International Journal of Business Excellence

ISSN online: 1756-0055 - ISSN print: 1756-0047
https://www.inderscience.com/ijbex

Developing an integrated framework of application of wearable devices in education

Ramakrishna Yanamandra

DOI: 10.1504/IJBEX.2020.10037904

Article History:

Received:	02 August 2020
Accepted:	31 December 2020
Published online:	10 January 2024

Developing an integrated framework of application of wearable devices in education

Ramakrishna Yanamandra

Skyline University College,
University City, Sharjah, United Arab Emirates
Email: ramakrishna@skylineuniversity.ac.ae

Abstract: The purpose of this paper is to explore the existing knowledge about wearable devices in general and in education sector in particular by highlighting their applications, benefits, motivating factors, barriers for user-adoption process and to develop an integrated framework of application of these devices to achieve positive outcomes in an educational institution. The study develops an integrated framework of wearable devices in education sector through a systematic literature review. This framework will act as a tool for encouraging the adoption and usage of wearable devices in education for enhanced teaching-learning process, reduction of costs and increasing the stakeholder satisfaction. It is found that the management of educational institutions should create awareness, conduct training programs, and develop professional and standard policy, to encourage teachers and students to adopt the wearable devices in their academic activities, teaching-learning, student engagement, interaction, assessment, evaluation and for providing transparent feedback.

Keywords: wearable technology; wearable devices; benefits of wearable devices; wearables; application of wearable technology in education; educational technology; technology-based teaching; COVID-19.

Reference to this paper should be made as follows: Yanamandra, R. (2024) 'Developing an integrated framework of application of wearable devices in education', *Int. J. Business Excellence*, Vol. 32, No. 1, pp.85–104.

Biographical notes: Ramakrishna Yanamandra is an Assistant Professor in Skyline University College, Sharjah, UAE. After serving as the Manager-Operations in a leading public sector organisation in India, he worked as an Assistant Professor in a Management Institution in India and moved to UAE. His areas of research interests include operations and supply chain management, project management, service operations management and lean management. He also conducted many management development programs in these areas.

1 Introduction

Advancements in technology have enabled the emergence and rapid growth of wearable devices (hereinafter referred to as WDs) in many sectors. These devices have the ability to record, analyse, recommend and report health and fitness related data to the users and doctors in healthcare sector (Attallah and Ilagure, 2018; Motti, 2019). In addition to health and sports sectors (Aroganam et al., 2019), these devices are also found to play a

very significant role in education sector (Fesol et al., 2018; Drew, 2020). WDs are found to improve students' interactivity and their engagement in teaching-learning process (Attallah and Ilagure, 2019). However, an in-depth understanding of their applications and outcomes is still at a nascent stage in education sector (Alvarez et al., 2016; Furtado et al., 2020; Chao et al., 2020). Also, the speed of adoption of these devices is little slow in education sector unlike the quick adoption of smart phone devices (Kalantari, 2017). Therefore, there is a need to establish the impact of applications of these devices by developing frameworks to encourage their growth (Sawaya, 2015; Amponsah and Ahmed, 2017). In view of this background, this paper develops an integrated framework of application of WDs in education sector by including diverse aspects which contribute to their implementation. The outcome of this study would be useful to the practitioners and researchers in academics.

It is expected that the growth of WDs market would reach more than 140 billion US dollars by the year 2026 (Hayward et al., 2016). It is also found that more than 20% of internet-connected adults regularly use a WD (Johnson et al., 2016).The technology used by WDs is broadly termed as wearable technology (WT). It is found to reduce cost and improve healthcare efficiency (Zheng et al., 2014; Moreira and Oliveira, 2016). It is defined as a technology embedded into accessories that can be directly worn on the body of a user (Tehrani and Micheal, 2014; Nnaji et al., 2020). Ability of these devices has grown from merely providing the usage data to providing useful recommendations to the patients on a 24/7 basis (Bloss, 2015). In spite of this, the share of global WDs in education sector is very less when compared to other sectors like medical and consumer(Grand View Research, 2018). But, it is found that there is an enormous scope for application of WDs in education sector too (Mukhopadhyay, 2015; Victor et al., 2015; Shadiev et al., 2018; Aroganam et al., 2019). WDs are found to provide a better teaching-learning environment for teachers and students (Sandall, 2016; Fesol et al., 2018; Nnaji et al., 2020), especially in the prevailing COVID-19 pandemic situation (Chao et al., 2020). Majority of WDs found to be suitable for sports and healthcare sector are also found to be suitable for teaching and learning activities. Drew (2020) found that WDs such as smart watches, fitness tracking bands, smart glasses, virtual reality (VR) headsets, and brain sensor head bands have widespread usage in education sector.

In spite of several benefits offered by WDs, the research on application of WDs is found to be confined only to healthcare and sports sectors. There is a need to establish the evidence and enhance the knowledge about the application of WDs to improve teaching-learning process in education sector (Alvarez et al., 2016; Amponsah and Ahmed, 2017).

Although several authors have developed frameworks and models related to the application of WDs, majority of them are found to be confined to healthcare and sports sector only. Moreover, all these frameworks are developed based on only individual aspects like decision-making process, adoptability by the users and technology infrastructure (Drew, 2020). A very few of them are focused on education sector by considering all aspects in an integrated manner. Therefore, this paper attempts to fill this gap by developing an integrated framework towards the application and implementation of WDs in education sector.

Based on the above discussion and literature review, the following research questions are proposed (Segura Anaya et al., 2018; Furtado et al., 2020).

RQ1 What type of WDs does the literature review mention about education sector?

RQ2 What benefits do the WDs provide to students and teachers in education sector?

RQ3 What factors influence the consumer decision-making process to adopt a WD?

RQ4 What are the 'enablers' for achieving the positive outcomes by implementing WDs in education sector?

RQ5 What aspects have to be integrated to achieve these outcomes by implementing WDs in education sector?

The paper is organised as follows: the initial part of the paper conducts a systematic literature review to identify the major types of WDs in health and education sector and motivation for adopting them. This review leads to the identification of gaps in the existing studies. The latter half of the paper develops an integrated framework of application of WDs in education sector. The remainder of paper provides discussion of this framework, findings and conclusions, implications and scope for future research.

2 Literature review

This section of paper focuses on existing research works related to WT, types of WDs, factors impacting their adoption, applicability in education sector and the gaps and weaknesses of those works.

2.1 Wearable technology

WT uses sensors and caters to the needs of broad range of users. Popular applications of these technologies are spread across fitness, self-monitoring of health, sports activities, and providing help to differently enabled and aged people (Bower et al., 2015; Chao et al., 2020). These electronic technologies have become popular as they are embedded in various types of small wearable instruments on different parts of the human body for several monitoring and recording purposes (Tehrani and Michael, 2014; Wintraub et al., 2020). This popularity has also increased the interests of researchers as the scope of these devices has expanded from just providing general benefits to highly specific and customised benefits based on the type of health issue (Zheng et al., 2014). WT has also expanded its scope to many areas in education sector (Tarabasz and Poddar, 2019).

2.2 Wearable devices

Emergence of internet-based technologies has contributed to the growth of studies related to WDs. These studies are related to areas like testing of newly developed devices (Angius and Raffo, 2008), comparison of these devices and clinical trials on humans (Wu and Luo, 2019). Studies also focused on market growth of these devices and projected that WDs market would be highly profitable in future (Park et al., 2015), reaching more than 140 billion US dollars by the year 2026 (Hayward et al., 2016; Park, 2016).

