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How gesture-based technology is used in education to support teaching and learning: A content analysis

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Abstract: This article reviews the 43 research articles of the past decade on gesture-based computing in education. The focus is on the primary question: how is GBC used pedagogically in education? Content analysis is used as primary method. A comparison of instructional intervention (of GBC) in different sub-education domains is reported.

Keywords: Gesture-based computing, gesture-based learning, instructional approach, content analysis

1. Introduction

The applications and developments of gesture-based technology have continued to increase and advance in the field of teaching and learning. Educational researchers are interested in investigating the effect of gesture-based device not only as a mean of natural input device but also the impact and effect it may make on learning in other aspects, such as memory (Chao et al., in press) and physical rehabilitation (Chang, 2011). The present paper is a follow-up to Sheu et al.'s (2013) earlier study in which 45 articles on gesture-based learning published in the years 2001-2012 were analyzed by using content analysis in terms of research method, subject domain, topic of learning content, types of gesture-based computing devices, and the intended settings. In this early descriptive report, experimental design research is the most common method employed (50%) followed by design-based research (30.8%). Nintendo Wii is the most used gesture-based device (44%). The largest percentage of this research is in the domain is in special education (40%). Additional analyses revealed the same trend in the use of Wii is which predominately was deployed in special education (70%). Among all identified learning topics, motor skill learning has the highest percentage (20%). When grouping these topics into three domains of knowledge (procedural, conceptual, and both), the result demonstrates that procedural type knowledge dominates gesture-based learning studies.

This paper takes a deeper look at these selected studies from a pedagogical perspective, addressing the question of how these gesture-based technology/computing devices are used in supporting and/or facilitating learning. We are also interested in how these technologies might be used differently when supporting different kinds of learning outcomes. In order to answer these questions, content analysis is used as primary method.

2. Method

2.1 Data Collection and Analysis

The data analyzed in this study covers research articles published in the years 2001-2012 and retrieved from five academic databases: the Education Resources Information Center Digital Library (ERIC), Educational Research Complete (ERC), Association for Computing Machinery Digital Library (ACM), the Institute of Electrical and Electronics Engineers (IEEE), and SpringerLink. The first two databases are educational. ERIC is considered the largest database in education and ERC collects most journals (1,200 titles) in education. ACM and IEEE contain the largest digital libraries in computing and engineering. However, a high percentage of the collection in these two databases are conference proceedings. In order to cover more journal articles in computer science, SpringerLink, which contains considerable journals in computer science, was added.

Retrieved bibliographic data (approximately 2,430 items) was subsequently filtered manually by the researchers based on the relevance, publication type (academic journal articles) and published year (2001-2012). A total of 43 articles were identified to be relevant to the topic of gesture-based learning and were analyzed in this study. Articles were included as related based on the following two criteria: (1) Empirical Research paper, other types of papers such as "news," "reviews," and "literature reviews," "colloquium," "editorial materials" and "commentary article" were all excluded from the study, and (2) containing a gesture-based learning component, in which the learner's gesture (body) involvement must relate to a target learning content in the learning process. Therefore, the use of gesture-based devices as a means simply for flipping eBooks and mobility of receiving and sending information were excluded. Studies purely focused on the technical efficiency of the device, gaming and robot design were also excluded.

Articles were reviewed to determine: (1) discipline/domain of the study, (2) topic of target learning outcome, (3) technology--gesture-based related devices used in the learning system, and (4) instructional approach/intervention of these gesture-based computing device indented to play.

3. Results and Discussion

3.1 Gesture-Based computing technology in education

The gesture-based computing (GBC) devices used in these articles include Wii, Kinect, robots, haptic tech, smart phone, tablet, multi-touch display, PDA, GPS, and the researchers' own design (a combination of several computing devices, such as barcode, sensor, camera, 3D glasses, etc.). High percentages of cases (more than 80%) used commercial made and ready to use equipment, such as Wii and Kinect. According to these articles, one of the major reasons is affordability. These have a relatively low cost of $130 (for a Kinect Xbox 360 or Wii) compared with other devices, such as interactive whiteboard (price ranges from US $700 to US $2,200). Such cost estimates do not include the price for custom-made alternative devices for persons with special needs that can be very expensive. In addition, they can be applied without computer programming background. In many cases, very little to no modification is required for educators to use it in their curriculum. For similar reasons (affordability, low maintenance), Exergames, using video-games for exercise activities, are popular in schools for promoting physical activities. It is expected to see more and more use of these ready-to-use products in classrooms, particularly in special education and physical education

3.2 How Gesture-Based computing is used in different domains

3.2.1 Special Education (21 studies)

GBC was used for performance support (job aid and assistive technology for daily use), training materials/systems (job training) and physical therapy (rehab).

Among these articles, Shih and his colleagues conducted a series of studies on using Wii and related products to support the learner with both physical and cognitive difficulties to learn daily life skills (motor skills) and specific job tasks (job training), physical rehab, and other behavior skill training. Shih's team also turned Wii into an affordable assistive technology, as a switch that can be operated by people with physical difficulty to handle typical switches. Burke et al. (2010) combined iPhone and other add-on devices as a performance support system that facilitates learning of skill sequences by simplifying complex tasks and providing cues (just-in-time support). Petersson and Brooks (2007) used a robotic device and camera to design an environment that allows children (4-6 years old) to play games as a type of play therapy. GBC, specifically Exergame, is also used in special education for promoting physical activity and for engaging autistic students for social interactions and skills (Hourcade et al, 2012; Porayska-Pomsta et al, 2012)

These studies show that these applications of GBC have a very positive impact on the learning results of the learners with physical difficulties, cognitive difficulties, or both. These findings are especially encouraging given that the cost is relatively lower than customized assistive technology.

