A SYSTEMATIC LITERATURE REVIEW OF THE BENEFITS OF UTILIZING PERVASIVE TOOLS IN HIGHER EDUCATION

Thian Li Lim, Xiamen University Malaysia
Angela Siew Hoong Lee, Sunway University

ABSTRACT

Despite the advantages that pervasive tools have brought to education, studies related to the use of pervasive tools are still unclear. The present study systematically reviews the impact of utilizing pervasive tools to provide a comprehensive analysis of 30 research articles published between 2010–2022. The main findings from this study include the types of pervasive tools used and the benefits of utilizing the pervasive tools for learning purposes. The findings of this study provide useful insights into the types of pervasive tools and the impact they have brought on students' learning processes in current higher education settings.

Keywords: *pervasive tools, pervasive learning, higher education, mobile application*

INTRODUCTION

The demand for mobile devices has promoted the development of pervasive learning in education sectors (Chin et al., 2020), with the use of pervasive tools like the use of mobile phones, wireless communication, or sensor technology, students are placed in a real-world setting (Hwang et al., 2011). These pervasive tools can assist students in identifying physical world objects in a designated learning environment, and provide dynamic support and direction whenever required (Chin et al., 2020). Hence, with the steadfast advancement in wireless and sensor technologies, studies focusing on using pervasive tools in an educational context are receiving attention (Mandula et al., 2011). Most researchers have been constructing a context-aware p-learning system, which incorporates learning materials and contextual information by utilizing pervasive tools (Mouri et al., 2017).

Some examples of pervasive tools, such as radio-frequency identification (RFID), readers equipped with the ability to locate and document students' learning behaviors in a real-life environment (Chin et al., 2015). To identify distant objects using radio waves, one of the short-range wireless communication technologies employed is RFID. To interrogate an RF transponder or tag within its radio range, it comprises an RF interrogator or reader. The item details stored in the memory are retrieved and stored via radio transponders. Using sensors and radio tags inserted into the environment, RFID can also be used to locate someone or obtain contextual data. Depending on the person, location, time, application, and device being used, this context information can be used to give a variety of automated services (Mandula et al., 2011).

Other examples are the sensor use of contactless smart cards, barcode tags, or sensor network nodes. It is possible that quick response (QR) codes are used in the context-aware p-learning environment and sensors can offer active and personalized support to students, which allows them to promote interest and drive in the classroom environment (Chin et al., 2015).

In the education literature, pervasive tools have been positively used in various studies, including English language learning (Chang, 2018), cultural heritage course learning (Chin et al., 2020), science

and technology course learning (de Sousa Monteiro et al., 2016), and others. Although pervasive tools have shown a huge impact and brought benefits to education, there are still limited studies associated with the use of pervasive technologies (Stojanović et al., 2020), and a completely practical p-learning environment is still uncertain (Hwang et al., 2008). To date, the definition of pervasive tools has been unclear and varied in different studies and researchers. A clear definition is needed as a better guide educators, researchers, and policymakers. This is beneficial for education in undergraduate settings, which aim to develop, strengthen, and build a learning process and environment which allow access to information pervasively, improving the level of knowledge obtaining, soft skills, motivation, and more in this digital world. When students engage in learning activities in a dynamic p-learning environment, these objectives can be achieved (Kong et al., 2017). Limited studies from the past focus on utilizing pervasive tools in Malaysian private universities (Lim & Lee, 2021). This study presents a systematic literature review to identify pervasive tool usage in higher education settings and to ascertain how pervasive tools affect the learning process of students.

Pervasive Learning

Pervasive learning (p-learning), which uses cutting-edge sensor technology, is an educational environment where students learn all around them. The students are located in a context-aware learning environment; however, it is possible they aren't even aware of how they are learning (Temdee, 2014). The delivery of educational content via mobile devices while taking into account the environmental context is the actual issue in p-learning. Delivering the appropriate content to the appropriate person, in the appropriate location, and at the appropriate time depends in large part on context (Mandula et al., 2011).

Context-aware p-learning is defined as "a learning approach that employs mobile devices, wireless communication, and sensor technologies in learning activities" (Hwang et al., 2008). In this modern and innovatively upgraded learning environment, students can connect with real-world problems (Chin et al., 2015) and can connect with real situations using pervasive tools to customize their personalized learning (Chin et al., 2015; Temdee, 2014). Students can interact with different devices, learning objects, and one another. Subsequently, p-learning empowers personalization and cooperation support at the same time (Temdee, 2014).

A great number of context-aware mobile applications were connected via sensing technologies, including the Global Positioning System (GPS), RFID, Wi-Fi, and Bluetooth (Ahmed et al., 2019). In other words, in order to make learning more immersive and efficient, an ideal p-learning environment should incorporate computing, communication, and sensor devices into the daily lives of students (Hwang et al., 2008; Ogata & Yano, 2004). Numerous studies have claimed that pervasive learning not only occurrs within the four walls of indoor classroom settings but also allows students to immerse into real-world educational settings, and this could significantly influence students' interest and engagement (Chin et al., 2020). Without a doubt, p-learning has led students to face a new way of exchanging information, constructing knowledge, collaborating, and interacting with one another. Nowadays, p-learning has become popular since pervasive tools have been widely introduced (Temdee, 2014).

