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Aligning Technology Education Teaching with Brain Development

Petros Katsioloudis
Old Dominion University, pkatsiol@odu.edu

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Petros Katsioloudis
Old Dominion University

Abstract

This exploratory study was designed to determine if there is a level of alignment between technology education curriculum and theories of intellectual development. The researcher compared Epstein's Brain Growth Theory and Piaget's Status of Intellectual Development with technology education curriculum from Australia, England, and the United States. The researcher hypothesized that there would be alignment between technology education curriculum, brain growth, and intellectual development theories. The results indicate that students could become more technologically literate citizens if technology education was presented to them earlier in their school careers. School systems and students may be missing an opportunity since technology education is not offered in most elementary schools.

Introduction

Little research exists on how cognitive learning occurs in the subject of technology education. Researchers face several persistent problems when attempting to develop clear interpretations or generalizations of the relationship between cognition, intellectual development, and technology education curriculum (Zuga, 2004). Reviews of industrial arts and technology education research conducted during the last half of the twentieth century have cited numerous studies involving cognition (Streichler, 1966; Householder & Dyrenfurth, 1979; McCrory, 1987; McCormick; Zuga, 1994). Cognitive research about technology education for the general educational purpose of technological literacy has suffered from a lack of coherent focus (Zuga, 2004). An exploratory study was conducted to identify whether technology education curriculum aligns with theories of intellectual development and brain growth.

For this study, the following was the primary research question:

Is there significant evidence that shows direct alignment between technology education curriculum and theories of intellectual development and brain growth?

The following hypotheses will be analyzed in an attempt to find a solution to the research question:

H_0: There is no significant evidence of direct alignment between technology education curriculum and theories of intellectual development and brain growth.

H_A: There is significant evidence of direct alignment between technology education curriculum and theories of intellectual development and brain growth.

Methodology

During the summer of 2012, an exploratory study was conducted as a means to perform the analysis between technology education curriculum and theories of intellectual development and brain growth. Researcher conducted the study at Old Dominion University using Epstein's brain growth theory and Piaget's stages of intellectual development and then compared them with Technology Education curricula from Australia, England, and the United States for direct alignment.

Review of Literature

According to McCormick (2004) there are two basic types of technological knowledge: procedural and conceptual. Procedural knowledge includes components such as design, problem solving, planning, systems analysis (or systems approach), optimization, modeling, and strategic thinking (heuristics, algorithms and metacognition). *Conceptual knowledge* involves systems related concepts that correlate with one another (McCormick, 2004). In addition to McCormick's two basic types of technological knowledge, Chester (2006) suggests a third type of knowledge labeled *strategic knowledge*; narrowly defined in terms of identifying and choosing between alternative algorithms. McCormick (2004) also stated that most technology education national curricula (e.g. Technology for All Americans Project 2000, DfEE/QCA 2000) deal with a limited range of *procedural* knowledge: design and problem solving. It indicates that we know very little about the process of learning for technical education. Specifically, McCormick states that we know little about how technologists use that process in a way that we could be drawn upon as tools in education and we also know little of their inter-relationships. During the last three decades it has been assumed that during an individual's change process there is a smooth and continuous curve of growth between brain function development and learning ability. Research (Shunn, 2010) related to brain function, cognitive development, and individual change models have challenged the validity of that assumption. Although there is strong evidence that the curve of growth between brain functioning development and learning ability is not smooth and continuous, the foundations of curriculum and instruction are still often based upon that premise (Sylvester, 1986).

According to Thomas (1986), for most of the 20th century teacher training institutions taught behaviorist theories, which were fragmented at best, and were heavily based on the behavior of laboratory animals. However, this bears in mind the following questions: is the behavior of a rat and a human the same? Do rats and humans learn the same way? Do rats and humans similarly respond to the same stimuli? Are the brains of a rat and human identical? According to Sylvester (1986), the forebrain occupies 45% of the rat brain mass compared, to 85% in humans. Frontal lobes occupy about 5% of the rat's brain compared, to 30% of the human brain. The cortex matures in about a month in a rat, compared to 10+ years in the human brain (Sylvester, 1986).

