Mobile Learning in Higher Education: A Classification Framework for Learning Applications

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Abstract

The focus in over two decades of mobile learning (m-learning) research has meanly been on PK-12 education. M-learning is seen as an important new development in PK-12 and higher education (HE). Yet, the ease of app identification is lacking. This paper aimed to classify different m-learning applications to ensure that they are more easily accessible to teachers. Such a framework has been proposed earlier. However, the technological approach misses, and the apps are mainly for PK-12 pupils. Thus, the current paper aimed to create a framework for (learning) apps for higher education, including their pedagogical and technological approaches. Overall, eleven different app types were identified and categorized into four main categories: practice, organization, social, and creation. Then the apps were further classified using their pedagogical design and instructional approach. The applications can be identified as skill-, content- or function-based applications with overlap in the different categories. Finally, the mobile platform and the features used were analyzed and included in the framework here it was found that most of the apps were hybrid applications which allow for a diverse set of features for the apps. Web based applications are the least prominent and provide the least amount of features.

1 Introduction

In the digital era, any household member has multiple mobile devices to their display. It is not strange for teachers and students alike to use their mobile devices in their daily lives. Students use note-taking apps, like Scribbler or OneNote, to taking notes while attending the lectures (Varadarajan et al., 2008). Teachers use Student Respond Systems, such as Socrative, to create interactive lessons (Roman et al., 2021). However, teachers note that new developments are required as more traditional methods fail to meet the expected results, Akhmetshin et al. (2019) states mobile learning as one of these new developments.

O'Malley et al. (2005, p. 7) defined mobile learning as "any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies". In combination with over two decades of mobile learning research, it shows that mobile learning technologies, such as student

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response systems, yield positive effects on learning outcomes in the classroom (Hunsu et al., 2016). Unfortunately, the retention of course material is lacking. Therefore, Hunsu et al. (2016) recommends teachers emphasize strategic lesson preparation to ensure more promising effects of mobile learning.

In order to assist in this preparation, apps should be easily accessible, and they should be applicable for the instructional approach the teacher wishes to apply. Instructional approach, also known as an instructional method, "include[s] how to organize learning materials, strategies for delivering, and managing activities" (Lestari et al., 2019, p. 156). An example of the need for accessible identification has been presented in the introduction of Cherner et al. (2014). A biology teacher is looking for an application to use for the students. However, the classification system for applications in the App Store made it challenging to find a suitable app. Thus, identifying different types of mobile learning applications is crucial for the accessibility of app identification.

1.1 Background

Goodwin and Highfield (2012) already concluded the limited accessibility for educators and parents when looking through the App Stores classification system. They suggested a classification for the pedagogical design of educational apps. Pedagogical design refers to the "plan or scenario that defines the format, content, and structure of the environment, the delivery systems, and implementation strategies" (Lowyck, 2002, p. 199). The resulting classification consisted of instructive, manipulable, and constructive applications. Additionally, there are preliminary findings for hybrid versions of Constructive/Manipulable and Manipulable/Instructive. Instructive apps deliver predetermined tasks which enlist a homogeneous response. This strategy is commonly known as 'skill-and-drill'. Manipulable apps use guided discovery and experimentation to involve the user in a predetermined context. Finally, constructive apps are used to create content or artifacts (Goodwin & Highfield, 2012).

Cherner et al. (2014) reflected on the paper of Goodwin and Highfield (2012) and stated the classification to be underdeveloped as it does not reflect on the value of the specific skills or purpose of the app. They suggested skill-, content-, and function-based applications with subcategories within as a classification that did include these skills and purposes. The three categories align with Bloom's revised Taxonomy as skill-based falls into remembering and understanding the content, content-based helps with applying and analyzing, and function-based with the evaluation and creation.

Bloom's Taxonomy is a hierarchy to define the different levels of thinking from lower- to higher-order. The revised version, created in 2001 by former students of Bloom, was used to define the levels as verbs rather than nouns. These changes were made to make the taxonomy easier to understand and assess compared to the original version from the 1950' (Conklin, 2005). Alford et al. (2006, p. 176) displayed Bloom's taxonomy using a pyramid. A pyramid for the revised taxonomy is displayed in figure 1.

Skill-based applications have been defined as useful for "recall, rote memorization, and skill-and-drill instructional strategies." (Cherner et al., 2014, p. 174). In higher education, it is to be expected that these kinds of applications use at least some sort of assessment as their strategy.

