Direct Manipulation Tablet Apps for Education: How Should We Understand Them?

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Exploratory Phase of a Research Program

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ABSTRACT

As the iPad and its competitors create a new product category – apps for mobile, multimedia tablets with touch and gesture interfaces – many are convinced that tablet apps will revolutionize education. For example, hand-controlled, direct manipulation features offer new ways to convey both spatial and abstract concepts, and progressive storylines can adapt to users in real-time. While the effectiveness of tablet apps for learning may seem obvious to new users, how and why particular apps might be effective is new research territory, and the relevance of existing learning theory is unknown. We describe a research program that will explore and analyze the design of existing educational apps, as well as the content of user and reviewer feedback, to develop propositions about design elements that make educational tablet apps effective.. Our research in progress will include experimental testing of hypotheses about principles of effectiveness and ongoing evaluation of the adequacy of existing theory.

Keywords (Required)

Tablets, User Interface, Educational Applications, e-Learning Theory.

INTRODUCTION

Since exploding onto the scene in early 2010, the iPad and its competitors have defined a new product category–a mobile, multimedia tablet computer with a touchscreen-enabled, gesture-based interface–that seems to inspire, among all who use it, the firm conviction that it will revolutionize education. This assumption seems intuitively obvious upon first use, particularly when trying out an application that exploits the platform's unique capabilities to deliver a captivating moment of learning However, understanding what makes for such moments, which design elements enable them, and whether or how they might be effective for learning, is new research territory. To get at these questions, one must consider the platform in the context of learning tools and technology.

A high level timeline of learning tools inlcudes three eras. The first era consisted of books supplemented with real world manipulatives that students could touch and use for learning; the second era included features from the first era combined with online tools accessed via desktop and laptop computers. The emerging third era includes highly interactive tactile and manipulation devices, along with adaptable, multimedia-supported learning storylines that go well beyond elements of the first and second eras in handheld tablets.

The emergence of popular tablet computers, especially the iPad, has resulted in a burgeoning market for educational applications that run on these tablet computers. Many school districts are considering adopting use of iPads into their curricula (Horn, 2011). There is anecdotal evidence of effectiveness of iPad applications, but a wide disparity in the popularity of such applications. The features of tablet computers that lend themselves to hands-on learning include, among others - the tapping, holding, and dragging for highlighting text, copying and pasting, or deleting and moving applications, and swiping and flicking to move through app pages and scrolling through text. A two-finger pinch gesture zooms in and out of the screen (a double tap works to zoom in as well). Moving two or more fingers in a circular gesture is rotates a screen and other elements (Chang, 2011).

To introduce our approach, we describe a research program that will explore and analyze the design of existing educational apps, as well as the content of user and reviewer feedback, to develop propositions about design elements that make educational tablet apps effective. Research will include experimental testing of hypotheses and ongoing evaluation of the adequacy of existing theory. The research approach will include classifying iPad applications, performing content and visual analyses of the applications, and proposing design and evaluation principles based on the results. Simultaneously we propose studying existing learning theories to see if they hold up, given the new paradigm of education that seems to be the hybrid of hands-on and electronic learning systems.

BACKGROUND – TRENDS THAT DEFINE A NEW CATEGORY

The advent and growth of tablet computers led to a growing expectation of their use in education. Educators expect to have more tablets per student than computers within five years. Apple CEO Tim Cook recently claimed that nearly a thousand K-12 schools in the U.S. have a one-iPad per-student deployment program for use during the school day (Horn, 2011). The growth in tablet sales accompanies a growing demand for educational applications that run on them. Apple's App Store has more than 20,000 educational applications (Apple in Education, 2012) that cover a diverse range of subjects including Math and Science, and some are available for download free of charge.

There is a tacit understanding that tablets will revolutionize pedagogy although there does not seem to be a clear understanding in both the academic and practitioner community as to how that will happen. While some applications are rated very highly, and downloaded frequently, many seem to fall flat. The vast majority of user reviews of educational apps are negative. For instance, out of 46,391 applications classified as "educational" in the Apple Applications Store, only 6794 applications are rated as deserving 4 or 5 stars on a scale of 1 to 5. What makes an educational application really succeed for people - what makes them "tick"as educational tools, is an open question. The marketplace is a natural mechanism where this struggle plays out, but trends of success are not yet clear. Given the potential for the educational market, as well as the versatility of the iPad-type platform (Jones et. al., 2011), a better understanding of how these applications can really unlock their potential for education, are worth our attention. Identifying the design principles and aesthetics that emerge, and understanding their eventual implications for pedagogy, may prove useful to designers, users, and researchers.