WDs are defined as electronic devices with similar functionality of a computer system which can be worn on the human body easily (Bower et al., 2015; Greiwe and Nyenhuis, 2020). These devices are available in a variety of types and forms and they can evaluate a person's sleeping patterns, emotional feelings, monitor vital health indicators like blood sugar levels, pulse rates, oxygen levels, heartbeat, body temperature, perspiration, calories burnt, etc. (Bloss, 2015, 2016; Segura Anaya et al., 2018). Also,

they have the ability to store, analyse, interpret and recommend data related to all these indicators (Greiwe and Nyenhuis, 2020).

Majority of WDs are connected either to a computer system or a smart mobile phone which works based on internet. These devices have taken many new forms and moved away from only wearing on the wrist to other versions like wearable cameras, smart glasses and devices which can be embedded in garments also (Bloss, 2015). Many companies have entered into this emerging market of WT and WDs to develop various products. For instance, Google glass, Galaxy Gear, Good on, Fit bit, Apple Watch, Geak Watch, and Jawbone, etc. are very popular in the market (Gao et al., 2015).

Modern WDs have the ability to perform many activities performed by doctors in the olden days. This resulted in the reduction of costs (Wu and Luo, 2019), increased the affordability of healthcare services (Sagahyroon et al., 2009; Kim et al., 2014a, 2014b), and eliminated the necessity of a person to perform these activities (Bloss, 2015).

2.3 Types of WDs and their benefits

The scope of WDs got expanded due to their emergence with an ability to customise them based on the type of problem. This section presents several types of WDs and some of the popular brands available in those types. WDs, started as healthcare wearable's in the market were initially perceived by many as useful for fitness and tracking fitness related activities like number of steps, diet and calories burnt, etc. Popular devices such as Jawbone, Fit bit and Kids Guardian are some examples of this category. The other category of WDs are purely related to medical applications, used by elderly people and patients for monitoring diseases like cancer, heart ailments, diabetes, autism, and some other health issues related to old age (Gao et al., 2015).

Patel et al. (2015) classified WDs as devices which are bio-implantable and devices which can be attached to clothes and body. Sensors used in WDs are classified as microcontroller, accelerometers, gyroscopes, magnetometers, global positioning system, heart rate sensors, pedometers, pressure sensors (Aroganam et al., 2019; Chao et al., 2020). Prominent medical applications of WDs include Glaucoma testing by SENSIMED AG and monitoring of an athlete's head injuries and blood clots by a wearable sensor developed by Stanford University (Bloss, 2011, 2012). Integration with wireless technology is one of the major factors in the success of WDs (Kim et al., 2014b; Park, 2016). This integration ranged from the development of a sensor for monitoring stress levels and physical activity to a sensor which has the ability to collect the data of electrocardiogram using Bluetooth (Wu and Luo, 2019).

A broad classification of WDs done by Segura Anaya et al. (2018) is presented in Table 1.

Studies related to the benefits of usage of WDs mention that these devices enhance quality of life, enable healthy lifestyle, reduce costs, reduce time in medical procedures, and improve overall efficiency of healthcare system (Segura Anaya et al., 2018). Many users also found benefits like reduction of obesity, ability to monitor mental status, provision of guidance to cancer survivors, monitoring patients with problems related to heart, pulmonary, diabetes, Parkinson's disease, autism and depression (Bloss, 2015; Wu and Luo, 2019). Their application is found to improve many aspects in education sector too (Attallah and Illagure, 2018, 2019; Fesol et al., 2018).

Table 1 Classification of WDs

Types of WDs	*Health benefits*	*Popular brands*
Life log technology	Provides information by recording audio, video and images of self and other loved ones.	Memo to, ZEO, sense cam
Pervasive technology	Ability to process human affective states and they provide support through real-time situations.	Empathy
Implantable technology	Store medical records and help people with disabilities of hearing and speech.	Cochlear products
BCI technology	A brain computer interface (BCI) monitors activities of brain through signals.	Neural ink products
Augmented reality technology	This technology integrates graphics into real world.	Google glass

Source: Segura Anaya et al. (2018)

2.4 Motivational factors for using WDs

The increasing popularity of WDs prompted various researchers to explore the motivational factors of users for adopting these devices. For instance, perceived compatibility, comparative advantage (Furtado et al., 2020), perceived control, personal innovativeness, perceived cost, perceived ease of use, perceived usefulness, attitude, and intention to use (Park, 2016) are found to be the most significant factors of motivation to use WDs. Quality, advantage, portability, easy availability, suitable appeal and cost are some other factors found to play a significant role in the adoption of WDs (Kim and Shin, 2015). Factors like hedonic motivation, suitability, influence by society, risk due to data security and privacy are found to be the major factors in the adoption of fitness devices. On the other hand, perceived expectancy, ease of use, severity and self-efficacy (Gao et al., 2015), transaction speed, age, ease of use, customisation and service delivery are found to be the major motivating factors in consumers' adoption of WDs in fitness devices (Furtado et al., 2020). Adoption of WDs and smartphones is found to be uniform in both males and females (Sakkthivel and Ramu, 2018).

2.5 Application of WDs in education sector

To be in line with the changing trends in technology in education, higher educational institutions need to continuously identify innovative solutions to improve their current teaching and learning processes (Fesol et al., 2018). Although the utility of WDs is found to be more prevalent in healthcare and sports sector (Chan et al., 2012; Aroganam et al., 2019), its application in education sector is also found to be improving in the recent past, resulting in the growing research interest of educators and researchers (Chao et al., 2020). In spite of this, there are very few recognisable studies in education sector on the adoption and application of WDs by institutions, teachers and students (Ponce et al., 2014; Bartlett-Bragg, 2014; Motti, 2019). Therefore, this research will add immense value to the existing body of knowledge in this aspect.

Usage of WDs is found to increase the level of interaction, self-monitoring ability, skill development and engagement of students in various academic activities (Attallah

and Illagure, 2018, 2019; Fesol et al., 2018) and these devices have the ability to re-design the relationship between teaching and learning (Bartlett-Bragg, 2014; Moreira and Oliveira, 2016). These devices are applied in teaching and learning activities in all fields of education like medical, management, science and technology, geography, history, arts, computers and at all levels of courses (Knight et al., 2015; Sapargaliyev, 2015; Motti, 2019). Educational institutions need to shift their focus from traditional methodologies to smart and innovative methodologies to achieve excellence (Amponsah and Ahmed, 2017) by developing a positive attitude towards the implementation of these technologies (Chawla and Joshi, in press).

Many other benefits of usage of WDs in education are engagement, motivation to students, provision of real-time experience to students, increased collaboration between students and instructors, enhanced creativity of students, creation of flexible learning environment and customised learning styles (Bower et al., 2015; Fesol et al., 2018; Attallah and Illagure, 2019). These devices also offer teachers and students a simple method for self-evaluation using similar concepts to fitness devices and mobile phone applications (Ponce et al., 2014; Goh et al., 2019). Conduct of examinations was found to be easer and the assessments were found to be more transparent using these devices in higher education (Sozudogru and Tuncay, 2019). Application of these devices is also found to improve the education service quality of students in academic institutions and it would become the need of the hour in future in business schools and other higher educational institutions (Al-Haddad et al., 2018). At the same time, these devices would facilitate the improvement of academic working environment, leading to the increasing rate of faculty retention (Gupta and Gomathi, 2018).