Content-based applications were defined for their "access to vast amounts of information, data, or knowledge by conducting searches or though exploring preprogrammed content" (Cherner et al., 2014, p. 175). These applications are glossaries, wikis, course content, or other applications that allow querying for data are expected. They should, however, not be used to complete a learning task according to Cherner et al. (2014).

Finally, for function-based applications the application is expected to assist "transforming learned content into usable forms" (Cherner et al., 2014, p. 176). According to Cherner et al. (2014) assessment is not contained within these types of applications as well as the content. Instead, it is used for creating textual descriptions, visual representations, or other presentations.

The research of both Goodwin and Highfield (2012) and Cherner et al. (2014) pointed out that most of the applications available are mainly focused on pupils rather than higher education students. Additionally, these frameworks consider the educational approach but do not include the technologies used to achieve these goals.

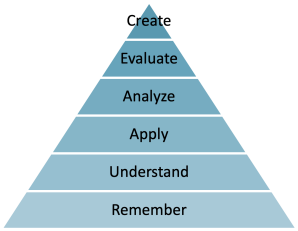


Figure 1: Bloom's revised taxonomy according to Conklin (2005).

The technology used within an application is of importance to understand an app's capability. The technology could be divided into two main categories, the platform the application is for and the features the application provides. Both the platform and features are intrinsically linked to each other, as not all platforms allow the full potential of some functionalities. Therefore, the link between mobile learning applications and technological affordances needs to be researched to provide a complete framework for mobile applications.

Therefore, the purpose of this paper is to provide a classification framework of HE apps foregrounding the pedagogical approach and technological affordances. The research question guiding this reads, *what are the different types of HE mobile (learning) apps, and what might be a pedagogically and technologically sound framework to classify these apps from a teaching and learning perspective?* To answer this question, the following two research questions need to be answered.

- What are the different types of mobile (learning) apps for HE, and what is their purpose?
- How can the HE mobile (learning) apps be classified considering the pedagogical and technological dimensions?

The meaning behind mobile (learning) applications follows from any application used in higher education to be taken into account. However, these applications do need to be used for learning. The difference between mobile (learning) applications and learning applications can be seen in, for example, note-taking applications. From the note-taking application itself, a student would not learn anything new, but when the application is used for taking notes in HE, it helps the student learn.

2 Method

A literature review, with qualitative data analysis, was conducted for answering both sub-questions. In a literature review, one examines current literature for a chosen subject (M. J. Grant & Booth, 2009).

2.1 Search Strategy and Study Selection

Utilizing PRISMA principles (Liberati et al., 2009), the paper selection started with collecting papers from IEEE explore, Science Direct, and Scopus. The papers were collected from 2008 onwards. This year was determined to mark the launch of both the Apple App Store and Google's Android Market, now known as Google Play. The papers were found using the following search terms, which were combined using boolean logic: "m-learning", "mobile learning", "app*", "pedago* approach", "technological approach", "classification", "higher education". These terms are important to the core of the research question. Using more terms would restrict or broaden the number of papers too much.

The initial search resulted in 352 papers. Eleven duplicates, nine non-English, and 41 conference documents that contained multiple articles were removed. The inclusion and exclusion criteria from section 2.2 were compared to the remaining papers using the title, abstract, and keywords. A total of 245 articles did not meet the criteria, resulting in 41 articles for an in-depth review. After this review, the final four papers were not appropriate for this study, resulting in a final of 37 papers. This process is represented in figure 2.

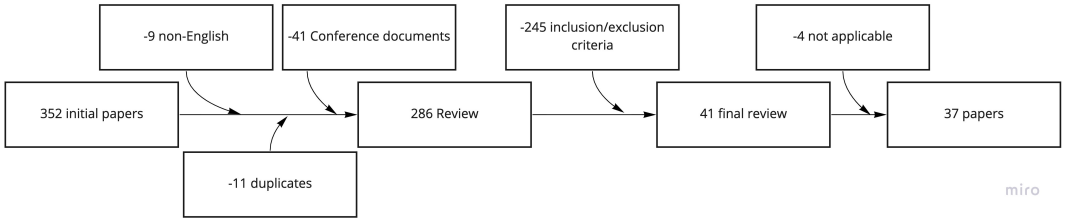


Figure 2: Diagram representing the literature search and selection.

2.2 Inclusion/exclusion criteria

For this paper, the inclusion and exclusion criteria as specified in table 1 and were utilized to exclude any results by making sure none of the exclusion criteria were included and the inclusion criteria are satisfied.

