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What are the educational affordances of wearable technologies?

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ABSTRACT

By providing users with hands-free access to contextually relevant knowledge, wearable technologies are poised to inspire a new generation of mobile learning design. However, in order for educators to harness the pedagogical opportunities of wearable technologies it is crucial for them to develop an understanding of their potentials, or 'affordances'. This paper analysed the perceptions of 66 educators from around the world who self-rated as having a 'good' or 'very good' understanding of wearable technologies to determine the key educational affordances and issues at stake. Qualitative thematic analysis of participant perceptions, as well as relevant literature, revealed fourteen affordances of wearable technologies and thirteen issues relating to their use. These clustered together into three emergent themes; 'pedagogical uses', 'educational quality' and 'logistical'. Utilising the insights of knowledgeable practitioners resulted in nine affordances and issues not identified in the literature, and within the literature there were three issues not identified by the knowledgeable practitioners. The implications of findings for the future of wearable technology learning design are also discussed.

1. Introduction

Wearable technologies constitute a shift from digital simulation (replication and separation) to digital augmentation (connectivity and responsiveness) (Viseu, 2003). Recently, there has been an explosion in the range of wearable technologies available to educators. As at 10th of April 2015 the Vandrico Wearable Technologies database (http://vandrico.com/wearables) includes 296 devices across a range of sectors including fitness, medical, entertainment, industrial, gaming and lifestyle sectors. For instance, head mounted display products such as Google Glass and Oculus Rift can provide users with audio-visual information to supplement their view of the world. Bracelet products such as Fitbit, Garmin, and Striiv include componentry for measuring motion and vital signs that has given rise to the 'quantified self' phenomenon (Swan, 2013). All of these products provide wireless connectivity, on-board analytics, and interfaces for hands-free feedback that avail a wide range of opportunities to educators.

There is considerable literature investigating the development and use of wearable technologies across a range of fields other than education. Wearable devices have been used for medical diagnosis, therapy of movement disorders, and administration of drugs (Son et al., 2014), for care and tracking of the elderly with Alzheimer's disease (Mahoney & Mahoney, 2010), and in conjunction with augmented reality to enable face recognition and subsequent overlay of personal information

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(Kim, 2003). However, there is a scarcity of research into the use of wearable technologies in education (exceptions include Coffman & Klinger, 2015; Wu, Dameff, & Tully, 2014; Yamauchi & Nakasugi, 2003; as discussed later in this paper).

While it is difficult to establish the exact prevalence of wearable technologies usage within education, the limited literature in this area would appear to indicate that the possibilities of wearable technology are not being fully harnessed for teaching and learning. One reason that educators may not be capitalising on the possibilities extended by wearable technologies is because they do not fully appreciate their action potentials, or 'affordances' (Bower, 2008). Without an understanding of the affordances of technologies, educators struggle to make appropriate or innovative use of them, which in turn may compromise the effectiveness of their teaching and student learning (John & Sutherland, 2005; Mishra & Koehler, 2006; Yoon, Ho, & Hedberg, 2005).

This paper reports upon an online survey that selected 66 of the most knowledgeable educators from around the world from a sample of 332 in order to examine what they perceived to be the key affordances and issues relating to wearable technologies. These results were then compared and contrasted with affordances and issues identified within the literature. The outcomes provide educators with a comprehensive conceptualisation of ways that wearable technologies may be utilised, and the key issues that need to be considered in their learning designs. It also addresses previous methodological issues surrounding classification of technology affordances by using thematic analysis of participant responses in conjunction with the research literature to derive a robust affordance framework.

2. Literature review

2.1. Research on the use of wearable technologies

In 2001, Barfield and Caudell defined a wearable computer as a:

> fully functional, self-powered, self-contained computer that is worn on the body … [and] provides access to information, and interaction with information, anywhere and at anytime (Barfield & Caudell, 2001, p. 6).

An important aspect of this definition is that the device provides access to, and interaction with, information (as opposed to a medical device such as a heart pacemaker or a pure information delivery device such as a traditional wrist watch).

Wearable technologies can incorporate a wide variety of sensors for measuring mechanical information (position, displacement, acceleration, force), acoustic information (volume, pitch, frequency), biological information (heart rate, temperature, neural activity, respiration rate), optical information (refraction, light wave frequency, brightness, luminance) and environmental information (temperature, humidity) (Barfield & Caudell, 2001). Wearable devices are 'aware' in so far that they can recognise, adapt and react to their owner, their location and the activity being performed (Viseu, 2003).

