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Beacons: A tool for 21st Century teaching and learning?

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Beacon technology was developed by Apple in 2013, and its initial use in secondary education has generated much enthusiastic descriptive and web-based claims of its potential. However, not only is there a paucity of academic study on its use in the classroom, but none of these claims have been critiqued. Additionally, if teachers are to use the technology in their pedagogy, they should know how to do so, theoretically and practically. This paper reports on research that was jointly conducted with a Year 10 Science teacher in an independent secondary school in the UK. Using an action research methodology, the research employed qualitative methods, such as observations, interviews and focus groups, to assess, from both the teacher's and pupils' perspectives, what affordances beacons have for pedagogy and what limitations constrain their use in practice. The results illustrated that beacons have several affordances for both teachers and pupils that, collectively, support constructivist approaches to learning. However, they also revealed technological and user limitations that affect both the use and efficacy of beacons in practice. Further research is needed to quantify the effect of beacons on pupils' learning. Longitudinal research is needed to verify these findings over time and with a larger sample.

Keywords: beacon technology; educational technology; pedagogy

Introduction

"Digital technology is now an integral part of education" (Selwyn 2016a, p. 1), both physically and pedagogically. It is a $5 trillion industry, with sales of educational software in 2011/12 in the US alone reaching $8 billion (Herold 2016; Selwyn 2016a). Such investment is based on an assumption that digital technology has a transformative and beneficial impact in the classroom (Selwyn & Facer 2013). Accordingly, not only are teachers encouraged to incorporate it into their teaching (Haydn 2013; Haydn, Stephen, Arthur & Hunt 2015), the use of digital technology has become normative practice in contemporary education (Selwyn 2016a).

However, teachers are the agents who determine whether educational technology is adopted or used in the classroom (Mueller, Wood & Willoughby 2008), but many resist or reject doing so (Selwyn 2013), often due to lack of knowledge or confidence (Hammonds, Matherson, Wilson & Wright 2013; Wood, Mueller, Willoughby, Specht & Deyoung 2005). Therefore, assuming that teachers perceive technology as a desirable element of their pedagogy, they not only need 'a better understanding of the nature and properties of technologies' (Conole & Dyke 2004, p. 114) but also to know what 'underpinning theories and approaches' support their use, especially if they

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are to adopt them in their pedagogy (Britain & Liber 1999). Therefore, this research sought to learn what affordances beacon technology has for pedagogical use and to link it to pedagogical methods.

Moreover, as this normative practice of digital technology is based on an assumption that technology's effect on learning is beneficial (Buckingham 2013; Livingstone 2012), 'everyone involved in education should develop a heightened sense of realism … about what technology can do in education and what it cannot' (Selwyn 2013, p. 165). Therefore, this research also sought to learn what limitations constrain beacon technology's pedagogical use in practice.

Beacon technology was introduced by Apple in 2013 – using the term 'iBeacon' – for use in the retail sector (Baldwin 2013). It has also been implemented effectively in the museum and marketing sectors (Lewis 2016), and its potential is envisaged in the education sector generally (Afshar, Rellinger, & Nilsson 2015; Corna, Fontana, Nacci & Sciuto 2015; Husni 2017; Lucas, Ma, & Chen 2016; Mareco 2015) and in the classroom specifically (Baty 2014). It was first trialled in a secondary school in Australia in June 2014, with the school claiming it has 'huge' potential (Frost 2014) and the software developer hailing it as a 'game-changer' (Elwood 2014). Since then other secondary schools in the UK have trialled the technology to similar acclamation (Smart 2014).

However, such claims have not been critiqued by academic research. Therefore, because of a lack of both critical and theoretical research into beacon technology's nascent use in classrooms, the research presented in this article used an action research methodology (McAteer 2013; McNiff 2013, 2016) to assess beacons' affordances and limitations and so develop new knowledge about their practical use in teaching and learning.

The research took place in an independent secondary school in the UK in June 2017. The school uses a software platform called 'Studywiz' and an app called 'eLockers'. The school issues iPads to pupils for the lesson. They log on with their own password, and then they can gain access to the eLockers app. The teacher is issued with her own iPad, which also has access to the eLockers app. The class was the joint lowest of seven Year 10 Chemistry sets and consisted of 16 pupils (11 male, 5 female), who the teacher (Mrs S) assessed as being of mixed ability (all participants' names in this paper are pseudonyms).

This article begins with an explanation of beacon technology, including a literature review of its use in teaching and learning. Then it outlines the methods used in the research. The research results are then discussed with regard to each research question in turn alongside *a posteriori* literature. It concludes that teachers can use beacons for constructivist approaches to learning but that they must do so selectively as there are several technological and user factors affecting beacons' pedagogical use and efficacy.

Beacon technology

Beacon technology uses Bluetooth Low Energy (BLE) to connect beacons (see Figure 1) to portable mobile devices when both are in close proximity to each other (beaconinsider 1995; Garg & Shukla 2016).

To use beacon technology, a user needs a beacon, a software platform with which to manage the beacon (such as Studywiz) and a receptive device (such as a smartphone or tablet) with a beacon-enabled app (such as eLockers) installed on it, through which the user can access the beacon's content, though only when the device's location services are activated (Garg & Shukla 2016; Lighthouse 2017).

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Figure 1. Some beacons made by different manufacturers.
Photo credit: Creative Commons: crowdsify

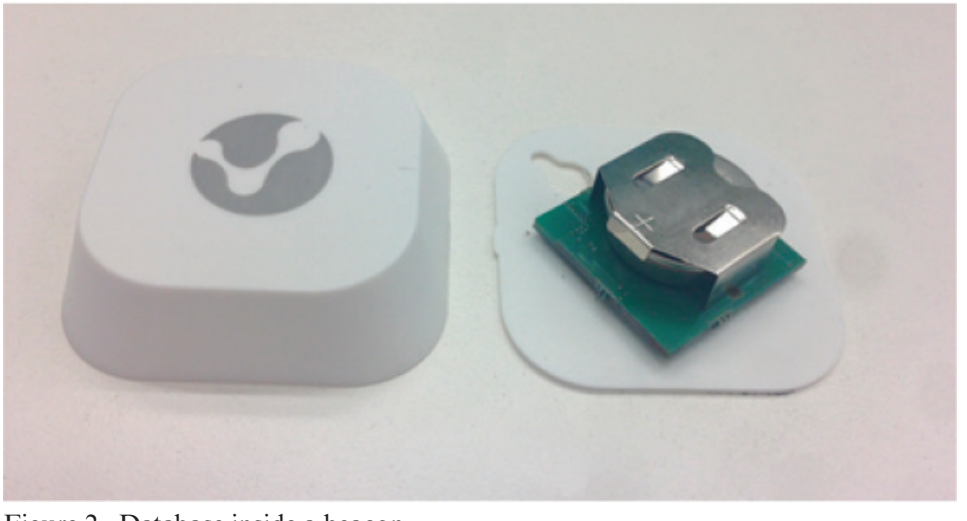

Figure 2. Database inside a beacon.
Photo credit: Creative Commons: shinesolutions.com

Beacons consist of a database inside a plastic casing (see Figure 2). They are 'passive' (McDonald & Glover 2016, p. 3) pieces of technology that simply 'push' their content to any receptive device.

