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Taking a signal: A review of gesture-based computing research in education

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ABSTRACT

This study used content analysis of journal articles from 2001 to 2013 to explore the characteristics and trends of empirical research on gesture-based computing in education. Among the 3018 articles retrieved from 5 academic databases by a comprehensive search, 59 articles were identified manually and then analyzed. The distribution and trends analyzed were research methods, study disciplines, learning content, technology used, and intended settings of the gesture-based learning systems. Furthermore, instructional interventions were also analyzed based on the learning context or the sub-education domain to which they belonged to ascertain if any instructional intervention was applied in these systems. It was found that experimental design research is the most commonly used method (72.9%) followed by design-based research (20.3%). The findings indicate that Nintendo Wii is the gesture-based device that is the most often used (40%), while the domain in which the technology is most frequently used is special education (42.4%). The same trend was also found in a further analysis which identified that the domain which uses Wii the most is special education (70%). Among all the identified learning topics, motor skills learning has the highest percentage (44%). When grouping these topics into three domains of knowledge (procedural, conceptual, and both), the result demonstrates that both procedural and conceptual type of knowledge are equally distributed in the gesture-based learning studies. Finally, a comparison of instructional intervention of gesture-based learning systems in different sub-education domains is reported.

1. Introduction

As revealed by the Horizon Report (Johnson, Adams, & Cummins, 2012; Johnson, Levine, Smith, & Stone, 2010; Johnson, Smith, Willis, Levine, & Haywood, 2011), gesture-based devices as an emerging technology have opened up new opportunities for learning. The features of gesture-based devices allow the user as a controller to interact with the computer more directly through the use of motions and movements as naturally as in daily life (Johnson et al., 2012), such as by using speech, gestures, body movements, finger flips and even facial expressions and eye movements (Johnson et al., 2012, 2011; Wojciechowski, 2012). For example, DephJS from MIT allows users to interact with the Google Chrome web browser through gestures. Other examples such as the 3Gear System, MudPad, LZI Technology, and ZeroTuch (Johnson et al., 2012) also allow users to interact with computers through gestures and hand movements.

Although initially gesture-based computing received great attention in gaming and in mobile devices, the potential for learning purposes has recently generated enormous interest among educators. The applications and development of gesture-based computing in training and education are continually expanding. Experiments and innovative teaching with these devices have been growing in many areas such as special education, physics, mathematics, physical therapy, arts, music, science, literacy, and social development (see the 2012 Horizon Report for a review). Educational researchers are not only interested in investigating the effects of gesture-based devices as a means of natural input, but also in the impact and effect it may have on other aspects of learning, such as memory (Chao, Huang, Fang, & Chen, 2013) and physical rehabilitation (Chang, Chen, & Huang, 2011). A sampling of exciting projects for the application of gesture-based computing

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includes EyeDraw, EyeMusic (Johnson et al., 2012), Marracle, and KinectEDucation. It is both an emerging technology in practice and a research topic of great interest. Due to its novelty and wide ranging areas of applicability, gesture-based learning is highly intriguing to educators, learning technology specialists, and researchers alike.

However, as indicated in the 2012 Horizon Report (Johnson et al., 2012), researchers and developers are gaining a realization that gesture-based computing within education requires "interdisciplinary collaborations and innovative thinking about the very nature of teaching, learning and communicating." Consequently, an analysis of gesture-based computing in education from a research perspective is essential for acquiring a better understanding of how these goals can be achieved (or advanced) and how the technology can be utilized to support learning. In this present study, the authors have analyzed the research on gesture-based learning published in the period from 2001 to 2013. This project was undertaken to answer the following questions:

(1). What is the status of the gesture-based learning articles published from 2001 to 2012? What was the growth trend of the journal publications on gesture-based learning in this period?
(2). What research methods were used in these studies?
(3). What gesture-based computing technology is utilized in education, specifically for teaching and learning?
(4). What were the primary disciplines of these studies? In addition, what learning topics or content areas were targeted by these gesture-based learning studies?
(5). How were these gesture-based computing devices applied pedagogically? Were there pedagogical differences in different learning domains (knowledge domains)?

2. Methodology

The purpose of this study was to explore and gain an understanding of the characteristics and the trend of studies on gesture-based computing in education with a specific interest in gesture-based learning systems that incorporate involvement of the learners' gestures related to the learning content. Content analysis is a suitable method to achieve this purpose. Content analyses have been conducted in a variety of professional fields for a similar purpose, such as in library and information science (Chang, 2012), psychology (Howard, Cole, & Maxwell, 1987), distance education (Rourke & Szabo, 2002), educational technology (Shih, Feng, & Tsai, 2008), educational psychology, and science education (Tsai & Wen, 2005). These content analysis studies have provided valuable insights into the overall research trends in each area as well as information and characteristics of particular topics. Over time, content analysis has proven to be a highly effective research method.

2.1. Data collection

The data analyzed in this study cover research articles published in academic journals from the years 2001 through 2013. The data were first retrieved individually from these five selected 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 while ERC collects most journals in education (around 1200 titles). ACM and IEEE contain the largest digital libraries in computing and engineering; a high percentage of the collection in these two databases, however, are conference proceedings. In order to include more journal articles in computer science, SpringerLink was added.

One of the challenges in this study was to identify a list of search terms for a comprehensive search. As a new research trend in education, the term "gesture-based computing" is relatively new and is not yet indexed as "controlled vocabulary" in the bibliographical database. There exist many alternative terms, such as gesture-based technology, gesture-based device, motion-sensor technology, etc., as the topic is still evolving. Moreover, gesture-based computing has intricate connections with other relevant technologies, for instance speech and facial recognition, motion sensor technology, robotic technology, haptic (touch or motion-based) feedback, and natural user interfaces, to name a few. As a result, it is necessary to use multiple terms to search databases in order to retrieve as many relevant articles as possible. Table 1 lists the search terms used to obtain the bibliographic records of articles from the databases. The search terms on gesture-based computing and related technology were collected. Additional terms describing the topics on gesture-based learning were also collected. Terms are grouped into three categories: (1) gesture-based computing related terms, (2) the cognition aspect, and (3) specific technology devices.

The database search began in December 2012. A final search was conducted on May 21, 2014 for possible new studies that met the selection criteria. Given the condition that a keyword search (lowest indexing level) was the default search setting for most databases, using a multiple-term search approach, it is expected to retrieve thousands of return hits with much irrelevant data. The retrieved bibliographic data (approximately 3018 items) were subsequently filtered manually by the researchers based on the relevance, publication type (academic journal articles), and published year (2001–2013). Titles and abstracts of the articles were first used for selection. In some cases, complete articles were reviewed to ensure their relevance to the topic of gesture-based learning. A total of 59 articles were identified as being relevant to the topic of gesture-based learning and were analyzed in this study. Articles were included based on the following two criteria:

Table 1
Search terms.

Group	Search terms/Phrases
Group 1	Gesture-based computing; gesture-based learning; gesture-based interaction; gestural-based interface; natural user interface; NUI; embodied interaction; bodily-kinesthetic intelligence; physical interaction; motion-sensor technology; haptic feedback
Group 2	Embodied learning; Embodiment & Cognition, body motion & learning
Group 3	Xbox Kinect; Nintendo Wii; iPad; iPod; iPhone; smartphone; tablet