The Validity of Technologies in Education: A Survey of Early Childhood Education Developmental Tools

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Abstract

Technology has proven to be effective and efficient in many aspects of life and learning. However, technology has also proven to inhibit the enhancement of developmental growth in certain circumstances with some audiences. This paper approaches the various applications of technologies in educational settings and reviews their effectiveness as learning tools in the area of early childhood – birth through age eight. Education developmental tools include: adaptive and assistive technologies, tablets, smartphone applications, computer software, robotic toys, and educational videos.

Surveys and studies of technology in early childhood required observing tools used in the broad areas of educational settings, which include the classroom and home environments. Analyzing these observations, along with previous studies and techniques, help indicate the difference between educational tools which were developmentally appropriate and based on research, versus those that were not. Final reviews of each system will be given on which forms of technologies are helpful or harmful, and effective or ineffective to specific audiences. We conclude with recommendations for studies investigating engineering for developing educational tools that are cognitively appropriate.

1 Introduction

Learning does not start at the age of five, nor does it stop outside of the classroom. In looking at the definition of play for early childhood educators we gain insight into a different kind of learning. *A Child's World* defines play as children being able to use materials in order to "stimulate senses, exercise muscles, coordinate sight with movement, gain mastery over their bodies, make decisions, and acquire new skills." Therefore, educational settings include wherever the child goes, as is supported by the concept of a flipped classroom[1]. Thus this paper will discuss the tools of the educational trade, particularly pertaining to computers and other forms of technology and whether or not they are developmentally appropriate, which is directly proportional to the technology's harmful or helpful nature.

2 Science of Early Childhood Development

Several distinct fields need to be understood before beginning the analysis of modern day tools and toys in their effectiveness. First is the term developmentally appropriate practice (DAP), which is an approach to teaching and care-giving which nurtures a child's physical, social/emotional, and cognitive development. These DAPs are grounded in research of developmental theories, and should meet children where they are in age developmentally, as individuals, and culturally[2,3]. Developmentally appropriate tools and toys allow children to investigate, manipulate and engage[4]. This paper will focus primarily on the cognitive developmentally appropriateness of technologies.

Jean Piaget, a leading pioneer in child developmental psychology, broke up children's developmental milestones into four primary cognitive stages: sensorimotor, preoperational, concrete operations, and formal operations. Another important figure in child psychology was Lev Semenovich Vygotsky. This Russian psychologist agreed with Piaget that the active engagement of a child's environment played a key role in their development, but also emphasized the importance of social interaction[5]. Vygotsky found that children learn constantly no matter what environment they are in and what may surround them. Children learn through interactions with people and materials, whether this be in a classroom, at home or outside[6]. This paper will focus on the first three cognitive developmental stages as they address early childhood age groups (birth through 8 years).

3 Outcomes and Understandings Achievable per Cognitive Age Group

To understand the stances of organizations on developmentally appropriate practices with technology, the outcomes and understandings achievable per cognitive stage must be reviewed[2,4,7,8,9,10,11]. Table 1 indicates the standard Piagetian cognitive stages and the typical age group associated with each. While there are other advances of the stages after the Tertiary Circular Reactions (TCR) stage, they are beyond the scope of this paper. The authors summarized these outcomes for reference, but it is worth noting that in the preoperational development stage, thinking is still not logical; thus, imaginative play and language are important manifestations in this period.

4 Purpose and Investment

Another area to review, in order to fully comprehend the importance of developmentally appropriate practices and tools, is the topic of investment. In reviewing brain studies conducted with children who lacked proper environmental surroundings, such as human interaction, a clear distinction is notable (Figure 1). The study proclaims that "Extreme environmental deprivation in infancy can affect the structure of the brain, resulting in cognitive and emotional problems." Figure 1 shows the PET scans of two different children, where the brain on the left indicates a child given proper environmental surroundings, while the right depicts a Romanian orphan deprived of said surroundings who consequently has a smaller brain and less cognitive

Table 1: The Cognitive Expected Outcomes and Understandings according to Piagetian Developmental Theory with the Authors' Definition of Substages for Increased Clarification