The reason for this uncertainty is that the modern tablets possess attributes that have not been seen in previous computing devices – in particular the tactile experiences. A study conducted to focus on that aspect was by Jones et. al (Jones et. al., 2011). They exposed heritage photographs to children in various forms – (i) simulated archive photographs to hold and examine wearing white cotton gloves and using a magnifying glass, (ii) digital images to touch and manipulate on a tablet device and (iii) digital images to access and look at on a large screen desktop device with normal mouse interaction. The children's affective and cognitive responses to photographs were measured. Responses to real photographs and photographs viewed via technologies were recorded and compared. Their findings included the fact that technologies such as the iPad seem to get ever closer to real world interaction metaphors via 'lightweight' gestured techniques. iPads seemed to invoke cognitive phenomena that would have otherwise been invoked by archive photographs. The authors' preliminary results indicate that children's responses to actual photographs and photographs viewed on an iPad are very similar. Another finding was that computers with large flat screens obscure children from other children in the classroom, and are problematic in terms of encouraging learning in a social context.

Another area of research to be explored is that the influence of tactile responses to traditional methods of learning. There has been a lot of research done in the area of educational psychology regarding auditory, visual and sensory forms of learning. In the early years of education, children learn through tactile manipulation. Learning tends to lose this aspect in higher levels of education, traditionally. It is possible that the tactile nature of tablets re-invigorates the innate sense of learning with fingers that is lost with aging. This could be one of the reasons that very young children take to the iPad naturally as this is the way much of their world works. With adults, it may reignite that vestigial sense of exploring with their hands that still lingers from their childhood.

Another recent event has been the advent of interactive textbooks in tablet computers. The smallest and least expensive tablet computer can store roughly eight to ten textbooks, along with other content. These textbooks can automatically play audio or video included with the book or later, read aloud in the case of select children's books, and use built-in Highlight and Note features. Over the next five years, digital textbook sales in the United States will surpass 25% of combined new textbook sales for the Higher Education and Career Education markets to more than $1.5 billion (Reynolds, 2011).

Given the popularity of tablet computers, it is likely that educational technology proponents and skeptics will debate the potential for technology in classrooms (Murray and Olcese, 2011). Our research goal is to study the relationship between application features and their impact on learning. We believe that our findings will apply to both applications as well as the burgeoning market for digital books.