One change, perhaps cultural, since the Barfield and Caudell definition is the shift away from the monolithic concept of the 'computer' to the more agile idea of 'technologies'. Wearable technologies may be quite lightweight and specific in their purpose, yet still highly intelligent in how they fulfil their intended function. More than just technical solutions, wearable technologies constitute a shift from computers as detached tools to technologies as embodied companions that become an extension of self (Viseu, 2003).

Another paradigmatic evolution that has taken place is the shift from individuals using wearable technologies in isolation to more socially oriented uses of data. For example, wearable technologies may enable users to exchange fitness information, play games in real-time, or see an event from someone else's viewpoint (Wu et al., 2014).

Taking into account these various elements and for the purposes of this study we will define wearable technologies as:

> *Wearable digital devices that incorporate wireless connectivity for the purposes of seamlessly accessing, interacting with and exchanging contextually relevant information*.

There are only a few empirical examples regarding the use of wearable technologies in education within the literature. In an early experiment, head mounted displays were used in history education to overlay incidents from the past and live scenes from the present so that students could acquire a more visceral sense of history in the actual places that it occurred (Yamauchi & Nakasugi, 2003). Participant responses indicated that they felt a deeper connection with historical events and greater empathy with the people involved (Yamauchi & Nakasugi, 2003).

More recently, wearable technologies (such as Google Glass) have been used during medical training role-play activities to provide a first person viewpoint and recordings (Wu et al., 2014). Recordings were then used to observe the amount of time participants spent focusing on different information sources, level of attention to the patient, and other metrics that informed reflective learning and group debriefing. The first-person viewpoint into the role-play and the novel observations that led to discussion of items that were not typical in role-play tasks that had occurred without the wearable device. The hands-free nature of the device meant that it did not interfere in the role-play in any way. This led the research team to conclude that wearable devices could offer unique advantages in role-play based learning contexts with few negative consequences (Wu et al., 2014).

In another recent trial by Coffman and Klinger (2015) teachers and students were provided with access to Google Glass to use during educational psychology and organizational behaviour classes. They found that the technology was able to be seamlessly integrated into the lesson to take pictures of student work, video record class activities, access the Internet and poll students for responses to questions (Coffman & Klinger, 2015).

In an early analysis of the educational possibilities of wearable technologies de Freitas and Levene (2003) identified three main potentials – the ability to access lecture material while students were on the move, the ability to augment the physical campus with virtual information and access to resources and the ability to offer virtual field trips by utilising recording capabilities. They also identified support of students with special needs as a significant potential of wearable technologies, through its ability to provide voice-activated interfaces for the blind or visual interfaces for those with literacy problems. The potential for greater collaboration was also identified as a significant opportunity, though limitations of small interfaces, limited processing power and slow connectivity were seen as issues (de Freitas & Levene, 2003).

Based on their pilot study observations, Coffman and Klinger (2015) distilled pedagogical benefits of wearable technologies such as Google Glass in particular, concluding that wearable technologies provide educators with the capacity to "access, interact, manipulate, and create content seamlessly while in the process of teaching" (p. 1778). They point out that students correspondingly have the ability to record their lesson activities, search the Internet for clarification of a concept during a class, or take notes while working in a team that can be shared with all members (Coffman & Klinger, 2015). From their preliminary explorations with Google Glass they identify the main potentials of the technology to be the ability to spark interest and creativity, the ability to facilitate collaboration, and the ability to improve feedback. The issues associated with the use of the technology were technical challenges such as maintaining Internet access and operating the interface, privacy concerns related to recording video or images, with the potential for student distraction also seen as a possible issue (Coffman & Klinger, 2015).

Wearable technologies raise the question of whether people can adequately multi-task in order to utilise wearable devices safely and effectively. Successful multitasking is possible in many circumstances, for instance if the additive demands of the task do not lead to cognitive overload (for instance, see Novak, Mihelj, & Munih, 2012). However, people are not always able to exercise the executive control functions or self-awareness to choose cognitively efficient ways of completing multiple tasks (Nijboer, Taatgen, Brands, Borst, & van Rijn, 2013). Students who utilise networked devices in class can choose to use them for productive (learning) purposes, but often use them for non-course related purposes that may impede academic performance (Kraushaar & Novak, 2010). This may result in them being 'co-present' – both attending a physical class but also interacting in an unrelated digital environment (Hassoun, 2014).

The capacity of wearable technologies to instantaneously broadcast information about ourselves and receive information about other people also raises a raft of privacy, ethical and social issues (Gill, 2008). For instance, if a team of medical practitioners are monitoring a patient (or a team of teachers are monitoring a student) at what point and in what way is the consent of the person being observed required? Ongoing use of intelligent technologies such as wearables could lead to deterioration of some skills (such as social intelligence), or at least constrain their development, as people become dependent on technology to support their cognition (Gill, 2008).