Cognitive Stage	Substage	Typical Age Range	Expected Outcomes/Understandings
Sensorimotor	Reflexes	birth - 1 month	use inborn reflexes for survival
	Primary Circular Reactions	1 - 4 months	where a child repeats behaviors that first occur by chance
	Secondary Circular Reactions	4 - 8 months	repeat pleasurable behaviors related to their environment
	Coordination of Secondary Schemes	8 - 12 months	coordinating multiple learned behaviors
	Tertiary Circular Reactions	12 - 18 months	becomes curious and experimental with their environment
	Mental Combinations	18 - 24 months	symbolic representation; emonstration of insight
Preoperational	Symbolic Function*	2 - 5 years	use of symbols, understanding of identities, understanding of cause and effect, ability to classify, understanding of numbers, empathy, and theory of mind
	Reverse Thinking*	5 - 7 years	conservation; ability to reverse thought processes mentally, such as counting backwards
Concrete Operations	Concrete	7 - 11 years	spatial thinking, cause and effect, categorization, seriation and transitive inference, inductive and deductive reasoning, additional conservation, and numbers and mathematics
Formal Operations	Formal	11 - adolescence	hypothetical-deductive reasoning

** These substages indicate the authors' definition to help distinguish a turning point in the Preoperational stage. This is referred to in books[5] but did not have specific names associated with this separation.*

functionality. While these scans show two extremes of a child's upbringing, the evidence supports the theory that lacking developmentally appropriate atmospheres and tools to assist the brain in forming its synapses can be detrimental to the child's ability to grow into a functioning adult. As Shonkoff and Phillips discuss in their book, children are born with all the brain functions they will ever be able to use. As the child grows, their brain forms the synapses and connections being tended to, and discards the ones not being nurtured[12].

Investment has been emphasized in multiple categories in studies such as the Carolina

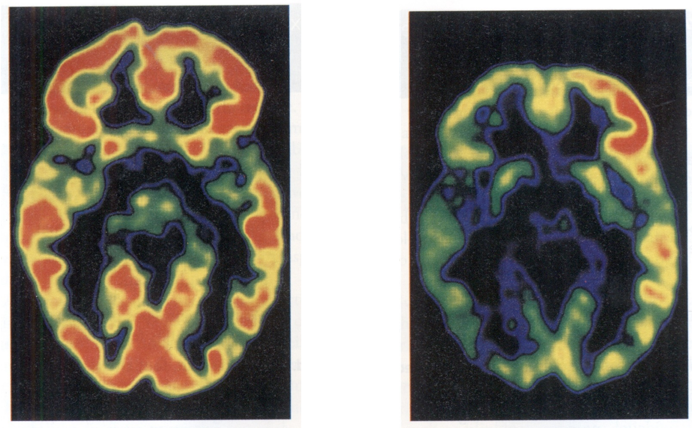

Figure 1: “A PET scan of a normal child’s brain (left) shows regions of high (red) and low (blue and black) activity. A PET scan of the brain of a Romanian orphan institutionalized after birth (right) shows less activity” and even a physically smaller brain.[5]

Abecedarian Project (ABC), and the Perry Preschool Project. The ABC is one of the oldest, widely known and cited early childhood interventions with long-term follow-up evaluations. Two groups of children born between 1972 and 1977 were assigned in infancy to the early educational intervention (treated) group or control group[13]. Essentially the treated group received DAP with trained early childhood education specialists, while the control group did not.

Campbell’s study reported on the medical impact of the project, indicating how one in four males were affected by metabolic syndrome in the control group, but none in the treated group[14]. Another study noted that with proper early intervention, cognitive developmental trajectories could be positively improved for biologically and socially vulnerable children; meaning children at risk of developing intellectual or cognitive disabilities benefited from DAP early childhood education[15]. Additional studies report on the economic value of early childhood education programs. These studies showed the businesses reported a communication and critical thinking skills gap. In North Carolina nearly 60% of workers were members of this gap[16]. The Education Trust reported that even though many military applicants had high school diplomas, they did not have the necessary reading, math, science or problem-solving skills to join the United States military forces[17]. Military leaders, such as Major General Charles Luckey, discussed the importance of pre-kindergarten (PreK) education and how it would provide the foundation for cognitive and character development[18,19].

