e-mentor
DWUMIESIĘCZNIK SZKOŁY GŁÓWNEJ HANDLOWEJ W WARSZAWIE
WSPÓŁWYDAWCA: FUNDACJA PROMOCJI I AKREDYTACJ KIERUNKÓW EKONOMICZNYCH

2021, nr 3 (90)

Bajak, M. (2021). Potential of beacons to enhance teaching and learning in stationary education. *e-mentor, 3*(90), 73–83. https://doi.org/10.15219/em90.1524

Maria Bajak

Potential of beacons to enhance teaching and learning in stationary education

Abstract

Dynamic technological progress is actively influencing the shape of modern education. Inventions that are constantly appearing on the market are often adapted to the needs of schools. One of the technologies that shows special potential in didactics is beacons. Beacons are small devices that can be used for communication, navigation and researching the recipient's behavior. These functionalities are used in the education process, enabling the creation of completely new learning experiences. According to research, they can be successfully used in the classroom, during the formal learning process, as well as in various institutions, such as in informal transfer of knowledge, for example in cultural institutions. These sensors can contribute to the creation of a dynamic space for the exchange of knowledge and experiences, which will automatically respond to the individual needs of the recipient. The main goal of this article is to present the possibility of using beacons in the context of stationary education. The considerations were based on a review of the available literature. The work draws attention not only to the problems of the sensors themselves, but also to the possibility of their cooperation with other technologies. The collaboration of technical tools may contribute to the creation of more comprehensive solutions and, as a result, an increase in the quality and efficiency of the education process. However, as the analysis shows – beacons can be a promising technology in education, but their use is niche. Perhaps in future years, there will be more such solutions that will enable a more accurate assessment of these sensors. The author intends to continue her research to support the adoption of the described technology in Polish educational institutions.

Keywords: technology in education, beacons, Internet of Things, communication with students, stationary education, educational projects using beacons

Introduction

The impact of new media on society is becoming increasingly apparent in almost every aspect of human life. Transformation in the technological environment has not remained neutral for education, which is actively adapting to current trends (Fazlagić, 2018; Hauer, 2017). Learning processes are becoming increasingly dependent not on the content being distributed, but on the way it is delivered (Arnold, 2011; Engeström, 2014). At the same time, new media is leading to the creation of a ubiquitous and pervasive digital environment (Weiser, 1991), which enables the introduction of creative teaching methods and continuous individual learning (Herczeg et al., 2019). The transformation of education can be considered both in the context of distance learning, hybrid and stationary learning. Digital technologies are most often associated with the first two forms of education, because it is in their nature to use modern communication methods in connection with the need to overcome the barrier of distance between the student and the teacher. However, digitization also extends to residential learning spaces, making classrooms and even entire schools and colleges smart (Squires, 2017). At the level of classroom teaching, the use of new technologies relates primarily to communication, exchange of resources (e.g., information, ideas) and sensory stimulation of students through audiovisual materials (Xianyang, 2018). The availability of modern educational tools enables a comprehensive transformation of education both through innovations in the deep structure of teaching methods, as well as their optimization in the practical dimension (Meisch, 2020). However, it should be noted that even in the case of new technologies, the human factor is

Maria Bajak, Cracow University of Economics, Poland, https://orcid.org/0000-0003-4769-7696

still essential to the success of the teaching process (Dumančić, 2019; Gurba & Rimanelli, 2018; Hosu & Hosu, 2019). One promising solution is beacons. They are a type of sensors that connect to a compatible device via Bluetooth and transmit information. Beacons can contribute to the creation of an educational space by composing a virtual learning experience while the student is physically present in the classroom. Tasks can be carried out individually or in a group in the learning process through play.

The evolution of digital technologies, their functions and possibilities enable the creation of a virtual learning environment (VLE). It is a dynamic concept that includes digital solutions in courses – both online and as a complement to traditional direct forms of education (Alves et al., 2017; Valsamidisa et al., 2014). This, in turn, can improve the attractiveness and value of messages, and as a result, have a positive impact on their reception, increasing the interest of students and the effectiveness of learning (Xianyang, 2018). Digital forms of education in this case create a one-to-one relationship with the student by creating a personal learning environment (PLE), which means systems supporting the individual achievement of educational goals using a package of appropriate tools and materials (Xu et al., 2020). The combination of both of these concepts (VLE and PLE) is the basis for constructing an intelligent learning space that can be called SMART Classroom.

The main goal of this article is to present the possibility of using beacons in the context of stationary education. It was decided to focus on this form of learning because the sensors require the physical presence of the user to connect with them. This eliminates their usefulness for distance education. The considerations were based on a review of the available literature. The criteria of its selection are described in the methodology section. Organizing the existing knowledge on this subject may help educational institutions in making decisions about using sensors in teaching and getting to know their full capabilities. As a result, it may suggest directions for creating more comprehensive solutions that will be able to contribute to a real improvement in the level of education.

Beacons as a new digital solution in the field of education

Permeation of the education sector by modern technologies has long been a common and desired phenomenon. Profiling didactics based on said development is a natural social process. The use of modern tools makes it easier to involve students in the classes. Moreover, as technological development has already become an integral part of society, the next generations of students increasingly expect it to be used in the classroom. This trend has a positive context. Properly used technologies can create a long-term positive impact on the effectiveness of education. Research by Ozerbas and Erdogan (2016) identified three basic determinants leading to a positive impact of multimedia on didactics:

- increasing the motivation of participants of the classes thanks to increasing the audiovisual attractiveness of the educational materials,
- the possibility of access to educational materials that are unlimited in time and space,
- making communication between students more attractive and fluid.

However, it should be emphasized that the observed positive impact of digital tools in education depends on the effective symbiosis of technology and the curriculum (Sinclair, 2009). What is more, this integration also allows information on the involvement of students and the achievement of goals to be collected, and as a result, a more effective validation of learning outcomes (Fjørtoft, 2020).

