

Wearable Learning Environments

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INTRODUCTION AND BACKGROUND

Wearable technologies have progressed over the past decade and have the potential to be used effectively in K–12 classrooms (Lee, Drake, & Williamson, 2015). Wearables have been around since the early 1960s (McCann & Bryson, 2009). Thorp and Shannon created a roulette wheel predictor, a wearable that would predict where the ball would land when playing roulette (McCann & Bryson, 2009). The device did not earn the title of the first wearable until 1966 when Thorp published the work

(McCann & Bryson, 2009). Another contributor to wearables was Steve Mann. Mann developed his first wearable system in the early 1980s, and it was composed of a head-mounted camera and a backpack (Mann, 1997; McCann & Bryson, 2009). Over the next 20 years, Mann's (1997) wearable continued to evolve into a less cumbersome device.

In the late 1980s and early 1990s, further progress in the area of wearable technology made smart glasses commercially available (Havard & Podsiad, 2017). After the introduction of the World Wide Web,



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researchers began sharing their wearable computing studies internationally (McCann & Bryson, 2009). The sharing of information enabled technology developers to combine the ideas of multiple wearables to create new technologies. In 1993, Platt and Starner combined smart glasses called the Private Eye and a one-handed keyboard to develop the first context-aware system (Havard & Podsiad, 2017). Throughout the 1990s, researchers developed additional wearables such as the Pathfinder system, which was the first wearable GPS, as well as prototypes for augmented reality systems (Havard & Podsiad, 2017).

In the early 2000s, the Lilypad Arduino was introduced and began as an academic research project (Buechley & Hill, 2010). "The LilyPad Arduino is a system for experimenting with embedded computation that allows users to build their own soft wearables by sewing fabric-mounted microcontroller, sensor and actuator modules together with conductive thread" (Buechley, Eisenberg, Catchen, & Crockett,

2008, p. 424). The Lilypad project was commercialized in collaboration with Sparkfun Electronics and sold as an e-textile construction kit (Buechley & Hill, 2010). Students in K–12 have used the Lilypad Arduino to make a "touch-sensitive shirt; makes silly sounds when touched in certain places and a police hat that makes siren noises when a switch is pressed" (Buechley & Eisenberg, 2008, p. 14). The Lilypad Arduino serves as the electronic component for many wearable devices.

Although advances in wearable technology have progressed significantly over the past few decades, researchers and educators are continually developing wearable devices and finding new ways to incorporate them into the academic curriculum. Currently, the usage of wearable devices occurs in a variety of ways in K–12 education. Educators and researchers across the globe have infused fitness activity trackers in schools to help students achieve instructional goals. Additionally, wearable technologies may be useful in STEM instruction and educational computing, as



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well as a valuable tool to engage students in collaborative learning experiences. Wearable devices are also being used with students to encourage educational gaming and free play. Though there are limitations associated with the use of wearable devices, these technologies have positive implications for teachers and students alike.

WEARABLE FITNESS ACTIVITY TRACKING DEVICES

The introduction of wearables for health-related purposes was not until the 1980s (Price & Rasmussen, 1980). Price and Rasmussen (1980) patented the invention of a wearable heart rate monitor for the wrist that detected and displayed one's pulse rate. The technology has evolved to fitness and activity trackers, smartwatches, and heart-rate monitor chest straps. Wearable technologies are used in K–12 classrooms to engage students in statistics instruction, monitor their physical activity, and motivate them to reach instructional and personal goals.

Wearable activity tracking devices have been used with K–12 students to assist in elementary statistics instruction. Lee, Drake, and Thayne (2016) used Fitbit Ultra and Fitbit One devices during physical education to teach students in Grades 3–8 foundations of statistics and data accuracy. A Fitbit device is a pedometer, or step counter, that uses a “three-axis accelerometer to detect movement” (Lee et al., 2016, p. 357). Steps gathered from the students' activity trackers were used as data to create histograms and provide students with an understanding of variability (Lee et al., 2016). Students created data plots to record trends in activity and used critical thinking skills to analyze differences in individuals' data (Lee et al., 2016). Lee et al. (2015) also used data collected from Fitbit Ultra devices to teach students how to identify measures of central tendency (Lee et al., 2015).

