Wearable Computers: Past, Present, and Future Possibilities

Byron Havard, Ph.D.
University of West Florida
Instructional, Workforce and Applied Technology
11000 University Pkwy - Bldg 70/107
Pensacola, FL 32514
bhavard@uwf.edu 850-474-2952

Courtney Hyland, M.Ed.
University of West Florida
Instructional, Workforce and Applied Technology
11000 University Pkwy - Bldg 70/110
Pensacola, FL 32514

Megan Podsiad, Ed.S.
University of West Florida
Academic Excellence in Instructional Strategies
11000 University Pkwy - Bldg 85/126
Pensacola, FL 32514

Nancy B. Hastings, Ph.D.
University of West Florida
Instructional, Workforce and Applied Technology
11000 University Pkwy - Bldg 85/123
Pensacola, FL 32514

Key Words/Descriptors: Wearable, K-12

Abstract

Wearable computers include a variety of body-borne sensory, communication, and computational components that may be worn on the body, under, over, or within clothing. These mechanisms have potential benefits for (a) human performance support, (b) cognitive and psychomotor learning, and (c) K-12 educational environments. This manuscript begins with a historical overview of wearable computers and then provides the readers with a current and future perspective of wearable use across a variety of educational environments with specific attention focused on K-12 environments. Examples of current research in wearables is highlighted, followed by limitations and future directions for research.

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). Wearable computers have been around since the early 1960s (McCann & Bryson, 2009). Thorp and Shannon created a roulette wheel predictor, a wearable computer 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 computer until 1966 when Thorp published the work (McCann & Bryson, 2009). Another contributor to wearable computers was Steve Mann. Mann developed his first wearable computer 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 computer 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, researchers began sharing their wearable computing studies internationally (McCann & Bryson, 2009). The sharing of information enabled technology developers to combine the ideas of multiple wearable computers 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 wearable computers 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 of 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, wearable devices are being used 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 have been paired with STEM instruction and educational computing, as well as a 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 to 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. More recently activity tracker wearables have been used in K-12 classrooms for educational purposes besides teaching students about health or fitness.

Statistics Instruction

High school students have used Garmin Forerunner heart rate monitors to practice interpreting visual displays of data, and fifth-grade students have used Fitbit Ultra device data to identify measures of central tendency (Lee et al., 2015). Lee, Drake, and Thayne (2016) chose to utilize Fitbit Ultra and Fitbit One devices during physical education and teach students grades 3-8 elementary statistics. 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). Fitbit is a pedometer, or step counter, that uses a "three-axis accelerometer to detect movement" (Lee et al., 2016, p. 357). The wearables were not used to teach students specifically about physical education but were used to teach students about data accuracy and statistics (Lee et al., 2015).

Project GETUP

Project GETUP (Gaming to Educate Teens to Understand Personal Health) was a study conducted to determine student engagement with tracking his/her health using Fitbit One devices (Schaefer, Ching, Breen, & German, 2016). Schaefer et al. (2016) discovered that student engagement declined over time, tried to cheat to log more steps, and there were several constraints that could have possibly affected the outcome of the data. The potential constraints included limited technology accessibility, design flaws, difficulty using the device, and device loss (Schaefer et al., 2016).

Motivational Tool

At the A. Harry Moore School at New Jersey City University, Fitbits are used to motivate students to move around during the school day (Pepe & Talalai, 2016). A. Harry Moore School is a laboratory school for "students with multiple physical, medical, and cognitive disabilities" (New Jersey City University, n.d., para. 1). The Fitbit serves as an activity tracker and steps counter display that aids in encouraging students to meet daily goals (Pepe & Talalai, 2016).

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. Building and programming wearables encourage creativity and facilitate cooperative learning among K-12 students (Ngai, Chan, Cheung, & Lau, 2009).

Science, Technology, Mathematics, Engineering (STEM) Instruction

Solving real-world problems with the use of the engineering design process is the cornerstone of STEM instruction. Learning through engineering design lessons allow students to connect content knowledge to real-world applications (Riskowski, Todd, Wee, Dark, & Harbor, 2009). Therefore, researchers have attempted to discover the impact of wearable technology and engineering design. WearTec researchers at the University of Nebraska have found evidence that intermediate students who participate in wearable technology programs have increased attitudes towards 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 in female students because it makes engineering and computing personally relevant to them (Barker et al., 2015). In addition, Barker et al. (2015) stated that 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.