Especially technologies in the area of the Internet of Things have great educational potential. Their use can generate a number of benefits for both the student and the teacher (cf. Atherton, 2019; Glover & McDonald, 2016; Kriz et al., 2016; Wu et al., 2016; Zimmerman et al., 2016). They can be used in a variety of institutions aimed at sharing knowledge, not only strictly educational, but also cultural, training and rehabilitation (e.g., social, psychological) organizations and others (Gmiterek, 2017; Lee & Choi, 2016; Manczak et al., 2020). One of the essential components of the Internet of Things are beacons. These are small sensors that use the Bluetooth communication standard to connect with devices running compatible software. In this article, both terms will be used interchangeably. Beacons enable user microlocation, data collection, and automatic transmission of programmed information (Bajak, 2019; Manczak et al., 2020). Their proper operation requires the use of a mobile application (Garg & Shukla, 2016; Manczak et al., 2019) which, on the one hand, enables the use of the devices, and on the other, determines their scope of operation. The fundamental tasks of beacons include detecting other devices, initiating a connection, and transferring data (de Cerio et al., 2017). Considering beacons from the perspective of communication with the user, their six basic functions can be distinguished in this regard (Sanak-Kosmowska et al., 2018):

1. Information function – providing the user with specific data on entering the sensor's range. The recipient receives a package of information that has been pre-programmed by the sender. The transferred knowledge can be tailored to individual needs, preferences and interests (Manczak et al., 2020). In the context of education, it will be based on providing educational materials to students.
2. Interactivity function – sending notifications as a result of a specific user behavior and actions taken by the user, as well as allowing messages to be responded to, for example, by answering or selecting one of the options. Communication can also be initiated by the user, if he/she sends a message via the application, informing, for example, about the need to help him/her – the beacon can indicate his/her location in such a sit-

uation (Bajak, 2019). This feature can ensure connectivity and interactivity in the classroom and support group work and educational games.

3. Navigation function – locating the user in space and showing him/her the way forward. Sensors can also be placed on objects to be able to find them quickly if needed. An important advantage of sensors is the fact that they are effective with high accuracy in navigation both inside and outside the building (Dudhane & Pitambare, 2015; Handojo et al., 2020; Zhao et al., 2014). At school, it can become a useful tool for gamification and movement games.
4. Research function – collecting data about the user about his/her behavior in real and virtual space. Monitoring the recipient's behavior is possible primarily thanks to the opportunity of microlocation by devices (Yamaguchi et al., 2017) and observation of their individual reactions to information and notifications appearing in the application after coming within the sensor's range. It can make it possible to collect information about students, their progress, strengths and weaknesses, and, as a result, to personalize the learning process.
5. Promotional function – activating sales and promoting various events, actions and social initiatives. The user is sending offers and messages based on the information collected so far about him/her, as well as his/her location – for example, when he/she is next to a given room, he/she receives information that in a few hours there will be a speech that may be of interest to him/her. On campus, it can support the promotion of entertainment and science events aimed at students.
6. Image function – shaping the desired image of an institution thanks to various actions carried out with the use of beacons. The very fact and the specific way of using sensors also contribute to shaping a specific profile of the organization in the perception of the recipient (Bajak, 2019). For schools, beacons can be a tool for building the image of a modern institution open to the needs of students.

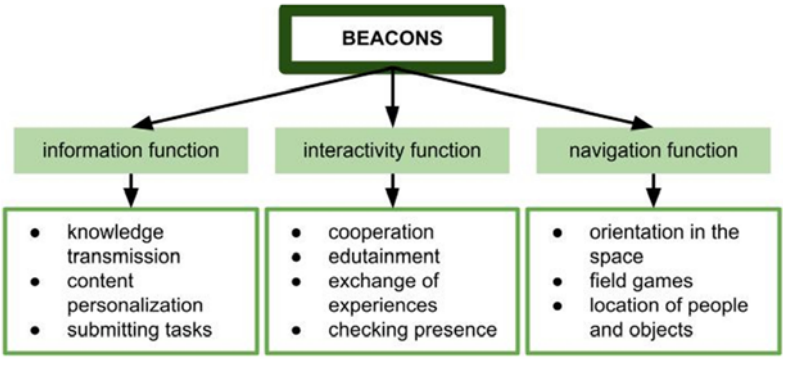
Applications that use beacons may implement all of them simultaneously or be based solely on one or more of them. Moreover, all indicated functionalities can be used in education. In practice, three of those functions are most commonly used: information, interactivity, and navigation (Figure 1) as they are relatively easy to implement while, for instance, the research function, requires the whole teaching and learning process to be rethought in a way that the data collected by beacons can help to personalize and enhance it to be used effectively. Therefore, the indicated functions should be analyzed first as the basis for solutions using beacons.

In the context of these considerations, it is necessary to emphasize that the basic functionalities of beacons can be extended as a result of equipping these devices with solutions such as, for example, Internet access, GPS transmitters (Bajak, 2021) or the use of various complementary technologies as part of the application supporting the sensors, which recognize, for example, augmented reality or artificial intelligence mechanisms.

Beacons as digital support for classroom teaching

Digital technologies have become an integral part of education (Selwyn, 2016). Various technological achievements, often initially implemented for the needs of completely different industries, ultimately find their application in teaching. It was no different with beacons. They are used both in the formal learning process in educational establishments and in the informal transfer of knowledge, for example in cultural institutions. These devices require direct contact with the recipient, so they are used only in projects carried out stationary. Beacons can contribute to transforming a classroom into a dynamic space, which creates conditions for learning through experience (Wan & Hodgson, 2019). The user may also have remote access to previously shared content via devices, which is true for hybrid forms of learning (cf. Griffiths et al., 2019), where sensors are, however, part of the real environment (schools, universities, etc.).

Figure 1
Main functions of beacons in education



Source: author's own work.