Goh et al. (2019) found that WDs in classroom observations are useful as teacher-student aids, to monitor student activities and postures, to analyse movements of students in classroom, to study student relationships and also to analyse students' data. Some of the successful and noted examples of usage of WDs in education are mentioned here. University of South Wales used VR head-mounted displays in engineering (UNSW, 2014), the University of Canberra (Canberra, 2014) and Macquarie University (Macquarie, 2015) have hosted workshops on the use of wearable technologies in education and training, and the University of Western Australia has used Fitbits in their Self eHealth Challenge (Glance et al., 2016). Drew (2020) and Sandall (2016) have found that the five most popularly used WDs in education are smart watches, fitness tracking bands, smart glasses, VR headsets, and brain sensor headbands.

The smart watches are used by teachers and students for applications like in-situ learning, conversion of speech-to-text and text-to-speech, voice recognition and as personal organisers. They are considered as the most precise information displaying devices in education and are found to be very useful to students with disability related to vision or focus (Labus et al., 2015). They also provide an enjoyable living if enjoyable learning is combined with it (Shadiev et al., 2018). The authors found that students were able to complete their tasks very fast. Application of smart watches in education is found to provide wide range of pedagogical opportunities to educators such as recording of information, better communication with the students, provision of timely and instant feedback, and for provision of well-timed and relevant push notifications to reach the students (Bower and Sturman, 2015; Mukhopadhyay, 2015; Dijkstra and Kooy, 2017).

Fitness tracking bands, originally meant for sports and health purpose are used widely in education for the purpose of tracking and comparing different physical exercises done by students and teachers/faculty members. Students can accumulate huge data through

fitness tracking devices and they can identify, analyse and map which of their activities generated the data (Victor et al., 2015; Ertzberger and Martin, 2016).

Smart glasses, most popularly Google glasses, are widely used in education sector and are successfully used to perform a transplantation activity in teaching students of medical education (Knight et al., 2015; Sapargaliyev, 2015; Chao et al., 2020). These devices collect information through sensors and save data from external devices like computer systems by using internet technologies or GPS or a simple Bluetooth facility. These glasses are also found to be highly useful in enhancing the teaching-learning processes and for conducting lab experiments in engineering and science. Google glasses also enable students to watch lectures remotely and observe remotely a surgeon performing a surgery in real-time (Swathi and Lanka, 2015; Kotsios, 2015). These devices are also capable of reminding students about their various academic deadlines, submission of assessments, and automatic attendance systems through facial recognition (Sivakumar, 2014; Sandall, 2016; Motti, 2019).

VR headsets are used to create a VR for students by the teachers while making them to visualise historical wars, natural disasters, volcano eruptions, and earthquakes in subjects like geography, history and astronomy, etc. Usage of VR headsets increased students' understanding and visualisation levels (Drew, 2020).

Similarly, brain sensor headbands such as oculus rift and muse are head mounted displays (HMDs), found to be very useful in focused training and for relaxation of mind (Attallah and Illagure, 2018). Google Expeditions is another VR WD that is used in education. It provides a unique classroom experience by enabling educators to accompany their students on guided virtual field trips (Wylie, 2016). Similarly, 'GoPro' camera is another popular WD which has the ability to record student experiences and provide an analysis of the same to teachers (McNally, 2016; Sandall, 2016; Hyndman, 2017). Hanna et al. (2017) conducted an investigation on the influence of student sitting postures on their health by designing a WD-based system to monitor activities of different students. In another investigation, a study conducted by Choo et al. (2017) analysed the effectiveness of a WD in mother-child communication data and titled it as language environment analysis (LENA). The study concluded that mothers felt improvement in their communication with the child. The above discussion and analysis answers the research questions RQ1, RQ2, RQ3 and RQ4.

The applications and benefits of WT and WDs in education sector have gained more importance during the prevailing COVID-19 pandemic situation. COVID-19 has compelled educational institutions around the world to switch over to online teaching and engagement of students. In spite of challenges, the teachers, students, managements of educational institutions and the governments have successfully conducted online teaching, assessments and evaluations with the help of virtual learning platforms using WDs. More specifically, schools, colleges and universities offering medical, management, arts, and science and technology programs have successfully implemented usage of these technologies. For instance, a chest-mounted smartphone device was used to teach medical students to enhance their clinical skills (Wintraub et al., 2020). In another situation, an electronic WD was used to monitor and sense COVID-19 symptoms in students and citizens (Josephine et al., article in press). One more instance of innovative usage of these technologies was quoted by Chao et al. (2020). The authors developed an interactive virtual surgical rotation device for teaching medical students in University of Pennsylvania.

A summary of literature review with major contributions of authors is summarised in Table 2.

Table 2 Summary of literature review

Author(s)	*Major contribution*
Chan et al. (2012), Tehrani and Michael (2014), Bower and Sturman (2015), Amponsah and Ahmed (2017)	Scope, definition and benefits of WT and devices
Patel et al. (2015), Greiwe and Nyenhuis (2020)	Definition of WDs
Bloss (2015), Tarabasz and Poddar (2019)	Continuous monitoring by WDs
Zheng et al. (2014), Segura Anaya et al. (2018), Fesol et al. (2018)	Cost reduction, efficiency improvement in healthcare
Mukhopadhyay (2015), Victor et al. (2015), Shadiev et al. (2018), Aroganam et al. (2019), Motti (2019), Chao et al. (2020)	Application of WDs in education sector
Bower and Sturman (2015), Sapargaliyev (2015), Ertzberger and Martin (2016), Sandall (2016), Drew (2020)	WDs will improve teaching-learning environment
Alvarez et al. (2016), Amponsah and Ahmed (2017), Fesol et al.(2018)	Influence of WDs on effectiveness in education sector needs to be established
Bloss (2015), Gao (2015), Aroganam et al. (2019), Sakkthivel and Ramu (2018)	Types of WDs and factors influencing their usage and adoption, gender influence in adoption
Park (2016), Fesol et al. (2018), Tarabasz and Poddar (2019), Wu and Luo (2019)	Benefits of WT and WDs
Awolusi et al. (2018), Haghi et al. (2017), Kalantari (2017), Nnaji et al. (2020)	Slow adoption of WDs and barriers to the adoption of WDs
Kim et al. (2014b), Drew (2020)	Smart glasses, smart shirts
Kim et al. (2014b), Wu and Luo (2019)	Wireless intelligent sensor for monitoring users' stress levels
Sagahyroon et al. (2009), Kim et al. (2014a, 2014b), Park (2016)	Integration of wireless and wearable technologies in the healthcare industry
Segura Anaya et al. (2018), Okpala et al. (2019)	Ethical issues in the usage of WDs
Attallah and Illagure (2018), Fesol et al. (2018)	Benefits of usage of WDs in education sector
Ponce et al. (2014), Gohet al. (2019)	Self-evaluation in classroom observations
Labus et al. (2015), Sawaya (2015), Sandall (2016), Moreira and Oliveira (2016), Al-Haddad et al. (2018), Gupta and Gomathi (2018), Sozudogru and Tuncay (2019), Drew (2020), Chawla and Joshi (in press)	WDs in education sector, need for shifting focus by the institutions, improvement in faculty retention
Victor et al. (2015), Ertzberger and Martin (2016)	Fitness tracking bands in education
Bower and Sturman (2015), Labus et al. (2015), Mukhopadhyay (2015), Shadiev et al. (2018), Dijkstra and Kooy (2017)	Smart watches in education

Table 2 Summary of literature review (continued)