The database is loaded by a user with resources or instructions. The beacon then broadcasts a BLE signal to be received by any device within its range that has the necessary app installed on it. The user then permits it to 'push' its content, such as a document or link to a website, which then appears on the screen.

Although there is much enthusiastic descriptive and web-based evidence of the potential of beacon technology in teaching and learning generally (Afshar, Rellinger, & Nilsson 2015; Elwood 2014; Smart 2014), no study has focused on the use of beacon technology in mainstream secondary education in the UK. Indeed, only three academic studies seem to have researched beacons' use in the classroom at all (McDonald & Glover 2016; Wu, Young, & Wen 2016; Zimmerman, Land, Maggiore, Ashley, & Millet 2016). However, not only do these studies simply

showcase ways of using beacons in the classroom without linking their methods to pedagogical theory but also, other than McDonald & Glover's (2016) identification of two constraints, none of them offers a critique of the use of beacons in teaching and learning – indeed, McDonald & Glover (2016) use the term 'transformative' in their title. Therefore, there is a need not only for a critical assessment of the use of beacons in mainstream secondary education in the UK but also for knowledge about which learning approaches teachers should use with them.

The three current studies suggest that beacons do have a positive effect on the teaching and learning process. From the pupils' perspective, beacons are popular and improve their confidence and interest in the learning process. They afford pupils choice not only over what they want to learn – albeit within predetermined contexts – but also over the depth and breadth of their learning. Thus beacons facilitate deep learning and 'could help to significantly improve' (Wu *et al.* 2016, p. abstract) pupils' academic progress and achievement, regardless of differences in prior levels of learning. However, McDonald & Glover (2016) caution that, if pupils do not know what the technology can do for them, beacons' efficacy will be limited. From a teacher's perspective, the studies suggest beacons should be used to create learning zones or for play-based learning, though again McDonald & Glover (2016) caution that their efficacy can be hampered by teachers' inability to access the equipment and by their unfamiliarity with the software.

However, not only is the reliability of these studies questionable, as they were carried out on samples that are too small (n = 50, 35 and 34, respectively) to be representative, but so too is their generalisability as they were carried out in unrepresentative contexts of learning. Wu *et al.*'s (2016) and McDonald & Glover's (2016) research focuses on tertiary students, who not only form the minority of pupils but are mature and would be able to exercise the responsibility inherent in learning with beacons. Conversely, Zimmerman *et al.*'s (2016) research focuses on primary children in the United States, who would not only need significant support and guidance to use the technology but who also have considerably different learning and study skills and abilities. Furthermore, it was conducted in an informal setting, which would have different pedagogical conditions compared to formal, classroom settings.

With the aim of the research being to learn more about the use of beacons in the classroom, the research questions were guided by the literature review:

RQ1: What affordances do beacons have for teaching and learning?
RQ2: What limitations constrain the use of beacons in teaching and learning?
RQ3: What pedagogical approaches could beacons be used for?

Methodology and data collection

Adopting an interpretive approach within a constructivist paradigm (Cohen, Manion, & Morrison 2011; Richard, Lewis, Nicholls & Ormston 2013), an action research methodology (McAteer 2013; McNiff 2013, 2016) was used to conduct a critical assessment of the use and practicality of beacons in teaching and learning. Full ethical approval for the research was given by the University of Bristol ethics panel (ID #53842).

As action research is an inductive, organic (McAteer 2013; McNiff 2013, 2016) and 'messy' (Mellor 2001) process of 'knowledge creation and theory generation' (McNiff 2013, p. 1), learning was developed over three action research cycles (McAteer 2013; McNiff 2013, 2016) (see Table 1). This paper follow Davis's (2007) suggestion to report such research in chronological order.

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Table 1. Reflections during three cycles of action research, presented using McNiff's (2016) format.

Research cycle	Date	Action	Reflection					Planning	
		What did I/we do?	Why did I/we do it?	What did I/we learn from it?	Significance of what I/we learned?		Other	What would I/we therefore like to learn next?	What action will enable me/us to investigate this?
					Positive	Negative			
1	7th June	Use iBeacons to teach Reactivity Series lesson instead of using usual, traditional style of teaching (only half the class was present)	To see if iBeacons make a difference to student engagement	iBeacons do seem to induce student engagement in the learning process, though with variable consistency and enthusiasm	We should continue to use them with those who it helped to engage with the learning process	We need to explore what other resources, activities will engage those who did not respond to iBeacons	Two variables at work - student-centred pedagogy & iBeacons - hard to know which was responsible for positive effect (are students this engaged in other, non-iBeacon student-centred activities?) Were pupils who engaged inconsistently the same as those who said they don't like learning per se in the questionnaire? (deeper cognitive issues here perhaps - e.g. fixed mindsets)	Was this a one-off occurrence, due to novelty? Are students as engaged in other lessons, learning about other topics? What other resources, activities, challenges, tactics could we use to further engage apathetic students?	Teach another lesson on a different topic with iBeacons See what difference a 'static' learning format makes Try different types of resources (e.g. interactive, dynamic, audio visual)

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Table 1. (*Continued*)