Beacons can contribute to the creation of an educational space by creating a virtual learning experience while the student is physically present in the classroom. Sensors connect the real and digital worlds by creating the possibility of education through empirical learning without leaving the school (Bajak, 2019). Tasks can be carried out individually or in a group in the learning process through play. These sensors are therefore a specific stimulus to build a broad and dynamic educational community that functions in parallel in the physical and digital spaces (Glover & McDonald, 2016). Their use generates a number of benefits – significant both from the teacher's and student's perspectives (Table 1). They make it possible to create a variety of lesson scenarios thanks to active access to content in the application (Kriz et al., 2016). As a result, they can facilitate, extend, and complement the education process (Glover & McDonald, 2018). According to research conducted by the team of Wu, Young and Wen (2016), their use supports deep learning and may contribute to the progress of scientific development achieved by students. Moreover, Zimmerman et al. (2016) draw attention to social interactions related to the use of sensors in the educational process. This applies to both beacon-stimulated scientific conversations between students (descriptive and conceptual), as well as the increase in the effectiveness of communication with the teacher and the resulting feedback. The observations of Atherton (2019) confirm the findings of other researchers so far. They also emphasize the possibility of personalizing the learning path for an individual student – controlling the pace, level of difficulty, and the challenges posed to him/her.

Beacons can be a helpful tool for carrying out tasks based on the core curriculum, as well as for conducting educational and integration games. However, proper involvement of students with the use of digital tools requires conscious pedagogical work. The quality of education carried out with the use of sensors depends on the specific capabilities of the software supporting the sensors. If it is unintuitive, and the prepared tasks and games turn out to be non-engaging, the experience of using the discussed devices will be negative for students. When deciding on solutions based on beacons, teachers are responsible for the development or selection of a platform that will create a space for the exchange of knowledge and experiences and will realistically contribute to enriching the lessons. This requires that they understand the solution being introduced, and its strengths and weaknesses, and that they define specific goals for its use. It is also worth examining the affinity of the sensors with other technologies. The introduction of compatible technologies may lead to the creation of completely new educational experiences.

Beacons as a part of the SMART classroom

The digital revolution has contributed to the creation of a paradigm of change in society, economy, and education, the dynamics of which is influenced, among others, by the widespread creation of technological combinations (Schwab, 2017). This tendency also applies to beacons (Bajak, 2021), which can be integrated in any way. The collaboration of beacons with other technologies can help create an environment that can be described as the SMART Classroom (cf. Bdiwi et al. 2019; Li et al., 2015; Lu et al., 2021; Phoong et al., 2019; Temkar et al., 2016). It is a concept assuming the creation of an intelligent educational space based on technologies from the sphere of the Internet of Things (Temkar et al., 2016) and other solutions in

Table 1
Basic advantages of using beacons in education

Advantages for the teacher	Advantages for the student
• possibility of implementing dynamic lesson plans	• creating opportunities for learning through experience and fun
• opportunity to develop a variety of exercises – both group and individual	• attractive form of shared materials
• building class commitment	• stimulating scientific and social interactions between students
• facility of increasing the quality of communication with students	• capability of increasing the quality of communication with the teacher
• possibility of obtaining detailed feedback	• providing individual materials at a convenient time for the student
• ability to observe and analyze the individual reactions of students to the materials provided	• possibility of personalizing the learning process
• opportunity to examine the effects of conducted classes	• facility of monitoring scrupulously achieved progress
• automation of selected processes, e.g. checking presence, sharing educational content	• increased involvement in the implementation of exercises thanks to their engaging and innovative formula
• capability of stimulating students' progress through gamification	• possibility of competing with other people in the form of games and activities, and receiving prizes

Source: author's own work.

the field of ICT (Bdiwi et al. 2019). SMART Classrooms enable the automatic distribution of educational and instructional materials, create a personalized environment for individuals and groups, and support, adaptive and mobile learning and all other activities related to didactics (Li et al., 2015; Pace, 2017). The Internet of Things involves connecting various devices and objects using solutions such as a local computer network, Wi-Fi, RFID, Bluetooth, ZigBee, 3G, 4G, and other wireless technologies (Hassan, 2016). Within this context, it is worth mentioning that beacons are, by definition, part of the Internet of Things (cf. Aftab, 2017; Bhargava, 2017; Miller, 2015; Pathak & Bhandari, 2018; Raj & Raman, 2017). Therefore, they should be treated as an integral part of the system connecting smart objects. The created network may be characterized by a different complexity of the structure (Zhang et al., 2010), which translates into the functionalities implemented by a given system. The development of the network with new components translates into the extension of the possibilities of its use and, as a result, an increase in usability. In the case of beacons, the above-mentioned data exchange standards can be implemented in two ways:

- direct retrofitting of beacons with additional transmitters enabling data exchange in a different standard (e.g., LTE),
- developing a network of intelligent objects by adding new devices to it that directly or indirectly cooperate with beacons.

In both of these cases, the functionalities available within a given system are extended, and as a result, its scope of possible applications increases.

In addition to solutions in the area of the Internet of Things, the SMART Classroom also uses other solutions in the area of ICT. The most popular of them are virtual and augmented reality, as well as artificial intelligence. These solutions also have significant educational potential (Keser & Semerci, 2019; Raman & Rathakrishnan, 2019). For example, beacons respond to user behavior and transmit information (Manczak et al., 2020), while VR / AR provides sensory stimulation (Ding et al., 2020). Such a combination draws attention in particular in the context of the possibility of creating educational games. The indicated technologies complement each other by creating a platform for interactive gamification that affects the senses. In turn, benefiting from the use of AI-based methods cooperating with technologies such as beacons is part of a novel and practical topic for technological development (Kose & Vasant, 2020). Sensors can locate the user and provide him/her with specific knowledge in the right place and time, while artificial intelligence is able to diagnose problems, analyze learning processes, independently adapt and generate personalized educational materials (Arnold et al. 2012), which in turn creates perspectives for creating comprehensive educational systems. The consolidation of technologies with particular perspectives in the area of learning can therefore have numerous advantages, such as, for example:

- extending the functionality of educational programs,
- ability to create an interactive and intelligent environment that affects the user's senses,
- a more effective adaptation of educational programs to the needs of individual users, including those with various dysfunctions,
- possibility of conducting multifaceted analyses of the educational process and its effects,
- supporting the processes of remembering and consolidating knowledge in the memory of students through their stimulation with various stimuli involving individual senses.