Thus, there are a multitude of possibilities and issues associated with wearable technologies. However, in order for educators to integrate wearable technologies into their learning designs and utilise them effectively in the classroom, educators need to first understand their use potentials, or 'affordances'.

2.2. Affordances of learning technologies

'Affordance' is a frequently used term in educational technology circles, but also one that has been used with several different meanings (Hartson, 2003; McGrenere & Ho, 2000; Oliver, 2005). James Gibson (1979) first coined the term 'affordance' as:

> what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill … It implies the complementarity of the animal and the environment. (p. 127, italics by Gibson)

Under Gibson's definition an 'affordance' exists as long as the person (or animal) can take the necessary actions to utilise it. For instance, a postbox is a 'letter-mailing-with-able' object whether or not a person recognises it as such.

The other frequently cited proponent of the term 'affordances' is Donald Norman, who describes an affordance as a design aspect of an object that suggests how the object should be used:

> the term *affordance* refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. A chair affords ('is for') support and, therefore, affords sitting (Norman, 1988, p. 9).

Norman's usage emphasizes the idea of 'perceived' affordances – that until an affordance is perceived it is of no utility to the potential user. According to Norman (1988) the real affordances of an object were not nearly as important – it is the perceived affordances that determine what actions the user performs and, to a greater or lesser extent, how to complete those actions.

For the purposes of this study, Norman's definition of affordances will be employed, as the study relates to educators' *perceptions* of how wearable technologies can be used for learning and teaching. Results depend on educators perceiving a possible use – if the use is there but not perceived then it is of no educational benefit.

2.3. Why analyse the affordances of technologies?

The success with which technology is utilised for learning and teaching depends on the educator's ability to appreciate the requirements within the learning context and subsequently select and utilise technologies in a way that meets those needs (John & Sutherland, 2005; Yoon et al., 2005). Many of the technologies available for educative purposes have not been designed specifically for learning and teaching, and thus the educator needs to analyse the affordances and constraints of such technologies to creatively repurpose them for the educational context (Mishra & Koehler, 2006). A focus on the affordances underlying the technologies makes the analytic approach of educational designers adaptable to changes in technology. It is precisely because technology changes so rapidly that we must shift our focus from purely understanding specific tools to also being able to analyse the educational merit of new tools based on their capabilities (Mishra & Koehler, 2006). It enables technology selection to be based upon explicitly identified learning needs rather than pure intuition or no reasoning at all.

2.4. Previous attempts to analyse technological affordances

There have been several attempts by educational researchers to define categories of affordances for technologies. For example, various small teams of researchers have attempted to define the affordances of mobile technologies (Churchill & Churchill, 2008; Cochrane & Bateman, 2010; Klopfer & Squire, 2008). Other researchers have presented frameworks for conceptualizing the affordances of information and communication technologies more generally (Bower, 2008; Conole & Dyke, 2004). Inherent in these attempts is the challenge of arriving at some sort of ontological consistency (where the elements being described relate to the same sorts of constructs), and where the bounds of an 'affordance' are drawn (for instance the functionality of the tool versus possible consequences of their use) (Boyle & Cook, 2004; Oliver, 2005). These ambiguities mean that there is often incongruity between frameworks that are actually aiming to define the same phenomena.

In order to differentiate between different types of affordances Kirschner, Strijbos, Kreijns, and Beers (2004) make the potentially useful distinction between technological affordances (described in a Normanian sense by their usability), as opposed to social affordances and educational affordances. The latter two classes of affordances are defined as follows:

- Educational affordances: characteristics of an educational resource that indicate if and how a particular learning behaviour could possibly be enacted within the context
- Social affordances: aspects of the online learning environment that provide social-contextual facilitation relevant to the learner's social interaction (Kirschner et al., 2004).

This extends the focus of affordances beyond the general opportunities subtended by the technologies to how they may be used for educative and interactional purposes.

Educational affordances have been defined for specialised technologies, such as blogs (Deng & Yuen, 2011) and 3D virtual worlds (Dalgarno & Lee, 2010). Yet in all of the cases above, the affordances of technologies have been derived essentially through thought experiments and analysis by individual or very small teams of researchers. The researchers have reviewed relevant literature and reflected upon technologies to determine what they believe to be the key action potentials availed. While this is often fruitful, it is possible that restricting the number of contributors to the analysis results in some useful affordances being overlooked, or that personal biases are evident in the affordance schemas that result.

This paper attempts to overcome the methodological limitations of previous affordance frameworks by drawing upon a wide sample of knowledgeable educators from around the world as well as the literature to address the question: "what are the educational affordances of wearable technologies"?