More research should be conducted to validate the positive effects (Chin et al., 2015). There is still a lack of empirical proof that supports the widespread integration of mobile and p-learning in higher education (Pimmer et al., 2016). Most of the students are interested in utilizing mobile and sensor technologies for p-learning, except for the disadvantage of higher device and connectivity costs (Mandula et al., 2011).

Characteristics of Pervasive Learning

According to Virtanen et al. (2017), the criteria for pervasive learning have not been systematically defined from the literature. The terminology has been utilized in the literature, however, the word and guidelines for this area of research are not yet clear. A scoping literature review study conducted by Virtanen et al. (2017) aimed to recognize criteria for a pervasive learning environment and revealed that the criteria and characteristics for a pervasive learning environment include "context awareness, interactivity, personalization, and flexibility" (Table 1). Context awareness gives students the flexibility to obtain learning materials and the opportunity to interact based on their situation and schedule. In context awareness learning situations, it supports individualized learning where feedback

was given based on students' situations, schedules, and activities. By using embedded function items—like RFID, barcodes, wireless networks, tags, and mobile devices—content awareness is facilitated. Interactivity between teachers and students, students and peers, and the use of synchronous and asynchronous ways to foster interactivity were all supported in this type of environment. Based on their schedules and learning requirements, students have the freedom to learn anytime and anywhere.

According to Yahya et al. (2010), the characteristics of p-learning include "permanency, accessibility, immediacy, interactivity, and context awareness." The information available will remain in the system unless the learners remove it, and students have the benefit to access the information anywhere, anytime, and instantaneously. In this kind of environment, students can communicate with instructors and classmates efficiently through pervasive tools, and the environment can adjust to students' real circumstances to prepare sufficient details and guidance for the students.

Table 1.
Criteria and Characteristics for the Pervasive Learning Environment

Characteristics	Definition
Permanency	Learners can never lose their work.
Accessibility	System access via pervasive learning technologies.
Immediacy	Learners get information immediately.
Context-awareness	Context-awareness systems with mobile devices, cell phones, cameras, functional objects, sensing technologies, internet, and networks.
Interactivity	Use of handheld devices and embedded sensors to finish tasks. Asynchronous or synchronous communication with tags, codes, and sensors.
Personalization	Location-based and personalized learning content and guidance. Location detection and situational learning material.
Flexibility	Personal guidance and supplementary learning material and instant feedback. Remote access/online access with mobile devices.

Adapted from Virtanen et al. (2017) and Yahya et al. (2010)

PREVIOUS RELATED STUDIES

More studies focusing on the integration of pervasive tools in education can be found in da Silva et al. (2021), Alnabhan et al. (2018), Wang et al. (2020), and Suartama et al. (2021). From the study of da Silva et al. (2021), ULearnEnglish was designed to assist the knowledge acquisition of English vocabulary according to the user's context. Using the 19 types of places used in the evaluation, the web service performed the database search for learning content related to the user's context. The results of the technology acceptance model (TAM) evaluation showed a positive response to localization use to assist the participants in their English vocabulary learning. The study from Alnabhan et. al. (2018) mainly provides context-aware and pervasive learning services fulfilled in several different user interaction levels and requirements. It was built on the Android platform by using the Java programming language. The previous study by Wang et al. (2020) developed a mobile device prototype Context-Aware Plant Ecology Learning System (CAPELS) that combined context-aware technology that aims to identify plant leaves. The context-aware system can provide appropriate botanical and growth environment knowledge with the support of sensors and, according to the situation factors at a given time, with a wireless network environment to students. The findings confirmed that the use of CAPELS has been shown to be more favorable to students and has been shown to enhance student learning motivation and knowledge. A study by Suartama et al. (2021) has proved that pervasive learning is effective in improving learning achievement. The findings indicate that learning activeness and learning achievement for students who have experienced pervasive learning was better than for students who learned by using e-learning. This is due to pervasive learning providing more dynamic learning methods tailored to students' learning preferences. It created a more conducive learning atmosphere for students. A number of studies have used pervasive tools in higher education, however, there is still a limited number of studies that provide an overview of the current status of the research about the benefits of utilizing pervasive tools in higher education. A lot of research was conducted in primary and secondary school contexts. This study will contribute to the education, information system field, and management of universities

and developers in understanding the importance of integrating pervasive tools in the teaching and learning process in order to promote more effective teaching and learning in the twenty-first century to meet each student's needs in this advancement of the technology era.