RESEARCH APPROACH

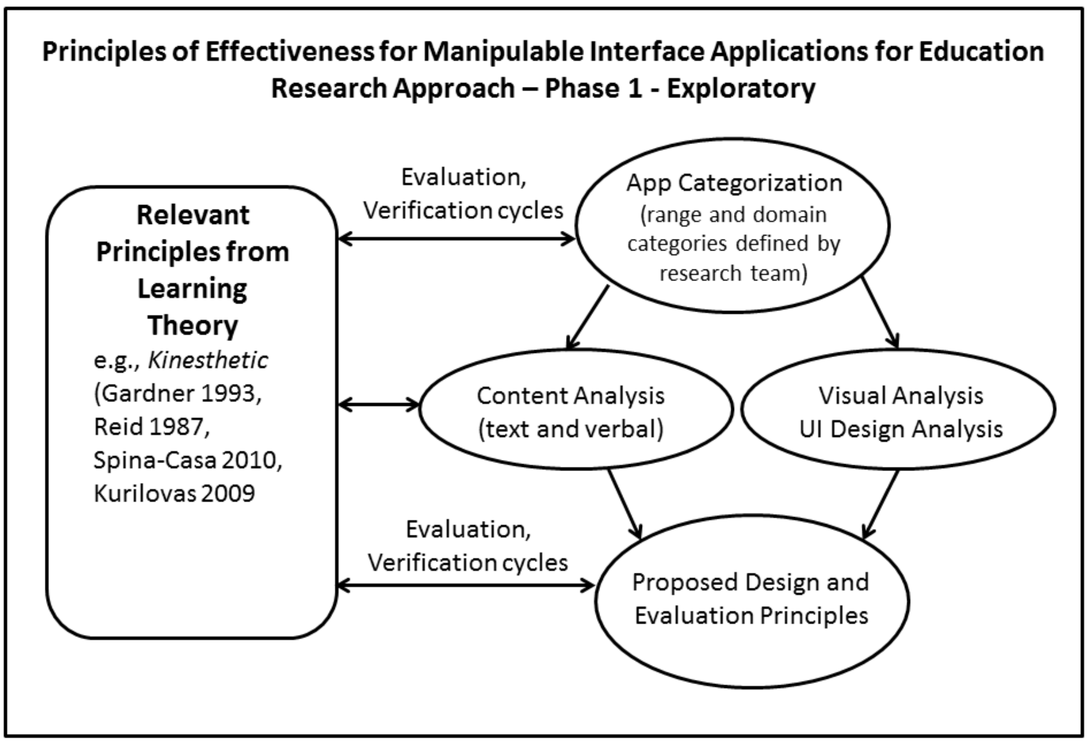

FIGURE 1: Research Approach

Tablet-based Educational Application Categorization

Our initial work on analyzing the scope of the available tablet-based educational applications begins with two steps:

1. A review of a judgment sample of available applications and identification of key dimensions that provide a basis for analytical categorization. At present, three preliminary dimensions have been identified by the research team: Manipulation/manipulability, induced reasoning type (including puzzle solving, pattern recognition, and others), and dynamism (e.g., animated, evolving story support versus static presentation).

2. Application of the three categorization dimensions to the top 100 available educational applications in the tablet-based app market. Each application is assigned a value (e.g., low/high) on each of the three dimensions.

App Categorization

The Apple Applications store, the largest available source for research of this type, will be used as a proxy for the tablet-based application market. The Apple app store includes application taxonomy with an Education category. The result of this initial step will be a clear understanding of the current state of functionality and focus of tablet-based educational applications.

Content Analysis

Qualitative and quantitative content analysis will be applied to relevant text available from multiple sources. These text sources will include, at minimum, online reviews of the field of applications under study. Both professional reviews of applications and user reviews of applications will be analyzed using standard content analysis approaches, supported by content analysis qualitative research software. In addition, in some cases the textual content of the application will be accessible for analysis. This analysis is exploratory in nature and will allow the researchers to define critical factors in perceptions of applications and recurrent themes intended to support theory development.

Visual Analysis

Visual analysis will be applied to the actual presentation of the individual applications. The approach to visual analysis will be conducted by a research team specialist in art and design using standard methods from that discipline. The dimensions of visual analysis will include, at minimum, stylistic analysis and classification, compositional elements, and use of color, contrast, and proportion.

LEARNING THEORY ELEMENTS AND THE CONTEXT OF APPLICATION DEPENDENCY

The Past and Future of Manipulation-based Learning: Recent Historical and Emergent Patterns

As recently as the 1990s, the practice of integrating various learning skills with use of computers varied widely at different academic levels, with more focus by teachers on younger rather than older students (Becker et al. 1999). In addition, the recent historical use of computers varied greatly by academic subject. While math instructors tended to persist in relying on their traditional skills, social sciences teachers seem to have welcomed and embraced computing skills objectives for students. The use of computers for education and skills reinforcement in mathematics was half to one third of the level found in disciplines such as English, science or business (Becker et al. 1999). This was consistent with early trends of focus on broader cognitive objectives in the higher secondary education levels. This pattern was exemplified by the most commonly stated objectives of teachers who assigned computer based work, including “finding out about ideas” and students “expressing themselves” (Becker et al. 1999). Teachers of math stated that they were much less likely to include computer-based work as an objective (Becker et al. 1999).

In addition, as recently as a decade ago, students in schools located in the computer intensive Silicon Valley area of California did not adequately take advantage of computer systems that they could easily access (Cuban et al. 2001). This pattern was found among teachers and high school students in schools located in areas of relatively high income and parent education. Researchers’ survey results indicated that lack of time on the part of teachers to locate and begin using software was an inhibiting factor (Cuban et al. 2001). In addition, computer application training was not easy to access a decade ago. Finally, the computers and software themselves were highly idiosyncratic and afflicted with bugs, which led to frustration for prospective users among the student and teacher populations (Cuban et al. 2001). Fortunately each of these limitations had declined significantly in effect in the ensuing decade, with the small tablet-class devices such as iPads that are the focus of this study now being used at the earliest ages and with the youngest students.