Alongside these questions, studying Epstein's brain growth theory and Piaget's theory of cognitive development, one can see that during the development of technology education curriculum these theories were not always taken under consideration. A summary of the literature relevant to this study follows.

Epstein's Brain Growth Theory

Herman T. Epstein, a former Brandis University biophysics professor, conducted research indicating that the human brain grows in spurts rather than in simple linear increments across time. In his book, *Learning to Learn: Matching Instructional to Cognitive Levels,* Epstein (1981) stated that there are brain growth spurts "during the age intervals of three to ten months old and from two to four, six to eight, ten to twelve or thirteen, and fourteen to sixteen or seventeen years" (Epstein, 1981).

Agreeing with Epstein's theory, researchers noted that during the early years, specifically from ages 3 to 6, most brain growth occurs in the "frontal circuits" of the brain, which are the areas involved in the "organization and planning of new actions" (Dixon & Williams, 1986). However, as children age, the growth moves toward the rear areas of the brain, the areas involved in learning language and understanding spatial relations (Dixon & Williams, 1986).

When researching brain and skull development, Epstein concluded that phrenoblysis (a term used to describe brain and mental growth) occurred in all studies. He described spurts in brain weight as crossing approximately six paths at each of the following periods:

- Three to ten months
- Two to four years
- Six to eight years
- Ten to twelve or thirteen years
- Fourteen to sixteen or seventeen years (Patterson, 1983)

According to Epstein's theory, only three of the above spurt periods will occur during a child's public school years. Correlated spurts can be supported by mental age and a number of intelligence based tests: memory, vocabulary, or language utilization. There is also evidence that these brain growth spurts correlate in age with learning capacity and are the same as the biological basis of Piaget's stages of cognitive development (Epstein, 1981).

Piaget's theory of cognitive development

From the point of view of development and cognition, Piaget (1965) described the emergence of a concept of speed as quantified motion. Children first notice movement in Piaget's Sensory Motor Stage, from birth to two years of age. The child develops action schemas when beginning to understand movement. By kindergarten or first grade, the child is typically able to quantify movement and other entities by magnitude. For example, the child can quantify motion with a magnitude variable called speed. In gaining the ability to quantify motion, the child develops action schemas or schemas of correspondence, which are mental representations allowing the child to understand the quantification (Piaget, 1965).

Huitt and Hummel's (2003) work builds on Piaget's stages of cognitive development theory. However, Huitt and Hummel suggest four cognitive development stages (see Figure 1):

1. Sensorimotor stage (Infancy). In this period (comprised of 6 substages), intelligence is demonstrated through motor activity without the use of symbols, and knowledge of the sub stages is based on physical interactions/ experiences (Huitt & Hummel, 2003).
2. Pre-operational stage (Toddler and Early Childhood). In this period (comprised of two substages), intelligence has been demonstrated through the use of symbols as language use matures and memory and imagination are developed. However, thinking is done in an illogical, irreversible manner (Huitt & Hummel, 2003).
3. Concrete operational stage (Elementary and Early Adolescence). In this stage (characterized by 7 types of conservation: number, length, liquid, mass, weight, area, volume), intelligence is demonstrated through the logical and systematic manipulation of symbols related to concrete objects (Huitt & Hummel, 2003).
4. Formal operational stage (Adolescence and Adulthood). In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts. Only 35% of high school graduates in industrialized countries retain formal operations since formal thinking is not common in adulthood (Huitt & Hummel, 2003).

Growth changes in some locations of the brain are not as active as others. Epstein (1981) called this functional activity relocation. He conducted studies suggesting a correlation between spurts of the brain and mental functioning. In order to support this theory, Epstein studied the slow growth periods (10-24 months old, 6-8 years old and 10-12 years old). During these periods it was unlikely that the individual would develop new thinking competencies required for new cognitive development. This would support the existence of slow growth periods (Brooks, 1983). Supporting Epstein's theory, Brandt (1998) wrote:

> As the child grows older the cells atrophy and the ability to learn spoken language is lost. Although learning a second language also depends on the stimulation of the neurons for the sound of that language, an adult certainly can learn a second language and learn to speak it very well. Therefore, is much more difficult to learn a foreign language after age 10 or so, and the language will probably be spoken with accent.

