children, based on their anthropometric measurements. It also covers case study applications of 3D printing in engineering design undergraduate studies. Research on existing educational toys and different child development stages was carried out. Concepts were generated from the collected data and the best concepts selected through ranking methods. Dimensioning of the selected concepts was based on the collected anthropometry data. STL files were used to manufacture the chosen concepts by means of 3D printing.

Children are active learners who use the physical environment in a direct, hands-on manner to develop different skills. Toy experts believe that educational toys play a large role in the development of children. They stimulate play, language and reading skills and help children achieve milestones in both gross and fine motor skills. The implementation of ergonomics and the consideration of children's anthropometry dimensions in the design of toys play an important role in ensuring safety and injury risk reduction of children during play.

The National University of Science and Technology (NUST) is exploring 3D printing technology in the lecture room for its BEng program; ready-to-use 3D printed gardening implements, Mass-Customization of Office Mini-Storage Products from 3D Printing and other research projects. 3D printing enables students in science, technology, engineering and mathematics (STEM) to visualize concepts.

BACKGROUND

Many of the children toys in the global market are imported from other countries, specifically China. The designers of these toys aim at achieving as good anthropometric match for as many potential customers in their country as possible. Thus the toys are custom designed to suit body dimensions of the children in that particular country yet the same toys are being exported and used by children across the world. Accidents and musculoskeletal health problems may occur due to incorrect product dimensions and sizes that do not meet the children's dimensional requirements.

Anthropometric data for children reflect general health status, dietary adequacy and growth and development over time (McDoweliet et al, 2008). Although several researchers have studied the anthropometry of children, they have most related their studies to nutritional, health and growth aspects (Khor et al, 2009). There are a few studies on the importance of child anthropometry in the design of various child products, specifically toys. Anthropometric measurements are necessary to form the data base which is required for the proper sizing of educational toys. Although the idea of considering child anthropometry in the design for child products is not new, the scarcity of avail-

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able sources on anthropometric data among early school aged children calls for more anthropometric research so as to customize the children toys.

With respect to higher education needs, STEM education is more demanding in terms of well equipped laboratories, prototyping needs, as well as building experimental conditions that match the practical world. The pass rate at NUST has been low due to inadequate facilities for STEM enrolled students. 3D printing helps students to bridge the gap between the practical STEM world and the lecture room. Ease of recycling prototypes is also very important to keep the STEM training costs low. 3D printing, coupled with modular design concepts, was proved to be the best choice in cost effectiveness.

LITERATURE REVIEW

This section covers recent, historical and empirical reviews laying the foundation for the present study. Information that is relevant for the anthropometric research for the design of educational toys is presented. The section gives an insight into anthropometry, educational toys and 3D Printing which are the main subjects used to meet the objectives of the chapter.

Anthropometry

Anthropometry is the science that measures the range of body sizes in a population (Pheasant & Haslegrave, 2005). In product design, anthropometrics is the use of body measurements to determine the optimum size for products for comfortable and efficient use. Designers integrate the use of anthropometric data in their design process to optimize the usability and functioning of a product while improving comfort and safety. Advances in 3D imaging technologies have facilitated the collection of these measurements and shapes among the elderly or children (Goto, et al 2015). There are two primary types of anthropometric measurements; structural (static) and functional (dynamic) measurement. Structural measurements are taken while the body is in a static position. These include skeletal dimensions (joint to joint measurement) and soft tissue measures in contour dimensions.

Dynamic measurements are taken while the body is engaged in some kind of activity like driving a car or reaching for objects. Engineering anthropometry is concerned with the application of both types of data to the design of the products people use.

Child Development Stages

Child development is the change or growth that occurs in children and the gaining of skills in all aspects of the child's life (Frost et al, 2008). It is often divided into three main areas; physical, cognitive, and social-emotional development.

Physical development fall into two main categories:

1. **Gross-Motor Development:** Involves improvement of skills using the large muscles in the legs and arms, such activities include running and bike riding.
2. **Fine-Motor Development:** The coordination of small muscles, in movements, usually involving the synchronization of hands and fingers with the eyes. Cutting, grasping, molding and writing are some of the activities that require fine-motor development.

Cognitive development is about how children learn, think and develop ideas. This is one of the areas of development that is strongly influenced by the experiences a child has. For example learning the names of animals is only possible if a child has been told them.

Social-emotional development is a child's ability to understand the feelings of others, control their own feelings and behaviours and get along with peers (Hoffman, 2013). Social and emotional development involves the acquisition of a set of skills. These include the ability to: