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Published version

MCDONALD, Kieran and GLOVER, Ian (2016). Exploring the transformative potential of Bluetooth beacons in higher education. *Research in Learning Technology*, 24 (1), p. 32166.

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ORIGINAL RESEARCH ARTICLE

Exploring the transformative potential of Bluetooth beacons in higher education

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(Received 6 May 2016; final version received 10 October 2016)

The growing ubiquity of smartphones and tablet devices integrated into personal, social and professional life, facilitated by expansive communication networks globally, has the potential to disrupt higher education. Academics and students are considering the future possibilities of exploiting these tools and utilising networks to consolidate and expand knowledge, enhancing learning gain. Bluetooth beacon technology has been developed by both Apple and Google as a way to situate digital information within physical spaces, and this paper reflects on a beacon intervention in a contemporary art school in higher education conducted by the authors intended to develop a situated community of practice in Art & Design. The paper describes the project, including relevant theoretical foundations and background to the beacon technology, with regards to the potential of using these devices to create a connected learning community by enhancing learning and facilitating knowledge creation in a borderless learning space.

Keywords: learning space; technology; community of practice; internet of things; design education

Introduction

Prior to the Industrial Revolution and the subsequent development of mass education, learning was a relatively unstructured process that relied heavily on interaction with others, such as in the ancient Greek model of Socratic Questioning, or through observation, practice and critique by an expert tutor, such as in the apprentice model used in Renaissance artists' studios. However, with the need to create a workforce with at least some rudimentary education as a result of the new demands of the industrial world, these models were replaced by increasing use of standardised curricula using standardised learning materials – the so-called 'factory model' of education based on behaviourist principles. However, as economies move away from manual labour and manufacturing, their societies require people capable and experienced in a different type of learning, with less emphasis on the production of standardised workers to fill standardised jobs, and more on the developing learners who are readily able to acquire assess and apply new knowledge and skills throughout their lifetime, in jobs which may have no other exact match in the world and that are constantly changing.

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Responsible Editor: Amanda Jefferies, University of Hertfordshire, United Kingdom.

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Citation: Research in Learning Technology 2016, 24: 32166 - <http://dx.doi.org/10.3402/rlt.v24.32166>

This need for a different type of learner is transforming education in ways that look more like large-scale versions of the pre-industrial models than the stereotypical idea of a classroom of students being completely directed in their learning by a teacher at the front of the room. A major factor in both the societal and economic changes driving this change and the methods by which the change is addressed within education is that of the growing use of and reliance on technology within these societies. Likewise, the value of interaction with other learners and experts is increasingly being recognised and facilitated through expanding use of technology to support investigation and communication among groups of learners. In recent years, the Connectivism learning theory conceived by Siemens (2005) has encouraged consideration of how technology mediates learning by supporting the social construction of new knowledge through the interaction with people, objects and environments. In addition, these changes to the vision of what education needs to be and the methods used to achieve them have also led to increased consideration of the spaces in which learning takes place, whether physical, virtual or a hybrid of the two.

Bluetooth beacons are an example of a simple technology that can be used to create connections and interactions between people, objects and spaces, and so offer significant potential for enhancing the ascendant social methods of learning by transforming learning spaces. This paper provides an overview of Bluetooth beacon technology and outlines some of the relevant theoretical underpinnings for their use in supporting learning. It also describes a project undertaken by the authors to use beacons as a method of fostering the development of a learning community among Graphic Design students at Sheffield Hallam University and concludes with a discussion of the potential benefits of Bluetooth beacons for enhancing learning, in addition to outlining other use cases for their introduction.

Beacons in more detail

Currently, there are two competing beacon technologies, Apple's iBeacon (introduced in 2013) and Google's Eddystone (introduced in 2015); however, while they are incompatible with each other, for the most part they work in a similar way. Both technologies send out a small piece of data, a unique identification number for iBeacon and either a similar identification number or a short URL for Eddystone, over Bluetooth to any devices within range. This data is then received by these other devices, processed by associated software and an appropriate action taken according to the data received, shown in Figure 1.

This means that, in the most basic usage, beacons can be used to trigger an associated action on any devices with the appropriate software within range of their signal. However, an additional layer of information can also be created by analysing

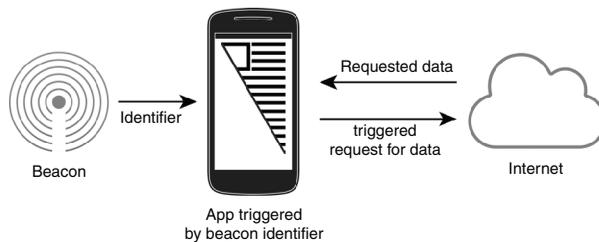


Figure 1. Typical beacon interaction process.

the strength of the signal to determine the distance from it. In this way, a single beacon could trigger different actions when a device is in its immediate proximity and when it is at the limit of its range. In common with the lighthouse metaphor used by these technologies, the beacons transmit only their presence and do not perform any active monitoring of devices within their range – meaning that they are not in themselves capable of tracking devices and, by extension, people.

The complexity of action that the beacons can perform depends partially on the type of signal being used and partially on the logic within the app that is being triggered by that signal. Eddystone's URL signals, the underpinning technology of Google's 'Physical Web' concept (<https://google.github.io/physical-web/>), offer a very simple way for objects and locations to transmit a web link to all devices within a defined proximity, whereas iBeacon and the equivalent mode in Eddystone can enable highly specific actions to be performed. This is possible through combining data available to the relevant app, such that a user in a specific location at a specific time might have a particular action triggered while the same user in the same place at a different time would have a different one triggered. For example, at the start of a lecture, the signal from the beacon triggers the app to download and open the slides and other materials that are going to be used in the session, while a few minutes later the same signal triggers the opening of a voting app. Likewise, the same information could be used to trigger different actions for people in the same place at the same time, such as by automatically directing students into different virtual collaboration spaces based on the group to which they are assigned.

Benefits

Discrete

The version of Bluetooth used by beacons, known as Bluetooth Low Energy or Bluetooth Smart, dramatically reduces power usage compared to older Bluetooth versions found in devices such as hands-free headsets and wireless speakers. This means that beacons can be small and run for several years on a compact battery, which in turn means that they can be discretely placed within an environment and left for an extended period of time with no need for maintenance. In addition, they still work when hidden from view, meaning that, unlike visual tags such as QR codes, they can be used without affecting the aesthetic of a space.

Passive

Unlike other similar technologies, beacons do not necessitate an individual making a conscious decision to access content, such as by deliberately scanning a QR code. This enables the beacons to be used to push information at individuals as they go about their normal activities rather than relying on the individual to actively seek out the information.

Multipurpose

The beacons perform a very simple task, namely alerting other devices of their presence, and leave it to the developers of software for those devices to decide how the information will be used. This means that, once a beacon infrastructure is in

place, it becomes a resource for use by multiple parties and for a variety of uses. Therefore, an infrastructure put in place to support way-finding can also be used by students to develop software that suits their own requirements. The use of the beacons for any particular purpose by one individual has no effect on others using them for a different purpose.

Potential issues

The simplicity of the technology means that there are several potential limitations that can affect the usefulness of the beacons in some situations. The most significant of these are:

Finite battery life

Commercial beacons are designed to be discrete and usable in a variety of environments, including both indoors and outdoors. As a result, the small size and need to be robust limit the effective size of the battery that can be used and also mean that it may not be possible to replace once it has lost charge.

Complex actions need bespoke software

While the ability of Eddystone to transmit URLs offers a simple method of sharing online resources, for more complex actions it is necessary to create custom software, such as mobile apps. This requires particular skills and expertise, meaning users need to install specific software and that the app needs to be updated whenever beacons are added, removed or repurposed.

Lack of remote management

In order to preserve battery life, commercial beacons typically do not feature any ability to connect to the internet. This means that there is no ability to remotely manage the information being transmitted by the beacons and any updates require being within range of the Bluetooth signal. While this is not typically an issue when the beacons are only transmitting a unique ID number, it may present problems when using Eddystone URLs instead; however, this can be mitigated by using a URL shortening service that allows short URLs that can be edited to refer to different online resources.