Author(s)	*Major contribution*
Sivakumar (2014), Knight et al. (2015), Sapargaliyev (2015), Swathi and Lanka (2015), Kotsios (2015), Sandall (2016), Sozudogru and Tuncay, (2019)	Application of smart glasses and smartphone devices in education
Wylie (2016), McNally (2016), Sandall (2016), Hyndman (2017), Drew (2020)	VR (Google Expedition, accelerometer enhanced gloves, GoPro camera, GPS devices, wearable video cameras
Hanna et al. (2017), Shadiev et al. (2018)	Usage of WDs for reminders
Amponsah and Ahmed (2017) Furtado et al. (2020)	Emphasised the need for developing an integrated framework and in-depth understanding of WDs

2.6 Barriers and limitations to the adoption of WDs

In addition to the multi-folded benefits provided by WDs on one side, studies also found that there are certain challenges and barriers towards the adoption of these devices on the other side. There are very few studies related to education sector in this aspect. Bower and Sturman (2015) found that excessive usage of WDs can negatively influence the users and also they can act as distractors in students' attention towards learning. Small screen size of most of these devices, technical issues, battery life, perceived breach to privacy, no formal policy and standardisation of institutions towards the adoption of WDs and WTs, copying and sharing of information during assessments (Bower and Sturman, 2015; Borthwick et al., 2015; Haghi et al., 2017; Awolusi et al., 2018) are found to be major barriers.

It is also found that lack of interoperability with existing technological infrastructure of the institutions in some cases is one of the barriers (Masum et al., 2013). Moreover, lack of additional brand image due to the adoption of WDs in the institution and lack of interest by many stakeholders are also some other barriers (Nnaji et al., 2020). Ethical protection of privacy is found to be another major barrier for adoption of WDs and it is important to protect ethical usage (Segura Anaya et al., 2018). Educational institutions can overcome many of these barriers by switching over to standardised platforms, by creating awareness about their positive outcomes, by providing training to all stakeholders, by developing a WT culture and by developing policies related to ethics (Segura Anaya et al., 2018; Okpala et al., 2019).

The remainder of this paper focuses on developing an integrated framework of application and implementation of WDs in education sector for achieving positive outcomes. This integrated framework provides the answer for the research question RQ5.

3 Methodology

An in-depth systematic literature review was conducted by collecting and analysing published literature from online databases like Scopus, ScienceDirect, IEEE Xplore and Proquest, since last 20 years following the guidelines of Kitchenham and Charters (2007) Xiao and Watson (2017). These authors defined a systematic literature review as a

'means of identifying, analysing and interpreting all available data relevant to the particular research question (RQ) or topic area, or phenomenon of interest'.

The collected literature was critically analysed to identify types of WDs and their benefits, user adoption process of WDs (Fesol et al., 2018), barriers to their implementation, scope for increasing their adoption, identification of enablers for improving their usage for achieving positive outcomes with a specific focus on education sector. The outcome of this study is development of an integrated framework for WDs in educations sector. The key words used for collecting literature were 'WT', 'WDs', 'benefits of WDs', 'wearable's, 'application of WT in education, 'framework of WDs', 'educational technology', and 'technology-based teaching'.

In the first phase of search, various studies related to WT were identified. In the second phase of search, articles related to the emergence of WDs, their definitions, their applications, types and benefits, barriers for adoption were analysed. In the third phase of search, articles related to types of WDs used in the education sector, scope for improvement, benefits to teachers and students, enablers for increased adoption were analysed. While doing the analysis of published literature, papers which mentioned exclusively about WTs, WDs, their applications in education and other sectors, user adoption process of these devices, factors influencing their adoption, and challenges in this process were considered. Papers which mentioned about technologies other than WTs and WDs, for instance, the desktops, laptops, smart boards and projectors were excluded for the purpose of analysis as these devices do not come under the focused area of this research. Some of the papers focused on teacher-centric benefits while other papers focused on student-centric benefits. Papers also focused on user adoption process and factors influencing their adoption.

Thus, based on this systematic review, six aspects are integrated to develop the framework. These six aspects are types of WDs, teacher and student-centric benefits, factors of their adoption and expected outcomes and the enablers.

4 Development of an integrated framework of WDs

Most of the published frameworks related to WDs have focused on healthcare and sports sectors. Whereas, the frameworks in education sector with specific focus on WDs are very limited. Moreover, studies in education sector have dealt with either one or two individual aspects like WT architecture and user adoption process or focused only on a single aspect like user adoption process. Very few models and frameworks were developed on WDs in education sector by considering all aspects in an integrated manner. Therefore, an integrated framework of WDs which covers all aspects related to these devices in education sector is essential in order to achieve the expected positive outcomes through their usage (Chao et al., 2020; Drew, 2020). This kind of unique framework will add immense value to the stakeholders in education sector.

Some of the current frameworks and models, developed with an exclusive focus on the applications of WDs in education sector are critically analysed in this section by highlighting their weaknesses. Research studies related to applications of WDs in education are scarce and there are lot of options and possibilities in this area for achieving more (Chan et al., 2012; Alvarez et al., 2016). For instance, Fesol et al. (2018) developed a framework for enhancing the learning experience in technical massive open online courses (MOOC) using WT. It considered WT dimension, MOOC design

dimension, self-motivation, and student engagement to achieve the outcome of course retention and course completion. However, this framework did not consider aspects like user adoption process, classification of benefits to teachers and students, and the basic enablers required for achieving positive outcomes. Similarly, the works of Attallah and Illagure (2018) focused on application of WDs in education, but did not develop any framework. In another study, Segura Anaya et al. (2018) developed a comprehensive framework of WDs in health education, but it focused only on ethical issues for protecting privacy of patients. These authors have recommended two enablers for achieving the outcomes of WDs, the first one is 'creation of awareness' and the second one is 'ethical policies'. These two enablers are included for developing the integrated framework in the present study. Similarly in another contribution by Ertzberger and Martin (2016) related to WDs, the teaching-learning process, ability to design customised curriculum, students' engagement and transparent communication were empirically tested. But, no framework on WDs was developed.

Goh et al. (2019) conducted studies related to classroom observations and concluded that WDs have very high potential to customise the teaching-learning process, to conduct several types of classroom observations in an innovative manner, and to observe and analyse students' relationships in groups for measuring their ability to work in teams. This study was also limited to mostly the classroom observations and did not emphasise on technology infrastructure, user adoption process and infrastructure for achieving positive outcomes through WDs. Similarly, a framework was developed by Alvarez et al. (2016) using four dimensions for learning through wearable applications. These four dimensions are context of use, readiness of student, pedagogy, and mode of representation. This framework was developed using three examples from Australian universities. The authors opined that a collaborative approach would facilitate achievement of positive outcomes very fast. This framework also did not focus on many aspects which are considered in the present work.

Therefore, due to the weaknesses of existing frameworks, the integrated framework developed in this paper becomes unique.

The proposed framework is developed by integrating aspects like types of WDs, teacher-centric benefits, and student-centric benefits, factors for adoption of these devices and enablers for smoother implementation in educational institutions.