In the light of the presented considerations and a thorough analysis of the literature on the subject, it can be indicated that beacons show educational potential (Table 2). However, these devices should be considered in a broader context – as one of the

Table 2
Potential of using beacons in education

Beacons	Information function	Interactivity function	Navigation function
As standalone devices	• automatic sending of materials on coming within range of the device • sharing content with the student in the right place and time • ability to generally personalize content	• supporting the exchange of experiences between students • facilitating tutoring • collecting information about the effects of the work • mutual communication about the effects of the work	• supporting the implementation of educational games based on the user's location • supporting user orientation in the space • automating the process of checking attendance
As part of the SMART Classroom	• conveying content that affects the sensory experiences of students • adjustment of shared content based on the individual characteristics of the student, • creating a dynamic space for knowledge transfer.	• increase in the interactivity of the system • independent analysis of the obtained feedback and drawing conclusions by the system • automatic adjustment of the system to the needs of students • creating a realistic interaction based on current conditions	• possibility of implementing complex field games and gamification • augmenting reality based on the user's location • creating an interactive educational space that reacts to user behavior in real time

Source: author's own work.

elements of the Internet of Things that can cooperate with other technologies.

It is worth pointing out that with a high degree of probability, the cooperation of beacons with other solutions in the area of ICT may lead to the accumulation of possible benefits. The use of beacons in cooperation with the discussed solutions, as well as any other educational solutions, can transform the classroom into an intelligent space that analyzes the environment, adapting to the current conditions, contributing to an increase in the quality and efficiency of the teaching process (Gligoric et al., 2015).

Research methodology

Until now, most of the articles on the use of beacons in education were based solely on the analysis of single implementation examples, or presentations of projects of this type of system. This is a selective approach that does not take into account the comparison between different solutions. Moreover, the literature lacks indications of their usefulness in education in a broader context that goes beyond the research conducted by the authors. This creates a research gap that needs to be filled. To accurately illustrate the potential of beacons in education, it was decided to first analyze the practical examples of their use in this area based on the secondary data. It is a preliminary literature review on a given topic, which will be used in the future for further quantitative and qualitative research. Reports, interviews and articles were used (Estimote, n.d.; Freehill-Maye, 2018; Fusco, 2016; https://uncheckin.unc.edu; Loughborough University, 2018; Radda & Hultin, 2018; Raths, 2018; Śpiechowicz, 2018; University of Regina, n.d.; Zimmerman, 2018), as well as data available from the App Store (https://www.apple.com/pl/ios/app-store/) and Google Play (https://play.google.com/store). The analysis was further supported by a review of world scientific literature. Some of the discussed solutions have been previously described in the form of case studies by other researchers (Bhattacharya, 2017; Burton et al., 2017; Dent et al., 2018; Griffiths et al., 2019; O'Connel & Frydenberg, 2019; Zhu & Xie, 2019). These considerations will constitute the theoretical foundation for further research on the use of beacons in education. At the same time, it should be emphasized that this topic still does not have a strong theoretical and practical basis. It is necessary to organize the knowledge on this subject and conduct empirical research. The main goal of this article is to present the possibility of using beacons in the context of stationary education. It was decided to analyze the possibilities, including the usefulness of the solutions that use beacons. The following specific questions were prepared:

- What tasks does the system perform?
- What new technologies support the solution?
- Is this software used in education?

As part of the work on this publication, available sources of knowledge were searched for information on university applications that use beacons. As a result, information on only 18 projects was obtained. The conducted research only fills the outlined research gap to a limited extent. They are only the first step to further analyses that are planned for implementation in the future. However, they helped to identify the spectrum of the use of beacons at universities and to indicate the directions of planned research.

Practical implementation of beacons in education

As part of the considerations, on the basis of the available sources of information, projects from 18 universities in Europe, North America and Asia were compared (Table 3). These are all of the projects about which the author was able to find information and which met the assumptions of the research. In order to be classified for comparison, the systems had to fulfil the following conditions:

- be implemented at universities,
- use beacons as an important element,
- be widely available and downloadable.

The selected projects were compared with each other in terms of the technologies used, the possibility of application in the education process, and the main goals of implementation.

Despite the potential of the use of beacons in the education sector, there are still few practical implementations of this type of solution. Moreover, as the comparison shows, only two of the studied cases (11.1%) were used in the teaching process during the classes (projects no. 4, 13). Most of the projects (66.6%) are aimed at assisting the user with navigation and providing information about the environment. Most of them show the user around the campus, but some are directed only at locating him/her in only a limited area, such as a library (projects no. 7, 8, 11, 18) or an arboretum (project no 6). An important area of activity of the analyzed beacon-based applications is also the promotion of university events (projects no. 1, 2, 5, 9, 13, 14). Another task of the discussed solutions that deserves attention is to ensure the safety of students on campus (projects no. 3, 16, 17). In view of the Covid-19 pandemic, this is an application that may grow in importance. Research shows that beacon-based solutions can support the detection of contacts with people infected with the SARS-Cov-2 virus (cf. Martin et al., 2020). Many European countries have chosen to base their official applications to limit the spread of the disease on solutions based on the beacon mechanism (cf. Barthe et al., 2021). Some solutions are focused solely on providing entertainment, such as the University of Illinois application (project no. 12), which shows places such as bars, cafes, and clubs. It also shows users where their friends are having fun. We cannot speak of any educational benefit here. Considering the discussed solutions from the perspective of the beacon function in communication with the user, the most important should be the information, navigation and interaction functions (Table 4), which confirms the assumptions made earlier. Interestingly,