Research cycle	Date	Action	Reflection					Planning	
		What did I/we do?	Why did I/we do it?	What did I/we learn from it?	Significance of what I/we learned?		Other	What would I/we therefore like to learn next?	What action will enable me/us to investigate this?
					Positive	Negative			
			To see if iBeacons make a difference to learning process	Most - Lots of collaborative and independent learning occurring; some students in control pace of own learning; clear evidence of improved learning Some - Apathetic students needed cajoling to stay on task Technological unreliability affects flow and focus of lesson	iBeacons enhance learning process with keen and engaged students	Immaterial with apathetic students Technology must be reliable for both teachers and students to have faith in it and for productive learning to occur		Was this a one-off occurrence, due to novelty? Are students as engaged in other lessons, learning about other topics? Will we learn the same when the whole class is present? How much of a difference will technological reliability/ efficiency make?	Teach another lesson on a different topic, with iBeacons, to whole class See what difference a 'static' learning format makes Iron out technological unreliability/ inefficiency

Table 1. (*Continued*)

Research cycle	Date	Action	Reflection					Planning	
		What did I/we do?	Why did I/we do it?	What did I/we learn from it?	Significance of what I/we learned?		Other	What would I/we therefore like to learn next?	What action will enable me/us to investigate this?
					Positive	Negative			
2	13th June	Use a 'static' format to teach rusting lesson with greater variety of resources	To see if changing the topic makes a difference to previous lesson's findings	Made little difference to results	iBeacons seem to enhance engagement regardless of topic		Success perhaps more to do with technological reliability and efficiency this lesson	Will this success be replicated with other types of activity?	Trial iBeacons with independent study (e.g. revision)
			To see what difference a 'static' learning format makes	Students and teacher prefer it for variety of reasons	'Static' learning format is more productive, efficient and popular than 'mobile' learning format		Appearances can be deceptive	Would 'moblie' format have been this successful if technology had been this reliable/efficient?	Try 'mobile' format now that technological problems have been ironed out

Table 1. (*Continued*)

Research cycle	Date	Action	Reflection					Planning	
		What did I/we do?	Why did I/we do it?	What did I/we learn from it?	Significance of what I/we learned?		Other	What would I/we therefore like to learn next?	What action will enable me/us to investigate this?
					Positive	Negative			
			To see what difference technological reliability/efficiency makes	Huge! All students engaged and on task for length of lesson	When technology is reliable and efficient, iBeacons can make a significant difference to student engagement and learning process		Many teachers may not persevere through initial problems and frustration to see these benefits		
	14th June	Use iBeacons for revision purposes	To see what difference iBeacons make to student engagement and learning with independent learning	Huge! All students not only engaged and on task for whole lesson, many went beyond expectations with quantity and/or quality of work produced	When technology is reliable and efficient, iBeacons can make a significant difference to student engagement and learning process in variety of tasks/disciplines		Reliability and efficiency of technology is key to iBeacons success in engaging students and enhancing their learning/study skills	Was this a one-off, due to novel method of revision?	Replicate process with other revision topics

Table 1. (*Continued*)

Research cycle	Date	Action	Reflection					Planning	
		What did I/we do?	Why did I/we do it?	What did I/we learn from it?	Significance of what I/we learned?		Other	What would I/we therefore like to learn next?	What action will enable me/us to investigate this?
					Positive	Negative			
			To investigate the quantity and types of resources needed	'Less is more' - quality is more important than quantity of resources	Resources of quality positively affect student engagement		Critical for teachers to plan and produce resources (and learning journey) with care beforehand	Which types of resource do students use most, is of most value?	Get student feedback on which resources they used
3	20th June	Replicate revision lesson with different topics/ resources	To see if initial success was down to novelty	Much less focus and engagement this lesson but all did work on revision – to varying degrees – without needing to be cajoled	iBeacons facilitate some learning in distractible pupils even in distracting conditions	iBeacons effect still subject to other extraneous factors – e.g. environmental factors	Some pupils make inappropriate choices when given a lot of choice	Would simplifying topics/choices help less able pupils to navigate/make better/more appropriate choices?	Make structure of learning progression more explicit

Table 1. (*Continued*)

Research cycle	Date	Action	Reflection					Planning	
		What did I/we do?	Why did I/we do it?	What did I/we learn from it?	Significance of what I/we learned?		Other	What would I/we therefore like to learn next?	What action will enable me/us to investigate this?
					Positive	Negative			
	21st June	Replicate revision lesson with scaffolded sub-topics	To see if simplified tasks benefit lower ability pupils more	Many did not get onto these tasks as they were still on previous tasks Some low ability pupils select wrong resource for chosen topic	Pupils are engaged, learning independently and at own pace		Need to find a way to make resources explicitly linked to topic	Would using folders to group topic resources collectively aid lower ability pupils' navigation and therefore selection?	Group resources in topic 'folders' on iBeacons
			To investigate student opinion on resources	Audio-visual resources (e.g. Explain Everything) are universally popular Low ability pupils reluctant to use higher thinking resources	Choice of resources encourages pupil engagement with learning	Some pupils do not push themselves to use higher level thinking resources	Underlines importance of pupils knowing rationale for learning to incentivise them to push themselves (e.g. relevance/ significance)	How can we encourage pupils to use more challenging resources to develop their cognitive ability?	Try differentiating resources (e.g. Level 1, 2, 3; Must, should, could)

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Lesson 1: The first lesson was about administration, during which the research was explained to the pupils, their permission was acquired and the Head of Technology helped the pupils to set up their tablets to receive the beacons' signal.

Action-research cycle 1 (lessons 2 and 3)

Following McDonald & Glover's (2016) recommendation and Hamilton's (2014) example, I created four learning zones (see Figure 3). I experimented with a 'mobile' learning format so the pupils progressed from learning zone 1 to 3, creating a 'learning journey', with each zone building on the knowledge and skills acquired in the previous one. The fourth was a 'Hint' beacon, which pupils could access for help. The beacons had been loaded by the Head of Technology for Mrs S.

From this cycle of research, we learned that beacons do seem to induce student engagement, albeit with variable consistency and enthusiasm. We also learned that beacons seem to enable engaged pupils to learn collaboratively, with some clear learning occurring. However, we were unsure not only about how much of these positive lessons were the result of novelty, but also how much effect the technological unreliability had had on the pupils. Nevertheless, a clear lesson learned was that the technology needs to be reliable for both the teacher and pupils to have faith in it and for it not to be an excuse for pupils to disengage with the learning.