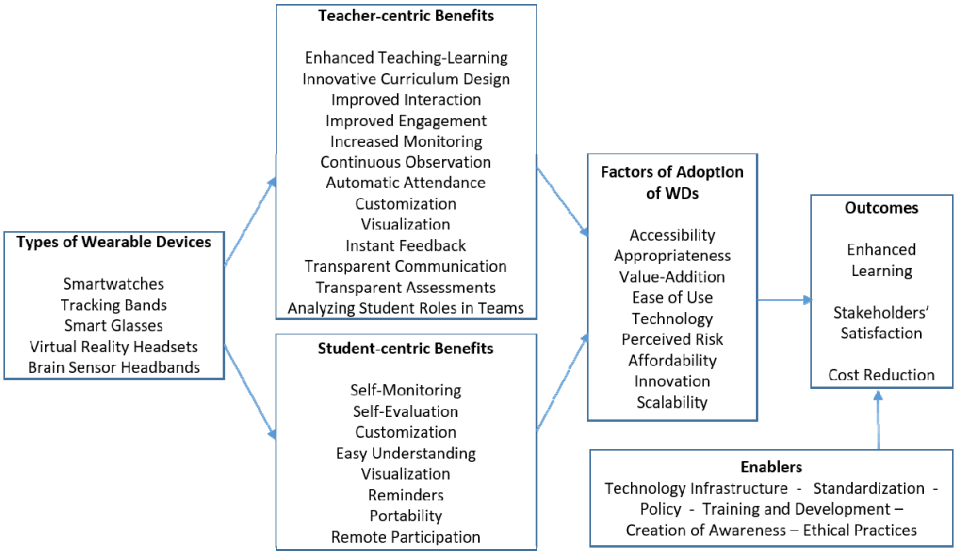
5 Discussion of framework and findings

After a careful and critical analysis of literature review presented in the previous sections, it is found that the scope of utilisation and implementation of WDs is very high in education sector too, similar to health and sports sectors. The author finds lot of similarities between the types of WDs used in other sectors to those which are used in education sector. Similarly, except the nature of their benefits of WDs, it is also found that the factors influencing the user adoption process and benefits are also similar between education and other sectors. Based on the systematic literature review and critical analysis of published works, this study developed an integrated framework of WDs as shown in Figure 1.

In this framework, six aspects related to WDs are considered to achieve the positive outcomes in an educational institution. These are, types of WDs, teacher-centric benefits,

student-centric benefits, factors of adoption of WDs, and enablers. The linkages among these aspects and the integration through the enablers is discussed in this section.

Figure 1 An integrated framework of application of WDs in education (see online version for colours)



The five types of WDs as classified by Drew (2020) in education sector are considered for first aspect of the framework. These devices provide several benefits to an educational institution irrespective of level of education. For the purpose of this research, all categories of higher educational institutions are considered as similar. Also, this framework is not developed specifically to any particular type of educational institute or specifically to any course or program.

The second aspect considered in the framework is benefits due to the adoption and usage of these devices. In the literature, these benefits are dealt in a very general and broad manner, but they are not classified based on type of stakeholder. As the two major stakeholders in any educational institute are teachers and students, the framework is developed considering the benefits to these two stakeholders broadly. The author proposes that there is a thin layer of difference in these benefits between a teacher and a student. The benefits are classified as 'teacher-centric' and 'student-centric'. Although adoption of WDs provide huge benefits to entire system in an educational institute, teachers and students are the main stakeholders as far the teaching-learning process is concerned.

Totally, 13 benefits are proposed to be teacher-centric, based on the research works of several authors. Enhanced teaching-learning (Alvarez et al., 2016; Sapargaliyev, 2015; Ertzberger and Martin, 2016; Sandall, 2016), opportunity to design innovative curriculum (Barlett-Bragg, 2014), improved interaction, improved engagement, increased monitoring, opportunity for continuous observation (Borthwick et al., 2015; Ertzberger and Martin, 2016; Goh et al., 2019), Automatic attendance capturing system (Motti, 2019), possibility of customisation of teaching based on level of students (Bartlett-Bragg, 2014; Ertzberger and Martin, 2016; Aroganam et al.,2019), visualisation (Wylie, 2016;

McNally, 2016; Sandall, 2016; Hyndman, 2017; Drew, 2020) are the first nine teacher-centric benefits.

The remaining four are, instant feedback, transparent communication, transparent and fair assessments, opportunity to analyse the behaviour of students while working in teams (Bartlett-Bragg, 2014; Borthwick et al., 2015; Bower and Sturman, 2015; Mukhopadhyay, 2015; Dijkstra and Kooy, 2017; Segura Anaya, 2018; Shadiev et al., 2018; Goh et al., 2019). Eight benefits are classified as student-centric benefits. These are, self-monitoring, self-evaluation, possibility of customisation, ability to understand easily, visualisation from student's perspective, and receiving reminders and alerts, portability and learning through remote participation(Barlett-Bragg, 2014; Bloss, 2015; Gao et al., 2015; Knight et al., 2015; Park, 2016; Attallah and Illagure, 2018; Shadiev et al., 2018; Aroganam et al., 2019).

Successful implementation and achievement of positive outcomes through WDs depends on identifying the significant factors in the user adoption process of these devices. The framework considered accessibility, appropriateness, value-addition, ease of use, technology, perceived risk, affordability, innovation as the most significant factors influencing the adoption process of WDs by users based on the works of Gao et al. (2015), Kim and Shin (2015) and Park (2016). These factors are considered both by teachers, students and also by the other users like patients, sports persons and many others who all intend to use the WDs. The factor 'scalability' has been included in the present study by the author, as it is considered to be a very important factor for upgrading the software in the WD from time to time to increase the lifetime and utility of the device.

Implementation of WT and usage of WDs in education sector will achieve broadly three objectives, enhanced learning, stakeholders' satisfaction and reduction of cost (Knight et al., 2015; Park et al., 2015; Victor et al., 2015; Segura Anaya et al., 2018; Goh et al., 2019). These objectives are achieved through the integration of appropriate types of devices, by understanding and matching the benefits for teachers and students, and by understanding their adoption process using 'enablers' to set a right a path.

The author proposes six enablers to achieve the objectives of adopting the WDs in an education institution. These six are, technology infrastructure (Masum et al., 2013; Bower et al., 2015; Attallah, 2018; Fesol et al., 2018), standardisation, policy towards implementation of WD (Bower and Sturman, 2015), training and development and creation of awareness (Okpala et al., 2019), ethical practices and protection of rights of users (Segura Anaya et al., 2018). These six enablers are discussed here.

Educational institutions need to develop appropriate technological infrastructure to promote and encourage the adoption and usage of WDs by teachers and students. This needs achievement of standardisation in terms of their implementation in course curriculum, pedagogy, assessments, evaluation and feedback. A comprehensive policy of institution towards WDs will motivate teachers to use them in the teaching-learning process for providing enhanced learning to the students. This policy may contain aspects like providing incentives to encourage teachers for using WDs and allotment of some percentage as a mandatory component in the assessments conducted through WDs. At the same time, adequate training should be provided to teachers, students and other supporting employees of the institution for better usage of WDs. During these training programs, an awareness session about the benefits of using these devices should be conducted to enable increased adoption of WDs.

Finally, implementation of any technology has its own drawbacks. One of the major drawbacks of using WDs in education sector is found to be lack of ethical policies to

protect the privacy, data security and rights of users in education environment (Segura Anaya et al., 2018). Adoption of ethical practices through an ethical policy will provide data security to the users and it will act as a 'major enabler' in achieving the expected outcomes using WDs. Implementation of this integrated framework of WDs would strengthen the teaching-learning process in educational institutions as it considers many diverse aspects as mentioned in the previous sections. This framework enables the educational institutes to identify an appropriate type of WDs for improving teaching-learning process and also to identify the type of benefit associated with it. It also enables the institutes to understand how the process of user-adoption can be encouraged by identifying the enablers. A meticulous implementation of the framework would guide the institutions to develop a path towards achieving effective teaching-learning process by using the WDs. By reducing the costs related to the maintenance of documentation in the form of hardcopies, the academic institutions can divert their funds towards WDs, enabling cost-effective implementation of these devices. Moreover, WDs also enable the reduction of human and paper-based activities, resulting in cost reduction. 'Enablers' mentioned in the framework play an important role in the implementation of WDs and they also act as supporting tools (for instance, technology infrastructure, training and development) in the effective utilisation of WDs in academic institutions.