Ability to spoof beacons

As the beacons simply announce their presence and do not communicate directly with nearby devices, there is no way to prevent malicious spoofing of a beacon to trigger an action in the wrong place. However, while this means that there are some potential uses for beacons that are more difficult to achieve, such as recording attendance at formal sessions, it would be possible to mitigate this by requiring being in proximity to several beacons rather than a single one – though this would make managing both the beacon infrastructure and the app actions more difficult.

Theoretical foundations

The influence of *people* on an individual's learning has been well established in the literature, as evidenced through a range of learning theories from the Zone of Proximal Development (Vygotsky 1978) to Connectivism (Siemens 2005). While these theories are explicit on the impact of people on the learning process, whether direct peers or more expert individuals, an important other aspect is often only implied – *space*. Yet, without spaces that support and encourage the coming together of individuals for learning, the potential benefits to learning are reduced. The recent growth into research on learning spaces (Ellis and Goodyear 2016; Kolb and Kolb 2005; Long and Ehrmann 2005) is evidence that the influence of physical space on learning is becoming increasingly recognised, while the discourse around Virtual Learning Environments is evidence of this same recognition in the digital sphere (Glover and Oliver 2008; Dabbagh and Kitsantas 2012; Williams and Jacobs 2004). The built pedagogies being developed as a result of these collisions between technology and space are leading to the development of 'borderless' learning spaces, where the physical and digital are integrated to enhance rather than dazzle (Oblinger and Lippincott 2006).

The Communities of Practice theory (Wenger 1998) describes a (frequently informal) approach to learning that is built around subject context and social interaction among peers within a shared space, while experts provide guidance and assist by facilitating the exchange of knowledge by members of the community. The use of online social networks in learning, whether as part of formal studies or an organic community of self-motivated lifelong-learners, utilises a 'network effect' (Fenwick and Edwards 2010) provided by these communities by enabling the incorporation of a wider range of people, including peers, experts and practitioners, within a common online space. This interrelationship between learning and social interaction is fundamental to Social Constructivism theory (Berger and Luckmann 1967), which posits that knowledge is constructed through the shared understanding of and interaction between individuals. The association between authentic spaces, practice and learning is also a central tenet of Lave and Wenger's (1991) Situated Learning theory, which expands on Vygotsky's (1978) work around the influence of a 'more knowledgeable other' on increasing a learner's understanding by also recognising the impact of the environment in which the learning takes place.

The pipe is more important than the content within the pipe. Our ability to learn what we need for tomorrow is more important than what we know today. Connectivism provides insight into learning skills and tasks needed for learners to flourish in a digital era. (Siemens 2005)

Siemens' Connectivism theory (2005) places the emphasis for learning in the future not on the acquisition of specific knowledge but on developing the skills to learn using whatever mechanisms are already in place and may come in the future. This is an explicitly digitally enabled learning theory, with its focus on the ability to retrieve information from sources ranging from other people through to online resources and non-human (i.e. machine) agents has parallels with the Hollan, Hutchins, and Kirsh (2000) concept of distributed cognition. It also recalls the work of Latour (1999), who suggests that technology can simplify the process of making connections between student, teacher and information by using these machine agents and other devices to

enable access and provide the ability to process information, filter, disseminate, remix and share.

This thinking about learning mediated through non-human agents leads to consideration of a range of technical developments that are beginning to have an influence on the idea of what it means to be a learner in the early-to-mid 21st century. The growth of mobile learning initiatives, along with the subsequent research into related affordances and impact (Hamm, Drysdale, and Moore 2014; Woodill 2014), and the associated links to the concept of ubiquitous/pervasive computing (Poslad 2009) positions technology mediated learning as breaking out from the confines of a dedicated physical learning space, such as a formal classroom, and instead making use of entire towns and cities as environments to support, facilitate and encourage learning (Buchem and Perez-Sanagustin 2013). In particular, by using technologies commonly found on smartphones and tablets, such as Wi-Fi, GPS and Bluetooth, highly situated, serendipitous learning experiences can be created through the learner's movements through different spaces and through the random interaction with other learners in their proximity.