Project GETUP (Gaming to Educate Teens to Understand Personal Health) examined the level of student engagement when tracking one's health using Fitbit One devices (Schaefer, Ching, Breen, & German, 2016). Thirty-four students ages 11 and 12 participated in the study over a 6-month period in an urban middle school afterschool program (Schaefer et al., 2016). Students monitored their weekly activity and synced step data to their personal computer (Schaefer et al., 2016). Schaefer et al. (2016) noted positive changes in physical activity for several students, although some students indicated significant anxiety associated with the wearable technology. Schaefer et al. (2016) also discovered that student engagement declined over time, as students tried to cheat to log more steps. Schaefer et al. (2016) identified several constraints that may have affected the study's outcome. The potential obstacles included limited technology accessibility, design flaws, difficulty using the device, and device loss (Schaefer et al., 2016).

WEARABLE DEVICES AS MOTIVATIONAL TOOLS

Researchers have identified wearable devices as potential motivational tools for K–12 students. Ul Amin, Inayat, and Shazad (2015) analyzed students' interest and motivation to learn with 24 students in the first grade. Ul Amin et al. (2015) programmed smartwatches to contain instructional material such as poems, spelling words, and shapes. The measurement of students' motivation and academic performance were at the end of a 10-week period. Researchers noted that both interest and motivation level increased over the course of the study (ul Amin et al., 2015). According to ul Amin et al. (2015), the “use of the gadget made them excited about their usual course, and they listened to their poems and words, again and again, to memorize them quickly” (p. 3). Additionally, students became motivated to

learn about time, due to their interaction with the smartwatch.

The integration of wearable devices into curriculum may impact students' level of intrinsic and extrinsic motivation. De la Guía, Camacho, Orozco-Barbosa, Luján, Penichet, and Pérez (2016) used smartwatches to examine motivation levels in 15 students while learning a foreign language. Smartwatches were used as a tool in a game to locate, identify, and match recipe ingredients (de la Guía et al., 2016). The game helped students practice common vocabulary words and conversational dialog in English (de la Guía et al., 2016). The smartwatches used Bluetooth technology to link with Internet of Things objects and then project objects onto a visualization board (de la Guía et al., 2016). Video cameras were used to observe students while playing the game and a survey was conducted to help determine students' level of intrinsic and extrinsic motivation (de la Guía et al., 2016). Researchers measured indicators of intrinsic motivation including curiosity, explorer collaboration, challenge, and control (de la Guía et al., 2016). Indicators of extrinsic motivation included points, rewards, competitiveness, and comments from the teacher and classmates (de la Guía et al., 2016). De la Guía et al. (2016) concluded although students exhibited characteristics of both intrinsic and extrinsic motivation, intrinsic motivation factors were more visible.

WEARABLES FOR INSTRUCTIONAL NEEDS

The use of wearable technology to meet instructional goals in the K–12 environment is occurring across the globe. Instructors are incorporating e-textiles and other wearable technology into instruction to improve attitudes and interest in STEM and engineering, as well as educational computing. STEM is the acronym used to “refer to the four separate and distinct fields we know as science, technology,

engineering, and/or mathematics” (Sanders, 2009). The United States encourages an integrated STEM curriculum to engage youth in competitive global professions in the fields of technology and engineering (Breiner, Harkness, Johnson, & Koehler, 2012). Lessons that incorporate the engineering design process allow students to connect content knowledge to real-world applications (Riskowski, Todd, Wee, Dark, & Harbor, 2009). Building and programming wearables also encourage creativity and facilitate cooperative learning among K–12 students (Ngai, Chan, Cheung, & Lau, 2009).