Recent patterns have led researchers to predict the transition of education from the classroom into “homes, libraries, Internet cafés, and workplaces,” where students of all types can determine what is best for their learning style, timing and location

(Collins and Halverson 2009). These expected trends suggest a dramatic need at all levels of education research and policy to start anew in re-conceptualizing the educational process. Some researchers claim that the digital revolution necessitates a clash between old and new educational models, with customized learning expected to take precedence over traditional, standardized learning, and "learning by doing" as a dominant pattern (Collins and Halverson 2009). These trends will lead to revisions in education that include schooling at home, the workplace, and the widespread use of online systems.

One of the most influential transformative trends will occur in computer based learning environments. This will lead to a shift in education back to parents and individuals, and digitally enabled interaction in an environment for an increasing proportion of education (Collins and Halverson 2009) , including such varied subjects as physical education, literacy, math and the sciences (Herrington, J., et al., 2008). While these trends will not build social relationships as well as traditional education, there is great potential for more engagement by students and computer enabled customized education for each student (Collins and Halverson 2009). This research study assumes that small, portable tablet-class devices will accelerate all of these trends.

E-Learning - Defining the Application Environment

E-learning systems can be evaluated in a very wide variety of ways. A common approach to defining major subsets of learning environments is that of classifying virtual learning environments and learning objects (Kurilovas and Dagiene 2009). These terms describe key parts of e-learning systems that are subject to evaluation and analysis in a variety of ways. Overall efficiency and effectiveness are always straightforward criteria. In a more specific level, the evaluations can be performed on the basis of presentation, accuracy, interaction, interoperability, and accessibility (Kurilovas and Dagiene 2009).

Presentation characteristics include system of aesthetics and the broadly defined learning design. Accuracy can be understood in terms of system content and processing. Interaction is understood in terms of usability and the potential for the system to provide feedback to users in ongoing interactions. Interoperability can be evaluated in terms of the ability of the system to work with various existing e-learning and system support platforms and protocols. Accessibility and reusability can be added as additional criteria to allow for an examination of potential system used by a wide variety of users, with varying educational, technical, and geographic limitations (Kurilovas and Dagiene 2009).

Virtual learning environments, a related term, combine digital systems and supporting electronic technology in pursuit of education (Maharg and McKellar 2004). The best designs maintain teaching and learning context independent from the structure of the application and platform (Kurilovas and Dagiene 2009).

E-Learning applications must be based on conceptual models of the world, including those accessed by touch, manipulation, verbal interaction, and the simplest of mathematical reasoning, that are developed over the experience span of the individual, beginning in childhood (Kaplan and Kaplan 1981). The models that are developed in the individual are inherently adaptable in healthy people, especially the young. Nevertheless, the human brain can only adapt to new information and new input over time, and there are inherent limitations on the amount of information that can be held in the mind and active memory at any given time (Kaplan and Kaplan 1981). Some researchers set this limitation at approximately 5 +/- 2 information items in memory at a time. However, this research has been largely focused on pure cognition, with visual and auditory input from seeing the reading and speaking. The simultaneous use of kinesthetic, spatial, and logical mathematical information input and output has been far less explored (Kaplan and Kaplan 1981). This may be particularly evident when experimentation and dynamic interaction is the context of application of the three intelligences, discussed in the following section.

Knowledge transfer in E-learning applications is best accomplished when the presented material has two primary characteristics (Kaplan and Kaplan 1981). First the material should be vivid, using symbols that capture the intention interests of the receiver. Second, information to be transferred should be "concrete so that it can be imagined and visualized. This research focuses on providing both vivid and concrete information via manipulable learning objects. This may be among the best possible approaches for superior knowledge transfer and assimilation. Graphic material that emphasizes visual spatial imagery is emphasized because learners "often use visual and spatial expressions to try to understand abstract concepts" (Kaplan and Kaplan 1981).