Laptops, notebooks, stationary devices, and wearables were excluded for not applying to either mobile learning or as a mobile device. Mobile devices are defined as "Computing devices that can easily be carried about and used on-the-go. Their main attributes are their portability and can often fit into one's hand. In addition, they efficiently perform the same functions that desktop or laptop computers do" (Adjin-Tettey & Akrobotu, 2018). The research is for applications in higher education which automatically excludes PK-12 and adult education. Furthermore, the article may not be in an E-book to exclude teaching material as we are looking for papers. For the inclusion criteria, any application used for learning in HE may be included. Therefore, the papers were not limited to apps created for teaching. This criterion makes the inclusion of an application or mobile device to be used for educational purposes. Last but not least, the setting needs to take place in higher education.

Inclusion	**Exclusion**
Higher educational setting	Mobile device is a laptop / netbook
Mobile learning is applied	Mobile device is stationary
Use of an application for educational purposes	Mobile device is a wearable
Use of an mobile device for educational purposes	Lower- or adult educational setting
	The paper is not in English
	The article is not an (E)book

Table 1: Inclusion and exclusion criteria

2.3 Analysis framework

The 37 papers have been coded over several categories: app type, purpose, instructional approach, pedagogical design, mobile platform, and app capabilities. The paper's introduction, method, and results have been analyzed using literature coding. Coding is used for identifying sections of data which are then labeled using a code (Linneberg & Korsgaard, 2019). There are two ways defined for coding data, inductive- and deductive coding. Inductive coding allows for acquiring codes directly from their source. This coding uses the terms the data already provide. Deductive coding is more narrow as it allowed for using predetermined codes to assign to the data (Linneberg & Korsgaard, 2019). A combination of both was used to allow for detailed coding of the pedagogical, instructional, and mobile platform while collecting the different types and purposes of the apps from the data itself and its features when mentioned.

2.3.1 Deductive codes

Pedagogical Design

For the deductive coding of the pedagogical design, the basis from Cherner et al. (2014) was used. Three categories were determined for classifying educational apps being: skill-based, content-based, and function-based. As described before, these categories alight with bloom's taxonomy. This connection indicates that when these categories are automatically linked to higher-order thinking, they reflect a particular pedagogical design.

Instructional Approach

The application's instructional approach has been taken into account to support the pedagogical design of the application. The instructional approach defines the strategy used to instruct the students. The instructional approach has been coded using a hybrid of deductive and inductive coding. First, a set of instructional approaches was prepared for their connection with technology. However, this list is most probably not exhaustive. Therefore, any missing approaches are taken into account as part of inductive coding. The selected approaches are:

Flipped classroom: Lesson components are prepared by the students at home, which allows for the lessons to be available for learning activities within the classroom (Tucker, 2012)
Personalized learning: A class meets core standards but in their way (P. Grant & Basye, 2014).
Game-based learning: The students play a game to achieve a defined learning goal.
Inquiry-based learning: Students use scientific approaches to discover new things (De Jong, 2006)
Expeditionary learning: Students are actively engaged in "real-world" activities to learn, meaning that students go on expeditions to experience and engage with their topic of study (Klein & Riordan, 2011; "Teaching Methods", n.d.).
Differentiated learning: Teachers address the needs of individual students (Mills et al., 2014).
Direct instruction: Students see the teacher solve a problem and then step by step also learn to solve the problem using guided instruction and exercises (Engelmann, 1980).

For game-based learning, it needs to be noted that Plass et al. (2015) states that there is a connection between game-based learning and gamification. For this paper it does not matter whether the learning activities are actual games or are designed to have gamification. Both are considered game-based learning as they both have elements of games to help with learning.

Lastly, although it does not sound like an instructional approach that uses technology, expeditionary learning is included. When exploring locations, there might be some technology required, for example, the camera of a mobile phone for taking pictures of an activity.

Mobile Platform

On mobile devices, there are different platforms which can execute an application. Luntovskyy (2018) distinguishes between four application platforms: website-based, a program that runs in the browser, a native application, which is a program installed on the device. Then there are hybrid applications for which both a website and native application exists, and progressive web app (PWA), a website-based application with native characteristics.

Different platforms have several benefits and drawbacks. Native applications have easier access to the sensors, camera, microphone, GPS, and other built-in features. However, it limits the ease of use of different operating systems. For example, android applications do not run on Apple devices unless they are also programmed separately for the Apple device. Web-based applications run on the browser, which allows them to be accessible from any operating system with an internet connection and a browser. Both hybrid and PWA are solutions to achieve the best of both worlds. Hybrid applications provide both web versions of their applications as well as native versions. An example of this is Microsoft office having native applications as a starting point, branching out to the web-based

office online in 2019 (Doll, 2019). PWA works a bit differently as they are in its core web-based applications which, can have icons on the home screen, access to native applications with the use of APIs, and allow for offline access using caching (Sheppard & Sheppard, 2017).