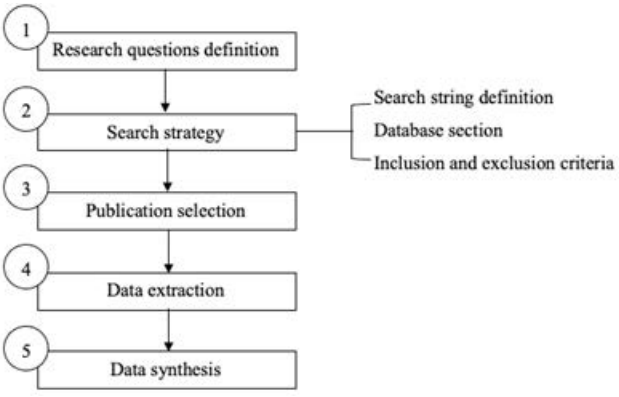
RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

The research objectives of this study are to identify types of pervasive tools that have been utilized in higher education and to determine the impact of the utilization of pervasive tools on students' learning progress. This study reviews the related literature review, discovers the research gaps, and presents a clear scope for answering the subsequent research questions: (1) What are the pervasive tools used in higher education? and (2) what are the benefits of utilizing pervasive tools in higher education?

METHODOLOGY

Figure 1 introduces the systematic literature review process guidelines proposed by Kitchenham and Charters (2007), Hanafizadeh et al. (2014), Mota et. al. (2019), and Virtanen et. al. (2017). The process includes: (1) identifying research questions; (2) determining keywords for searches in English; (3) selecting the databases for keywords search; (4) deciding the inclusion and exclusion criteria of research articles; (5) searching and revising of articles procedure implemented; (6) extracting wdata from selected articles; and (7) displaying the results acquired in the review.

Figure 1.
Methodological Phase of Systematic Review



RESEARCH QUESTIONS DEFINITION

This study's research objectives are to explore the publications published between the years of 2010–2021 on utilizing pervasive tools in higher education and the effect of utilizing pervasive tools on students' learning processes. In this phase, research questions were established.

SEARCH STRATEGY

The Definition of Search String

The process outlined below was used to define search keywords and search strings:

1. Keywords are derived from research questions and related publications.
2. Synonyms and alternate spellings are identified.
3. Synonyms and alternate spellings insert the Boolean operator OR.
4. To combine different search phrases, use the Boolean operator AND.

Database Selection

This study reviews the literature on technology adoption in the related field databases, including the main sources of publications in IEEE Xplore (ieeexplore.ieee.org/Xplore/guesthome.jsp), ScienceDirect (www.sciencedirect.com), SpringerLink (link.springer.com), and ACM Digital Library (dl.acm.org/dl.cfm) from 2010–2022. High-impact works were extracted for this study. In order to execute the search strings, this study used the related databases (Fahimnia et al., 2015). Table 2 presents the search string for the selected databases.

Table 2.
Databases and Search Strings

Database	Search String
IEEE Xplore, ACM, ScienceDirect, Web of Science	"ubiquitous learning" OR "U-learning" OR "Pervasive learning" OR "P-learning" OR "ubiquitous learning environment" OR "pervasive learning environment" AND "higher education" AND "ubiquitous computing" OR "Pervasive computing" AND "university" AND "ubiquitous technology" OR "pervasive technology" OR "ubiquitous tools" OR "pervasive tools"

Criteria for Inclusion and Exclusion

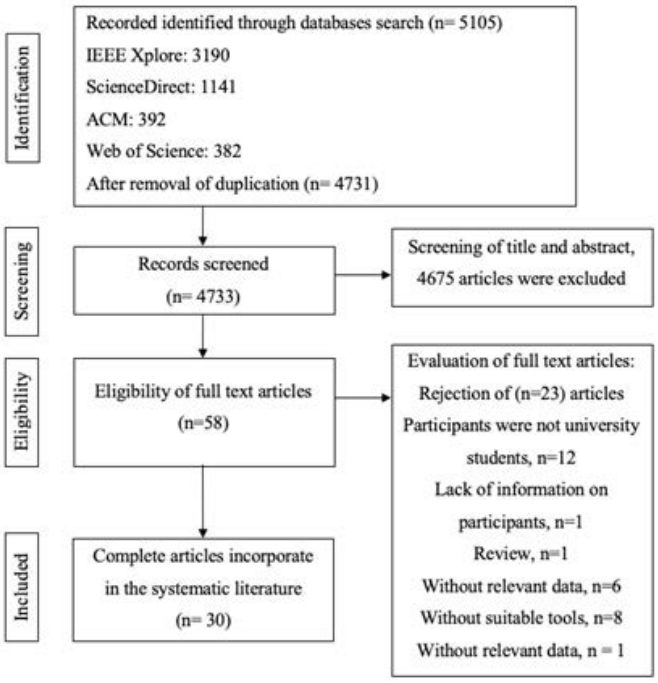
Studies were included if they were original studies and met the following criteria: (1) concentrates on pervasive tools, pervasive learning, and the usage of pervasive tools in the environment; (2) the research was carried out in higher education

settings; (3) the research adopts a quantitative and/or qualitative research method (describes study populations, participants, experimental procedure, or quasi-experimental); (4) the research discusses the study population, and the target population is undergraduate students from the higher education context; (5) the outcomes of the use of pervasive tools and pervasive learning were well defined; (6) the articles have been published between 2010–2021; and (7) the articles have full text available for retrieval. Studies were excluded from this study if: (1) the research did not focus on using the pervasive tool, pervasive learning, and learning environments; (2) they were reviews or recommendation studies; (3) the focus is not on the education context in the higher education setting; (4) the target audiences involved are not university undergraduate students; (5) the research is mainly concentrated on electronic learning or mobile learning; (6) the research is performed in a primary or secondary school; (7) pervasive tools were not used for educational purposes; (8) the research only investigates students' perception of pervasive learning without involving or explaining any particular learning task or instruction; and (9) the research explains the pervasive tools or system without assessing the impact and advantage of the utilization.