Therefore, in the second cycle of research, we wanted to resolve the technological issues to remove the influence of technological unreliability. We also wanted to try a 'static' learning format, as we suspected that some pupils' disengagement could have been caused by the 'mobile' learning format. We also wanted to see if the positive effects on some pupils were sustained. We were also interested in learning what

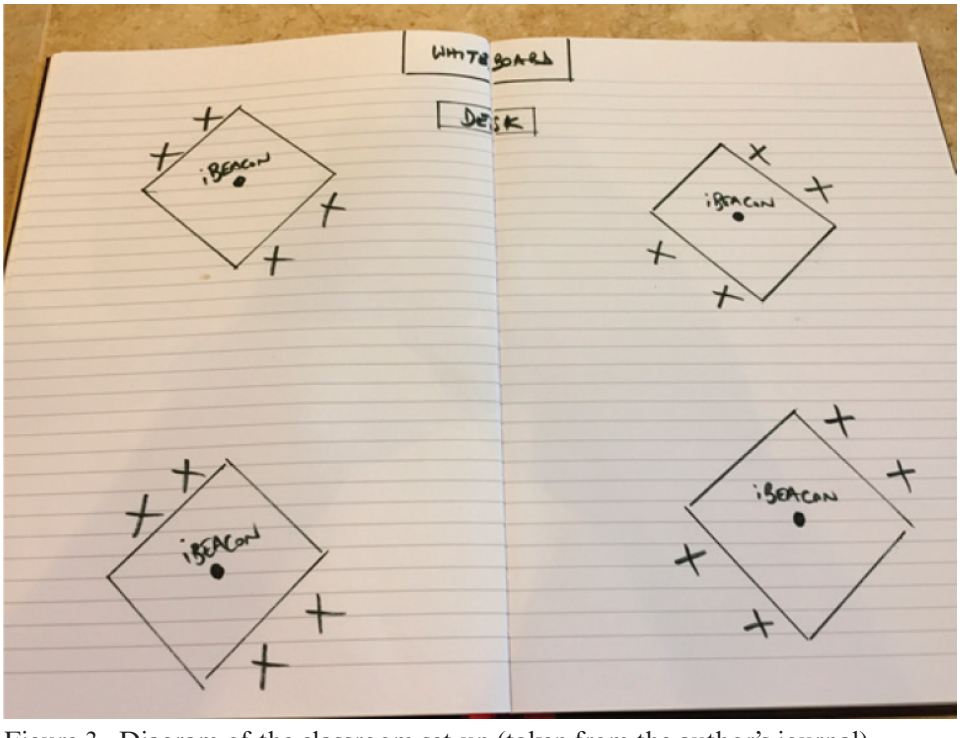

Figure 3. Diagram of the classroom set-up (taken from the author's journal).

difference different resources had on the pupils' engagement and learning. In retrospect, these were too many foci to research in one cycle.

Action-research cycle 2 (lessons 4, 5 and 6)
For this cycle, not only had Mrs S learned how to load the resources herself – and put a greater variety of resources on the beacons – she had been equipped with the Classroom app, which enabled her to allocate, manage and monitor centrally all pupils' iPads. We also used a static learning format, whereby the 'learning journey' was put on each beacon, and the pupils went through the stages of learning *in situ*.

From this cycle of research, we confirmed that technological reliability is essential for the fluidity of the lesson and for pupils' engagement and learning with beacons. Additionally, we also learned that teachers could use beacons successfully in a static format. Furthermore, with pupils just as engaged in the second cycle with a different topic and format, we felt that beacons were indeed having a positive effect on student engagement and their learning. It also seemed that a variety of resources of different types did enhance the pupils' engagement and learning.

In the third cycle of research, to be used for revision purposes, we wanted to see if beacons had a similarly beneficial effect on pupils' engagement and learning in independent learning. It would also be interesting to see if the 'mobile' format worked better now that the technological issues were resolved. We also wanted to learn more about what types of resources were most effective in enhancing pupils' engagement and learning.

Action-research cycle 3 (lessons 7, 8 and 9)
For this cycle, we decided to maintain the static format as we wanted to learn about the other foci of interest. The pupils were given not just two topics to choose from but also several subtopics within each. Mrs S provided a variety of resources for each subtopic, from online videos to personally made, bespoke resources, and used the Classroom app to assign each pupil an iPad and set all necessary settings.

From this cycle of research, we learned that, when technology is reliable and efficient, beacons can make a significant difference to the student engagement and learning process in variety of constructivist tasks. We also learned that resources of quality positively affect student engagement and that providing fewer resources of quality is more productive than providing a quantity of resources. However, we also learned that some pupils need supervision over the choices they make.

Data analysis

The dataset was subjected to thematic analysis (Braun & Clarke 2006; Butler-Kisber 2010), as Braun & Clarke (2006) indicate that it is an easy method to apply, enabling researchers to make meaning out of the subjective experience of participants (which aligned with the research questions) and that it can reveal unanticipated findings (as was the case in this analysis). Additionally, it is appropriate for action research in particular, as it 'allows researchers to generate theory from data rather than apply theory through practice or test practice against theory' (McAteer 2013, p. 108).

As is common with action research (McAteer 2013; McNiff 2013, 2016), significant themes and learning were identified as they started to emerge during the data collection stage. After data collection, the dataset was analysed to become familiar with the 'holism' (Cohen *et al*. 2011, p. 427) of the data, thereby also incorporating an internal validity check (Cohen *et al*. 2011; McNiff 2013, 2016). A 'course-grained analysis' (Butler-Kisber

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2010, pp. 30–31) of the dataset was then conducted to identify relevant data on the *a priori* themes of affordances and limitations of beacons. Thereafter, further 'fine-grained analysis' (p.31) of these data was conducted to discover *a posteriori* subthemes.

Results and discussion

This research sought to generate new knowledge about the practical use and efficacy of beacons in teaching and learning. Results are presented and discussed together thematically around the three research questions that focused this study: affordances of beacon technology, its limitations and the pedagogical approaches teachers could use it with. Table 2 summarises the results.

In addition, as recommended by Green (1999), *a posteriori* literature will be reviewed concurrently.

RQ1: What affordances do beacons have for teaching and learning?

This research illustrated that beacons have several affordances to support student-centred pedagogy. These can be divided into affordances for pupils and affordances for teachers.

Affordances for pupils

Pace of learning

Beacons afford pupils the ability to control the pace of their own learning:

> … the beacons … allow the individual pace … I wasn't having to move the class on. (Mrs S)

This shift in their ability to control the pace of their learning was appreciated by the students themselves:

> … it's made it easier to learn as I can go at my own pace and not others'. (George)

Table 2. Summary of research results.