Table 3
Overview of universities using beacons

No.	Institution	Technologies used	Used in education	Main tasks
1.	American University	Beacons, Virtual Reality, Augmented Reality	No	• guided tours around the campus • applying augmented reality objects to the surroundings • providing information about services offered on the campus and events taking place • 360° video sharing
2.	Bentley University	Beacons	No	• providing information about facilities located on the campus • sending notifications about nearby events
3.	Columbus State University	Beacons	No	• increasing the safety of students • ability to report suspicious behavior • indicating the location of students to the security services
4.	Hong Kong Polytechnic University	Beacons	Yes	• checking presence • running quizzes and games • sharing information and files
5.	Loughborough University	Beacons	No	• checking presence • sharing schedules • navigating around the campus • sending notifications about events
6.	Penn State University	Beacons	No	• locating the user • sending information about nearby objects
7.	Radford University	Beacons, QR Codes	No	• organization of outdoor games and activities • encouraging exploration of the library
8.	St. John's University	Beacons	No	• navigating through the library • indicating the location of the books you are looking for • information sharing
9.	Stony Brook University	Beacons, NFC, QR Codes	No	• sending information and multimedia • navigating around the campus • promoting events
10.	Texas Agricultural and Mechanical University	Beacons	No	• navigating around the campus • alerting about threats
11.	University of Edinburgh	Beacons, QR Codes	No	• navigating through the library • sharing information and files
12.	University of Illinois	Beacons	No	• navigating around the campus • sending information about attractions and events • indicating the location of friendly users
13.	University of Hawaii Maui College	Beacons	Yes	• managing groups of students • submitting tasks • providing information about services offered on the campus and events taking place
14.	University of Lodz	Beacons	No	• navigating the campus and the city • sending information about attractions and events • sharing knowledge about educational programs and all necessary documents
15.	University of North Carolina at Chapel Hill	Beacons	No	• checking attendance
16.	University of Oklahoma	Beacons	No	• navigating around the campus • indicating a safe location in the event of an emergency
17.	University of Regina	Beacons	No	• sending information when a threat is detected
18.	Virginia Polytechnic Institute and State University	Beacons	No	• navigating through the library • transmission of information and files • conducting quizzes

Source: author's own work.

Table 4
Functions of beacons in the considered solutions

Function	Percentage of all solutions	Project numbers
Information	72.2%	1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 18
Interactivity	61.1%	2, 3, 4, 5, 6, 7, 10, 13, 15, 17, 18
Navigation	66.7%	1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 16, 18
Research	0%	–
Promotional	38.9%	1, 2, 5, 9, 12, 13, 14
Image function	22.2%	1, 9, 12, 14

Source: author's own work.

none of the researched projects is aimed at using the research function of beacons (data collection and analysis)[1].

Interestingly, only four researched applications (projects no 1, 7, 9, 11) use other technologies apart from beacons. All others are based solely on sensors. Most of them (projects no. 7, 9, 11) are supported by other technologies including solutions from the area of the Internet of Things. Only one solution (project no. 1) uses virtual and augmented reality. However, there is no indication that any of the analyzed software makes significant use of artificial intelligence. These mechanisms are not used to upgrade the functionality of the system, but only to support it to the necessary extent. Due to the purpose of the projects, we cannot describe any of them as a SMART class. As defined in this article, it is a concept assuming the creation of an intelligent teaching space based on cooperation between various solutions from the sphere of the Internet of Things. None of the examined solutions create such a multidimensional educational space.

It is worth noting that apart from official university applications, some universities conducted research involving the design of solutions based on beacons. For example, at universities such as the University of Economics in Bratislava, Chalmers University of Technology, Gothenburg, and the Asian Institute of Technology, such programs were designed and tested by research teams and students (cf. Glover & McDonald, 2016; Jurkovičova et al., 2015; Karlsson et al. 2016; Puckdeevongs et al., 2020). However, despite positive user feedback, they were not implemented on a larger scale. In order to indicate the reasons for resignation from the implementation of the above-mentioned solutions and a small number of implementations of systems cooperating with beacons, further research is essential. The indicated problem is also discussed in other scientific papers on sensors that concern their use in various public institutions. The authors point to barriers such as (Bajak, 2021; Karlsson et al. 2016; Manczak et al., 2020; Puckdeevongs et al., 2020):

- limited sources of financing,
- insufficient knowledge of the technology by users,
- occurrence of technological imperfections (e.g. devices do not always connect to the application, software errors).

Difficulties such as skepticism and unfamiliarity with the solution by recipients can be reduced by properly conducted education and marketing communication. Educational establishments can actively contribute to disseminating the solution despite initial audience concerns. On the other hand, limitations related to incorrect operation of devices are more difficult to combat by educational institutions. Their occurrence is influenced by technology providers and solution developers who should strive to offer a well-functioning system. In this area, good practice includes testing the beacons and compatible applications before implementation, regular monitoring of their operation, and exchange of experiences with organizations that previously decided to use the sensors.

Summary

The literature analysis shows that beacons show potential as devices supporting stationary education. They can be used to achieve educational goals both as part of systems based solely on this solution, and can be supported by other technologies. Especially the latter solution seems to be attractive. It is creating perspectives for the implementation of the SMART Classroom concept. The practical implementation of this idea enables the achievement of four basic benefits in the context of education (Li et al., 2015):

- integration of the virtual and physical environment creates the capability of contextual awareness of the technological solutions used, manifested by the possibility of adjusting individual parameters to the current conditions,
- providing adaptive support for the educational process, personalization of teaching content, interaction support, as well as support for conducting classes of various profiles,
- creating the possibility of collecting, storing and analyzing data to optimize the teaching process,

[1] Checking presence is treated as part of the interactivity function.

- introducing students into the context of classes thanks to digital educational aids, stimulating participants' motivation, engaging their creativity, and creating opportunities for practical learning.

Unfortunately, there are still too few practical implementations of this type of project to confirm these assumptions with certainty. Only a few universities around the world use beacons in their applications. Moreover, the vast majority of them do not use the devices for educational purposes. Identifying the reasons for this state of affairs comprises a research gap that requires analysis and searching for answers. Therefore, further implementations should be monitored and research in this area should be continued.

The potential of using beacons in education, as discussed in this study, is an important issue for further analysis. Although this topic appears in the literature quite frequently, it is usually presented in general terms as part of the analysis of other corresponding issues. Currently, only a few works deal with the matter of the use of beacons in education in an extensive way. In most cases, the attitude of the authors toward this technology is approving (cf. Atherton, 2019; Glover & McDonald, 2016; Kriz et al., 2016; Wu et al., 2016; Zimmerman et al., 2016), and a comprehensive analysis of the technology is still missing in the context of didactics. The presented work focuses on the advantages of using beacons in education, while the possible difficulties generated by beacons are only mentioned. This thread will be supplemented in the future. In addition, it is planned to conduct qualitative and quantitative research at universities in Poland that decide to implement the solution. This will make it possible to give a practical context to the considerations on beacons that have been conducted so far.