PUBLICATION SELECTION

Figure 2 shows the flow diagram which outlines the process of the identification and selection of studies. During the initial search of the keywords from Table 2, the selected databases produced a total of 5,105 records, including 372 duplicates, and 4,733 articles were retrieved after the removal of the duplicates. The following step was to screen the titles and abstracts, in which a total of 4,675 articles were excluded. Double screening for the abstracts helped maintain consistency and ensure the quality of the works selected. A total of 58 articles were identified as full-text articles when assessed for eligibility. Fifty-eight articles were retrieved for comprehensive text screening. After a rigorous, detailed review of the full-text articles, only 30 complete articles were selected for analysis according to the inclusion and exclusion criteria, and after 23 further articles were excluded due to the following reasons for not meeting the criteria: participants from the study were not university students (n=12); there

Figure 2.
Publication Selection Process



was a lack of information about the participants (n=1); articles were reviews (n=1); articles did not have data analysis in the study (n=6); and studies did not use suitable tools (n=8).

DATA EXTRACTION

In this section, information was extracted form from the selected articles to collect reliable and accurate data. Each of the primary papers was read in detail in this step, and the necessary data was extracted using Microsoft Excel. Table 3 shows the information which was included in Microsoft Excel, as the extracted data of this systematic review include author(s), publication year, title, objective, country, university, participants, subject, methodology, research strategy, pervasive tools, benefits and impact of pervasive tools, and features/functionality.

DATA SYNTHESIS

In order to address the research questions of this study, data synthesis was carried out to examine and summarize the proof gathered from the research articles that were included. This is accomplished by bibliometric-based tabulation and visualization techniques. The Microsoft Excel tool was used to tabulate and visualize the data. The researcher worked on multiple readings and

Table 3.
Extracted Data from the Final Included Papers

Data	Description
Author(s)	Name of the author(s).
Publication Year	The year of the paper was published.
Title	The title of the paper.
Objective	The research objective of the study.
Country	The location where the studies were conducted.
University	Location of the study was carried out.
Participants	The representative group of the data collection in the studies.
Subject	The subject (course) of experiment was carried out.
Methodology	Qualitative, quantitative, and etc.
Research Strategy	Survey, experiment design, interview and etc.
Pervasive Tools	Pervasive tools used in the study.
Benefits and Impact of Pervasive Tools	The findings and results of the survey/experiment design.
Features/Functionality	Features/functionality of pervasive tools offered.

interpretations of the original data. The data were then formalized into categories based on Table 3. These items were considered based on the research questions and objectives of this study. The reporting of the results followed the protocol from the study of Arksey and O'Malley (2005).

RESULTS AND DISCUSSIONS

Based on the inclusion and exclusion criteria and abstract screening, a total of 30 articles were determined as eligible for the process of review by the two authors. In regards to the standard of the research design, the review process was carried out individually by the two authors for all the selected articles. A discussion was conducted with one other to solve the differences in the interpretation. The following criterion was applied to organize the identified articles: the year of the publication and the country from which the articles originated.

Figure 3 indicates the number of research articles published on integrating pervasive tools in higher education settings learning every year. It is noticeable that the number of publications decreases in the years 2013 and 2014. In the year 2015, it shows a rise in the number of publications, and it is believed that the increment happened at a time when mobile devices were more popular and had greater availability. After the pandemic, the use of pervasive tools is receiving attention in 2022.

Figure 3.
Paper Per Year

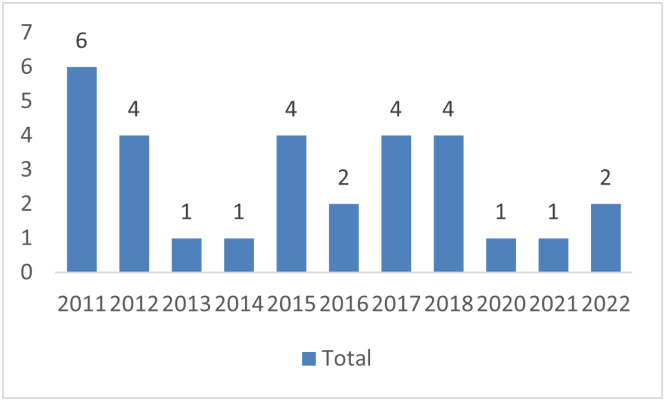
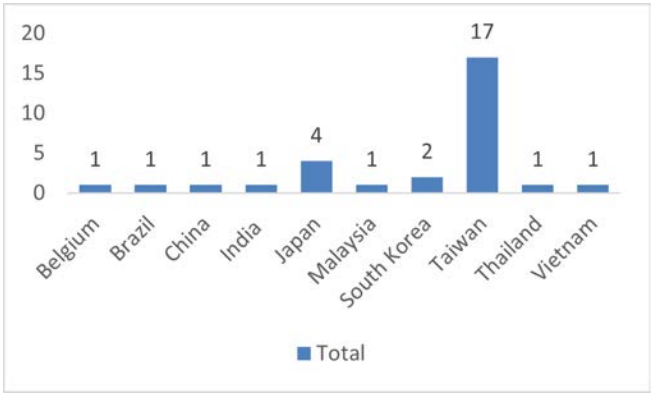