Affordances	For pupils	• Pace of learning • Choice of learning • Challenge of learning
	For teachers	• Ability to focus on individual students
Limitations	Technological	• Proximity • Unreliability • Inaccessibility
	User	• Procedural knowledge • Production of bespoke resources • Pupils' attitude
Pedagogical approaches	• Enquiry-based learning • Independent learning • Individualisation • Personalised learning	

> I was also able to learn as slowly as suited to me so I could understand topics better. (Amy)

Mrs S felt this affordance benefitted the higher and lower ability pupils in particular:

> … those who needed to move on had moved on and those who wanted to go slow could go slow …

An important reason for this was because the lower ability pupils could seek help either from a 'hint' resource on the beacon or from Mrs S herself, while the higher ability pupils could get on with learning uninterrupted. Importantly, this was recognised by the pupils themselves. Hugo acknowledged that 'it has changed how much I learned because I worked faster than we do in normal lessons … I do not have to go as slow as the slowest person', whilst Ollie remarked that 'things that I did not understand properly before, either by the teacher having to move on or not making sense in my head, I feel I now know'.

The ability for pupils to control the pace of their own learning is a key factor in engaging students with their learning (Bransford, Brown, & Cocking 2000), and this research illustrates that beacons have this affordance.

Choice of learning

Beacons afford students choice over their own learning, albeit within a given context. This affordance was facilitated through Mrs S's ability to provide a variety of resources of both type and challenge on a particular topic:

> They were using what they chose to use, they had a range [of resources]. They had all decided 'Well, I like this, I don't like that'. They picked what they wanted to use.

This affordance was appreciated by the students, especially when it came to revision ('You can work on your own stuff and on what you don't understand' [Amy]).

Pupils also valued the affordance beacons gave them to choose how they learn:

> I feel that the beacons helped me choose what way I wanted to learn. (Barney)

> Because I can choose my approach of learning, it has increased how much I learned … Things that I did not understand properly before, either by the teacher having to move on or not making sense in my head, I feel I now know because I am given several ways to learn. (Ollie)

> The beacons have enabled me to learn in different ways and using different methods. (Freddie)

However, we found that some pupils needed supervision to ensure they had made the right choices and were using appropriate resources:

> Some of them didn't make very wise choices, so you had to guide them to a better choice for the [topic] they were on. (Mrs S)

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> Lots of them started at the wrong place, which was interesting … [for example], [student] was insisting she wanted to do the alkenes, which is the hardest bit … I guess it's how mature they are in making these decisions. (Mrs S)

This exemplifies the claim that some pupils will make inappropriate, even detrimental, choices and so weaken the effectiveness of this affordance (Selwyn 2016a). However, it also illustrates that, if used persistently, beacons could help pupils to develop the meta-cognitive skills of self-learning integral to successful independent learning (Meyer, Haywood, Sachdev & Faraday 2008).

Learner choice is a fundamental tenet of progressive education (Bransford *et al*. 2000; Green *et al*. 2005) and a key factor in motivating students (Bransford *et al*. 2000), and this research illustrates that beacons afford learners considerable choice. It also supports Zimmerman *et al.*'s (2016) research, which claims that beacons enable students 'to control the depth and breadth of … content presented, based on their proximity to pre-selected [resources]' and that they enable pupils to pursue their own learning interests and needs, albeit within a predetermined context and considering limitations that affect pupils' efficacy in using it (see following).

Challenge of learning

Through these affordances of pace and choice of learning, beacons afford students the ability to challenge themselves in their learning, for instance, by selecting differentiated resources or tasks that are of higher cognitive demand.

In addition to challenging themselves, pupils were also able to be challenged by Mrs S, whether orally:

> I liked being able to have those conversations … sort of saying, 'Well done, move on, do the next bit, come on it's up to you, make a decision'. I liked, sort of, putting it back on them a bit more,

or through beacons' affordance for her to provide pupils with resources during their learning:

> I liked the fact that with someone like Hugo I could say, 'Right … here's an extra bit', and the fact that in the middle of a lesson you could add something else on if you wanted to. (Mrs S)

Providing challenge is a key factor in motivating learners (Paris 1997), and this research illustrates that, subject to the provisos above, beacons afford students challenge in their learning, albeit within a given context.

Affordances for teachers

Ability to focus on individual students

With pupils having responsibility for their own learning, the teacher is afforded more time and ability to focus on the individuals within a class, whether with a difficulty ('I loved the fact that I could add things mid-lesson to someone that needed a bit of extra support …' [Mrs S]) or to hand back work:

> The feedback could be very much more personalised, and you could take time to go round and speak to them … I did like the fact you could go round and do the individual feedback on work, which I think is a bonus. (Mrs S)

Therefore, this research supports Zimmerman *et al.*'s (2016) finding that beacons make teachers' communication with their students more efficient, which is significant because effective teacher communication and feedback is essential if student learning is to be productive (Assessment Reform Group 1999; Bransford *et al.* 2000).

Implications

This research illustrates that beacons afford pupils the ability to control the pace, choice and challenge of their learning – albeit within predetermined contexts. Collectively, these characteristics are essential in engaging and motivating learners in learning (Bransford *et al.* 2000; Paris 1997). Indeed, this was the effect on some pupils in this research, particularly those of lower ability:

> Ollie, Barney and Max, they just got on with the work. Simon was very engaged and got on with the work. James even, who doesn't do anything, got on with the work. So I think that they actually engaged with it and progressed. (Mrs S)

as the pupils themselves acknowledged:

> It has made me more engaged as I want to get my sheets done. (James)
> It made me stay concentrated. (Simon)
> I feel more engaged and interested. (Ollie)

Additionally, these affordances mean that engaged pupils are unhampered by others in the class and are able to improve the quality and quantity of their learning, particularly those of lower ability:

> I think those who were engaged and got on with the tasks answered [questions] well … they have definitely shown that they have made some strides forward. (Mrs S)

Consequently, Mrs S felt that some students had pushed themselves further with beacons than she felt they would have done without:

> … they all did the work, they all did the tasks, they all completed it.

Consequently, these findings support not only Wu *et al.*'s (2016) and Zimmerman *et al.*'s (2016) claims that beacons can enhance student learning but also Murphy's (2016) claims that educational technology generally can enhance pupil engagement, motivation, collaboration, teacher–student interaction and depth of learning and understanding in the classroom. Furthermore, these findings suggest that beacons enable low ability students to learn as productively as higher ability students in the same lesson. This is significant as it suggests that beacons may help pupils in developing depth or mastery of learning, an aspect of learning that is gaining profile (Claxton 2013; Claxton & Lucas 2016; Guskey 2010).