References

Aftab, M. U. (2017). *Building Bluetooth Low Energy Systems*. Packt Publishing.

Alves, P. Miranda, L., & Morais, C. (2017). The influence of virtual learning environments in students' performance. *Universal Journal of Educational Research, 5*(3), 517–527. https://doi.org/10.13189/ujer.2017.050325

Arnold, R. (2011). *Assisted learning: A workbook*. Bildungstransfer.

Arnold, K. E, & Pistilli, M. D. (2012). Course signals at Purdue: using learning analytics to increase student success. In *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge* (pp. 267–270). ACM. https://doi.org/10.1145/2330601.2330666

Atherton, Ch. (2019). Beacons: A tool for 21st Century teaching and learning? *Research in Learning Technology, 27*. https://doi.org/10.25304/rlt.v27.2127

Bajak, M. (2019). Equal opportunities for people with disabilities in public institutions through beacons. *Oxford Conference Series*, 55–64.

Bajak, M. (2021). *Wykorzystanie beaconów w komunikacji marketingowej*. Polskie Wydawnictwo Ekonomiczne.

Barthe, G., De Viti, R., Druschel, P., Garg, D., Gomez Rodrigez, M., Ingo, P., Kremer, H., Lentz, M., Lorch, L., Mehta, A., & Schoelkopf, B. (2021*). Listening to Bluetooth beacons for epidemic risk mitigation*. https://doi.org/10.21203/rs.3.rs-150227/v1

Bdiwi, R., de Runz, C., Faiz, S., & Cherif, A. (2019). Smart learning environment: Teacher's role in assessing classroom attention. *Research in Learning Technology*, *27*. https://doi.org/10.25304/rlt.v27.2072

Bhargava, M. (2017). *IoT Projects with Bluetooth Low Energy*. Packt Publishing.

Bhattacharya, D., Canul, M., Knight, S. (2017). Case study: Impact of the Physical Web and BLE beacons. *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 4262–4265). https://doi.org/10.24251/HICSS.2017.516

Burton, K. T., Burton, J. & Archer, A. (2017). Using proximity beacons to connect physical & virtual library spaces: A case study. *Virginia Libraries*, *62*(1). https://doi.org/10.21061/valib.v62i1.1329

de Cerio, D., Hernández, A., Valenzuela, J. L., & Valdovinos, A. (2017). Analytical and experimental performance evaluation of BLE neighbor discovery process including non-idealities of real chipsets. *Sensors*, *17*(3), 499. https://doi.org/10.3390/s17030499

Dent, V., Takeuchi, K., Turner, B., Ball, H., Fuchs, C., Jusino, A., & Karnik S. (2018). Wayfinding Serendipity: The BKFNDr Mobile App. *Code4lib, 42*. https://journal.code4lib.org/articles/13811

Ding, Y., Li Y., & Cheng L. (2020). Application of Internet of Things and Virtual Reality Technology in College Physical Education. *IEEE Access, 8*, 96065–96074. https://doi.org/10.1109/ACCESS.2020.2992283

Dudhane, N., & Pitambare, S. (2015). Location based and contextual services using Bluetooth beacons: New way to enhance customer experience. *Lecture Notes on Information Theory, 3*(1), 31–34. https://doi.org/10.18178/lnit.3.1.31-34

Dumančić, M. (2019). Smart education in smart city and student model. In I. Roceanu (Ed.), *15th International Conference eLearning and Software for Education. New technologies and redesigning learning spaces*. Volume II (pp. 64–71). https://doi.org/10.12753/2066-026X-19-077

Engeström, Y. (2014). *Learning by expanding*. Cambridge University Press.

Estimote. (n.d.). *Zondr helps over 10,000 students in Illinois discover places and events*. Retrieved June 4, 2021, from https://community.estimote.com/hc/en-us/articles/204922678-Zondr-helps-over-10-000-students-in-Illinois-discover-places-and-events/

Fazlagić, J. (2018). Wykorzystanie zasobów cyfrowych w oświacie. *e-mentor, 1*(73), 10–16. https://doi.org/10.15219/em73.1334

Fjørtoft, H. (2020). Multimodal digital classroom assessments. *Computers & Education, 152* https://doi.org/10.1016/j.compedu.2020.103892

Garg, A., & Shukla, L. (2016). Beacon technology. *Asian Journal of Computer Science Engineering, 1*(1), 9–12. https://bit.ly/3xz3b6j

Freehill-Maye, L. (2018, November 20). *Beacons beckon on campus*. University Business. https://universitybusiness.com/beacons-beckon-on-campus

Fusco, D. (2016, March 22). *Penn State University taking attendance using beacons*. Evo Things. https://evothings.com/penn-state-university-taking-attendance-using-beacons/

Gligoric, N., Uzelac, A., Krco, S., Kovacevic, I., & Nikodijevic, A. (2015). Smart Classroom system for detecting

level of interest a lecture creates in a classroom. *Journal of Ambient Intelligence and Smart Environments, 7*(2), 271–284. https://doi.org/10.3233/AIS-150303

Glover, I., & McDonald, K. (2016). Exploring the transformative potential of Bluetooth beacons in higher education. *Research in Learning Technology, 24*. https://doi.org/10.3402/rlt.v24.32166

Glover, I., & McDonald, K. (2018). Digital places: Location-based digital practices in higher education using Bluetooth beacons. In T. Bastiaens, J. Van Braak, M. Brown, L. Cantoni, M. Castro, R. Christensen, G. Davidson-Shivers, K. DePryck, M. Ebner, M. Fominykh, C. Fulford, S. Hatzipanagos, G. Knezek, K. Kreijns, G. Marks, E. Sointu, E. Korsgaard Sorensen, J. Viteli, J. Voogt…. & O. Zawacki-Richter (Eds.), *Proceedings of EdMedia: World Conference on Educational Media and Technology* (pp. 950–959). Association for the Advancement of Computing in Education (AACE). https://www.learntechlib.org/primary/p/184298/