Epstein's growth spurt theory, Piaget's stages of intellectual development, and Huitt and Hummel's cognitive development stages all suggest that the curve of growth between brain functioning development and learning ability are not smooth and continuous. If the research supports this theory, technology education curriculum developers should consider it. Due to its popularity, especially by instructional designers, Epstein, Piaget and Huitt and Hummel's research have evoked attempts to develop technology education curricula that take into account learners' cognitive development stage and brain functions. *The Standards for Technological Literacy: Content of the Study of Technology* (ITEEA, 2007) is not a curriculum, but the foundations by which each technology education program can build.. According to these standards, teachers decide the depth of what is to be taught in each school grade. Below are examples of two Standards for Technological Literacy Standards, the Design and Technology standards from England, and Technology standards for Australia, as well as their overall relevance to the Epstein, Piaget, and Huitt and Hummel theories.

The International Technology and Engineering Educators Association (ITEEA, 2007) created the Standards for Technological Literacy based on the following basic tenets:

- To offer a common set of expectations for what students in technology laboratory classrooms should learn
- To offer concepts that are developmentally appropriate for students
- To provide a basis for developing meaningful, relevant, and articulated curricula at the local, state, and provincial levels
- To promote content connections with other fields of study in grades K-12. (ITEEA, 2007, p. 13)

Standards of Technological Literacy

Standard 1

Students will develop an understanding of the characteristics and scope of technology.

- Grades 6-8
  - Corporations can often create demand for a product by bringing it into the market and advertising it.

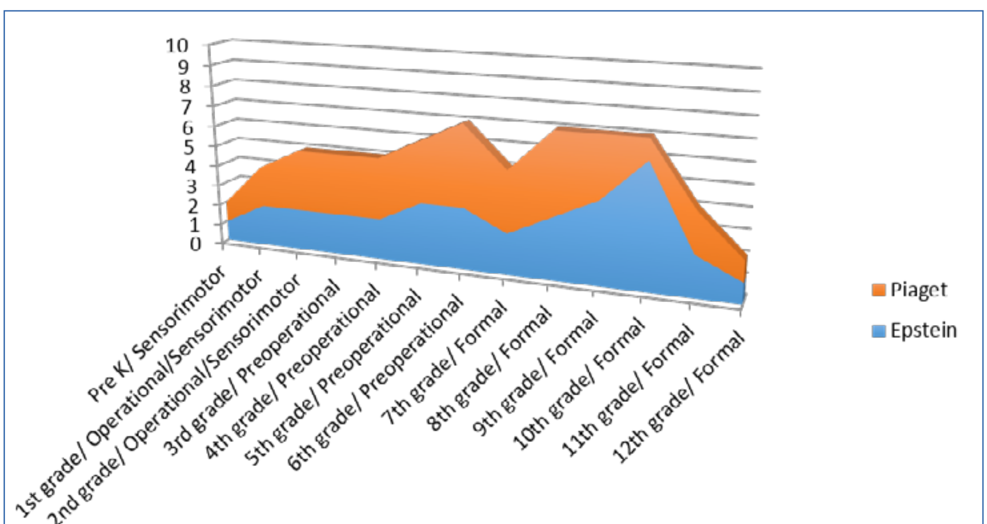

Figure 1. Brain growth periodization model (William, 1986, p.2)

- The nature and development of technological knowledge and processes are functions of the setting.
- The rate of technological development and diffusion are increasing rapidly.
- Inventions and innovations are the results of specific, goal-directed research.