Researchers have investigated the influence of wearable technology on the engineering design process (Barker, Melander, Grandgenett, & Nugent, 2015). Researchers who work on the WearTec project at the University of Nebraska investigated the use of e-textiles with students in fourth through sixth grade (Barker et al., 2015). Students used the engineering design process to build e-textiles and also engaged in computing and circuit building (Barker et al., 2015). According to Barker et al. (2015), intermediate students who participate in wearable technology programs have more positive attitudes toward STEM, including motivation to learn, self-efficacy and learning as a whole (Barker et al., 2015). WearTec researchers also found that the use of e-textiles in instruction has been shown to increase interest and participation among female students because it makes engineering and computing personally relevant to them (Barker et al., 2015). Also, Barker et al. (2015) stated the instructional goals of wearable technology are closely related to the goals of the engineering design process; therefore, making the use of these technologies a natural addition to STEM education.

The WearTec project also examined students' ability to conduct basic educational computing skills (Barker et al., 2015). Researchers in this study required students to identify issues with computing and cir-

cuitry, as well as troubleshoot possible solutions to computing problems (Barker et al., 2015). Students were required to program the device and master coding to ensure the e-textile would operate properly (Barker et al., 2015). Barker et al. (2015) found e-textiles “allow participants to combine computing technology, circuitry and aesthetics to create projects that are personally meaningful” (p. 73).

Researchers created a flexible, durable e-textile called the TeeBoard that allows students to practice basic educational computing skills (Ngai, Chan, Cheung, & Lau, 2010). Ngai et al. (2010) wanted to develop an e-textile where students may make mistakes that are easily correctable and does not require extensive training or expensive tools (Ngai et al., 2010). Ngai et al. (2010) recognized students in the study would have limited knowledge of educational computing, and therefore, chose the Arduino Lilypad platform because of its feasibility of use. Researchers also developed and utilized the programming system called BrickLayer that students used to program sensors, lights, and buzzers on the TeeBoard (Ngai et al., 2010). During the 5-day workshop, middle school students learned “basic programming concepts such as conditionals, loops, and sequential logic” (p. 49). Programming techniques allowed students to use creativity when developing their TeeBoard, as each group added a unique touch to their e-textile (Ngai et al., 2010).

The TeeBoard project also promoted collaborative learning with K–12 students (Ngai et al., 2009). During a 5-day workshop, 25 students ages 11–16 worked in small groups to assemble and program the TeeBoards (Ngai et al., 2009). Researchers observed several students working on different aspects of one garment at the same time, as they recognized the need to work simultaneously with other students to accomplish instructional goals (Ngai et al., 2009). Students also presented the final e-textile product to other class members at

the end of each workshop session (Ngai et al., 2009).

Middle and high school students from different communities collaborated on a wearable project called Engineering Brightness (Fogarty, Winey, Howe, Hancox, & Whyley, 2016). Fogarty et al. (2016) used 3D printers to develop wearable wristwatches with solar-powered lights for children in underdeveloped countries to read at night without electricity (Fogarty et al., 2016). Students from an elementary school in the United Kingdom, a middle school in Colorado and a high school in Canada, worked collaboratively using online conferencing applications, such as Skype (Fogarty et al., 2016). Students shared information about circuits, collaboratively planned and designed the wearable wrist watches, and deepened their understanding of the technology, as well as its philanthropic impacts (Fogarty et al., 2016).

WEARABLES FOR GAMES AND OTHER USES

The incorporation of wearable technology into playtime fosters creativity in young children, encourages physical activity, and allows students to play independently (Rosales, Sayago, & Blat, 2015). Wearable technology has also been piloted in classrooms to assist students with hearing impairments with the use of Google Glass and Quick Response (QR) codes (Parton, 2017).