Gmiterek, G. (2017). Wykorzystanie aplikacji mobilnych w muzeach – przegląd i analiza polskich projektów. *e-mentor, 2*(69), 25–39. https://doi.org/10.15219/em69.1296

Griffiths, S., Wong, M. S., Kwok, C. Y. T., Kam, R., Lam, S. C., Yang, L., Yip, T.L., Heo, J., Chan, B. S. B., Xiong, G., & Lu, K. (2019). Exploring Bluetooth beacon use cases in teaching and learning: Increasing the sustainability of physical learning spaces. *Sustainability, 11*(15). https://doi.org/10.3390/su11154005

Gurba, H., & Rimanelli, M. (2018). Quality measures, human factor and failures of e-learning. *Labor et Educatio, 6*, 37–59. https://doi.org/10.4467/25439561LE.18.003.10230

Handojo, A., Octavia, T., Lim, R., & Kurnia Anggita, J. (2020). Indoor positioning system using BLE beacon to improve knowledge about museum visitors. *TELKOMNIKA Telecommunication, Computing, Electronics and Control, 18*(2), 792–798. https://doi.org/10.12928/TELKOMNIKA.v18i2.14886

Hassan, Q. (2016). *Innovative research and applications in next-generation high performance computing*. IGI Global.

Hauer, T. (2017). Technological determinism and new media. *International Journal of English, Literature and Social Science, 2*(2), 1–4.

Herczeg, M., Winkler, T., & Ohlei, A. (2019). Ambient learning spaces for school education. Sociology. In *Proceedings of 12th annual International Conference of Education, Research and Innovation ICERI 2019* (pp. 5116–5125). https://doi.org/10.21125/iceri.2019.1240

Hosu, R., & Hosu, I. (2019). 'Smart' in between people and the city. *Transylvanian Review of Administrative Sciences*, *15*, 5–20. https://doi.org/10.24193/tras.SI2019.1

Jurkovičova, L., Ĉervenka, P., Hrivíková, T. & Hlavatý, I. (2015). E-learning in augmented reality utilizing iBeacon technology. In C. Watson (Ed.), *Proceedings of the 10th International Conference on e-Learning* (pp. 25–26). ACPIL.

Karlsson, E., Nygren, O., Gamboa, M., & Thander, F. (2016). ArQuest: Augmented reality in education. In *Proceedings of the 12th Student Interaction Design Research Conference. SIDeR 2016.* IDM.

Keser, H., & Semerci, A. (2019). Technology trends, Education 4.0 and beyond. *Contemporary Educational Researches Journal, 9*(3), 39–49. https://doi.org/10.18844/cerj.v9i3.4269

Kose, U., & Vasant, P. (2020). Better campus life for visually impaired University students: intelligent social walking system with beacon and assistive technologies. *Wireless Networks, 26*, 4789–4803. https://doi.org/10.1007/s11276-018-1868-z

Kriz, P., Maly, F., & Kozel, T. (2016). Improving indoor localization using Bluetooth Low Energy beacons. *Mobile Information Systems,* 1–11. https://doi.org/10.1155/2016/2083094

Lee, H. E., & Choi, H. S. (2016). Improvements of the Korean tourism application, visit Korea, for foreigners-based on beacon functions. *International Journal of Software Engineering and Its Applications, 10*(4), 103–116.

Li, B., Kong, S. C., & Chen, G. (2015). Development and validation of the Smart Classroom inventory. *Smart Learning Environments*, *2*(3), 1–18. https://doi.org/10.1186/s40561-015-0012-0

Loughborough University. (2018, February 19). *Are you ready for digital for attendance recording?* https://www.lboro.ac.uk/internal/news/2018/february/are-you-ready-for-digital-for-attendance-recording.html

Lu, K., Yang, H. H., Shi, Y., & Wang, X. (2021). Examining the key influencing factors on college students' higher-order thinking skills in the smart classroom environment. *International Journal of Educational Technology in Higher Education, 18*(1). https://doi.org/10.1186/s41239-020-00238-7

Manczak, I., Sanak-Kosmowska, K., & Bajak, M. (2019). Reasons to use beacon technology as a tool to study audience behaviour in museums. *Cultural Management: Science and Education*, *3*(2), 83–94. https://doi.org/10.30819/cmse.3-2.05

Manczak, I., Sanak-Kosmowska, K., & Bajak, M. (2020). Zastosowanie beaconów w komunikacji z niepełnosprawnym turystą kulturowym (na przykładzie muzeów miejskich). *Turystyka Kulturowa, 5*(116), 116–139. http://turystykakulturowa.org/ojs/index.php/tk/article/view/1180

Martin, T., Karopoulos, G., Hernández-Ramos, J. L., Kambourakis, G., & Fovino, I. N. (2020). Demystifying COVID-19 Digital Contact Tracing: A Survey on Frameworks and Mobile Apps. *Wireless Communications and Mobile Computing*, *2020*. https://doi.org/10.1155/2020/8851429

Miller, M. (2015). *The Internet of Things: How smart TVs, smart cars, smart homes, and smart cities are changing the world*. Que Publishing.

O'Connell, J., & Frydenberg, M. (2019). Building the Physical Web: A campus tour using Bluetooth Low Energy beacons. *Information Systems Education Journal*, *17*(5), 22–31. https://files.eric.ed.gov/fulltext/EJ1219538.pdf

Ozerbas, M. A., & Erdogan, B. H. (2016). The effect of the digital classroom on academic success and online technologies self-efficacy. *Educational Technology & Society, 19*(4), 203–212.

Pace, M. (2017). Adapting literature to the language classroom. *PUPIL: International Journal of Teaching, Education and Learning, 1*(1), 1–13. https://doi.org/10.20319/pijtel.2017.11.113

Pathak, N., & Bhandari, A. (2018). *IoT, AI, and Blockchain for .NET: Building a next-generation application from the ground up*. Apress.