Collaborative Learning

Also in line with the engineering design process, the use of wearable technologies promotes collaborative learning with K-12 students (Ngai et al., 2009). Researchers using e-textiles for computing circuit design observed several students working on different aspects of one garment at the same time, recognizing the need to work simultaneously with other students to accomplish their goal (Ngai et al., 2009). Even students attending different schools have the ability to collaborate with to create and produce wearable technologies. Middle and high school students working with the Engineering Brightness project used 3D printers to develop wearable wrist watches with solar-powered lights so children in underdeveloped countries can read at night without electricity (Fogarty, Winey, Howe, Hancox, & Whyley, 2016). Using online conferencing applications, such as Skype, students worked collaboratively to learn necessary information on circuits, plan and design the wearable wrist watches, deepening their understanding of the technology, as well as its philanthropic impacts (Fogarty et al., 2016).

Educational Computing

Wearable technology gives K-12 students an opportunity to master instructional goals, as well as designing and creating projects using educational computing (Barker et al., 2015). Although wearable technology shows promise in the area of educational computing, it comes with some significant challenges that researchers are aiming to improve. Researchers created the TeeBoard in an attempt to utilize e-textiles in a way that allows students to make mistakes that are easily correctable and does not require extensive training or expensive tools (Ngai et al., 2009). The TeeBoard project is just one example of how e-textiles and other wearable technology permeate the K-12 curriculum.

Wearables for Games and Other Uses

Researchers have found that incorporating wearable technology into play time 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.

Gaming and Play

Not only does wearable technology spark interest for young children, it may also serve a valuable purpose when playing games. 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 et al., 2010). Students used their computational puppets to collect honey and communicate with other students acting as bees, the beehive, and flowers. Although students attempt to win the game by bringing the most honey to the beehive, they also realize the importance of working quickly and communicating with the other bees (Peppler et al., 2010).

Researchers facilitated a workshop with middle school students that encouraged them to creatively modify existing games to include wearable controllers (Vasudevan, Kafai, & Yang, 2015). Students used computational construction kids to design and create wearable controllers that coincide with the Flappy Birds computer game. The children that participated in the workshop 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 that were created for use during free play for young children (Rosales et al., 2015). The FeetUp accessories encourage movement, as they only chirp when both feet are off the ground (Rosales et al., 2015). In a similar fashion as those listed above, these 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).

Assistive Technology

Students with significant hearing impairment 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 their glasses which prompts an American Sign Language video to appear via augmented reality (Parton, 2017). Students are also able to gesture 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).

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 one 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 in an effort to combat this challenge. Other limitations included privacy and ethical concerns, data storage, and data displays (Lee et al., 2015).

As researchers conduct studies in K-12 settings, they 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 during 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 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 wearable computers that are user-friendly and guide students through basic computing functions (Ngai, Chan, Cheung, & Lau, 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, wearable 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 Cantero et al., 2016, p. 377). Since wearable technologies allow students and teachers to monitor their actions while collecting data, they have the ability to 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, Inayat, & Shazad, 2015).

References

Barker, B., Melander, J., Grandgenett, N., Nugent, G., Slykhuis, D., & Marks, G. (2015, March). Utilizing wearable technologies as a pathway to STEM. In *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 69-78).

Borthwick, A. C., Anderson, C. L., Finsness, E. S., & Foulger, T. S. (2015). Special article personal wearable technologies in education: Value or villain?. *Journal of Digital Learning in Teacher Education*, *31*(3), 85-92.

Buechley, L., & Eisenberg, M. (2008). The LilyPad Arduino: Toward wearable engineering for everyone. *IEEE Pervasive Computing*, *7*(2), 12-15.

Buechley, L., Eisenberg, M., Catchen, J., & Crockett, A. (2008, April). The LilyPad Arduino: using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 423-432). ACM.

Buechley, L., & Hill, B. M. (2010, August). LilyPad in the wild: how hardware's long tail is supporting new engineering and design communities. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (pp. 199-207). ACM.

de la Guía Cantero, E., Camacho, V. L., Orozco-Barbosa, L., Luján, V. M. B., Penichet, V. M., & Pérez, M. L. (2016). *IEEE Transactions on Learning Technologies*, *9*(4), 366-378.