3 Results and Discussion

This section presents the findings and discussion to the two sub-questions stated in section 1. Section 3.1 discusses the different types of mobile (learning) applications and their purpose. After which section 3.2 discusses the classification of the app types in four parts using the following order: pedagogical design, instructional approach, mobile platforms, and technological affordance. Finally, in section 3.3 the research contribution is discussed.

3.1 Mobile (Learning) App Types and Purpose of Use

The types of mobile learning applications were inductively coded with the framework suggested by Cherner et al. (2014) in mind. From this coding, eleven app types have been identified. The applications were divided into four categories: 1) Organization, 2) Creation, 3) Social, and 4) Practice.

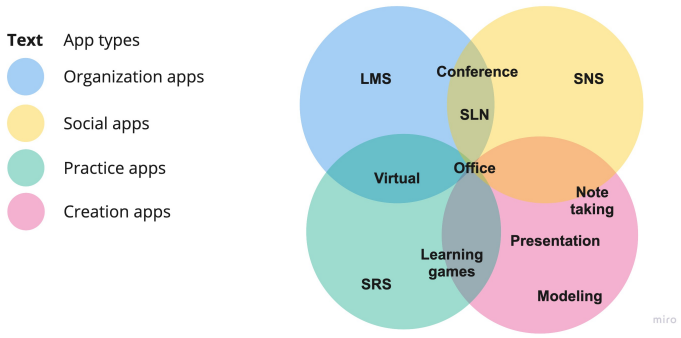


Figure 3: The collected app types sorted over four categories. Each color represents a category, the overlap between categories shows hybrid categories.

The app types found are divided within the categories, similar to Cherner et al. (2014). Eleven different app types have been identified. The following sections clarify which categories have been found. Additionally, a Venn diagram of the categories with their app types can be seen in figure 3.

The first type of application is part of the organization category. Organizational applications are apps that are used for planning, grading, and aligning content (Akhmetshin et al., 2019; Kumar et al., 2020). The most common app found in the organization category is the Learning Management Systems (LMS). It is the most widely used type of learning technology and offers an infrastructure for administration, management, assessment, and collaboration (Kumar et al., 2020).

The next category is social. Social applications are used for interaction between all sorts of people. This category houses Social Networking Sites (SNS), which are used for various social activities ranging from chatting, updating students, and posting snippets of content in various auditory and visual forms (Tang & Hew, 2017). Additionally, there are Conference applications that are application used for communicating online. These applications support collaboration when physical meetings are unfeasible (Tereshchenko et al., 2020)

An interesting finding is an interaction between the LMS and SNS. Prestridge (2014) argues that LMS has a different kind of interaction between student and teacher than SNS. On the other hand, there is Chilivumbo (2015) where Facebook was used as an LMS to provide content for the students. Another app type, named Social Learning Network (SLN), was derived from respecting these two types. Dalipi et al. (2017, p. 190) also distinguished this type as a different type of applications and

defined it as a type of applications that "encapsulates scenarios in which several people learn from one another through structured interaction". Which, in its turn, include a wide range of applications from Question and Answer sites to SNS used as an educational platform.

In the practice category, Learning Games and Student Respond Systems (SRS) are present. Learning Games use gamification elements to achieve learning goals (Troussas et al., 2020). At the same time, SRS are applications used to gather input from the students (Roman et al., 2021). The primary differentiation between the two types is where the app is used and the application's goals. SRS is more likely to be used during lectures to gather input from all students (Akhmetshin et al., 2019; Roman et al., 2021), while Learning Games are more individual for the student itself. Although some Learning Games might have a social aspect to them by having chat functionalities, leader boards, or other types of suggestions for opponents (Aguiar-Castillo et al., 2020; Troussas et al., 2020), in the end, you play the game for yourself only.

The category for creating has applications used for making something from the learning material. Note-taking applications allow a user to create notes from the material using both a stylus or keyboard as input (Varadarajan et al., 2008). Modeling applications are used to make models, like Autodesk(Modlo et al., 2020), or diagrams, like Draw.io or Lucidchart (Bower & Torrington, 2020). Finally, presentation applications are used to create presentations; examples of this type of application are Prezi (Akhmetshin et al., 2019), or more commonly known Microsoft PowerPoint (Bower & Torrington, 2020).