- Grades 9-12
  - Usefulness of technology
  - Development of technology
  - Human creativity and motivation
  - Product demand

Standard 2

Students will understand the core concepts of technology:

- Grades 6-8
  - Systems
  - Resources
  - Requirements
  - Trade- offs
  - Processes
  - Controls

- Grades 9-12
  - Systems
  - Resources
  - Requirements
  - Optimization and trade-offs
  - Processes
  - Controls (ITEEA, 2007, pp. 210 - 211)

Design and Technology Standards in England

Rasinen (2003) stated that compulsory school in England is divided into four key stages: key stage one (grades 1-2, ages 5-7), key stage two (grades 3-6, ages 8-11), key stage three (grades 7-9, ages 11-14) and key stage four (grades 10-11, ages 14-16). As identified below, in key stage three of the program of design and technology, the key concepts include designing and making, cultural understanding, creativity and critical evaluation.

- Designing and making:
  - Understanding that designing and making has aesthetic, environmental, technical, economic, ethical, and social impacts on the world.
  - Applying knowledge of materials and production processes to design products and produce practical solutions that are relevant and fit for purpose.
  - Understanding that products and systems have an impact on quality of life.
  - Exploring how products have been designed and made in the past,
    how they are currently designed and made, and how they may develop in the future.

- Cultural understanding:
  - Understanding how products evolve according to users' and designers' needs, beliefs, ethics, and values and how they are influenced by local customs and traditions and available materials.
  - Exploring how products contribute to lifestyle and consumer choices.

- Creativity:
  - Making links between principles of good design, existing solutions and technological knowledge to develop innovative products and processes.
  - Reinterpreting and applying learning in new design contexts and communicating ideas in new or unexpected ways.
  - Exploring and experimenting with ideas, materials, technologies and techniques.

- Critical evaluation:
  - Analyzing existing products and solutions to inform designing and making.
  - Evaluating the needs of users and the context in which products are used to inform designing and making.
  - Exploring the impact of ideas, design decisions, and technological advances and how these provide opportunities for new design solutions (Curriculum Authority, 2007).

Technology Standards for Australia

According to Rasinen (2003), in Australia technology is one of eight subject areas studied in schools and is divided into four content areas, called strands. Those strands are designing, making and appraising; information; materials and systems.

Technology Process

Level 1

1.1 Investigates the forms and identifies the uses of everyday products.

1.2 Generates ideas of own designs using trial and error.

1.3 Undertakes simple production processes with direction.

Level 2

1.1 Investigates and identifies the uses and effects of products.

1.2 Generates designs and recognizes some practical constraints.

1.3 Plans production processes and makes products, systems, processes, and services.

Level 5

1.1 Investigates and explains how the design, production, and use of technologies are affected.

1.2 Creates and prepares design and production proposals.

1.3 Organizes, implements and adjusts production processes based on detailed production plans.

Level 6

1.1 Analyzes how needs, resources, and circumstances affect the development and application of particular technologies.

1.2 Creates and prepares detailed design and production proposals.

1.3 Organizes, implements and adjusts production processes involving efficient use of time.

Level 7

1.1 Analyzes the costs and benefits of particular technologies and the values.

1.2 Creates and prepares detailed design and production proposals.

1.3 Organizes, implements and adjusts production processes

Level 8

8.0 Analyzes the design, development and marketing of technologies to identify needs and opportunities for innovation.

1.1 Creates and prepares design and production proposals that show evidence.

1.2 Implements and manages production processes to make optimum use of human and physical recourses (Technology and Enterprise, 2003).

Conclusions

When comparing Epstein and Piaget's theories to the *Standards for Technological Literacy*, the *Design and Technology Standards in England*, and the *Technology Standards for Australia*, it appears that an opportunity may have been missed. These theories suggest that students may have the capacity to become technologically literate at a very early age. In fact, many young people today understand the use of technology at a very early age. In addition to understanding how to use technology, young people should also have the capacity to understand how that technology actually works. For example, in the United States, technology education is not normally available in elementary grades; however, both Piaget and Epstein support the theory that sensorimotor and brain growth occurs during that specific timeframe in a student's academic life (see figure 2).