3. Method

In order to ascertain the educational affordances of wearable technologies, an online survey was designed to elicit the insights of Higher Education experts in the learning technology field. The first part of the survey included demographic items relating to the respondents' institution, country, teaching areas, age, years of teaching experience, and gender. This section also asked respondents to rate their ability to use computers and the Internet for learning and teaching, as well as to rate their knowledge of wearable technologies. Both of these included Likert scale response options of 'very poor', 'poor', 'fair', 'good' and 'very good'. The second part of the survey asked participants about ways that wearable technologies could be used to enhance university learning and teaching, ways in which wearable technologies might make the job of an educator easier or more productive, ways in which wearable technologies could make the life of students easier or more productive, and foreseeable issues that may be encountered when using wearable technologies in educational contexts. Google Glass and Oculus Rift were used as examples in order to provide respondents with concrete examples of what is meant by 'wearable technologies'. Participants were also asked to rate the usefulness of eight specific use cases as well as the ease with which the use cases would be achieved, though this data has not been integrated into the current analysis.

Calls to participate in the survey were distributed to the members of the following scholarly organisations via their respective websites and/or electronic mailing lists: Australasian Society for Computers in Learning in Tertiary Education, Open and Distance Learning Association of Australia, Higher Education Research and Development Society of Australasia, European Distance and E-learning Network, Asia-Pacific Society for Computers in Education, International Forum of Educational Technology and Society, Professional and Organization Development Network in Higher Education, Society for Teaching and Learning in Higher Education (Canada), and Association for Learning Technology (UK). The Call was also posted to several other online learning and educational technology networks and communities such as ITFORUM, MirandaNet, WWWEDU, and DEOS (Distance Education Online Symposium), as well as shared with various special interest groups of the American Educational Research Association, EDUCAUSE, and the Joint Information Systems Committee (UK). Additionally, a number of smaller professional societies focused on specific areas relevant to or associated with topic of the present study (e.g., mobile learning, virtual/augmented reality in education) were targeted. In all, over 30 national and international channels were used to disseminate the call.

The survey was opened from the 29th of September 2014 to the 24th of November 2014. It resulted in 322 responses from 16 different countries. Responses that did not contain complete demographic data or did not contain substantive responses to the main body of the survey were deleted. This resulted in a sample of 214 participants.

In order to select participants who had a firm insight into the educational affordances of wearable technologies two criteria were used:

i) participants self-rated their knowledge of wearable technologies as ‘good’ or ‘very good’; and
ii) participants self-rated their ability to use computers/the Internet for learning and teaching purposes as ‘good’ or ‘very good’.

The rationale for the inclusion of the first criteria was that without a good knowledge of wearable technologies it would be difficult to interpolate their affordances. The justification for the second criteria was that without a good general understanding of how technology can be used for learning and teaching purposes they may fail to understand how wearable technologies may be utilised. This resulted in 66 respondents (25 female, 41 male), with an average of 11 years of tertiary teaching experience and 15 years of teaching using computers/the Internet.

Qualitative data analysis techniques in line with Neuman (2006) were applied to analyse responses to questions about the ways that wearable technologies could be used for learning and teaching, ways they could make the job of an educator easier or more productive, ways they could make the life of students easier or more productive, and foreseeable issues that may be encountered. This involved three phases:

1. Open coding – a first-pass qualitative coding of the data to condense it into preliminary analytic categories.
2. Axial coding – a subsequent re-examination of the data to refine the coding scheme, as well as understand relationships between the categories and organise them into themes.
3. Selective coding – a late-stage look at the data coded under certain themes to choose representative and pertinent examples for reporting purposes (Neuman, 2006).

All analysis was performed using the NVivo 10 Computer Assisted Qualitative Data Analysis Software (CAQDAS) system. The CAQDAS not only facilitated organisation of the data, but also key methodological processes such as tracking coding decisions using memos and use of the node tree structure to support consolidation of categories into themes (in alignment with Hutchison, Johnston, & Breckon, 2010).

So as to acquire an initial sense of the data for coding purposes the qualitative responses were initially queried to determine 50 most popular keywords by word frequency, with an allowance for some degree of synonym usage. CAQDAS matches were set to half way between similar and exact to enable some clustering of similar terms, with a minimum word length of 4 characters to ensure those terms were substantive. Examples of more frequent keywords that related directly to the use of wearable technologies included ‘support’, ‘access’, ‘view’, ‘record’, ‘augment’, ‘privacy’ and ‘cost’. Frequent recurrence of similar keywords could then imply a possible category for coding purposes.