Project information

Background

In January 2016, Sheffield Hallam University's arts and design department, the Sheffield Institute of Art moved into new accommodation that had been designed from the outset to support the studio-based learning approach traditional to these creative disciplines. Now, instead of students being timetabled in different rooms around the campus depending on the type of learning activity being undertaken, the students have all of their classes in large, multi-purpose, discipline-specific studios that provide an academic home for both students and the academic staff. In addition to the benefits of having a designated learning space for all formal sessions, the studios are also available for students to use outside of their time-tabled learning regardless of whether another formal session is using part of the room. This provides new opportunities for the students to mix with and view the work of students from other years of the course, encouraging a wider potential community of practice and enabling a greater range of potential inspiration than was previously the case. This module was also designed to give students the opportunity to connect with professionals in the graphic design industry beyond the institution.

This move, and the opportunities for exploring innovative teaching methods and technologies that the new space provides, was used by the authors as a catalyst for exploring the potential of technology to enhance the student learning experience with a group of 100 second-year undergraduate Graphic Design students. The studio into which these students were to move was formed from three-quarters of a large, roughly square, open area and was divided into three notional, loosely bounded zones based on the locations of equipment, resources and furniture – Presentation, Production and Collaboration (Figure 2). This subdivision of the space into zones, based primarily on the activity, intended to take place within assisted in targeting resources to students based on the type of learning that they are involved in at any particular time and enabled students to informally use the space even when another group was taking part in a formal teaching session.

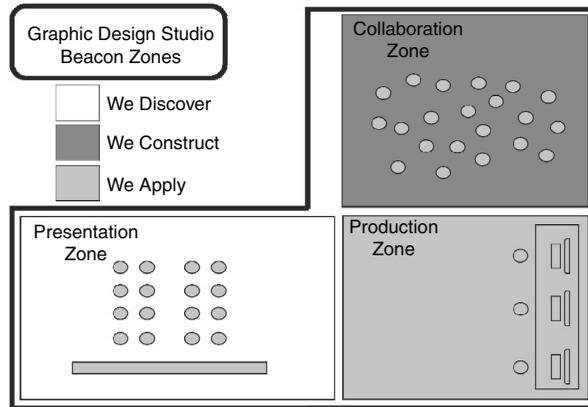


Figure 2. Simplified diagram of the learning space and the notional zones.

Hypothesis

The division of the studio into zones allows digital resources to be targeted into the spaces where they are most appropriate. Therefore, the authors hypothesised that bridging the gap between physical and online spaces and communities would help create a more productive learning community than the previous method of working with each in relative isolation.

Methodology

In order to ensure that the digital spaces and tools being ‘brought into’ the physical studio were appropriate and useful to the students, an initial set of focus groups and an online survey were conducted with the students. The aims of these were to identify online tools and collaboration spaces that the students were already using and to elicit ways in which their learning, and experience of learning, could be enhanced.

Based on the findings of these data gathering exercises, an intervention was developed that used beacons to address the requests from the students by connecting the physical spaces with the tools that the majority were already using. This intervention was active during the module, and subsequent, semi-structured interviews with representatives of the cohort and with the module leader were held to evaluate its impact. The interview participants were identified as part of the initial online survey, where respondents were able to register their interest in taking part in the post-intervention study cohort.

Overall approval for the project and research instruments was obtained from the university’s Research Ethics Review Panel.

Findings of initial investigations

The initial investigations were designed to elicit information in three areas, namely how and where the students prefer to work, the digital tools and resources that they find most beneficial to their practice and any ideas for improving their learning and their experience as a graphic design student and aspiring professional. Of the 100 students enrolled on the module, 34 completed the survey.