Key Learning Models: The Dominant Model of Learning, Tactile Learning and the Key Intelligences Model

Jean Piaget's learning models have been highly influential in education, neuroscience and psychology for several decades. The Piaget learning models are based several key elements that describe how the learner adapts to information from the world. Four of the elements have high relevance to the manipulable object research in this study (Atherton 2011). These include:

- Assimilation - of information from the external world
- Accommodation - in which the brain and mind adapt to, and ideally retain and integrate, information from the external world
- Classification - of learning objects based on common characteristics
- Operation - or "working things out," often through physical, manipulation based methods

Tactile Learning

Tactile learning models, on the other hand, apply an entirely different conceptual frame. Certain younger adults, as well as children, can be identified as tactile learners. Designs of video games and software for learning have historically tended to ignore the tactile learning function and tactile learners, who naturally focus on touch and manipulation for learning experiences (Spina-Caza 2010). Graphical imagery has been stressed, with neglect of the other four human senses, as well as interaction by manipulation. Adding touch-based interaction to visual and text input in a learning environment may actually reduce, rather than increase the overall burden to thought and comprehension (Spina-Caza 2010).

In general, human touch-based perception is a "local sensorial capability" that allows multiple levels of simultaneous, learner controlled learning input (Sestili and Starita 1989). "Tactile augmentation" as a feedback mechanism has been employed to increase the realism and engagement of virtual reality systems (Hoffman 1999). One approach to this function is possible in this research is vibrational feedback built into the surface of the tablet device.

Tactile feedback has a recent history as a source of learning and interaction reinforcement. Tactile modes of feedback can be used to guide manipulation movements, increase "immersion" in a virtual environment (Hoffman 1999). These functions have application the tablet-based system in this study, and in general to enhance and overcome weaknesses in the virtual learning system. Fingers and hands are typical focal areas for tactile and vibrational feedback.

Intelligence Functions Targeted in This Research

Researcher Howard Gardner developed theories of intelligence that transcended the Piaget-based concepts and approaches that had been so thoroughly embraced in educational research during the last 50 years (Gardner and Hatch 1989). Piaget's theories were based in part on experiential assimilation and accommodation by the mind to experiences, with a single method of handling symbolic (semiotic) input as a function of intellectual development. Gardner, on the other hand defined separate functions or processes in intelligence and human learning that dealt with language/linguistic, mathematical/numerical, picture-based, and physical gesture-based symbols in him and mind (Gardner and Hatch 1989). These separate functions have obvious implications for intelligence development. In addition, the separate functions may be particularly well addressed by e-learning systems that can integrate numerical, pictorial, and gesture manipulation learning functions. This research draws strong and broad-based support from the seven intelligences defined by Gardner and his team.

Of the seven intelligences defined by Gardner (Gardner and Hatch 1989), three are of particular importance to this study and provide a basis for understanding some of the mechanisms involved in tablet-based, manipulation focused e-learning systems. These include:

- *Bodily-Kinesthetic Intelligence*- this "intelligence" refers to "the ability to control one's bodily movements and to handle objects skillfully"
- *Spatial Intelligence* - defined as "capacities to perceive the visual spatial world accurately and to perform transformations on one's initial perceptions."

- *Logical mathematical intelligence* – the "Sensitivity to, and the capacity to discern, logical or numerical patterns," in addition to sequential reasoning ability.

CONCLUSION

Given the extraordinary interest in and popularity of iPad educational applications, it is essential to develop a good understanding of their effectiveness. Existing learning theories such as the tactile learning theory suggest that adding touch-based interaction to visual and text input in a learning environment may actually reduce cognitive load. The iPad's tactile features such as gesturing with a double-tap, dragging, pinching or flicking to control the screen are examples of such touch based interaction. It will be interesting to see if the existing tactile learning theories can accommodate for the iPad's digital gesturing.

Our research is will help determine which classical learning principles and theories hold up in the new paradigm of tablet based education. Content analysis and visual analysis will help define essential design elements that contribute to the effectiveness of such apps and will suggest hypotheses to be tested. Experimentation to study these dimension will help lead to more effective technical designs, and the results of our experiments will provide app makers with concrete design guidelines on how to make effective applications for education. Finally, the results will provide a basis for exampling implications for existing e-learning pedagogy and e-learning theory.

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