The open coding phase focused on classifying the affordances and constraints of wearable technologies into preliminary categories as emergent from the respondent comments and according to Norman's definition of perceived affordances. These included themes such as communication, augmented data, efficiency, engagement and legal issues.

The axial coding phase incorporated a refinement of categories through repeated revision of the data, and also provided the opportunity to consolidate consistency of coding and category demarcation. This phase also involved an analysis of categories into thematic dimensions. The three affordance dimensions which emerged were ‘pedagogical uses’, ‘educational quality’, and ‘logistical and other implications’.

In the selective coding phase the categories were once again revisited to select epitomic responses, as well as pertinent responses that may not have been representative but held insight with relation to the category or theme in question. To this extent, frequencies of responses were not considered to be an indicator of either the importance or the educational potential of the affordance, but rather the popular awareness of the affordance. That is to say, it was possible that only one or a few of the respondents were aware of a particular affordance of wearable technologies, but that the identified affordance had potential for educational purposes. The selective coding phase provided a further opportunity to revisit the categorisations to uphold consistency of classification.

Following the selective coding phase the responses of an additional 33 people who had rated their knowledge of wearable technologies as ‘fair’ were examined. All the items raised within these responses fit within the categories and themes that had already been identified, providing evidence that thematic saturation has been reached. It was also observed that responses of these additional participants tended to be less elaborate and less specific than the respondents who self-rated as ‘good’ or ‘very good’.

The research team collaborated during the analysis in order to derive a mutually agreed coding scheme. For instance, after the first pass of the open coding phase, the team met to discuss categories that were emerging and examined the data to determine appropriate boundaries between categories. Similarly, during axial coding the team discussed and agreed upon category merging and thematic arrangements. Further collective refinement of categorisations were performed during the final selective coding and reporting phase, for instance where the more general ‘enhanced environment’ category was removed from the categorisation because the team decided it could not be clearly delineated from other categories and was already implicitly present within many of them. Thus, we believe this work accords with that of Armstrong, Gosling, Weinman, and Marteau (1997), who found that while different qualitative researchers may have labelled or ‘packaged’ the classification schemes slightly differently, there was a general consensus on the underlying basic themes present.

The results of the coding process are presented, with affordances presented first followed by constraints. Explanations rely heavily on participant voices wherever possible in order to promote reliability of reporting.

4. Results

4.1. Affordances of wearable technologies

4.1.1. In situ contextual information

The most frequently identified educational affordance of wearable technologies (58 out of 66 participants) was the ability to provide in situ contextual information. This could include “giving the student the ability to search for additional background information, or a more advanced version could be using links to the real world to trigger augmented events”. As well as typical examples relating to the provision of results from text-based searches, some participants imagined a future where wearable technologies could be used to receive unobtrusive subtitles for audio conversations or superimpose colour frequency analysis while viewing chemical samples (for instance).

4.1.2. Recording

The majority of participants ($n = 42$) also identified recording of information as a pedagogically beneficial use of wearable technologies. For example, students could “record not only class sessions, but could also use [wearable technologies] out in the field to show what they are doing, either as individuals or as a group”. There were several educational extensions based on the ability to record, for instance the capacity to automatically scan and index notes taken in class.

4.1.3. Simulation

Simulation was identified by many ($n = 39$) as a useful pedagogical affordance of wearable technologies. For instance, it could enable students to “experience riskier scenarios and perhaps fail at them, without suffering real world consequences”. Example simulation scenarios included surgical procedures, providing a working engine of any size, touring a medieval village, and enlarging and manipulating very small objects (such as molecules).

4.1.4. Communication

Nearly half of the respondents ($n = 29$) identified communication as a valuable affordance of wearable technologies. This included the opportunity to integrate communication streams into the daily work routines of study and participatory learning. For example students could “work together in the field, on study tours of institutions, on work placement, and in focused study activities/projects”. Wearable technologies were also seen to afford the ability for teachers to intuitively communicate with students across multiple sites, as well as “remove barriers to current human interfaces and open up more human forms of interaction through gesture and sight line interaction”.

4.1.5. Engagement

In addition to the pedagogical uses described above, many respondents ($n = 26$) felt that wearable technologies could impact on the quality of the educational experience through increased engagement. This could be anything from alerts that appear “after eye-tracking notices attention has wandered through to more engaging immersive educational experiences that allow learning in more natural ways”.

4.1.6. First-person view

Wearable technologies afford the ability to offer a first-person point of view ($n = 25$). For instance, a medical educator could teach “doctors how to perform during surgery”, or a student in the front row of a lecture theatre could share their viewpoint of a lesson with a remotely located student. It could also be used to take students to locations that they would not otherwise be able to access on mass, for instance “private companies and archaeological dig sites”.