Finally, there are some hybrid applications, mainly situated between practice and organization is virtual, including virtual reality (VR) and Artificial Reality (AR) applications (Ever & Rajan, 2018). This application type is considered hybrid due to its wide range of options for content (Hew & Cheung, 2013). Office applications are used for text markup, table structuring, and any other type of office-related applications (Baranova et al., 2019). These apps are a bit special as they can fit in all categories with the correct reasoning. However, its central position has been chosen to be creating, as it always allows for processing gathered knowledge into a new form.

3.2 Classification of Mobile (Learning) Apps: Pedagogical, Instructional and Technological Dimension

3.2.1 Pedagogical Design

Using the classification proposed by Cherner et al. (2014), all applications have been coded on which design the application used for their content. The coding used as described in the method was skill-, content-, or function-based. Where the skill-based application mainly focused on remembering and understanding the content. Content-based applications were used for applying and analyzing content. Finally, functional-based applications are for evaluating and creating. Given these aspects, a table was created matching the content approach with the application types, resulting in the table in figure 2.

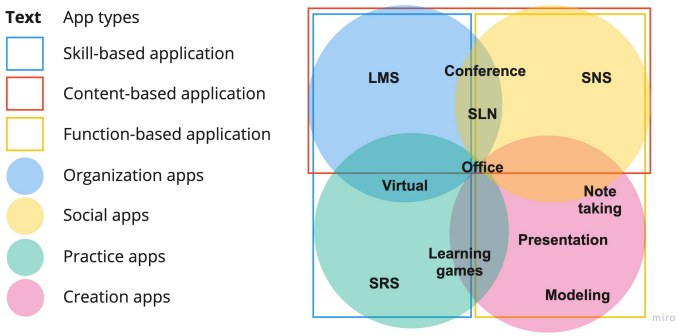


Figure 4: The eleven app types sorted over the four categories, extended with the pedagogical design.

Type	Skill	Skill / Content	Content	Function	Content / Function	Skill / Content / Function	Multi-purpose	NA	
LMS	0	4	3	0	0	0	1	0	Organization
Organization	0	0	1	0	0	0	0	0	Organization/ Social
SLN	0	0	2	0	0	0	0	0	
Conferance	0	0	0	0	0	0	0	1	Social
SNS	0	1	3	4	1	1	2	1	Organization/ Social/ Practice/ Creation
Office	0		1	2	2				
Note taking	0	0	0	2	0	0	0	0	
Presentation	0	0	0	1	0	0	0	0	Creation
Modeling	0	0	0	0	1	0	0	0	Practice/ Creation
Game	1	0	1	0	0	1	0	0	
SRS	3	0	0	0	0	1	0	0	Practice
Practicing	3	0	0	0	0	0	0	0	Practice/ Organization
Virtual	2	0	0	0	0	0	1	0	

Table 2: No. of paper for each app type per pedagogical design. The app types are sorted by category. Each color represents the category color of the app type in figure 3.

In table 2 the different categories and mobile app types as proposed in section 3.1 can be seen, highlighted in their respective colors and order. From this, it appears that most of the organizational applications are content or skill/content applications. The social applications fall mostly in content and function type applications. Creation applications are focused on function-based applications, and the practice applications are foremostly skill-based applications. The updated Venn diagram can be found in figure 4. The results are not a surprise when looking at the way the skill-, content- and function-based applications are defined in terms of Bloom's revised taxonomy that has been used as a way to describe these base types of applications in Cherner et al. (2014).

Skill-based applications lay in line with the remembering and understanding layers of the revised taxonomy. Any application that helps the student by familiarizing with different topics will be in skill-based applications (Cherner et al., 2014; Goodwin & Highfield, 2012). Practicing with topics and receiving information about these topics falls perfectly in line with this. Therefore practice and organization are the categories that fall in line with skill-based applications.

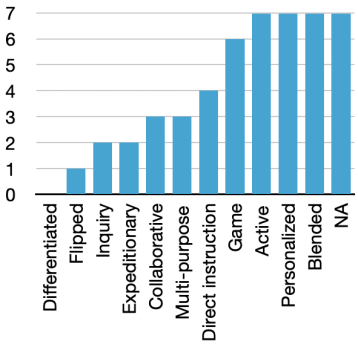
Content-based applications apply application and analysis of content as their strategy (Cherner et al., 2014; Goodwin & Highfield, 2012). These strategies are commonly executed in environments where someone needs to go through the material or discuss the material. For example, a student may apply their knowledge when creating a podcast (Finlay et al., 2008), or analyze the content by answering students' questions within their LMS (Akhmetshin et al., 2019).