6 Conclusions

It is concluded that emergence of wearable technologies and WDs will bring sweeping changes in the way educational institutions operate in future. There is no exaggeration in saying that the current traditional methodologies of teaching-learning in education will no longer be effective if the full potential of WDs is utilised. Content-based teaching will get replaced by device-oriented teaching through which the student engagement and learning will happen (Bartlett-Bragg, 2014; Nnaji et al., 2020).

It is also concluded that in order to achieve expected outcomes through WDs, it is essential to identify suitable types of WDs depending on level of study, nature of education program, level of students, and need. A critical analysis of perceived benefits of using WDs will enable identification of purpose and objectives of their usage. In order to do this analysis, an understanding of factors influencing user adoption process of WDs is required as depicted in the integrated framework.

Educational institutions should implement 'enablers' by setting standard policies towards WDs and by protecting the privacy rights of all users of these devices in the education environment. At the same time, it is important to motivate the users through training and awareness programs to increase the adoption level of these devices. Therefore, it is concluded that an integrated framework which considers all the aspects mentioned above will provide a direction to educational institutions towards successful adoption and usage of WDs. Thus, the integrated framework developed in this paper becomes the unique contribution of this research as this kind of framework has not been developed by considering many aspects to achieve positive outcomes in education sector.

7 Implications of the study

Findings of this study provide two major implications, one from the theoretical perspective to researchers and the other from a practical perspective to the major stakeholders in educational sector. The study attempted to fill the gaps in the existing works related to WDs in education sector and expanded the theoretical knowledge by introducing the concept of 'enablers' and by classifying the benefits as teacher-centric and student-centric to arrive at an integrated framework.

On the other hand, from a practical perspective, the educational institutions can achieve positive outcomes through a careful and systematic implementation of this framework in their processes using WDs. Implementation of this framework provides reduction in the cost of operations of an educational institution. At the same time, this integrated framework will also enable the achievement of enhanced learning which results in improved satisfaction of stakeholders.

8 Scope for future research

There is lot of scope for future research in this area as this industry of WDs itself is in the nascent stage of its growth. This study is purely based on theoretical perspective and it can be expanded by validating the proposed integrated framework through an empirical investigation among different educational institutions.

Moreover, this study is not specific to any particular level or a program, for instance, medical, management, arts, science, etc. Future works can be conducted by focusing on specific programs and levels of students. Benefits of application of WDs and the user adoption process may differ depending on the nature and level of program offered by the institute. The perception of stakeholders about WDs may vary in an institute which offers medical education with that of another institute which offers management education. Therefore, program-specific and education level-specific research will be of greater interest and value in future.

Also, the findings of this study may not be generalised to other sectors as the study is focused on education sector only. Developing policies to protect ethical issues while using WDs in educational sector would also be an important future research topic.

References

Al-Haddad, S., Taleb, R.A. and Badran, S. (2018) 'The impact of the education services quality on students satisfaction: an empirical study at the business schools in Jordan', *International Journal of Business Excellence*, Vol. 14, No. 3, pp.393–413.

Alvarez, V., Bower, M., De Freitas, S., Gregory, S. and De Wit, B. (2016) 'The use of wearable technologies in Australian universities: examples from environmental science, cognitive and brain sciences and teacher training', in Dyson, L.E., Ng, W. and Fergusson, J. (Eds.): *Mobile Learning Futures – Sustaining Quality Research and Practice in Mobile Learning*, pp.25–32, University of Technology, Sydney.

Amponsah, C.T. and Ahmed, G. (2017) 'New global dimensions of business excellence', *International Journal of Business Excellence*, Vol. 13, No. 1, pp.60–78.

Angius, G. and Raffo, L (2008) 'A sleep apnoea keeper in a wearable device for continuous detection and screening during daily life', *Computers in Cardiology*, Vol. 35, pp.433–436.

Aroganam, G., Manivannan, N. and Harrison, D. (2019) 'Review on wearable technology sensors used in consumer sport applications', *Sensors*, Vol. 19, pp.1–26, DOI: 10.3390/s19091983.

Attallah, B. and Ilagure, Z (2019) 'Evaluating the affordances of wearable technology in education', *International Journal of Grid and Utility Computing*, Vol. 10, No. 1, pp.22–28.

Attallah, B. and Ilagure, Z. (2018) 'Wearable technology: facilitating or complexing education?', *International Journal of Information and Education Technology*, Vol. 8, No. 6, pp.433–436, DOI: 10.18178/ijiet.2018.8.6.1077.

Awolusi, I., Marks, E. and Hallowell, M. (2018) 'Wearable technology for personalized construction safety monitoring and trending: review of applicable devices', *Automation in Construction*, Vol. 85, pp.96–106, https://doi.org/10.1016/j.autcon.2017.10.010.

Bartlett-Bragg, A. (2014) 'Wearable technologies: shaping the future of learning', *Training & Development*, Vol. 41, No. 3, p.13.

Bloss, R. (2011) 'Electronic sensor 'in your eye' helps in treating glaucoma', *Sensor Review*, Vol. 31, No. 3, pp.293–294.

Bloss, R. (2012) 'Mouth sensor helps researchers track concussions', *Sensor Review*, Vol. 32, No. 3, pp.199–202.

Bloss, R. (2015) 'Wearable sensors bring new benefits to continuous medical monitoring, real time physical activity assessment, baby monitoring and industrial applications', *Sensor Review*, Vol. 35, No. 2, pp.141–145.

Bloss, R. (2016) 'Embedded medical sensors, an emerging technology to monitor hearts, brains, nerves and addressing other medical applications for improved patient care', *Sensor Review*, Vol. 36, No. 2, pp.115–119.

Borthwick, A.C., Anderson, C.L., Finsness, E.S. and Foulger, T.S. (2015) 'Special article personal wearable technologies in education: value or villain?', *Journal of Digital Learning in Teacher Education*, Vol. 31, No. 3, pp.85–92.

Bower, M. and Sturman, D. (2015) 'What are the educational affordances of wearable technologies?', *Computers & Education*, Vol. 88, pp.343–353, https://doi.org/10.1016/j.compedu.2015.07.013.

Bower, M., Sturman, D. and Alvarez, V. (2015) 'Perceived utility and feasibility of wearable technologies in higher education', in *Proc. 15th World Conference on Mobile and Contextual Learning*, mLearn, Sydney.

Canberra (2014) 'UC workshop: using Google glass in class' [online] http://www.canberra.edu.au/aboutuc/media/monitor/2014/may/9-google-glass (accessed 8 July 2020).

Chan, M., Estève, D., Fourniols, J.Y., Escriba, C. and Campo, E. (2012) 'Smart wearable systems: current status and future challenges', *Artificial Intelligence in Medicine*, Vol. 56, No. 3, pp.137–156.

Chao, T., Frost, A.S., Brody, R.M., Byrnes, Y.M., Cannady, S.B., Luu, N.N., Rajasekaran, K., Shanti, R.M., Silberthau, K.R., Triantafillou, V. and Newman, J.G. (2020) 'Creation of an interactive virtual surgical rotation for undergraduate medical education during the COVID-19 pandemic', *Journal of Surgical Education*, Vol. S1931-7204, No. 20, pp.30232–30234, DOI: 10.1016/j.jsurg.2020.06.039.