4.1.7. In situ guidance

Wearable technologies were also seen by many (n = 20) to afford the opportunity for in situ guidance. This extends upon the provision of contextual information and general communication to provide “real time supervision” of a process. For instance, trainee counsellors and teachers could receive guidance during initial professional experience. It could also be used to assist people with special needs, for instance by helping “students with autism interpret expressions”.

4.1.8. Hands free access

As well as pedagogical uses and educational impact, wearable technologies were also seen to enhance the learning experience through logistical and other pragmatic implications. For instance, several participants (n = 17) discussed how wearable technologies enabled hands free activity, meaning that someone could operate a piece of equipment at the same time as sending or receiving in situ information or guidance.

4.1.9. Feedback

Some respondents (n = 15) identified the specific ability of wearable technologies to provide unobtrusive and contextualised feedback. For instance, teachers could “receive instant feedback during lectures from students via local chat or even Twitter [enabling] the flow of the class to continue without question interruptions, but still providing students with answers to their questions”.

4.1.10. Efficiency

Several respondents (n = 12) discussed how wearable technologies afforded greater efficiencies in learning and teaching contexts. They could provide “faster access to information”. One respondent commented how this meant that they “check communication streams less often, thus freeing me up to concentrate more on what I am writing, reading or doing”.

4.1.11. Presence

Wearable technologies were seen by some (n = 11) to potentially “enable students to interact with other students in a social learning setting where the sense of presence is enhanced”. For example, students could “meet using the wearable technologies in a 3D immersive environment to discuss lectures, readings and prepare group presentations”.

4.1.12. Distribution

Some of the participants (n = 8) suggested that wearable technologies could be useful for the distribution of resources. For instance as part of collaborative project work students could disseminate any sources that they observed, for instance “pooling video clips as they go”. The teacher could also “give notes to students watching a live scene without interrupting the scene”, in addition to any in situ contextual information that was being provided by intelligent agents or student searches.

4.1.13. Free up spaces

A few participants (n = 5) raised the potential of wearable technologies to make workstations obsolete for some people, for instance because “day to day [Information Technology] activities will be freed up from the requirement to be at a desk”.

4.1.14. Gamification

Gamification was also mentioned by a few (n = 5) respondents. For instance, wearable technologies could afford the capacity to turn the world into a playing field, where students are provided with situated challenges and receive augmented gaming data from their devices.

4.2. Issues relating to the use of wearable technologies

4.2.1. Privacy

Almost half of the respondents (n = 28) saw privacy as a if people are able to surreptitiously take photos and record videos. This may require educators and institutions to form policy surrounding “when to record and when not; levels of publicness: research (offline uses only) versus publication for widest exposure”.

4.2.2. Cost

Many people (n = 26) also saw cost as a practical issue, with prices of wearable technologies far in excess of mobile devices and therefore rendering the devices “inaccessible” to many students. If they are to become integrated into learning and teaching practices then educational providers need to be asking “are they available in the institution, are they [in]expensive and thus available to ALL students”.

4.2.3. Distraction

A number of educators (n = 18) felt that wearable technologies could distract student focus, and hence negatively impact on the quality of learning that occurs. Wearable technologies make it even easier for students to be “viewing non-subject related materials on their [wearable technology] and therefore not engaged in learning”. With wearable technologies teachers are “unable to tell what a student is actually doing, whereas it is always possible to look over the shoulder with a screen-based device, it is not possible with a wearable”, thus making it harder for educators to monitor and manage distractions.

4.2.4. Technical problems

Several respondents (n = 14) felt that technical problems were likely to constrain the practical use of wearable devices, for instance network connectivity. One respondent raised several other examples, including “restrictions due to the use of proprietary apps, battery autonomy, human–system interface design issue, accessibility (i.e. Google Glass work with right eye only)”.

4.2.5. Lack of support

Some educators (n = 8) felt that the lack of effective support could impose a practical constraint on the use of wearable technologies for learning and teaching. For instance, teachers may have “limited skill in use of the technology in teaching … innovators will take it up but many staff never will [be in the] current generation”.

4.2.6. Cheating

Some educators (n = 6) felt that wearable technologies could negatively impact on the learning environment if students used them to cheat. For instance, this could be an issue with online test taking where “a student would record a test and share it with others”. With advancements in wearable technologies it may be possible for students to be “cheating on exams in ways imperceptible to a proctor”.

4.2.7. Legal issues

A few respondents (n = 4) felt that the use of wearable technologies may lead to legal issues. For example, “students recording informal interactions with staff then bringing complaints [could lead] to staff being much less willing to deal with students informally.”