However, it must also be noted that several pupils remarked how they felt they were *less* engaged in their learning as a result of learning with beacons, though this appeared to be a result of antipathy towards constructivist learning rather than the technology itself (see following).

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RQ2: What limitations constrain the use of beacons in teaching and learning?

Both personal experience and socio-critical literature (Livingstone 2012; Selwyn 2016a, 2016b) suggest that educational technology has its constraints, limiting its potential use, benefit and effect in practice. Therefore, this research also assessed factors that limit the affordances of beacons in reality. These can be divided into technological and user limitations.

Technological limitations

We encountered several technological issues that impacted on the efficacy of beacons in both the teaching and learning processes.

Proximity

When beacons were too close together, students picked up different beacons at the same time and therefore had access to multiple or wrong resources simultaneously. It was impossible to tell which resources were on which beacons. However, this issue was solved by minimising the broadcasting range of the beacons and by putting further distance between learning zones.

Unreliability

The first lessons were beset by unreliable technology. However, this issue was solved by Mrs S checking the beacons before the lesson, and any beacons that weren't working were swapped.

Accessibility and infrastructure

Supporting findings by McDonald & Glover (2016), a frequent problem was Mrs S's inability to access the technology because of the school's intranet system creating barriers:

> If you have problems with your Wi-Fi in your school, or if you have problems with your … access permissions or this or that, then it's compounded. So I suppose it would depend on how well your school is already set up.

Practical implications

The most significant consequence of the technological limitations in those initial lessons was student disengagement. Not only were distractible students able to be 'silly' – as one such pupil admitted ('The whole thing was quite stop-start … that allowed people like me with low attention spans to diverge from time to time' [Ed]) – but also, as a class: Mrs S admitted that 'we'd lost them before we'd even started'.

Mrs S's most prevalent feeling resulting from these initial technological problems was one of frustration ('I was very frustrated to start with, with all the things I had to find out and learn'), exemplifying claims that the slow uptake of technology by teachers is because of such experiences (Hammonds *et al.* 2013; Selwyn 2013, 2016b). However, it is important to note that all these technological issues were overcome

through the Classroom manager app, support from the IT department and through the teacher's and students' growing confidence and procedural knowledge. Consequently, by the end of the research, all technological issues had been resolved and the beacons worked reliably. Yet Mrs S acknowledged that this would not have happened had she not persevered with it:

> … with all these things, it's getting over those first hurdles, isn't it? It's having the drive to continue and not give up, because I think a lot of people without a reason would have probably gone 'Ugh! I can't do this. Stop!' when it didn't work instantly. Whereas, actually, it didn't take much to sort of get over quite a lot of those difficulties.

This reinforces the importance of training and supporting both teachers and pupils when incorporating such technology into pedagogy (Mueller *et al*. 2008; Wood *et al.* 2005).

User limitations

Socio-critical literature suggests that the use and potential of technology is limited by the human who uses it (Buckingham 2013; Livingstone 2012; Selwyn 2016b; Selwyn & Facer 2013). This was very much a limitation of the use and efficacy of beacons in the classroom. Indeed, it was compounded in this context by the fact that there were two users of the technology: the teacher and the students.

Users' procedural knowledge

Describing herself as 'non-techy', Mrs S had many difficulties in the first lesson because, initially, she did not know how to operate the technology, supporting findings by McDonald & Glover (2016). Additionally, the pupils' lack of knowledge also contributed to technological issues. Much of the start of initial lessons was taken up with problems of logging on (such as students not remembering passwords) and accessing beacons' signal. Many students needed lots of help from the 'non-techy' teacher and a more able student to get going.

However, these issues were solved by Mrs S using the Classroom manager app to pre-assign iPads to students and centrally control the settings of each one. Additionally, she managed to 'get over quite a lot of those difficulties' simply through practice and playing with the technology and through the support and guidance of the IT department.

Not only does this support Gibson & Pick's (2000) claim that hidden affordances can be discovered or learned through instruction or playing and that this can take 'much exploration, patience and time' (p. 17), it reinforces claims that teachers must be given the necessary technological resources and especially human support when seeking to incorporate technology into their pedagogy (Mueller *et al*. 2008; Wood *et al.* 2005).

Teacher constraints

Many teachers are resistant to using educational technology (Selwyn 2013, 2016b; Wood *et al.* 2005), but even if a teacher is willing to use them, we found two main factors that affect the efficacy of beacons in the classroom: a teacher's lack of procedural knowledge (see preceding) and the production of bespoke resources.

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Production of bespoke resources

In order to be 'fit for purpose', resources need to be 'tailored to [the students] specifically, not just the knowledge that they need to know, but also their ability' (Mrs S). This is achieved through the teacher providing not only a variety of resources ('It's the variety, I think, because they all like different things, so … they were all using different resources for different bits' [Mrs S]) but also bespoke resources ('Because you make it, you can do what you want with it. I think it's the personalisation that makes those impressive' [Mrs S]). Consequently, the resources the teacher provides can also enhance beacons' affordance for individualisation (see following).

However, while Mrs S acknowledged that the quality of the resources was important, the two biggest factors affecting her ability to produce resources of quality were her knowledge about how to do it (procedural knowledge) and time:

> If you don't have the time or the know how to do that [make the resources] then I think they are not going to be very useful.

Pupil constraints

This research illustrated two issues that affect the use and efficacy of using beacons in the classroom: pupils' procedural knowledge (see preceding) and their attitude towards learning with beacons.

Pupil attitude

A significant finding is that students differ in their motivation and receptiveness to the new technology. The data illustrated that students seem to have divided opinions about learning with beacons – perhaps along lines of academic ability and of gender, with boys preferring them to girls, though this requires further research. Nevertheless, previous research has not found that pupils do not like learning with beacons, and this therefore requires further comment.

Reasons for pupils' divided opinion

Analysis of the data illustrated the factors behind such divided opinion (see Table 3).