Often, a college education is considered to be a big investment in a person’s career capabilities. Yet the research shows that the early childhood years help form the foundation of a person’s cognitive functions[12]. Therefore, early childhood developmentally appropriate practices and tools is an investment in a person’s education as well.

5 Videos

Many researchers agree that showing videos to children in early childhood leads to poor development[20,21,22]. Zimmerman discusses how heavy television viewing in these years is bad for language, math and reading development, and that adult speech interaction with a child is far more valuable in developing these cognitive functions[23]. Companies such as Baby Einstein advertised that their products, made for children from 2 years and younger, helped improve their readiness for school years. However, studies showed that these sorts of baby videos actually decreased a child's learning ability over parents simply reading to their child[24,25]. These and other studies led to the recent declaration of the American Academy of Pediatrics (AAP) to emphasize that children from birth through 18 months should not have *any* screen time[26].

The AAP and Bavelier report that for children, ages 2 to 5, television programs such as *Dora the Explorer* can improve upon language processing skills. Dr. Bruce Perry argues that whether watching television has a positive or negative influence comes down to the appropriateness of the material and the timing of its presentation in a child's development[27]. While a child in the concrete or formal operation stages of development may see a program like 'Cyberchase', which promotes mathematical skills, can benefit from viewing such a program, an infant or toddler should not be exposed to such programs as they have yet to develop the necessary attributes to comprehend the material.

6 Applications for Phones and Tablets

When children have a toy or tool that performs a task for them, from birth through preschool age, they do not learn. Even digital books can be harmful as they decrease a child's comprehension of content or a parent's reading interaction with the child, as visual effects are distracting[28]. Some applications (apps) may seem like play in their interactive activities with the story being presented to children. These apps may help improve visual and motor functions, but they do so at the cost of reading comprehension and language processing[29].

The infant and toddler apps are particularly inappropriate and harmful according to brain research[30]. The AAP in their most recent statement issued a call to action by industry leaders to "Work with developmental psychologists and educators to create design interfaces that are appropriate to child developmental abilities, that are not distracting, and that promote shared parent–child media use and application of skills to the real world, [and urged industry leaders to] cease making apps for children younger than 18 months until evidence of benefit is demonstrated."[26]

A better tool for this age group would be a set of blocks with different shapes (typically triangles, boxes, circles and stars are used) accompanied with a small table with matching holes for each block's shape. This toy encourages hand-eye coordination development along with the basic understanding of the scientific method. For example, as the child holds a square block and attempts to put it into the circular hole in the table, the block will not fall through the table. However, after several attempts they come across the square hole and the block falls through.

This process encourages the child to realize that if the block is the same shape as the hole, then the block will fall through the table.

7 Computer Software

In White's study on integrating computers into classroom environments, it was discovered that teachers were lacking in the understanding of developmentally appropriate tools[31]. The importance of using computers wisely was reiterated by Dr. Bruce Perry. In discussing its usefulness, Dr. Perry indicates that many computer applications help children improve motor skills for writing, and some help with reading and mathematical skills in the presentation of a video game[27]. These studies focused on children in or past the reverse thinking stage (refer to Table 1), which shows that computer programs are not effective with children not yet at this cognitive stage of development.

8 Embedded Tools

Embedded tools consist of simple sensors, such as a button, and outputs such as motors, lights, and speakers. These include the categories of adaptive and assistive technologies and the typical tools of the early childhood education trade – toys. The field of embedded tools is the best form of computers in education for children who are not developmentally ready for the other applications. Baby gyms and play mats are great uses of embedded technology for said cognitive groups.

However, some toys still implement developmentally inappropriate tasks. Examples include products which primarily have switches that proclaim words, letters or phrases which are marketed towards infants and toddlers; these products are not appropriate until the stage where symbolic representation is achievable. Interacting with technology does not teach them as they have yet to form those connections/synapsis. Therefore, this would not be considered play; reading with or being read to by a physical person is the more appropriate scenario when first learning about letters and words.