Ways of working

The respondents were all in agreement that confidence in using digital technology was beneficial to their current studies and likely to be in their on-going development as a professional designer, with 26 (76%) stating that it offered *considerable* benefit and the remaining 8 (24%) recognising at least *some* benefit. A similar result was found for the importance of being confident in the use of digital tools as part of professional practice, with 24 (71%) stating there was *considerable* benefit, 8 (24%) claiming there was *some* benefit and the remaining 2 (6%) stating there was *minimal* benefit, with no students reporting that there was likely to be no benefit at all.

The question of where the students preferred to learn and undertake their design work was split between working alone at home (9; 26%), working in the studio in informal groups with peers ($n = 12$; 35%) and working alone in the studio (4; 12%), with the remaining students (9; 26%) having no real preference. This split between working alone and communally in the studio was also reflected in the amount of time students spend in that space outside of formal sessions, with 21 (61%) spending less than 5 hours, 5 (15%) spending between 5 and 10 hours and the remaining 8 (24%) using the studio for over 10 hours outside their timetabled sessions.

Tools

The digital tools that were suggested by the students as being particularly useful for their learning and on-going development fell into two broad categories. The first were those that are directly used as part of the course and in which they will need to become proficient in order to work as professional graphic designers, principally the creative software suite from Adobe such as InDesign and Photoshop. The second were those tools that they use to discover, curate and share the works of others that they find inspirational or useful in some way or those that they can use to raise their own profile when developing an online presence with which to promote themselves to potential employers or for freelancing work, in particular the use of social media tools with a strong emphasis on imagery such as Instagram, Pinterest and Tumblr.

Suggestions for improvements

When asked to select the three most valuable aspect of the studio as a learning space, there was particularly strong representation for the following options: academic staff presence and availability (20; 59%); the ability to use their own devices (18; 53%); opportunity to mix and collaborate with peers (16; 47%); access to technical support and resources (9; 26%); and physical and virtual showcasing space (5; 14%). Additional support for these being the most valuable aspect of the space come from the students' responses regarding specific improvements that could be made where 13 (41%) wanted improved abilities to use their own devices; 13 (41%) wanting more opportunities to showcase and critique work; 12 (37%) asking for improved methods of receiving key information for the course; and 9 (28%) wanting more collaborative spaces in which to develop a community of practice.

Intervention outline

Based on the information received from the students in the initial investigations, paired with an understanding of the capabilities of beacons and the resources available to develop a pilot intervention, the authors made the decision to make use of the zones that had been set up within the studio (Figure 2). These were used to target online resources that were appropriate to the activities intended in those areas, that were based around tools that the students were already using, and that addressed the improvement areas highlighted by the students.

As the students had requested more timely information about the technical aspects of their graphic design practice, a beacon was placed in the 'Production' zone to direct them to online training resources related to the core tools and techniques of the discipline, as well as some more inspirational materials to explore as necessary and information on how to use the specialist equipment in this part of the studio. The 'Presentation' zone was viewed as a slightly more formal space occupied by the academic staff and the place where their presence in the studio was most obvious, therefore a beacon was placed in this area that led to a Tumblr blog curated by the tutors to collate resources that they found useful and stimulating for their own work as practicing graphic designers. In contrast, the 'Collaboration' zone was viewed as a less formal breakout space for students to share and comment on their peers' ideas and work-in-progress, therefore the beacon placed here pointed to a Pinterest board that collated Instagram posts with a module-specific tag by using the IFTTT ('If This, Then That') online service to automate the collation process. As all of the zones were overlaid with resources that were publicly available on the web, the primary purpose of the beacons was to prompt the students to access and interact with the resources and to build upon the existing demarcation within the overall studio space by reinforcing the intended activities for each zone.

Wherever possible, the choice of platform or tool used in each zone was based upon whatever was the best fit for the intended purpose selected from those that the students were already using. Due to this focus on the student's existing digital practices, there was a need to ensure that the teaching staff were able to make use of the same tools and to articulate their use in this particular project to the students. Where possible, many of the complex workflows were automated using IFTTT, allowing the focus to be purely on the content being posted to these shared spaces and the building of the community around them. However, a small amount of informal training was provided to the academic lead to ensure that he or she understood the processes and could answer questions from the students without the delay of having to refer back to the authors.