Fogarty, I., Winey, T., Howe, J., Hancox, G., & Whyley, D. (2016, March). Engineering brightness: Using STEM to brighten hearts and minds. In *Integrated STEM Education Conference (ISEC), 2016 IEEE* (pp. 5-12). IEEE.

Havard, B., & Podsiad, M. (2017). Wearable Computers. In *Handbook of Research on Instructional Systems and Educational Technology* (pp. 356-365). IGI Global.

Lee, V. R., Drake, J. R., & Thayne, J. L. (2016). Appropriating quantified self technologies to support elementary statistical teaching and learning. *IEEE Transactions on Learning Technologies*, *9*(4), 354-365.
Lee, V. R., Drake, J., & Williamson, K. (2015). Let's get physical: K-12 students using wearable devices to obtain and learn about data from physical activities. *TechTrends, 59*(4), 46-53.
Lindberg, R., Seo, J., & Laine, T. H. (2016). Enhancing Physical Education with Exergames and Wearable Technology. *IEEE Transactions on Learning Technologies*, *9*(4), 328-341.
Mann, S. (1997, February). "Smart clothing": Wearable multimedia computing and "personal imaging" to restore the technological balance between people and their environments. In *Proceedings of the fourth ACM international conference on Multimedia* (pp. 163-174). ACM.
McCann, J., & Bryson, D. (Eds.). (2009). *Smart clothes and wearable technology*. Cambridge, UK: Woodhead Publishing.
New Jersey City University (n.d.). *A. Harry Moore School*. Retrieved from http://www.njcu.edu/academics/aharrymoore
Ngai, G., Chan, S. C., Cheung, J. C., & Lau, W. W. (2009). The TeeBoard: an education-friendly construction platform for e-textiles and wearable computing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 249-258). ACM.
Ngai, G., Chan, S. C., Cheung, J. C., & Lau, W. W. (2010). Deploying a wearable computing platform for computing education. *IEEE Transactions on Learning Technologies*, *3*(1), 45-55.
Parton, B. S. (2017). Glass vision 3D: Digital discovery for the deaf. *TechTrends, 61*(2), 141-146.
Pepe, C., & Talalai, S. (2016, October 17). Implementing wearable technology at schools boosts engagement, motivation. *EdTech: Focus on K-12, Spring 2017*. Retrieved from https://edtechmagazine.com/k12/article/2016/10/implementing-wearable-technology-schools-boosts-engagement-motivation
Peppler, K., Danish, J., Zaitlen, B., Glosson, D., Jacobs, A., & Phelps, D. (2010, June). BeeSim: Leveraging wearable computers in participatory simulations with young children. In *Proceedings of the 9th International Conference on Interaction Design and Children* (pp. 246-249). ACM.
Price, E. G., & Rasmussen, L. C. (1980). *U.S. Patent No. 4,195,642*. Washington, DC: U.S. Patent and Trademark Office.
Riskowski, J. L., Todd, C. D., Wee, B., Dark, M., & Harbor, J. (2009). Exploring the effectiveness of an interdisciplinary water resources engineering module in an eighth grade science course. *International journal of engineering education*, *25*(1), 181.
Rosales, A., Sayago, S., & Blat, J. (2015). Beeping socks and chirping arm bands: wearables that foster free play. *Computer*, *48*(6), 41-48
Schaefer, S. E., Ching, C. C., Breen, H., & German, J. B. (2016). Wearing, thinking, and moving: Testing the feasibility of fitness tracking with urban youth. *American Journal of Health Education, 47*(1), 8-16.
ul Amin, R., Inayat, I., & Shazad, B. (2015, April). Wearable learning technology: A smart way to teach elementary school students. In *12th Learning and Technology Conference, 2015. 35752 2015.* (pp. 1-5). IEEE.
Vasudevan, V., Kafai, Y., & Yang, L. (2015). Make, wear, play: remix designs of wearable controllers for scratch games by middle school youth. In *Proceedings of the 14th International Conference on Interaction Design and Children* (pp. 339-342). ACM.