4.2.8. Overreliance on wearable technology

If students always use wearable technologies to support learning then some educators (n = 4) could see how this might impede independent thinking. It may lead to students “relying on the technology to give them answers and/or steps to take next … [which] can take away from the learners ability to think critically on an ongoing basis”.

4.2.9. Development of software

A final logistical issue raised by a few participants (n = 3) was the current difficulty in “developing the required material”. One educator pointed out that “staff will need to rely on commercial or open source programming for wearable technologies and it is likely that they will not achieve exactly what the teacher is after, only what the designer was thinking they might want”.

4.2.10. Technology before pedagogy

According to two respondents there was also a risk of educators becoming excited about wearable technologies as a “new gadget” rather than “designing learning activities that put pedagogy before the technology”.

The affordances and issues identified by participants are now compared with the existing literature on wearable technologies to derive an overarching affordance framework.

5. Discussion

Many of the affordances of wearable technologies identified by the respondents were also identified in the literature, for instance: access to in-situ information, recording and feedback (Coffman & Klinger, 2015), communication and distribution of resources (de Freitas & Levene, 2003), hands-free access and first-person view (Wu et al., 2014), simulation through re-enactment and increased engagement and presence through immersion (Yamauchi & Nakasugi, 2003). Yet none of these sources came close to identifying all of the affordances outlined by their colleagues. Moreover, none of the researchers identified in-situ guidance or gamification as a pedagogical use, nor the qualitative impact of enhanced efficiency, or the way in which wearable technologies could logistically free up space.

Similarly, many of the wearable technology issues raised by respondents were also identified in the literature, such as student distraction and technical problems, (Coffman & Klinger, 2015), as well as overreliance on wearable technologies and privacy issues (Gill, 2008). However, some educational quality concerns relating to wearable technologies were not identified within the literature – specifically the increased potential for cheating and the risk that educators place technology before pedagogy when designing their classes. Nor were key logistical obstacles of cost, technical support, legal issues or software development costs identified within the literature. Some educational quality concerns with wearable technologies were identified within the literature by not raised by respondents, namely the need to familiarise oneself with the interface may impact on the educational quality (Coffman & Klinger, 2015), as well as the potentially lower processing power of small wearable devices and the interface limitations of smaller screens (de Freitas & Levene, 2003).

Table 1
Summary of the affordances of wearable technologies and issues associated with their use.

	Pedagogical uses	Educational quality	Logistical and other implications
Affordances	•In situ contextual information •Recording •Simulation •Communication •First-person view •In situ guidance* •Feedback •Distribution •Gamification*	•Engagement •Efficiency* •Presence	•Hands-free access •Free up spaces*
Issues		•Distraction •Cheating* •Overreliance on wearable technology •Technology before pedagogy* •Familiarisation with interface+ •Small interfaces+	•Privacy •Cost* •Technical problems •Technical support* •Legal issues* •Development of software* •Processing power+

* Denotes issues raised by participants that were not found in the literature.
+ Denotes issues raised in the literature that were not identified by respondents.

Table 1 provides a summary of the affordances and issues of wearable technologies, grouped into the three emergent themes of 'pedagogical uses', 'educational quality', and 'logistical and other implications'. It includes the items raised by participants that were not found in the literature (marked with an '*'), as well as issues raised in the literature that were not identified by respondents (denoted by a '+').

The fact that there were a number of items that were raised by participants that were not identified within the literature, as well as some issues that were raised within the literature but not by respondents, serves as a methodological touchstone. Drawing upon broad samples of expert knowledge resulted in the identification of more affordances and issues than referring to the literature alone. It is possible that previous affordance analyses that relied solely on reviews of prior research may have been strengthened by also drawing upon surveys of knowledgeable practitioners. Using this approach for an emerging class of technologies was particularly relevant as there were fewer existing use cases and scholarly references to draw upon, as opposed to more established technologies such as virtual worlds or mobile devices more generally.

In a few cases there were disparities between the literature (particularly early literature) and the perceptions of respondents. For instance, whereas Viseu (2003) previously proposed that an important feature of wearable technologies was that they move beyond simulation, a large number of respondents felt that the ability to safely simulate experiments and be immersed in a geographically remote setting was a useful affordance. This further highlights the value of using the perceptions of a large sample of knowledgeable educators rather than simply relying upon literature in order to determine affordances of technologies.