Chawla, D. and Joshi, H. (in press) 'Attitude as a mediator between antecedents of mobile banking adoption and user intention', *International Journal of Business Excellence.*

Choo, D., Dettman, S., Dowell, R. and Cowan, R. (2017) 'Talking to toddlers: drawing on mothers' perceptions of using wearable and mobile technology in the home', *Integrating and Connecting Care*, Vol. 239, pp.21–27, https://doi.org/10.3233/978-1-61499-783-2-21.

Dijkstra, A. and Kooy, E. (2017) 'The learning model of smart phone feedback applications in the field of e-health applied to the step counter', in Orji, R., Reisinger, M., Busch, M., Dijkstra, A., Kaptein, M. and Mattheiss, E. (Eds.): *Proceedings of the Personalization in Persuasive Technology Workshop, Persuasive Technology, CEUR Workshop Proceedings*, Amsterdam, The Netherlands, pp.45–49.

Drew, C. (2020) 'Wearable technologies for education | 5 examples' [online] https://helpfulprofessor.com/wearable-technology-for-education-examples-benefits-limitations/#1_Smart_Watches (accessed 2 July 2020).

Ertzberger, J. and Martin, F. (2016) 'Use of fitness bands by teachers in the classroom', *Tech. Trends*, Vol. 60, pp.392–397, DOI 10.1007/s11528-016-0079-7.

Fesol, S.F.A, Salam, S. and Bakar, N. (2018) 'Framework for enhancing learning experience with wearable technology in technical MOOC', *Journal of Telecommunication, Electronic and Computer Engineering*, Vol. 10, No. 2, pp.83–91, e-ISSN: 2289-8131.

Furtado, N.G., Furtado, J.V., Vieira, L.C. and Da Silva, R.C. (2020) 'The influence of technology payment adoption in satisfaction: a study with restaurant customers', *International Journal of Business Excellence*, Vol. 21, No. 2, pp.209–230, DOI: 10.1504/IJBEX.2020.107580.

Gao, Y., Li, H. and Luo, Y. (2015) 'An empirical study of wearable technology acceptance in healthcare', *Industrial Management & Data Systems*, Vol. 115, No. 9, pp.1704–1723, DOI: 10.1108/IMDS-03-2015-0087.

Glance, D.G., Ooi, E., Berman, Y.E., Glance, C.F. and Barrett, H.R. (2016) 'Impact of a digital activity tracker-based workplace activity program on health and wellbeing', in *Proceedings of the 6th International Conference on Digital Health Conference*, Montreal, Vols. 11–13, pp.37–41.

Goh, F., Carroll, A. and Gillies, R.M. (2019) 'A review of the use of portable technologies as observational aids in the classroom', *Information and Learning Sciences*, Vol. 120, Nos. 3/4, pp.228–241.

Grand View Research (2018) 'Wearable sensors market size, share and trends analysis report by sensor type, by device (smart watch, fitness band, smart glasses, smart fabric), by vertical, by region, and segment forecast 2018–2025' [online] https://www.grandviewresearch.com/industry-analysis/global-wearable-sensor-market (accessed 22 June 2020).

Greiwe, J. and Nyenhuis, S.M. (2020) 'Wearable technology and how this can be implemented into clinical practice', *Current Allergy and Asthma Reports*, Vol. 20, No. 8, p.36, DOI: 10.1007/s11882-020-00927-3.

Gupta, A. and Gomathi, S. (2018) 'Influence of human resource practices on faculty's intention to stay in higher education management institutes', *International Journal of Business Excellence*, Vol. 15, No. 2, pp.256–268, DOI: 10.1504/IJBEX.2018.091915.

Haghi, M., Thurow, K. and Habil, I. et al. (2017) 'WDs in medical internet of things: scientific research and commercially available devices', *Healthcare Informatics Research*, Vol. 23, No. 1, pp.4–15.

Hanna, F.A., Jacobs, K. and McLoone, H. (2017) 'The effect of a wearable device prompting high school students aged 17–18 years to break up periods of prolonged sitting in class', Vol. 56, No. 3, pp.475–482, DOI: 10.3233/WOR-172513https://content.iospress.com/articles/work/wor2513.

Hayward, J., Chansin, G. and Zervos, H. (2016) 'Wearable technology 2016–2026 markets players and 10-year forecasts', *ID Tech Ex Research* [online] https://www.idtechex.com/research/reports/wearable-technology-2018-2028-markets-players- forecasts-000606.asp (accessed 22 June 2020).

Hyndman, B.P. (2017) 'A simulation pedagogical approach to engaging generalist pre-service teachers in physical education online: the go pro trial 1.0', *Australian Journal of Teacher Education*, Vol. 42, No. 1, pp.84–102.

Johnson, L, Becker, S.A., Cummins, M., Estrada, V., Freeman A. and Hall, C. (2016) 'NMC horizon report', *Higher Education Edition*, The New Media Consortium, Austin, Texas.

Josephine, M.S., Lakshmanan, L., Resmi, R., Nair, V.P., Ganesan, R. and Jothikumar, R. (article in press) 'Monitoring and sensing COVID – 19 symptoms as a precaution using electronic wearable devices', *International Journal of Pervasive Computing and Communications*.

Kalantari M. (2017) 'Consumers' adoption of wearable technologies: literature review, synthesis, and future research agenda', *International Journal of Technology Marketing*, Vol. 12, No. 3, pp.274–307.

Kim, H., Park, E., Kwon, S.J., Ohm, J.Y. and Chang, H.J. (2014a) 'An integrated adoption model of solar energy technologies in South Korea', *Renewable Energy*, Vol. 66, pp.523–531, https://doi.org/10.1016/j.renene.2013.12.022.

Kim, J., Lee, B., Jung, S. and Chung, W. (2014b)'Intelligent mobile healthcare by wearable health shirt with wireless sensors', *Sensor Letters*, Vol. 12, No. 6, pp.1034–1037.

Kim, K.J. and Shin, D. (2015) 'An acceptance model for smart watches: implications for the adoption of future wearable technology', *Internet Research*, Vol. 25, No. 4, pp.527–541.

Kitchenham, B. and Charters, S. (2007) 'Guidelines for performing systematic literature reviews in software engineering.', in *EBSE Technical Report, Software Engineering Group, School of Computer Science and Mathematics*, Keele University, Department of Computer Science, University of Durham.

Knight, H.M., Gajendragadkar, P.R. and Bokhari, A. (2015) *Wearable Technology: Using Google Glass as a Teaching Tool*, Case Reports, bcr2014208768, http://dx.doi.org/10.1136/bcr-2014-208768.

Kotsios, A. (2015) 'Privacy in an augmented reality', *International Journal of Law and Information Technology*, Vol. 23, No. 2, pp.157–185.

Labus, A., Milutinović M., Stepanić, D., Stevanović, M. and Milinović, S. (2015) 'Wearable computing in e-education', *Journal of Universal Excellence*, Vol. 1, No. 1, pp.39–51.

Macquarie (2015) 'Wearable technologies place in education' [online] http://teche.ltc.mq.edu.au/wearable-technologiesplace-education/ (accessed 8 July 2020).

Masum, H., Lackman, R. and Bartleson, K. (2013) 'Developing global health technology standards: what can other industries teach us?', *Globalization and Health*. Vol. 9, No. 49, DOI: 10.1186/1744-8603-9-49.