Analysis of their comments illustrated that their issues were mainly to do with student-centred learning, including the need to learn independently, the ease of distraction and the lack of didactic instruction, rather than towards the technology *per se*:

> … it's hard if you don't have any self-discipline, because there's no one there like telling you, you've got to rely on yourself to do it, and if you don't have that level of discipline then there's no point, you are not going to get any work done. (Freya)

Interestingly, Mrs S theorised that they were disaffected because the traditional approach had suited them, unlike the higher and lower ability students, who had been impeded by it:

> [They] … missed that kind of guidance of me going, 'Now do this, now do that'. They didn't like the fact that they were driving it.

Table 3. Factors influencing pupils' positive and negative opinions of learning with beacons.

Positive	Negative
• Interactivity • Contextualised resources • Various complementary resources • Pupils' ability to choose what they learn • Pupils' ability to control the pace of their own learning • Increased self-responsibility • Increased enjoyment in learning • Increased engagement in learning process • Increased quantity of learning • Increased quality of learning and understanding	• Unfamiliarity and novelty • Need for self-responsibility • Incompatibility with own learning preferences • Decreased engagement in learning process (mainly because of the ease of being distracted) • Decreased enjoyment in learning • Decreased quantity of learning • Decreased quality of learning and understanding • iPads are seen as tools for entertainment not learning • Pupils have too much 'screen' time in life anyway

Significantly, this was confirmed by a pupil:

> For the people who like working at a slower or quicker rate, obviously, that's going to help them, whereas I can work at the rate that [the teacher] normally works at, so it just didn't seem very good for me. (Freya)

Therefore, this research also illustrates that beacons will not benefit all pupils, as some do not like learning with them because of an antipathy towards constructivist, student-centred pedagogy. This supports not only critics of constructivism, who claim that it is not a 'one size fits all' approach to learning (Kirschner, Sweller and Clark 2006; Mayer 2004; Osborne 1996; Young and Muller 2010) but also claims that teachers need to have a range of teaching methods to suit the pupil as much as the learning objective or task (Bransford *et al*. 2000; Brown 2012; Selwyn 2016b).

RQ3: What pedagogical approaches could beacons be used for?

This research illustrates that, collectively, the affordances for pupils to control the pace, choice and challenge of their learning and for teachers to focus more on individual students create several pedagogical affordances, such as for enquiry-based learning, independent learning and personalised learning. However, it is critical to note that these affordances are only realised if the pupil is willing to learn.

Enquiry-based learning

Beacons afford the teacher the ability to deliver enquiry-based learning. Defined as 'a broad umbrella term to describe approaches to learning that are driven by a process of enquiry' (Kahn & O'Rourke 2005, p. 1), this approach was used effectively to develop pupils' learning in the second research cycle:

> I also thought that the way that things were … given to us, it was almost like a treasure hunt thing, and I thought that was much more efficient and it helped me learn more. (Ed)

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We therefore concluded that beacons would support research and other enquiry-based tasks. Enquiry-based learning is promoted as a contemporary approach to learning (Leat 2017) because of its development of pupils' 21st Century or 'soft' skills (Adams Becker, Freeman, Giesinger Hall, Cummins & Yuhnke 2016; Warschauer & Matuchniak 2010).

Independent learning

Beacons afford the teacher the ability to deliver a pedagogical approach in which 'the responsibility for the learning process [shifts] from the teacher to the student' (Meyer, Heywood, Sachdev & Faraday 2008, p. 1). This approach was used effectively for revision in the third research cycle:

> One of the boys [Ollie] said it was the most he'd ever learned. (Mrs S)

Indeed, pupils themselves felt it was effective:

> I remember more than I did without beacons and I feel I am less confused now. (Ollie)
>
> It has made it better and increased memory for exam. (Harry)
>
> It has made me remember much more. (Simon)
>
> Before it was easy to forget before, but now I can remember a lot. (Sam)
>
> I have remembered more because I have learned more in the time because I have worked faster. (Hugo)

This research therefore supports not only other studies, which found that independent learning 'improve[s] academic performance, increase[s] motivation and confidence, [increases] student awareness of their limitations and their ability to manage them and enable[s] teachers to provide differentiated tasks for students' (Meyer *et al.* 2008, pp. 1–2) but also studies that suggest that technology has a useful role in independent learning (Meyer *et al.* 2008).

However, some of the pupils disliked this approach to revision or felt that it had no benefit for reasons such as the following:

> In terms of factual-based topics, I remembered less as I have a specific way of learning which does not match up to watching videos, etc. (Amy)
>
> I don't feel I remember much as there is so much to take in. (Grace)
>
> It hasn't changed anything because I'm a visual learner and it works for me if you can create your own posters, but you had to do this online not on paper. (Alice)
>
> I remembered things from filling out the sheets but not really by the iPads. (Lucy)
>
> I remember not as much by using this way. I like learning by writing it out. (George)
>
> I feel that I remember less using iPads, as I prefer not to use them to work. (Freddie)

However, these opinions reflect pupils' fixed approaches to learning rather than their attitude towards the technology *per se*. They also support critics of constructivist approaches to learning (Kirschner, Sweller & Clark 2006; Osborne 1996; Selwyn 2016b; Young & Muller 2010).

Individualisation

Beacons afford the teacher more time to spend with individual students, for example, to help them with a difficulty or to hand back work:

> I think it's the individualised learning journey that's improved and I think it's the fact that you can happily spend time with individuals because everyone's got something to be getting on with. (Mrs S)

Not only does this support Zimmerman *et al.*'s (2016) finding that beacons make teachers' communication with their students more efficient, which is significant because effective teacher communication and feedback is essential if student learning is to be productive (Assessment Reform Group 1999; Bransford *et al*. 2000), but it also suggests that beacons afford increased individualisation.

Individualisation is highly regarded as a pedagogical approach. Not only does Bloom (1984) regard one-to-one tuition as the most effective method of pedagogy (cited in (Wiliam 2011)), but also individualisation has a particularly beneficial effect on teaching and learning: facilitating more feedback, affording teachers better relationships with and knowledge of pupils and more differentiation (Blachford 2012), and it is especially effective when combined with collaborative work (Baines, Blatchford & Chowne 2007). Consequently:

> my colleagues and I have argued that it would be particularly valuable to concentrate on strategies for increased personalized, appropriate instruction, in line with the research literature. (Blachford 2012, p. 70)

Therefore, this research illustrates that beacons have an affordance for individualised learning, a method of teaching defined as 'instruction calibrated to meet the unique pace of various students' (Basye 2016) in which 'individual students can progress through the curriculum at different speeds, based on their own particular learning needs' (*Ibid*.). Individualised learning:

> … serves students who may need to review previously covered material, students who don't want to waste time covering information they've already mastered, or students who need to proceed through the curriculum more slowly or immerse themselves in a certain topic or principle to really get it. (*Ibid*.)