Results

At the conclusion of the intervention, a semi-structured interview was held with student representatives of the cohort to explore their impressions from the pilot, and an interview was later held with the module leader to both explore the students' views from his perspective and to gain his own insight into the project. During the course of the interview, several major themes emerged and these are detailed here along with relevant commentary from the module leader.

Closeness

While an overarching objective of the project was to use the technology and studio space to aid in the development of a community of practice among the students, the interview revealed that the integration of technology as a means for tutors to share works that they find personally and professionally interesting or inspiring resulted in the students developing a stronger informal connection to, and understanding of, the academic. The students specifically identified this connection as sense of feeling ‘closer’ to their tutors as a result of being more connected to them through the online networks and by both parties being increasingly visible in the same space.

Student: Definitely I think everyone has felt, and I don’t know if that because of the beacons or whatever, you can tell everyone is closer to the tutors this module than any other module that we have done. [...] Everyone has been just felt more confident going up and speaking to [the tutors] and has just built up a better relationship with the tutors than just tutor-student.

This feeling of closeness and the connections that both created it and then were encouraged by it have expanded the pathways for insight, particularly in sharing the iterative design process students have undertaken while producing their final pieces for submission. In design disciplines and projects, the process is just as important as the outcome and this informal peer network, mediated in part by the beacons, facilitated points for interjection and reflection by staff and students. The ability of academic staff to maintain this connection outside formal sessions was a shift in dynamic highlighted by staff and students. The concept of ‘social presence’, or in this case the student and tutor occupation of a digital space, has suggested changes in practice that would benefit both parties.

Student: Yes it would be useful when you don’t have sessions but he is still finding and posting stuff you can still get to it whenever you’re in the studio.

However, the feedback suggests that this closeness is likely to present significant challenges, particularly around managing student expectations and the blurring of traditional boundaries between the professional and personal online domains.

Tutor: I’m a little unsure as it connects me to [the students] in ways I’m a little uncertain about as most of them use [Instagram] for their private life and suddenly seeing someone was [on holiday] when they should have been in and students off for legitimate reasons but they are posting things that seem to contradict [these reasons].

Showcasing

The potential to showcase and create efficiencies using digital is a potentially powerful facet of contemporary curriculum design. This is particularly evident from the students, who viewed digital creation, critiquing and submission as a way to speed up the process by removing limiting factors associated with the physical objects.

Student: In structured peer reviews, [...] I know we had done one a few weeks back where we had to print off A3 sheets and get it all prepped whereas if it was all on a digital platform, for instance connected by a tablet or something like that, it’s easier than having to fight over the printers and print everything off.

The students were also able to articulate some of the affordances of working in a more digital, online way. In particular, they were conscious of the ability to showcase their work with external designers and agencies when looking for employment.

Student: ‘Kind of feels like it could be done like a digital “New Designers” [event] which [would help students get] their work out there to get employed. That would be really good’.

Integration of digital and analogue practice

As shown above, the students were particularly keen to make greater use of digital tools and practice, seeing these as a significant aspect of the future of the graphic design industry. However, the module leader was more cautious about moving more toward a fully digital module experience, pointing out that while digital working can be more efficient, there is a strong analogue and printed aspect to the discipline that the students need to be constantly aware of and understand.

Tutor: There is something about the reification – to reify is to lock solid – digital spaces are often not as reified because they can be constantly changed, updated, etc. There is something about the level of finality about the printed act that I’m not sure is necessarily present in digital. [...] I’m not disputing there might be potential in [working more digitally] but I wonder what the student’s motivation is – one of convenience?

Therefore, it is clear that embedding digital in the curriculum is a challenge and finding correct points of entry for fit alongside the core concepts of the module had proven difficult. Even though the students had previously used the digital platforms that were shared through the beacons, one of the challenges for them was around permission and confidence to take hold of this fully. In reflection, the academic team was also breaking new territory in considering the best way to successfully embed the tools and technologies in order to encourage enough engagement to achieve the crucial tipping point for student adoption.