Finally, the creation category contains the higher-order thinking skill of creation and evaluation (Cherner et al., 2014; Goodwin & Highfield, 2012). It might seem weird to have note-taking in this category. However, notes are meant to be taken and revised afterward (Makany et al., 2009), which means that any note-taking application should allow evaluation of the notes created. Now, both higher-level order skills have been applied on notes. Presentations and models are easier to accept within the function-based application as both need to be created.

3.2.2 Instructional Approach

In figure 5a the different instructional approaches found in the literature has been plotted by amount of times it has been found. From this, it can be seen that blended, personalized learning are the most prominent and active learning, followed by game-based. This distribution can be explained when looking at the instructional approach plotted against the app types can be seen in figure 5b.

When looking at figure 5b it is clear that personalized and blended learning is present in the two major app types, LMS and SNS. Both these platforms allow teachers to create personal ways for the students to learn (Prestridge, 2014; Singh & Miah, 2019) and can be used complementary to regular education (Manca, 2020). Additional to them being personalized or blended are the applications being multi-purpose. Multi-purpose is defined to allow for the different methods to fit within one app type,



(a) No. of papers per instructional approach.

Type	Flipped	Active	Direct instruction	Connectivism	Collaborative	Inquiry	Expeditionary	Game	Blended	Personalized	Multi-purpose	NA
LMS		1							2	3	2	2
Organization												1
SLN										1		
Conferance												1
SNS		2	1	1		1	1		4	3	1	1
Office		1	1			2						2
Note taking		1			1							
Presentation		1										
Modeling		1	1			1						
Game							1	3				
SRS			1		1			1	1			
Practicing		1	1					1				
Virtual	1				1			1	1			

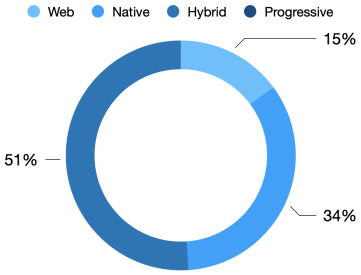
(b) No. of papers for app types per instructional approach sorted by category using the same legend as table 2.

Figure 5: Distribution of the instructional approach.

depending on the user to fill it in. Kiryakova et al. (2014) argues how LMS can be used to implement gamification within a course. However, when one instructor uses the LMS for gamification, it does not mean that all other instructors need to use it for gamification too. They could instead use it as personalized learning tool like discussed in Oyelere et al. (2018). This shows how the instructor determines what instructional approach is used for the same tool, therefore the tool is multi-purpose.

The main contributor to the popularity of active learning is for being a broad approach. Active learning is defined as "short course-related individual or small-group activities that all students in a class are called upon to do, alternating with instructor-led intervals in which student responses are processed, and new information is presented" (Felder & Brent, 2009, p. 2). This type of instruction is widely applicable in different scenarios, explaining the wide range of to which it applies. In addition, active learning covers many different app types allowing the total number of papers covering active learning to add up relatively quickly. The definition of active learning also implies that direct instruction is also a form of active learning, which explains why direct instruction follows a similar pattern to active learning.

The game-based learning approach nicely falls within the practice category defined in section 3.1. It can be explained by the nature of practicing applications which can be enhanced using game-based elements to increase the engagement in practicing (Aguiar-Castillo et al., 2020; Dalipi et al., 2017; Edmonds & Smith, 2017; Svela et al., 2019). Collaborative and connectivism roughly connect by their nature to have students work together. This connection combines practicing with social apps as these types of applications can be used for collaboration by the use of chat systems (Reilly et al., 2014), competitive systems (Taylor, 2020), or even by just discussing together (Conley et al., 2020). Inquiry-based and expeditionary learning were found to be relatively more minor contributors to the literature found. These types of learning are more specific to an activity that is introduced to a course (Edmonds & Smith, 2017; Menkhoff & Bengtsson, 2012; Woxland et al., 2017) rather than something multiple people can use and give their twist. Finally, one paper was found for Flipped classroom. An explanation for this approach is so sparingly found is because this way of learning can also be done in the form of a different instructional method. This instructional approach is a form of instruction that is exceptionally applicable to m-learning, as the student's learning is done before class. Therefore the m-learning itself is categorized within a different instructional method, while the course follows flipped-classroom (Tucker, 2012).