Figure 4 displays the 30 selected studies published regarding the benefits of learning using pervasive tools in university settings in each country. The results showed Taiwan was the leader in the implementation and experimentation of using pervasive tools, followed by Japan and South Korea. Belgium, Brazil, China, India, Malaysia, Thailand, and Vietnam have published one study. In Malaysia, it shows that only one study was focusing on using pervasive tools in higher education settings.

Figure 4.
Paper Per Country



The analyzed articles cover various subjects, including English language learning (Chang, 2018; Chang et al., 2018; Moreno & Vermeulen, 2015), cultural heritage courses (Chin et al., 2018; Chin et

al., 2020), English vocabulary learning (Huang et al., 2012), language learning (Mouri et al., 2016), the botanical garden of the Museum of Natural Science (Wang et al., 2015), and others. In addition, employing questionnaires were the primary quantitative research method for data collection. Most of the studies implemented experiments by dividing the participants into a control group (without using pervasive tools) and an experiment group (using pervasive tools) to compare the learning performance and achievements after using pervasive tools as part of their learning process.

FIRST RESEARCH QUESTION

Results were analyzed to answer each research question in detail in this section. This research seeks to address the first research question: "What are the pervasive tools used in higher education?"

According to the findings from the systematic literature review, several pervasive tools were identified to be used in indoor and outdoor settings for educational purposes. Table 4 summarizes the pervasive tools used in a total of 30 selected articles from 2010 – 2022 in different countries.

Table 4.
Summarization of Types of Pervasive Tools Used from Selected Articles

PDA with a GPS sensor, PDA with RFID readers	Context aware situation-based technologies could detect GPS and mobile devices
Mobile devices (PDA, smartphone, laptop/netbook, tablet) with wireless network	QR code
Mobile devices installed with p-learning system (preload with software	RFID reader, RFID tags
Mobile application	GPS technology
Mobile device with RFID	Cloud computing platform

In the systematic literature review analysis, mobile devices were identified as the most used devices in higher education institutions and for learning purposes.

SECOND RESEARCH QUESTION

This research seeks to address the second research question: "What are the benefits of utilizing pervasive tools in higher education?"

The results of the systematic literature review mainly show positive results from using the pervasive tools. Table 5 presents the findings and relevant information about the review.

From the analysis of the 30 selected papers, pervasive tools were found to have an impact and brought benefits to students in various ways, including (1) enhancing learning achievement and performance; (2) providing real-life experience; (3) personalizing learning; (4) increasing motivation; (5) increasing interest and interaction; (6) providing free access to learning materials; (7) enhancing learning experiences and opportunities; (8) bolstering excitement to use the system; (9) enhancing learning efficiency; (10) building confidence; (11) providing timely assistance; (12) providing enjoyment; (13) helping to search for information and solutions; (14) increasing computing skills; and (15) better communication.

FUNCTIONS AND FEATURES WOF PERVASIVE TOOLS

Table 6 presents the functions and features of pervasive tools. According to the results from this study, pervasive tools were used to achieve different tasks for educational purposes and brought benefits to students in different categories, helping students to achieve their tasks in different ways. The use of pervasive tools can be categorized into different categories, namely (1) inquiry and general use, (2) communication, (3) construction of knowledge, (4) and expression. Technology for inquiry and broad usage is for general and learning purposes; communication is to assist students to engage in the learning process; construction of knowledge was to assist learners to develop new ideas, construct new ideas using pervasive tools, and be able to understand and apply. Learning through expression can be defined as engaging students personally—sharing, expressing, and being able to construct ideas (Sedek et al., 2012).