It should be noted that we initially examined the extent to which the affordances identified by respondents could fit neatly within the technological, social and educational affordances framework presented by Kirschner et al. (2004). This turned out to be problematic, because affordances that were social (such as 'communication') were also highly educational (enabling collaboration with peers and the teacher), just as affordances that were technological (such as 'recording') again subtended obvious educational advantages. Thus, we believe our affordance framework relating to pedagogical uses, educational qualitative impact and logistical/other considerations provides clearer delineation between categories and at the same time is authentically grounded by empirical data. We see all of our affordances as educational affordances in the sense proposed by Kirschner et al. (2004).

Like any study there were limitations to this investigation. The fact that people self-rated their knowledge of wearable technologies and their ability to use computers and the Internet for learning and teaching is a potential weakness of this study. However, given the qualitative approach to data analysis that was adopted, the perceptions of all participants could be cross-validated against one another before epitomic or novel examples were selected. Consequently, self-selection into this group did not pollute the data as much as if a quantitative approach involving averages and other stochastic measures were used to report findings.

Educators did not raise any pedagogical use cases that could not be accomplished using wearable technologies. For instance, with a blog it may be difficult to achieve real-time collaboration between remote participants; respondents to the wearable technologies survey did not raise any educational uses that could not be achieved. This could be due to the powerful features available through wearable technologies, however it is also possible that the design of the questions did support elicitation of these sorts of responses.

Using Google Glass and Oculus Rift as concrete examples of wearable technologies in the survey may have biased responses towards visual wearable technologies at the expense of other wearable technologies such as wrist-bands, rings and watches. Thus, while the responses of participants undoubtedly identified affordances of wearable technologies, it is possible that the list that has been identified is not exhaustive.

As well, the use of perceived rather than actual educational affordances could be seen as a weakness of this investigation. The study drew upon insights from a sizeable sample of educators who self-rated as knowledgeable with wearable technologies and capable with the Internet, so that collective intelligence could be utilised. The trade-off with utilising this methodology is that it does not functionally analyse the technologies themselves to determine the educational affordances (in a Gibsonian sense), and thus there is a possibility that some affordances were overlooked or remained unidentified by respondents. There is undoubtedly scope for further analysis of wearable technologies using a range of methods as new devices and approaches emerge.

The scope of this paper should also be noted. While the affordances of wearable technologies were identified, no claims were made about how wearable technologies can or should be used to positive educational effect. Ways in which the expanding array of wearable technologies can be used across discipline areas and learning contexts to improve student outcomes is an area that requires extensive further research.

6. Conclusion

This paper drew upon a sample of 66 international educators who were knowledgeable in the area of wearable technologies, as well as scholarly literature in the field, in order to ascertain the affordances and issues of wearable devices. Using Donald Norman's (1988) definition of perceived affordances, wearable devices were seen to offer a range of pedagogical uses (in situ contextual information, recording, simulation, communication, first-person view, in-situ guidance, feedback, distribution and gamification), afford benefits to educational quality (engagement, efficiency, and presence), and subtend logistical advantages (hands-free access and free up space). At the same time they raise several educational quality issues (potential distraction, cheating, overreliance on wearable technology, placing technology before pedagogy, familiarisation with the interface and small interfaces) as well as general logistical and other issues (privacy, cost, technical problems, technical support, legal issues, development of software and processing power). The approach of drawing upon a broad sample knowledgeable educators as well as the literature resulted in the identification of more affordances and issues than drawing upon one or other of these sources in isolation.

With all of these affordances it is evident that wearable devices have the potential to facilitate a new era of learning. Possibilities include students undertaking fieldwork to provide a first-person view of their activities to their classmates; language learners receiving real-time translation scaffolding to support vocabulary acquisition; students sending data captures to video-logs in real-time; integrating augmentations into the view of students to safely perform experiments or experience remote environments; recording all learning interactions and instruction for replay and reflective reprocessing; and the teacher collecting assessment data, monitoring performance and assessing student practical work from the first-person view based on a task being performed by the whole class at once. All of this aligns with Roy Pea's (1985) vision of technology not only as an amplifier of cognition but also as a reorganiser of mental functioning that results in cultural redefinition. But the question is, will educators capitalise on the educational opportunities availed by wearable technologies, and will this in turn enhance learning?

We turn to Donald Norman himself for final words on wearable technologies:

> Can wearable devices be helpful? Absolutely. But they can also be horrid. It all depends upon whether we use them to focus and augment our activities or to distract. It is up to us, and up to those who create these new wearable wonders, to decide which it is to be (Norman, 2013; para. 21).

We should not expect the affordances and constraints of wearable technologies to be the key influence on learning, but rather whether teachers and learners are able to perceive and utilise those affordances to positive effect. By raising awareness of the affordances and associated issues of wearable technologies this paper aimed to support their successful use of wearable devices in learning designs and classes, both now and in years to come.

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