Phoong, S. Y., Phoong, S. W, Moghavvemi, S., & Sulaiman, A. (2019). Effect of Smart Classroom on student achievement at higher education. *Journal of Educational Technology Systems, 48*(2), 291–304. https://doi.org/10.1177/0047239519870721

Puckdeevongs, A., Tripathi, N. K., Witayangkurn, A., & Saengudomlert, P. (2020). Classroom attendance systems based on Bluetooth Low Energy Indoor Positioning

Technology for smart campus. *Information, 11*(6), 329. https://doi.org/10.3390/info11060329

Radda, P., & Hultin, L. (2018, September 12). Texas A&M University advances engineering education with state-of-the-art complex built on Aruba mobile-first solutions. *Business Wire*. https://bwnews.pr/3vE8Wht

Raj, P., & Raman A. C. (2017). *The Internet of Things: Enabling technologies, platforms, and use cases*. CRC Press.

Raman, A., & Rathakrishnan, M. (2019). *Redesigning higher education initiatives for Industry 4.0*. IGI Global.

Raths, D. (2018, July 8). A mobile guide to library resources. *Campus Technology*. https://campustechnology.com/articles/2018/08/07/a-mobile-guide-to-library-resources.aspx

Sanak-Kosmowska K., Bajak M., Filip J., & Kargula N. (2018). Uwarunkowania i przesłanki wykorzystania beaconów w mobilnej komunikacji marketingowej. *Marketing i Rynek, 25*(10), 17–23.

Schwab, K. (2017). *The Fourth Industrial Revolution*. Penguin UK.

Selwyn, N. (2016). *Is technology good for education?* Wiley.

Sinclair, G. B. (2009). Is Larry Cuban right about the impact of computer technology on student learning? *Nawa Journal of Language and Communication, 3*(1), 46–54.

Squires, D. (2017). Augmented Reality Application Classroom Development: New technology and new media, education and intelligent classrooms. *Journal of Educational Technology, 14*(1), 1–6.

Śpiechowicz, P. (2018, March 13). *#UniversityDiversity*. https://biuroprasowe-uni-lodz.prowly.com/28412-universitydiversity

Temkar, R., Gupte, M., & Kalgaonkar, S. (2016). Internet of Things for Smart Classrooms. *International Research Journal of Engineering and Technology, 3*(7), 203–207.

University of Regina. (n.d.). *Emergency Notification System (ENS)*. Retrieved June 4, 2021, from https://www.uregina.ca/emergency/ens/index.html

Valsamidisa, S., Kazanidisa, I., Petasakisa, I., Kontogiannisb, S., & Kolokithaa, E. (2014). E-learning activity analysis. *Procedia Economics and Finance, 9*, 511–518. https://doi.org/10.1016/S2212-5671(14)00052-5

Wan, S., & Hodgson P. (2019). Engagement for learners with multiple intelligence using location-based technology. In *Proceedings of the 11th International Conference on Education and New Learning Technologies. EDULEARN19* (pp. 1484–1488). IATED.

Weiser, M. (1991). The computer for the twenty-first Century. *Scientific American, 265*(3), 94–104. http://dx.doi.org/10.1038/scientificamerican0991-94

Wu, Y. W., Young, L. M., & Wen, M. H. (2016). Developing an iBeacon-based ubiquitous learning environment in smart green building courses. *International Journal of Engineering Education, 32*(2), 782–789.

Xianyang, Z. (2018). New media classroom teaching of college ideological and political course with innovation. In *Proceedings of 4th International Conference on Education, Management and Information Technology (ICEMIT 2018)* (pp. 902–905). https://doi.org/10.25236/icemit.2018.203

Xu, X., Chan, F. M., & Yilin, S. (2020). Personal learning environment: an experience with ESP teacher training. *Interactive Learning Environments, 28*(6), 779–794. https://doi.org/10.1080/10494820.2018.1552872

Yamaguchi A., Hashimoto M., Urata K., Tanigawa, Y., Nagaie, T., Maki, T., Wakahara, T., Kodate, A., Kobayashi, T., Sonehara, N. (2017). Beacon-based tourist information system to identify visiting trends of tourists. *Proceedings of International Conference on Artificial Life and Robotic* (pp. 480–483). https://doi.org/10.5954/ICAROB.2017.OS8-2

Zhang, K., Han D., & Feng, H. (2010). Research on the complexity in Internet of Things. In *International Conference on Advanced Intelligence and Awareness Internet (AIAI 2010)* (pp. 395–398). https://doi.org/10.1049/cp.2010.0796

Zhao, X., Xiao, Z., Markham, A., Trigoni, N., & Ren, Y. (2014). Does BTLE measure up against WiFi? A comparison of indoor location performance. In *Proceedings of 20th European Wireless Conference* (pp. 263–268). VDE. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1085.261&rep=rep1&type=pdf.

Zheng, L. (2018). Practice of „Internet Thinking + Dichotomy Classroom" Teaching Mode in New Media Advertising Teaching. In *Proceedings of 1st International Conference on Education, Art, Management and Social Sciences 2018 (EAMSS 2018)* (pp. 381–385). https://doi.org/10.23977/eamss.2018.079

Zhu, H., & Xie, Y. (2019). Research on application of Beacon-based location technology in American universities. *IOP Conference Series: Earth and Environmental Science, 252*(5). https://doi.org/10.1088/1755-1315/252/5/052002

Zimmerman, E. (2018, December 10). How can beacon technology help universities boost student engagement? *EdTech Magazine Higher Education.* https://edtechmagazine.com/higher/article/2018/12/how-can-beacon-technology-help-universities-boost-student-engagement-perfcon

Zimmerman, H. T., Land, S. M., Maggiore, Ch., Ashley, R. W., & Millet, T. (2016). Designing outdoor learning spaces with iBeacons: combining place-based learning with the Internet of learning things. In C.-K. Looi, J. L. Polman, U. Cress, & P. Reimann (Eds.), *Transforming Learning, Empowering Learners: 12th International Conference of the Learning Sciences, ICLS 2016* (pp. 942–946). https://repository.isls.org//handle/1/349

Maria Bajak is an assistant at the Department of Marketing at the University of Economics in Krakow. For three years, she has been dealing with the subject of the Internet of Things, and in particular, beacons. She analyzes the possibilities and prospects of using the indicated devices in marketing communication. Moreover, the author's particular research interests concern the issues of equal opportunities and corporate social responsibility.