Wearable technologies serve a valuable purpose for playtime and gaming for young children. The creators of the BeeSim game used e-textile puppets with students ages 7–8 to illustrate how complex systems operate by using honeybees as a participatory simulation (Peppler, Danish, Zaitlen, Glosson, Jacobs, & Phelps, 2010). The first two versions of BeeSim did not use wearable technologies, but instead, focused on the premise of the game (Peppler et al., 2010). The current prototype, BeeSim

Version 3.0, uses LilyPad Arduino as the electronic platform (Peppler et al., 2010). There is a wireless component called the XBee Wireless Module embedded in the students' gloves that allow for seamless communication between the bee puppets and the hive (Peppler et al., 2010). Students used their computational puppets to collect honey and communicate with other students acting as bees, the beehive, and flowers. LED lights situated on the puppet illuminate to notify the student that their computational bee has successfully communicated with other players (Peppler et al., 2010). Students win the game by bringing the most honey to the beehive. However, they also realize the importance of working quickly and communicating with the other bees (Peppler et al., 2010).

Wearable technologies may also be used to facilitate constructionist gaming (Vasudevan, Kafai, & Yang, 2015). Constructionist gaming refers to the process of "making rather than playing your own games for learning" (Vasudevan et al., 2015, para. 1). Vasudevan et al. (2015) analyzed the impact of constructionist gaming on students' level of interest in computing. Researchers facilitated a 4-month-long workshop with 12 middle school students and analyzed students' ability to creatively modify existing games to include wearable controllers (Vasudevan et al., 2015). Students used computational construction to design and create wearable controllers that coincide with the Flappy Birds computer game. Students' wearable controllers were connected to a platform called MaKey MaKey (Vasudevan et al., 2015). MaKey MaKey is an interface that is ideal for beginners and is compatible with almost any software (Silver, Rosenbaum, & Shaw, 2012). Students were encouraged to be creative; therefore, each computational glove looked slightly different and codes varied from student to student (Vasudevan et al., 2015). This workshop provided students with an opportunity to participate in the creation of the controller, as well as the

activity of testing and playing with their final product.

Other technologies, such as Wearable Sounds, Statue and FeetUp, are wearable accessories created for use during free play with young children (Rosales et al., 2015). Rosales et al. (2015) piloted three wearable accessories with 24 students enrolled in an after-school program. Students' interactions were examined during playtime while wearing the computational accessories. The Statue is a game that uses a computable belt pouch to monitor students movement (Rosales et al., 2015). The pouch is equipped with "a Lilypad microprocessor, an accelerometer, LEDs, and a piezo speaker" (Rosales et al., 2015, p. 43). Socks called FeetUp uses pressure sensors, LED lights, and sound to encourage movement, as they only chirp when both feet are off the ground (Rosales et al., 2015). Wearable Sounds, or WS, uses a wearable armband that produces sound when in motion (Rosales et al., 2015). While wearing WS, students may select different sounds to be emitted while they move during playtime (Rosales et al., 2015). These three wearable accessories allow students to express themselves creatively through play, sometimes creating new and alternative games to those suggested by the researchers (Rosales et al., 2015).

The use of wearables may also be as assistive technologies for students with hearing or sight impairments. Students with significant hearing impairments may benefit from the development of Glass Vision 3D, which uses a Google Glass application for assistance in the classroom. For this project, Google Glass was used in conjunction with QR codes, allowing students to scan the codes with glasses, prompting an American Sign Language video to appear via augmented reality (Parton, 2017). Parton (2017) piloted this study with fifth-grade students who have hearing impairments. Students can use gestures to access videos on the glasses, rather than use their voice, because many

students with hearing impairments are not comfortable with verbal language (Parton, 2017). Parton (2017) found students to be capable and excited about using Google Glass technology in the classroom to make their classroom come to life.