DISCUSSION

This systematic study reviewed extensive literature to determine the current state of pervasive tools studies in the higher education context—including the types of pervasive tools used in higher education settings—define the definition of pervasive tools, and investigate the impact of using pervasive tools for learning purposes. A systematic approach was used for answering two research questions. This review incorporates studies that were published between 2010–2022. After applying multiple systematic processes, a total number of 58 eligible full-text articles were selected to be assessed. Only 30 full articles were selected for

Table 5.
Benefits of Using Pervasive Tools

No.	Author(s)	Tools	Benefits of Using Pervasive Tools
1	Chang (2018)	Personal Digital Assistant (PDA) with GPS and installed u-learning system	Enhance learning achievement; personalize interactivity; enhance the real life experience of locality; more concentration, interest, and better performance
2	Chang et al. (2018)	PDA with GPS sensor	Enhance performance, motivation, and context awareness with experience learning in real situations; higher learning interest and interaction
3.	Chin et al. (2020)	Location-based context-aware technologies could detect GPS, and mobile devices	Improve overall learning capability and satisfaction; more interesting and enthusiastically engaging activities; own control of learning pace; free access to learning materials
4	Chin et al. (2015)	QR code, smartphone installed with the p-learning system	Enhance results, learning interest, expectations, engagement; allows for higher levels of engagement and satisfaction; able to relearn teaching materials; gain knowledge through observation; more confident and positive
5	Chin et al. (2018)	Smartphone installed with p-learning system, QR code	Enhance learning performance and authentic learning experiences; independently engage in learning activities; build self-confidence
6	de Sousa Monteiro et al. (2016)	Mobile application, tablet, wireless network	Enjoy and share knowledge with peers; new features; tools in the learning environment able to motivate students
7	Huang et al. (2012)	Mobile device with RFID	Increase students' intention to use; excitement to use the system; better concentration; useful; more accepted
8	Hwang et al. (2011)	Mobile phone with QR code	Prefer to get assistance and instructions from the learning system; willing to use it to support learning
9	Jeong & Hong (2013)	Mobile devices—PDA	Improve learning efficiency, effectiveness, and performance
10	Kong et al. (2017)	RFID, QR codes, and cloud computing	Stimulate students' interests; allow for timely assistance; enhance students' problem-solving skills
11	Mandula et al. (2011)	RFID	Enable to gain the educational content according to the situation; automatically get assignments and exam marks when presented in the classroom
12	Moreno & Vermeulen (2015)	Mobile application	Enjoy the activities provided; learn something new; improve motivation; positive attitude toward the mobile application
13	Mouri et al. (2017)	Smartphone installed with p-learning system	Increase learning opportunities enables students to experience indirectly what other students experienced
14	Mouri et al. (2016)	Smartphone installed with p-learning system	Increase learning opportunities and learning effect; able to save learning activities and share by using the system
15	Mouri et al. (2018)	Smartphone installed with p-learning system	Enable students to experience indirectly what other people experienced; a useful tool in finding words
16	Ogata et al. (2011)	Smartphone installed with p-learning system	Acquisition of knowledge is enhanced; having a live, straight view of the physical real-world environment augmented by a real- time contextual awareness of the surrounding objects; personalized learning; useful to recall the situation of the words used
17	Sedek et al. (2012)	Smartphone, laptop/netbook, tablet	Improve job performance, especially for learning purposes
18	Shih et al. (2015)	Mobile application	High learning satisfaction; develop better learning habits; build confidence and positive attitudes
19	Shin et al. (2011)	Mobile application	Usability; convenience; availability; functionality
20	Temdee (2014)	Mobile phone and p-learning system	Satisfaction with the functionality and adaptability provided; enjoyable; more effective collaborative learning
21	Tsai et al. (2017)	Mobile application, PDA, or mobile phone	Better computing skills and learning effectiveness

22	Tsai et al. (2012)	Mobile devices, RFID reader, RFID tag, wireless communication	High reliability and validity; user-friendly; present realistic and real-life instruction; browse documents based on students' requirements for advanced learning
23	Tsai et al. (2011)	PDAs with RFID readers	Attain information; timely guide; an increase of knowledge; active learning
24	Wang et al. (2015)	Mobile devices, RFID, QR code, wireless communication	Enhance learning intention; access digital resources; help learners address problems; expand and organize personal knowledge
25	Yang & Wang (2011)	Mobile application and cloud computing platform	Obtain information; positive views to the interface design; stability; interactivity; usefulness; clearly displayed information; communication function to facilitate collaborative learning
26	Yang et al. (2012)	Mobile devices, QR code	Provide support of reflection prompt strategies of learning materials; interesting; satisfying
27	Yao (2017)	GPS technology, QR code, p-learning system, wireless network	Improve learning, learning willingness, interest, and motivation; enhance understanding and the ability to apply in daily life; acquire learning materials by using a smartphone or mobile device; more efficient and precise memorization
28	Huynh et al. (2022)	Mobile phone	Improve oral skills and performance; enhance interaction; boost learners' motivation, as learners think that learning task is more attractive and meaningful
29	Tseng et al. (2021)	Sensor, augmented reality (AR) technologies with ubiquitous learning applications	Increase students' learning performances in the class; enhance students' understanding of the concept of knowledge; actively offer feedback and suggestions
30	Wu et al. (2022)	Mobile application	Enhance students' comprehension of subject topic and lead students to have a positive learning experience; positive effects of learning both cognitively (learning outcomes) and affectively (student perceptions)