One instance where switches that speak words and phrases is appropriate is with a Big Mack Switch. This assistive technology allows children who have no verbal language to use technology switches that communicate for them[32]. Other tools which speak to a child include FM Listening Systems which block background classroom noises and amplify what a teacher is speaking. These are useful for children with hearing impairment, autism spectrum disorder and language-processing issues[33].

For another embedded-based implementation, the Fisher-Price Code-a-Pillar^{TM} defines an effective embedded toy for its targeted audience (3 to 6 years). The Code-a-Pillar has multiple segments which interlock together, and each has a specific function to perform; these actions include move forward, turn right 90 degrees, turn left 90 degrees, and a sound action. The segments are connected together and conducted in sequential order starting with the motorized head. So if the child puts a straight segment behind the head and then a right segment behind the straight, upon pressing the start button, the Code-a-Pillar would first go forward then turn right by 90 degrees.

9 Conclusions

Research typically presents recommendations for tools based on age ranges; however, those ranges are based on the theories of cognitive development. Therefore, the conclusions are presented as such by cognitive developmental stage, which is correlated to brain maturity[a]. Table 2 gives an empirical review breakdown of each technology discussed and its developmental appropriateness by cognitive substages. The following criteria was used in forming Table 2: 1 = Harmful, Not Effective; 2 = Somewhat Harmful, Mostly Ineffective; 3 = Helpful or Harmful, and Effective or Ineffective, depending on the specific tool or toy; 4 = Mostly Helpful and Effective (with educational viability reported); 5 = Helpful and Effective.

For the DAPs discussed in Table 2, logical thinking refers to the concept of being able to have cohesive thoughts, which is the process of one thought moving distinctly to another. Logical reasoning means that the child has begun to understand skills, such as spatial thinking, cause and effect, categorization, seriation and transitive inference, inductive and deductive reasoning, additional conservation, and numbers and mathematics.

10 Discussion and Recommendations

This paper reviewed theories behind cognitive developmentally appropriate techniques and tools surrounding the early childhood age groups. As the authors and discussed research suggests, there is a lack of communication and understanding of developmentally appropriate tools in the marketing and engineering fields. This in turn leads to tools being marketed towards incorrect age groups of children and the engineering of tools which are entirely inappropriate developmentally, and therefore harmful. The information from Table 2 indicates what technological tools and toys are harmful versus helpful, and ineffective versus effective.

Due to these factors, it is important for parents, guardians and educators to look into each product and asses their developmental appropriateness for the cognitive stages in consideration. The authors recommend that more research be conducted in the field of engineering for developing educational tools that are cognitively appropriate.

Acknowledgment

The authors thank the Department of Educational Leadership at the University of North Carolina at Charlotte and the Early Childhood Education Department at Stanly Community College for their expertises and guidance throughout the process of this paper.

[a] For more detailed lists of recommended tools and toys by age and stage, please refer to these references[4,26].

Table 2: Results of Empirical Review of Developmentally Appropriateness of Technologies by Cognitive Substages

	Technology DAP and Scores							
	Videos		Apps for Phones and Tablets		Computer Software		Embedded	
Cognitive Substages	Score	DAP	Score	DAP	Score	DAP	Score	DAP
Reflexes - TCR	1	Not used	1	Not used	1	Not used	3	Adult Interactions
Mental Combina-tions	2	1 hr/day with adult	2	1 hr/day with adult	2	1 hr/day with adult	4	Encourages Adult Interactions
Symbolic Functioning	2	1 hr/day with adult	2	1 hr/day with adult	3	1 hr/day with adult	4	Encourages Interactions, and Logical Thinking
Reverse Thinking	3	Encourages Logical Thinking	3	Interactive, Encourages Logical Thinking	4	Interactive, Encourages Logical Thinking	4	Encourages Interactions
Concrete	4	Encourages Logical Reasoning	4	Encourages Logical Reasoning	5	Encourages Logical Reasoning	5	Encourages Logical Reasoning

Note: Developmentally Appropriate Practice (DAP)

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