LIMITATIONS

Although the use of wearable technology in the K–12 environment yields positive outcomes in many occasions, researchers and educators have also determined that there are significant concerns to address in the future. Researchers noted that using Google Glass for over 1 hour caused the device to overheat. Therefore, the students had to wait until the glasses were cool before further use (Parton, 2017). Classroom teachers stated that, although wearable technologies sparked interest for their students, instruction took significantly longer than other technologies, such as iPads, even though the outcome was similar (Parton, 2017).

Researchers have also acknowledged that not all schools can afford Fitbits or wearable technologies for students (Lee et al., 2016). Schaefer et al. (2016) noted that it was “difficult to obtain all of the necessary technological resources” (p. 13) to sync wearable fitness devices in their urban afterschool program. Researchers discovered the limitations with school firewalls when uploading Fitbit data to the online website (Lee et al., 2015). Additionally, students may have limited access to the Internet at home to sync wearable device data to online locations (Schaefer et al., 2016). It is possible for school technology specialists to set up temporary accessibility to provide students with online access to their Fitbit data to combat this challenge. Other limitations include privacy and ethical concerns, data storage, and data displays (Lee et al., 2015).

As researchers conduct studies in K–12 settings, they have noted small sample size as a significant barrier in generalizing their

findings to a larger population. Barker et al. (2015) stated that because their sample size consisted of only 21 participants in the WearTec study, “the results cannot be generalized to the target population as a whole” (p. 74). These concerns were also echoed by Ngai et al. (2009), who indicated that the sample size of 25 was a limitation of their project. Ngai et al. (2009) stated it is “crucial that it be feasible to run larger-sized workshops” with qualified instructors (p. 56). Additionally, researchers noted that they wished to not only expand their sample size but also with participants of varying age groups. In the Rosales et al. (2015) study, the authors described their desire to test wearable devices with teenagers and adults who they thought “could also benefit from wearables that support their interest in play and social interaction through technology” (p. 47). Regardless of barriers, it is evident that researchers have an overwhelming desire to continue and expand studies of wearable devices for educational purposes.

CONCLUSION AND FUTURE DIRECTIONS

Over time, wearable technologies have continued to advance in both quality and quantity of features offered for consumers, as well as students in K–12 environments (Lindberg, Seo, & Laine, 2016). Researchers and educators alike are creating and presenting wearables that are user-friendly and guide students through basic computing functions (Ngai et al., 2010). With future research, wearables may be easier to incorporate into instruction, allowing both students and teachers the ability to reuse and reprogram interfaces so that they can be modified for other instruction and scaffolded for various concepts in the curriculum (Peppler et al., 2010). Creating wearables such as e-textiles enable students to participate in tactile learning that supports child development and free play (Rosales et al., 2015). Additionally, wear-

able technologies allow students to learn creatively through the use of STEM disciplines and the engineering design process, which encourages success in higher education (Riskowski et al., 2009).

Future studies may consider training educators in wearable technologies and their implementation to discover how wearables can be incorporated into science, technology, engineering, and mathematics curriculum and instruction (Barker et al., 2015). Limited technology access in some communities may present a challenge when integrating wearables into the K–12 environment (Schaefer et al., 2016). Adapting wearables into education would require a smooth transition by incorporating these technologies a little at a time to avoid a backlash if some technologies do not work as effectively as initially anticipated (Borthwick, Anderson, Finsness, & Foulger, 2015).

It is clear through the various studies discussed above that the analysis of data “captured through wearable technologies and the Internet of Things represents an invaluable source of information” for students and instructors alike (de la Guía et al., 2016, p. 377). Since wearable technologies allow students and teachers to monitor their actions while collecting data, they can look at data from a new, more personal perspective (Lee et al., 2015). Instructional time will essentially be saved in the long run due to quick and efficient data collection using wearables, although additional time may be spent initially learning how to operate these devices (Lee et al., 2015). Based on the current research, students in the K–12 environment are not only benefiting from the use of wearable technologies in the classroom, but they are also open to their use in coordination with other learning tools and strategies (ul Amin et al., 2015).