Table 6.
Functions and Features of Pervasive Tools

Author(s)	Types of Pervasive Tools	Functions and Features	Task Category (Benefits)
Chang (2018)	PDA with a GPS sensor	PDA can display information connected from GPS; GPS can position the learner's present location	Construction of knowledge (listen and observe in a real environment)
Chin et al. (2020)	Location-based context-aware technologies could detect GPS and mobile devices (pervasive guided learning system)	Provide guidance; direct access and learn information from the real world; mobile devices can be used to review teaching materials	Construction of knowledge
Chin et al. (2015)	QR code	Sensors provide both effective and flexible support, develop curiosity, and promote dynamism in the classroom	Expression
	Smartphone installed with p-learning system	Smartphone to access information contained in the QR code; students are able to access learning materials by utilizing smartphones and scanning QR codes located in real situations	Construction of knowledge
de Sousa Monteiro et al. (2016)	Mobile application	Communication; interaction; sharing knowledge; notifications; making friends; discussions	Communication
Yang & Wang (2011)		Get information; encourage mobile learning and collaborative learning to finish the jobs	Communication

Huang et al. (2012)	Mobile device with RFID	Sense the location of the students; provide students with educational materials in real-world situations	Construction of knowledge
Jeong & Hong (2013)	Mobile devices (PDA, smartphone, laptop/netbook, tablet) with wireless network	Accommodate the learning priority of students, which allows students to choose the course session and construction; calculate the students' learning preferences	Construction of knowledge
Sedek et al. (2012)		Inquiry and general use; communication; expression and construction use	Inquiry and general use
Yao (2017)		Mobile devices sense the user's present location to discover the corresponding environmental details and cater to appropriate learning information.	Construction of knowledge
Mandula et al. (2011)	RFID	RFID is one of the short-range wireless communication technologies used to catch remote object ID using radio waves; discover a person or obtain contextual information using electronic sensors and radio tags embedded inside the surrounding environment	Construction of knowledge
Tsai et al. (2012)	RFID reader, RFID tag	RFID—sense the code in the tag and deliver it to the learning system with wireless communications; identify the location of the student; display relevant learning jobs, additional materials, or learning instruction; detect students' locations, contexts, and individual needs	Construction of knowledge
Mouri et al. (2018)	Smartphone	Record past and current learning experiences; visualize and analyze learning logs; share experiences, location, and information	Construction of knowledge
Yang & Wang (2011)	Cloud computing platform	Calculate and examine the information collected	Construction of knowledge
Yao (2017)	GPS technology	Obtain learning content	Construction of knowledge

analysis. The remaining articles were excluded from this study since they did not meet the inclusion criteria, such as participants were not university students, there was a lack of information about the participants, the studies did not providing relevant data, and the studies did not use suitable tools for the experiment. In the analysis stage, the selected articles were then extracted and divided into different categories in the Excel file, such as author(s), publication year, title, objective, country, university, participants, subject, methodology, research strategy, pervasive tools, benefits and impact of pervasive tools, and features/functionality.

The findings of this systematic review show that most of the studies were from Taiwan (17 studies), followed by Japan (4 studies). Only one study has been accomplished in developing countries, such as Malaysia, Thailand, and Vietnam. In the study conducted by Lim and Lee (2021), the pilot test results show that students from private universities in Malaysia are determined and prepared to use pervasive tools in the learning process. Thus, there is a need to implement the use of pervasive tools in Malaysia's higher education or to investigate the acceptance and behavioral intention of pervasive tools in Malaysia's higher education (Lim & Lee, 2021). The results show that pervasive tools have been used in different subjects, including English language learning (Chang, 2018; Chang et al., 2018; Moreno & Vermeulen, 2015), cultural heritage courses (Chin et al., 2018; Chin et al., 2020), English vocabulary learning (Huang et

al., 2012), language learning (Mouri et al., 2016), the botanical garden of the Museum of Natural Science (Wang et al., 2015), and others. The outcome of this study indicates that pervasive tools used in higher education include mobile applications (de Sousa Monteiro et al., 2016; Moreno & Vermeulen, 2015; Shin et al., 2011; Shih et al., 2015; Tsai et al., 2017; Yang & Wang, 2011), mobile devices with a pervasive learning system (Chang, 2018; Chin et al., 2015; Chin et al, 2018; Chin et al., 2020; Mouri et al., 2016; Mouri et al., 2017; Mouri et al., 2018; Ogata et al., 2011; Temdee, 2014; Yao, 2017), mobile devices with a sensor (Chang et al., 2018; Huang et al., 2012; Hwang et al., 2011; Tsai et al., 2011; Tsai et al., 2012; Wang et al., 2015; Yang et al., 2012), mobile devices (Jeong & Hong, 2013; Sedek et al., 2012), and RFID (Kong et al., 2017; Mandula et al., 2011).

Different types of pervasive tools have been used in indoor and outdoor settings for educational purposes. Pervasive tools that have been used include PDA with sensors; mobile devices; mobile devices installed with a p-learning system; mobile applications; mobile devices with RFID; context-aware situation-based technologies that could detect GPS; QR codes; RFID readers and tags; GPS technology; and cloud computing platform. The mobility and portability of mobile devices have promoted ubiquitous, personalized, and interactive learning (Huynh et. al, 2022).