McNally, J.C. (2016) 'Learning from one's own teaching: new science teachers analyzing their practice through classroom observation cycles', *Journal of Research in Science Teaching*, Vol. 53, No. 3, pp.473–501.

Moreira F. and Oliveira, L. (2016) 'Wearable devices in education: trends and challenges', in proceedings of *The 10th annual International Technology, Education and Development Conference (INTED2016)*, Valencia, Spain, 7–8 March.

Motti V.G. (2019) 'Wearable technologies in education: a design space', in Zaphiris P. and Ioannou, A. (Eds.): *Learning and Collaboration Technologies. Ubiquitous and Virtual Environments for Learning and Collaboration, HCII 2019. Lecture Notes in Computer Science*, Vol. 11591, Springer, Cham, https://doi.org/10.1007/978-3-030-21817-1_5.

Mukhopadhyay, S.C. (2015) 'Wearable sensors for human activity monitoring: a review', *IEEE Sensors Journal*, Vol. 15, No. 3, pp.1321–1330.

Nnaji, C., Okpala, I. and Awolusi, I. (2020) 'Wearable sensing devices: potential impact and current use for incident prevention', *American Society of Safety Engineers, Professional Safety*, Vol. 65, No. 4, pp.1–9.

Okpala, I., Nnaji, C. and Awolusi, I. (2019) 'Emerging construction technologies: state of standard and regulation implementation', in Cho, Y.K., Leite, F. and Behzadan, A. et al. (Eds.): *Computing in Civil Engineering 2019: Data, Sensing and Analytics*, pp.153–161, American Society of Civil Engineers, Reston, VA.

Park, D., Choi, J. and Kim, D. (2015) 'The influence of health apps efficacy, satisfaction and continued use intention on wearable device adoption: a convergence perspective', *Journal of Digital Convergence*, Vol.13, No. 7, pp.137–145.

Park, E. (2016) 'Understanding the emergence of WDs as next-generation tools for health communication', *Information Technology and People*, Vol. 29, No. 4, pp.818–732.

Patel, M.R., Dalvi, S.I., Kuzhiyil, X. and Tashakkor, E.V. (2015) 'Wearable electronic device and method for securing same', Patent No. US9747433B2.

Ponce, B.A., Menendez, M.E., Oladeji, L.O., Fryberger, C.T. and Dantuluri, P.K. (2014) 'Emerging technology in surgical education: combining real-time augmented reality and wearable computing devices', *Orthopedics*, Vol. 37, No. 11, pp.751–757.

Sagahyroon, A., Raddy, H., Ghazy, A. and Suleman, U. (2009) 'Design and implementation of a wearable healthcare monitoring system', *International Journal of Electronic Healthcare*, Vol. 5, No. 1, pp.68–86.

Sakkthivel, A.M. and Ramu, N. (2018) 'Investigating the gender influence on technology adoption model towards smart phones-evidences from emerging economies', *International Journal of Business Excellence*, Vol. 16, No. 1, pp.35–46.

Sandall, B.K. (2016) 'Wearable technology and schools: Where are we and where do we go from here?', *Journal of Curriculum Teaching, Learning and Leadership in Education*, Vol. 1, No. 1, pp.74–83.

Sapargaliyev, D. (2015) 'Wearable technology in education: from handheld to hands-free learning', in Li, K.C., Wong, T.L., Cheung, S.K.S., Lam, J. and Ng, K.K. (Eds.): 'Technology in education. Transforming educational practices with technology', *Communications in Computer and Information Science*, Vol. 494, Springer, Berlin, Heidelberg, https://doi.org/10.1007/978-3-662-46158-7_6.

Sawaya, S. (2015) 'Wearable devices in education', in Redmond, P., Lock, J. and Danaher, P.A. (Eds.): *Educational Innovations and Contemporary Technologies*, Palgrave Macmillan, London, https://doi.org/10.1057/9781137468611_3.

Segura Anaya, L.H., Alsadoon, A., Costadopoulos, N. and Prasad, P.W.C. (2018) 'Ethical implications of user perceptions of WDs', *Science and Engineering Ethics*, Vol. 24, pp.1–28, https://doi.org/10.1007/s11948-017-9872-8.

Shadiev, R., Hwang, W.Y. and Liu, T.Y. (2018) 'A study of the use of WDs for healthy and enjoyable English as a foreign language learning in authentic contexts', *Educational Technology & Society*, Vol. 21, No. 4, pp.217–231.

Sivakumar, R. (2014) 'Google glass in education', *Conflux Journal of Education*, Vol. 2, No. 2, pp.27–30.

Sozudogru, O. and Tuncay, N. (2019) 'Using wearable devices in educational assessment: smartphone exams', in Nasiri, N. (Ed.): *Wearable Devices – The Big Wave of Innovation 2019*, pp.1–14, DOI: 10.5772/intechopen.84324.

Swathi, T.N. and Lanka, S. (2015) 'Wearable technology a new paradigm in educational universities', *International Journal on Computer Science and Engineering (IJCSE)*, Vol. 7, No. 4, pp.48–52.

Tarabasz, A. and Poddar, G. (2019) 'Factors influencing adoption of WDs in Dubai', *Journal of Economics and Management*, Vol. 36, No. 2, pp.123–144, ISSN: 1732-1948.

Tehrani, T. and Michael, A. (2014) 'Wearable technology and WDs: everything you need to know', *WDs Magazine, WearableDevices.com* [online] http://www.wearabledevices.com/what-is-a-wearable-device/ (accessed 20 June 2020).

UNSW (2014) *Entering the Virtual World* [online] http://www.engineering.unsw.edu.au/emag/news/entering-virtual-world (accessed 8 July 2020).

Victor, R.L., Drake, J. and Williamson, K. (2015) 'Let's get physical: K-12 Students using WDs to obtain and learn about data from physical activities', *Tech. Trends*, Vol. 59, No. 4, pp.46–53.

Wintraub, L., Xie, M., Issa, M., Jeyakumar, Y., Nelms, M., Sharma, D., Teitelbaum, D., Otremba, M., Sirianni, G., Nyhof-Young, J. and Leung, F.H. (2020) 'Wearable technology and live video conferencing: the development of an affordable virtual teaching platform to enhance clinical skills education during the COVID-19 pandemic', *Canadian Medical Education Journal*, Vol. 11, No. 5, pp.121–125.

Wu, M. and Luo, J. (2019) 'Wearable technology applications in healthcare: a literature review', *Online Journal of Nursing Informatics (OJNI)*, Vol. 23, No. 3 [online] https://www.himss.org/resources/wearable-technology-applications-healthcare-literature- (accessed 25 June 2020).

Wylie, J. (2016) *Google Expeditions: Lesson Ideas & Support for Schools*, Owlcation – Academia, [online] https://www.himss.org/resources/wearable-technology-applications-healthcare-literature-review.

Xiao, Y. and Watson, M. (2017) 'Guidance on conducting a systematic literature review', *Journal of Planning Education and Research 2019*, Vol. 39, No. 1, pp.93–112, DOI: 10.1177/0739456X17723971 journals.sagepub.com/home/jpe.

Zheng, Y.L., Ding, X.R., Poon, C.C.Y., Lo, B.P.L., Zhang, H., Zhou, X.L., Yang, G.Z., Zhao, N. and Zhang, Y.T. (2014) 'Unobtrusive sensing and WDs for health informatics', *IEEE Transactions on Biomedical Engineering*, Vol. 61, No. 5, pp.1538–1554.