Tutor: It’s almost as if Instagram is [...] not a space to get into discussions. I think that been quite important for me to understand that. It has its role but it’s kind of suspended in a strange way – a space without criticism?

Value of space to the development of community

The ability to asynchronously scaffold students’ learning and provide challenge outside the formal sessions is an important aspect of a studio-based learning culture. The students predominantly enjoy studying in the studio and ensuring accessible content at the time of need in the physical space was important, while also being able to engage with the resources and activities from outside the studio offering an added layer of convenience and flexibility.

Student: This studio is fantastic! I’ve never seen so many people actually coming to Uni to do their work and that’s created a little community.

Therefore, the studio has been a central anchor for this intervention and a welcome development for the students. It has stimulated further engagement, collaboration and attracted students to learn inside and outside of formal teaching sessions.

As a result, through the integration of ‘home’ spaces, both physical and digital, a greater sense of a peer-led learning community has developed within the cohort.

Student: Everyone has their own little areas and intermingle. It helps your design practice in itself as you can go and see what other people are doing and gain inspiration from them or help people with what they are doing. It’s good that everyone is communicating with each other now and that’s largely because of the studio

Student: I think [the benefit of] the Pinterest thing is the curation of everyone’s work, so on the same token that when everybody is the studio you can walk round and have a look at everyone’s work, [...] if you’re not in the studio [the fact that] that [the Pinterest board collates work] from the hashtag off Instagram helps ease of access to other people’s work and see what other people are doing and building the community that way.

Tutor: Yes, they built a studio culture running through that module that was largely conditioned by the opportunities of the space.

Barriers

The main barriers identified were those related to familiarity with the technologies being used and access to appropriate equipment. In particular, as the online tools selected for the intervention were informed by the students’ existing practices, technical familiarity presented a larger barrier to the tutors than the students. From a learning and engagement perspective, the tutor’s comments suggest that a significant barrier was in getting the students to appreciate the potential value of developing a digital community prior to point at which it would have had the most value for them.

Tutor: I think there was close to 90 out of 100 of them following [the Instagram account, but] it that might have taken 5 or 6 weeks to build from early adopters, and the frustrating thing was it was the first thing we wanted to use it for when we all went to [visit design studios in] London. This is the place we really want to see what you do.

Awareness of, and experience with, all of the various platforms being used by both staff and students as part of the learning community was an issue for the students. While the ‘official’ channels that were developed and promoted as part of the intervention were known to the students and used by them, the informal nature of the learning community and the studio work ethic meant that they may have missed some of the other online spaces that were being used by the cohort.

Student: You have got the Instagram, the Pinterest, pretty sure there is a twitter feed as well, I found a Facebook one this morning didn’t know that existed.

Suggested future development

Efficiency on campus came through as a real priority for students, particularly them having access to information at the exact place and time that it is required or appropriate. One suggestion for example was the beacons could be deployed in specific locations to deploy key information that was interchangeable.

Student: like this morning, for instance, with the [assessment] hand-in. We had on the whiteboard on the corner what needed to be done, whereas the tutors could post [through the beacon] exactly what need to be handed in when so it could be used for that advantage.

A strong theme of personalisation was raised by the students as something that beacons could facilitate. In particular, the use of beacons to trigger actions within an app that relate directly to the individual, rather than transmitting a generic web address to any device in range, was thought to be a powerful mechanism for encouraging engagement and ensuring awareness of critical information. Being able to target messages at groups or individuals as they move through the campus, based on knowledge of where they are, who they are and their past activity, was seen as a potentially powerful use for the beacons.

Student: I think the push notifications would encourage people to use it more, you could get annoyed but people would use it a lot more if every time they walked in there was a notification. If it's a constant reminder it could be a good way of getting [key information] across.

The intervention provided lots of points for the tutors to think about regarding how, when and why to incorporate digital and online practices into their teaching, both on this module and the rest of the course. In particular, it has encouraged reflection on how information has been curated and presented to the students prior to the intervention and how that process could be modified in the future as a result of the technology available to the staff and students.