The findings of this review are in line with the results of similar studies and indicate the majority of investigations have shown that most of the students are in favor of using pervasive tools in learning, as the tools provide wide advantages to them. From the findings, the benefits of using p-learning tools are evidence of improving students' learning performance, increasing their level of motivation, providing support during the learning process, allowing the learning process to take place at anytime and anywhere, and engaging students more in the learning process where they can easily follow the lessons. Pervasive tools are effective and efficient in assisting in learning. Apart from that, a pervasive learning system stimulates better problem-solving progress and motivates students in decision-making and responding more quickly (Kong et al., 2017). In addition, students are ready and willing to accept and use pervasive tools in the learning process. A study by Azizan et al. (2022) concludes that students nowadays desire more interactivity in education. Students hope for instructors to be active online and responsive, which motivates students more in their studies and is important in twenty-first century learning skills, in both online and offline modes of learning. In addition, students appreciate the option of personalized learning, with diverse learning preferences and needs, and with devices that offer versatility, accessibility, and affordability.

In addition, the results of the findings are consistent with Alnabhan et al. (2018): pervasive tools are able to enhance students' learning motivation and knowledge, and expose students to real-life experiences. Students who have experienced pervasive learning were more successful than students who learned using e-learning, as pervasive learning was tailored to suit individual students' needs and was able to increase students' interest and interaction (Suartama et al., 2021). From the findings, other benefits of utilizing pervasive tools in higher education include the ability to freely access the learning materials; students were more excited to use the learning system more; and students appeared to be more confident and enjoyed the learning experiences. Students were able to search for information and solutions easily by themselves, which improved their computing skills.

Functions and features of pervasive tools were presented in this study, too. The use of pervasive tools can be categorized into different categories, namely (1) inquiry and general use, (2) communication, (3) construction of knowledge, (4) and expression. This study provides insight and a huge impact to understanding the utilization of pervasive tools. System designers and instructors will be able to more clearly witness the importance and impact of integrating pervasive tools (Lim & Lee, 2021). The current educational system's emphasis on e-learning and its inability to adequately customize knowledge and fulfill the needs of learners in the twenty-first century are shortcomings. As a result, this study is essential to address the difficulties raised. This study will help the area of education and information systems understand how pervasive tools affect the teaching and learning processes to assist twenty-first century teaching and learning that meets the needs of each individual student in this era of technological innovation (Lim & Lee, 2021).

CONCLUSION

This review provides an outline of published research studies on pervasive tools between 2010–2022. A systematic approach was adopted for answering two research questions. This study follows the systematic literature review process guidelines proposed by Kitchenham and Charters (2007), Hanafizadeh et al. (2014), Mota et al. (2019), and Virtanen et al. (2017). A total number of 55 full articles were retrieved for full-text screening, and 30 full articles were selected for analysis according to the inclusion and exclusion criteria. The information from the 30 full articles was then extracted using Microsoft Excel. The data were then formalized into categories. Based on the results, a summary of types of pervasive tools was listed. Mobile devices were identified as the most used devices in higher education institutions and for learning purposes. In addition, utilizing pervasive tools in higher education has brought vast positive results and an impact on the learning process, including (1) enhances learning achievement and performance, (2) provides real-life experience, (3) personalizes learning, (4) increases motivation, (5) increases interest and interaction, (6) provides free access to learning materials, (7) enhances learning experiences and opportunities, (8) bolsters excitement for using the system, (9) enhances learning efficiency, (10) builds confidence, (11) provides timely assistance, (12) increases enjoyment, (13) improves searching for information and solutions, (14) increases computing skills, and (15) better communication. Furthermore, the functions and features of pervasive tools were discussed. As such, integrating pervasive tools in higher education is expected to bring huge benefits to students.

Based on the findings, it can be concluded that pervasive tools in higher education are relatively new in Malaysia, Thailand, India, Vietnam, China, Brazil, and Belgium. Limited research has been conducted in the higher education context. There is a great need for more exploration in this area of field, too. In conclusion, as the current trend is moving from e-learning to m-learning and p-learning, this systematic review is valuable for universities, academicians, and developers. The results of this systematic review can open new opportunities for academicians to realize the use of pervasive tools and the benefits of integrating them into the teaching and learning processes. Additionally, the results of this review can help academics and researchers to realize the limitations and gaps in this area, as well as future works for pervasive tools.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The existing area of study about pervasive tools still has some gaps and limitations. There are few or no studies conducted so far about how pervasive tools in higher education should be designed and what features and functions should be considered in the p-learning design process, which is barely reviewed in literature. This limitation points out the lack of systematic research surrounding pervasive learning. Furthermore, this study was conducted in 2022 and it may not cover all the papers published at the time this study is published. More studies may be obtained by modifying or adding other relevant keywords to the search string. There are several areas for future research. There is a lack of studies investigating students' acceptance of the pervasive tool. Future research might, for example, develop a pervasive tool for students in higher education and investigate students' acceptance and intention to use it in the learning process. In addition, future research can consider investigating students' use of pervasive tools at the primary school level. Studies relating to the population at the primary school level were excluded from this study.

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