(a) No. of applications per platform represented in percentages.

Type	Web	Native	Hybrid	Progressive
Skill	4	10	1	0
Skill / Content	0	6	1	0
Content	0	9	10	0
Function	0	4	9	0
Content / Function	0	2	4	0
Skill / Content / Function	0	2	1	0
Multi-purpose	1	0	2	0
NA	0	0	2	0

(b) No. of applications for pedagogical design per mobile platform.

Type	Web	Native	Hybrid	Progressive
LMS	0	4	3	0
Organization	0	0	0	0
SLN	0	0	2	0
Conferance	0	0	1	0
SNS	1	2	10	0
Office	0	1	4	0
Note taking	0	1	1	0
Presentation	1	0	1	0
Modeling	0	0	1	0
Game	0	3	0	0
SRS	3	1	0	0
Practicing	2	1	1	0
Virtual	1	2	0	0

(c) No. of applications for the app types per mobile platforms sorted by category using the same legend as table 2.

Figure 6: Distributions of the applications mobile platform

3.2.3 Mobile platforms

In figure 6a it can be seen that the vast majority of the applications found to support both native- and web-based versions of their app, making it hybrid applications. Second, in line is the native applications with representing one-third of the applications found. Finally, 15% of the applications were found to be web-based only, which leaves 0% for the PWA.

This preference for platforms can be explained by the advantage native applications have over web-based applications. Native applications allow for the use of native features of the mobile device like the camera, sensors, or GPS. Web-based applications, however, have the advantage of being available regardless of the platform. Hybrid applications, therefore, have the best of both worlds, with the drawback of having to support the different platforms continuously. Native applications might, therefore, still be in demand for their use of native features while reducing the need to support multiple browsers. While web-based applications have the advantage of supporting the least amount of platform, reducing the amount of input it can receive from the sensors (Luntovskyy, 2018).

Figure 6b shows a plot of the platforms against the different instructional approaches. It shows that hybrid applications are mainly content- and function-based applications. On the other hand, native apps are mainly skill- and content-based applications and web-based applications are found solely among the skill-based applications, having one exception for multi-purpose. This distribution can be explained by the needs of the different instructional approaches. Skill-based applications do not require much input from outside as it only has to display the assignment, take the users input, verify the solution and continue, see, for example, how 'Kahoot!' works (Akhmetshin et al., 2019). This means that there are not many restrictions on the platform, making it available for any of the found platforms. Content-based applications need to display content and make sure it is appropriately displayed. This might constrain devices with smaller screens or require proper use of mobile-design principles to ensure the application works as intended (Chilivumbo, 2015). Therefore more hybrid applications can be found to allow the user to choose the platform they see fit. Finally, function-based applications have the most constraint, as it needs to allow the user to create and evaluate content with ease. In addition, different sorts of applications require different platforms, which explains the preference for both hybrid and native applications.

The distribution of platforms can further be examined in figure 6c. This figure shows the distribution of platforms for each pedagogical design. Most notable is the clustering of the web- and native-based applications around the practice category while lacking hybrid-type applications. The

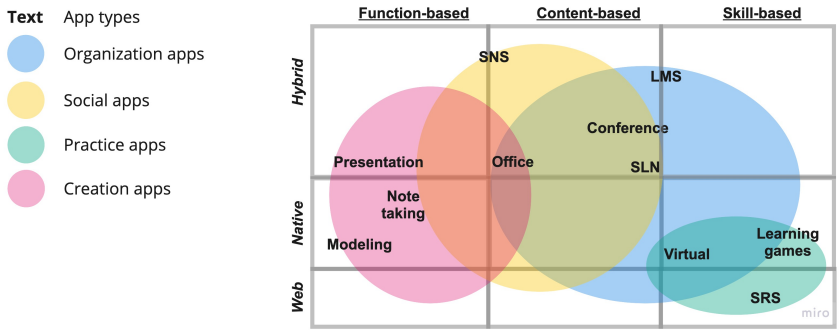


Figure 7: The eleven app types distributed over their respective category, pedagogical design, and most common mobile platform.

other three categories mainly associate with hybrid applications. Combining this figure with figure 6b and the Venn-diagram in figure 4 results in the updated framework of figure 7. This figure shows a complete picture of what type of platform one can expect when looking for an app in either its pedagogical design or category of application.

3.2.4 Features

From the literature, 15 types of features were found rather than explicit features. The types allow connections to be seen more efficiently rather than when individual features would be used. The most notable example of this is 'consume'. This type of feature includes any consumption of content for a learning activity, whether reading, listening, watching, or even using a product to understand its contents. The types of features are described below.