Tutor: What's interesting with [this pilot] is, in sessions we would usually photograph and post something. I was pinging a lot of work on, partly because I was thinking I must fill this Tumblr, so it was just bang, bang. But I suppose I haven't really reflected on this and the amount of posts that congregate there and the things we think are interesting compared to what we would talk about on a daily basis. That's interesting for me to reflect on that and that's actually very quick to do!

Discussion

While the project described in this paper was an exploratory study to identify whether there are opportunities to use beacons as a mechanism to support better use of learning spaces, in particular, the specialist studio space that was the focus of the intervention, it is apparent that even this extremely simple use, when combined with an appropriate physical space, can have an impact on students' learning and interaction. It is interesting to note that the students developed a feeling of 'closeness' to their tutors partly as a result of a continued digital presence from the course academics through the Tumblr blog accessed through the beacon. This suggests that, even though the same resource could be accessed from outside the studio, using the beacons to strongly situate this presence within the studio had a positive effect on the students.

From the interviews with both staff and students, it is clear that, once a certain level of familiarity with the technology was obtained, the beacons effectively faded into the background and became a convenient method of being prompted to check for updates to the online spaces. Instead, unless their attention was explicitly drawn to the beacons, the participants' discussion centred around the underlying platforms and the effect on interactions within the student cohort. By selecting the online platforms based on those that the majority of the students were already using, the barrier for the students to participate was reduced – though, in this particular case, the burden of learning and adapting to a new platform and way of working was transferred to the tutors.

Overall, it would appear that the original hypothesis for the project was, in this small pilot, found to be an accurate prediction of the effects of the intervention. While the small scale and focus of this project limit the ability to make direct inferences regarding the potential for beacons in higher education more widely, the increasing demand from students for personalised, just-in-time information through their mobile devices suggests that use of beacons will continue to grow and increase in the complexity of interaction they enable. This is likely to result in greater benefits to the students and enable alternative and novel method of peer and tutor interaction within the learning space. Increasingly, we see student expectation in universities demanding 'smart' responses regarding resource, spaces, communication, curriculum design and employability opportunities and Bluetooth beacons, if implemented appropriately, have the potential to address these expectations.

Conclusion

In spite of their simplicity, beacons offer many ways to support a wide variety of learning, and more general student experience, initiatives. In particular, beacons offer a supportive lever to build broad and dynamic learning communities that can exist in the physical and digital space both synchronously and asynchronously. For learners, this offers connection, timely access to context-specific information and the ability to share and collaborate in learning on campus in a range of spaces, across the web and potentially around the world with peers, academics and professionals. For academics, the technology can enable more flexible delivery, broaden pedagogical approaches, open up the learning space to internal and external expertise, and encourage an exploratory and connectivist approach to learning that makes use of a multitude of different spaces.

The inclusion of non-human agents in the learning process offers the possibility to shape, support and disrupt learning. Considering learning mediated through these non-human agents, such as an infrastructure built from mobile apps that leverage beacons, institutional data sources and external services to target learners with highly personalised, contextual information, leads to consideration of technical developments that are beginning to influence what it means to be a learner in the early-to-mid 21st century. While there are, and will continue to be, challenges around digital confidence and fluency from both students and staff, there is a growing pressure from both of these groups to integrate technology into learning and teaching practice that is unobtrusive and supports them in ways in which they want to work. The line between formal, timetabled, face-to-face sessions and informal, non-timetabled, self-directed learning becomes blurred in these spaces linking the physical and the digital.

Coupled with the growth in use of mobile devices by students and academics, beacons have significant potential to dramatically transform learning by offering new ways to students to interact with their peers and tutors. At the same, time they also provide an infrastructure that can be utilised for a myriad of other purposes, both planned and organic, to enhance the overall experience of learning and teaching, and of other aspects of higher education organisations such as outreach and cultural enrichment. The potential benefits of beacons suggest that they are a powerful, yet simple, unobtrusive and flexible technology that can be applied to a wide variety of situations within higher education.

Acknowledgements

This research has been supported through an internal Teaching Enhancement Fund, and through a Google Internet of Things Research Award.

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