The *Design and Technology Standards in England* use terms such as understanding, application, and exploring for key stage three (grades 7-9, ages 11-14). These terms promote the idea of conceptual and strategic knowledge and correlate with Piaget's formal operational stages; however, according to Epstein, a growth spurt does not occur until the age of twelve. Per the Australian standards, both girls and boys should study technology during the compulsory years of schooling (years 1-10), as well as in secondary programs, which lead into more specialized programs (Rasinen, 2003). Figure 2 identifies that both Piaget and Epstein theories support that older students should receive more conceptual and strategic knowledge versus specialized and procedural knowledge.

According to Epstein (see figure 1), between six to eight years of age, a remission takes place and the brain does not grow or function at its higher peak. However, according to the *Standards for Technological Literacy* this age is when students should be exposed to new conceptual type knowledge and words such as development, creativity, and understanding are being used in the standards language.

The essence of matter, the origins of the universe, the nature of the human mind; these are the profound questions that have engaged thinkers through the centuries (National Research Council, 2000). As one can see from Figure 2, the Piaget and Epstein theories are not the same, but they correlate with one another. However, the standards upon which the three different countries base their curricula ndo not necessarily follow the same path. The bottom line is that the standards used for any educational content should consider the cognitive abilities of the students. As technology (and engineering) education continues to change with the needs of society, curriculum developers must consider how we can help students become technologically literate at a much younger age. Our very technologically based world depends on these young minds to move the current technology revolution into the next century. Upon completion of this study the researcher believes that there is no significant evidence of direct alignment between technology education curriculum and theories of intellectual development and brain growth. In order to have a more thorough understanding of the relation between technology education curriculum and theories of intellectual development and brain growth, it is imperative to consider further research.

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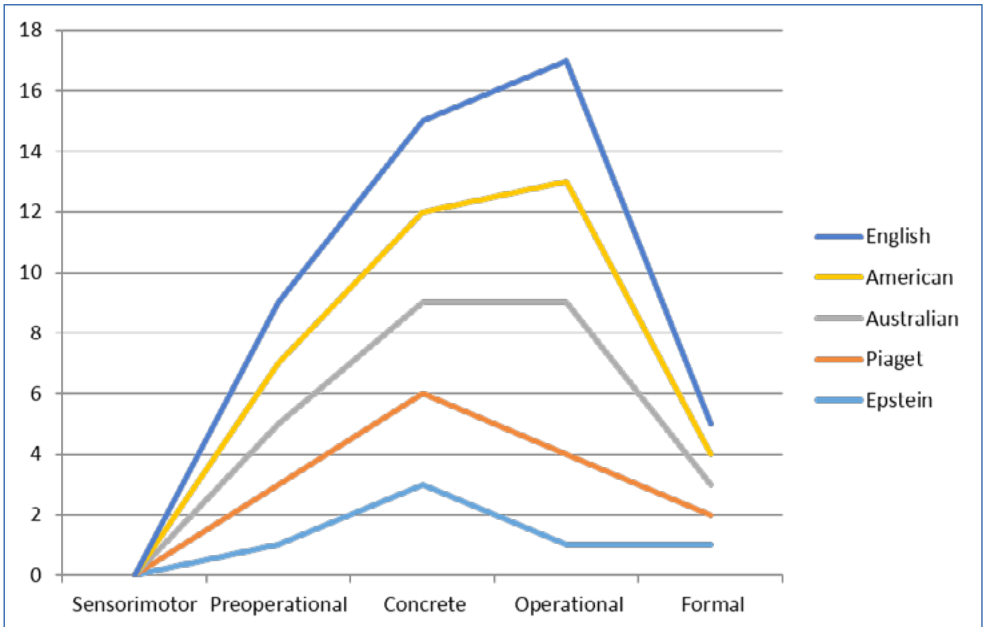

Figure 2. Connection between standards and theories

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Dr. Petros Katsioloudis is an Associate Professor and the Industrial Technology Program Leader in the Department of STEM Education and Professional Studies at Old Dominion University, Norfolk, VA. His research focuses on improving teacher and student performance in STEM Education, enhancing the development of a national STEM-educated Workforce and Engineering graphics with an emphasis in Technical Visualization. He can be reached at pkatsiol@odu.edu.