Significantly, individualisation and students having responsibility for and the ability to control the pace and content of their learning are key components of personalised learning (Courcier 2007), a branch of student-centred pedagogy that is gaining high political profile. At its core is the laudable principle of maximising the learning process for each individual student to enable them to 'fulfil [their] potential' (DfES 2004, p. 4) by tailoring it to their individual difficulties, abilities and interests (Adams Becker *et al.* 2016; West-Burnham 2010). Although it is criticised for a variety of reasons (Dainton 2004; Guldberg 2004; Hartley 2007; Johnson 2004), not only has personalised learning

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been recommended, both nationally (Gilbert *et al.* 2006) and globally (Adams Becker *et al.* 2016), as the pedagogical means to meet the challenges facing 21st Century education, but also, as "technology is the key to personalised learning" (DfES 2005, p. 3; Walker & Logan 2009), 'technologically-enhanced' personalisation of education is cited as the pedagogy for the 21st Century (Adams Becker *et al.* 2016; Green, Facer, Rudd, Dillon & Humphreys 2005).

Consequently, this research suggests that beacons could be a tool for 21st Century education.

Limitations

These conclusions are subjective, unrepresentative and highly contextualised as they are based on data collected using an action research methodology in an independent secondary school in the southwest of the UK with a small (n = 16), convenient sample. Furthermore, the opinions of these pupils are unlikely to represent those of others in the year group or in the rest of the school, let alone those of students nationally or internationally.

However, these limitations are inconsequential, as the principles of action research (McNiff 2013) mean that conclusions drawn from it are still generalisable because other practitioners can see what learning applies to their own practice in different contexts (Mejia 2010):

> the greater the particularisations of descriptions, the greater the potential to throw light on possibilities for action in other situations. (Elliott 2007, p. 238)

Furthermore, this research satisfies Elliott's (2007) nine criteria for assessing the quality of action research (see Table 4) as recommended by McMahon & Jefford (2009).

Conclusions

This research shows that beacons afford students the ability to control the pace, choice and challenge of their learning, and they afford teachers more time and the ability to focus on the needs and requirements of each individual student. Collectively, these affordances support constructivist approaches to learning generally and individualised and personalised learning in particular. They may also help pupils engage with their learning and develop their learning skills, such as mastery or depth of learning and meta-learning. Indeed, it also suggests that persistent use of beacons may help the development of these pupils' meta-cognitive skills.

However, their use in practice is complicated by several factors. Not only are there technological issues – which can be resolved through the provision of technical support and through user training and practice – there are also user issues, which are potentially the more destabilising factor. The use and efficacy of beacons are dependent upon both teachers' and pupils' procedural knowledge. This has implications for training and practice.

Furthermore, teachers need to consider the pupils with whom they use beacons as they may be more effective with higher and lower ability pupils than with middle ability pupils. However, it may not be as simple as this because of each pupil's personal attitude towards learning with beacons. This research shows that pupils have divided attitudes towards learning with beacons – seemingly regardless of the academic

Table 4. Elliott's criteria for assessing quality of action research (adapted from Elliott 2007).

Criterion	Description
Relevance	It focuses on a problem that is of practical concern to the teachers involved.
Triangulation	It involves a gathering of data from the different points of view of the teacher, an observer and students.
Criticality	It enables teachers to call their existing stock of professional knowledge (tacit theories) into question and to test it against evidence gathered in their practical situation.
Contextual understanding	It extends teachers' understanding of their situation in a way that opens up new possibilities for action.
Reflexion	It is a deliberative and self-reflexive process in which the teacher calls into question both his or her teaching strategies (means) and the aims (ends) to which they are directed, and then modifies each by reflecting on the other.
Scrutiny	It is a rigorous conversational process in which the teacher opens up his or her practice to the rational scrutiny of students and peers, 'in-voices' their views of the action situation and in the process demonstrates a disposition to subordinate his or her own prejudices to the search for an overlapping and un-coerced consensus.
Integrity	It is a process in which the teacher displays: • Integrity in the pursuit of his or her educational aims and values. • Curiosity about other people's interpretations of the action situation. • Objectivity and honesty about his or her own motives and reasons for action. • Open-mindedness towards the views of others and respect for their freedom of thought and action.
Agency	It enlarges the teacher's sphere of personal agency in the practical situation through the realisation of his or her educational aims in a sustainable form.
Description	It enables a teacher to generate a description of the complexities of the case in sufficient detail to be of universal significance to other teachers.

benefit they may bring – and this makes the use and efficacy of the technology in the classroom very subjective. If teachers choose to use beacons for constructivist learning, some students will flourish independently, while others will need more support and supervision.

Moreover, much of pupils' antipathy towards learning with beacons is a result not of the technology *per se* but of struggling with student-centred, constructivist learning. This reinforces contemporary arguments that constructivist learning is not a one-size-fits-all pedagogy and that teachers need to use a variety of teaching methods, traditional and constructivist, as different approaches suit different objectives, tasks and pupils. Therefore, teachers need to consider the fitness for purpose of beacons, not only with the learning approach and task but also with the individual pupils who use them.

Therefore, this research illustrates that beacons are simply a 'means for assisting teachers in making instruction better' (Hammonds *et al.* 2013, p. 40) and that teachers should use them appropriately and selectively (Livingstone 2012). Not only should teachers consider the '"goodness" of fit' (Selwyn 2016b, p. 80) between the required

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approach to learning and the learner but also between the 'learning task and the learning technology' (*Ibid*.; Bower 2008).

Finally, the claim that beacons are a 'win/win' for teachers and students (Smart 2014) needs to be qualified. It is more accurate to say that beacons could be a 'win/win' for teachers and students when they operate reliably and when used by willing teachers, teaching certain tasks, in certain ways to certain pupils.

The research revealed other lines of enquiry that would be interesting to research further, such as possible divisions in pupils' attitudes towards beacons along lines of gender and of academic ability. Additionally, it would be useful to broaden the sample not only to see if the opinions and experience of these students are reflected by the whole student body of the school and over a longer period of time but also to schools of different socio-economic status. Furthermore, it would also be useful to quantify the influence of beacons on the academic progress and attainment of pupils who do like learning with beacons.

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