3.2.2 *Science & math education (8 studies)*

These articles described the use of GBC to support scientific discovery learning by providing simulations, digital manipulatives, and as a tool as part of larger experiments. Ochoa et al (2011), Pendrill and Rohlen (2011), and Wheeler (2011) used programs they designed specifically for use in physical experiences, to be run on Wii remote and iPhone 4. Abrahamson et al. (2011, 2012) created their own GBC learning system, called MIT, a combination of various technologies, such as screen, program, controller etc. for discovery-based math instruction. Lists of instructional tactics (tutorial tactic) were embedded into discovery learning. Majgaard et al (2011) created digital manipulatives (robotic education tool and number blocks) for learning abstract math concepts. Christodoulou et al. (2008) used haptic technology to create simulations for various science concepts for students to explore as a "metaphor" of feeling associated with the concepts. In general, simulations, digital manipulatives, and tools for experiments were the primary types of instructional interventions reported using GBC in science education.

3.2.3 *General education (7 studies)*

Application of GBC is also found in learning emotions, social behaviors, and in facilitating collaboration. Barakova & Lourens (2010) used a robot in a game for children to learn emotions and social behaviors. Bekker et al (2010) used six designs of interactive play objects for children to interactive play with objects to simulate social interaction and physical play. Another creative application of GBC was to create tangible objectives on learning oral hygiene by Sylla et al. (2012), who created a giant tooth and toothbrush for preschool children to interact with. Through playing, children learn the abstract concepts of germs on teeth and how to clean them.

3.2.4 *Physical Education (3 studies)*

Di Tore et al (2012) used Kinect for a visual-motor game to improve 5th grade students' integration skill. Grieser et al (2012) used Wii Fit with college students for balance training. Vernadakis et al (2012) compared Wii Fit and traditional methods on balance training with colleague students and found that Wii is equally effective as traditional training. While there are other traditional approaches that are equally effective for fitness training, video-game exercise (Exergame) brings additional motivation and fun into the activity. Additionally when using these technologies, exercise and activity, were logged automatically and can be compared and used for further instructional strategies, such as showing accomplishments, friendly completion in games among students, and visualization of each part of exercise.

"Wii therapy" in special education or "Exergame" in physical education are effective for a similar reason, including affordability. Students are familiar with the devices and with minor or no modification, it can be turned into an instructional technology (or assistive technology). As such, no high level programming skills are required to run the system.

3.2.5 *Other fields in education related fields (4 studies)*

Four out of 43 studies were used not in K-12 education system. Kotranza et al (2009) created a simulation with physical fake breast, sensor, virtual reality, and glasses for medical students to learn breast exam procedure training. Aleotti and Caselli (2011) used a data glove, motion tracker, and haptic feedback device to operate and manipulate objects in VR for product assembly and disassembly training. Binder et al. (2004) created a physical interface (tangible objects) for architecture and interaction design students for inspirational learning.

The use of GBC in these three studies was more complicated than the cases we have discussed in previous sections. The scale and complexity of the learning content in the reported learning context in these studies were also higher. The interventions were required to provide proper simulations when going through each stage of complex procedural tasks. By providing safe and lower cost environment (compared to real materials and situations in these fields), learners were allowed to engage learning in complex and higher level skill learning, such as imitation, manipulation, developing precision, articulation, so that these skills became naturalized (Dave, 1967).

4. Conclusion

Overall, there are two major characteristics of gesture-based technology: its kinesthetic aspect and the fact that it is gesture-based. With these characteristics, GBC provides an interface that allows users to interact with computers with body-movement, gestures, voice, and even eye movements. With such features, it expands and enhances all kinds of learning experiences, such as discovering learning, experiential learning, and game-based learning by providing various instructional interventions, such as simulation, digital manipulatives, performance/instructional support (job aid, cuing system, just-in-time information etc.), and tools for experiments (physics experiments). According to these studies reviewed for this paper, these already effective instructional interventions are especially helpful for learners who have physical difficulties using a keyboard and mouse. Similarly, GBC's kinesthetic aspect seems to have higher advantages to enhance psychomotor skills learning in various ways, such as imitation, manipulation, precision development etc.

All reviewed studies show positive impact and learning effect of these gesture-based learning systems. There are advantages of using gesture-based devices in the learning process. Some believe it is related to kinesthetic memory especially in cases involving complex, three-dimensional motor skills (Minogue & Jones, 2006) and embodied interaction that abstract math concepts can be learned through playing manipulatives or tangible objects (Abrahamson et. al., 2011, 2012). However, it is not clear how these kinesthetic-related information processes or embodied cognitions work for improving learning. Related research remains at a primitive stage. Interdisciplinary studies and collaborations cross different fields are required in order to explore the full potential of kinesthetic and gesture-based technology for teaching and learning.

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