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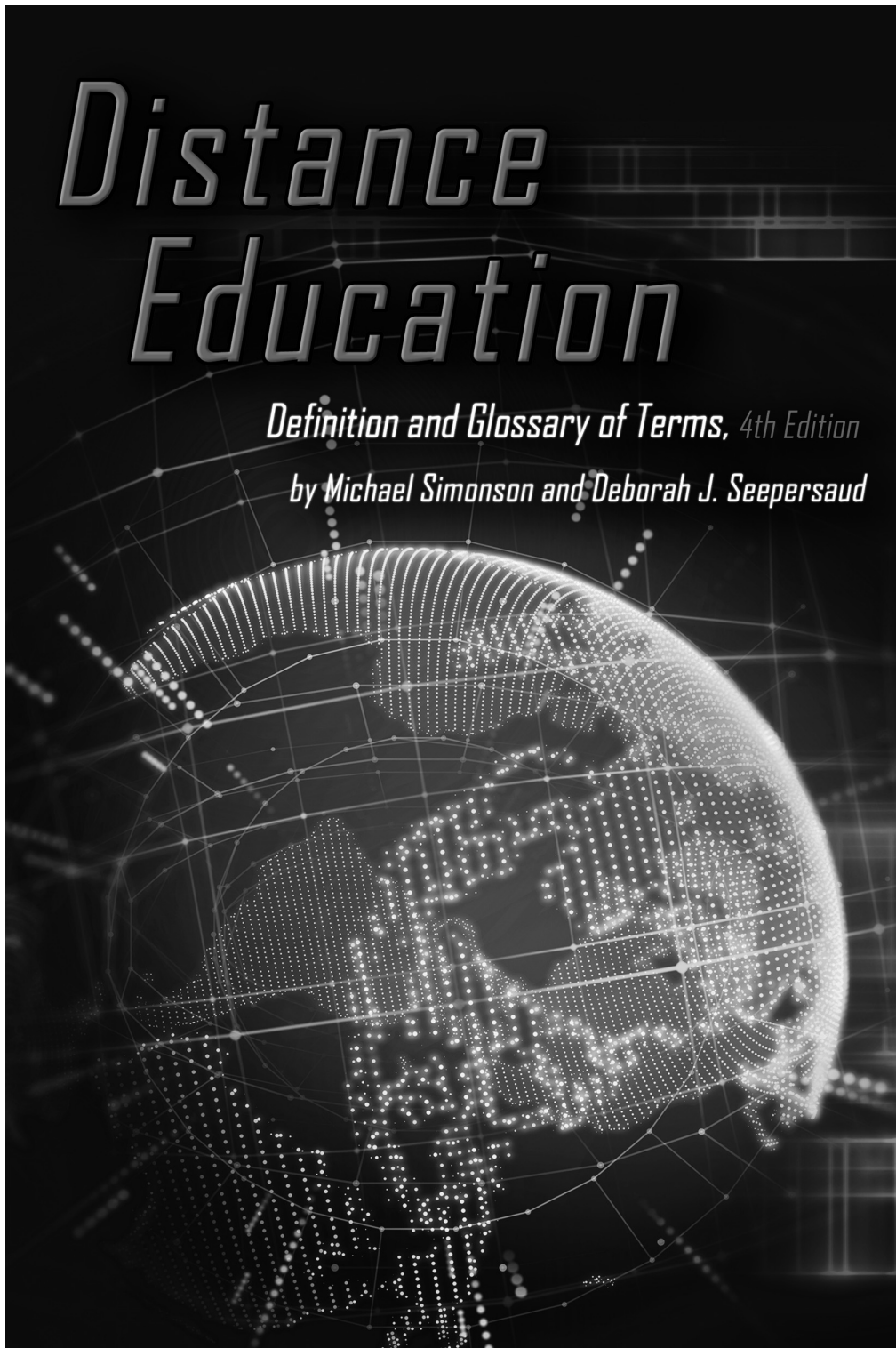
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