AR: Using artificial reality.
Assess: Evaluating, quizzing, grading or any other type of validation overwork
Gamified: Applying game-elements.
Create: Creating text, data, presentations, or any other visual or textual piece of content.
Share: Sharing content with peers or like-minded.
Consume: Watch, read, listen, or using provided content.
Discuss: Discussing provided or self implied topics related to the material.
Call: Video or audio conferencing for educational purposes.
Message: Synchronous or asynchronous speaking with someone related to the course.
Organize: Ability to order content or material for use.
Download: Download provided material to own device.
Upload: Upload material to provided application.
Query: Search within the material for specific elements.
Push: Sending out a message or announcement to one or multiple users.
GPS: Using GPS for location tracking.

Type	AR	Assess	Gamified	Create	Share	Consume	Discuss	Call	Message	Organize	Download	Upload	Query	Push	GPS
Web	0	4	3	0	1	0	0	0	0	1	0	0	0	0	0
Native	2	10	2	3	3	4	4	0	7	2	0	3	0	4	1
Hybrid	0	3	2	5	9	7	2	2	6	6	3	6	2	1	0
Progressive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3: No. of applications per mobile platform for each feature type.

The different platforms used allow for various features for the application. In table 3 the distribution between the 15 types of features and the platforms is displayed. Here it is easily visible that hybrid applications allow for the most diverse spectrum of features. On the other hand, web-based applications are the platform with the least amount of functionality. The difference between native and hybrid applications is the most interesting. Here it can be seen that hybrid applications allow for downloading and querying, while native applications allow for GPS and AR technology. For downloading, it can be noted that although there exist applications that allow downloading to the device, it is more common for native applications to show content within the app itself. For GPS and AR applications, native components of the mobile device are used, namely the camera and GPS. This is because these features are more easily accessible using native technology.

Something to note about figure 3 is that it shows that calling is only mentioned under hybrid applications. This difference is not mentioned because the calling is attributed to both native and hybrid applications. However, most messaging applications that allow for calling also have a web version that does not allow for calling. An example is WhatsApp. Within the native application, calling a contact or even several is no problem. However, in the web version, it is not possible to call or be called.

Type	AR	Assess	Gamified	Create	Share	Consume	Call	Discuss	Message	Organize	Download	Upload	Query	Push	GPS
Organization	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
LMS	0	5	0	1	0	2	1	4	4	5	0	1	0	3	0
SLN	0	0	1	0	1	1	0	2	2	2	0	1	0	0	0
Conferance	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
SNS	0	2	0	1	6	5	0	0	4	3	2	3	1	1	0
Office	0	1	0	4	3	2	0	0	0	0	0	2	0	0	0
Note taking	0	0	0	2	1	1	0	0	1	0	1	0	1	0	0
Presentation	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Modeling	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0
Game	0	3	1	1	0	0	0	0	0	0	0	1	0	0	1
SRS	0	4	2	0	0	1	0	0	0	0	0	0	0	1	0
Practicing	0	3	1	0	0	0	0	1	0	0	0	1	0	0	0
Virtual	2	1	1	0	1	0	0	0	0	2	0	0	0	0	0

Table 4: No. of applications per app type utilizing the feature types sorted by category using the legend from table 2. Clustered areas are visualized using black borders.

In table 4 the types of mobile applications are plotted against the types of features. Four areas were identified and clustered using a black border around them for visualization. Firstly, an area around discussion, message, and organization are highlighted within the app types of LMS and SLN. These two app types allow content to be organized, discussed and also allow messaging between students. The close connection between these two types has already been discussed in section 3.1, this further highlights the connection. Secondly, a connection between SNS, office, and note-taking applications can be seen with the features of creating, sharing, and consuming. These apps are closely related to creating content and sharing it among peers while further allowing for the content to be seen within the app. This connection highlights the close relationship between Social and Creation types of applications. Thirdly, also within the social category is the relation between organizing, downloading, and uploading content. Additional to this, messaging also relates to these features, as discussed in the first point. Peers may contact each other for content, which is then uploaded and downloaded. These applications also provide storage space for the content of the course (Chu et al., 2015), further strengthening the relationship. Finally, there is a relation between assess and gamified features within the practice category. Its connection is least surprising since gamification is used for engaging students when assessing (Plass et al., 2015).

3.3 Contribution

Earlier Cherner et al. (2014) identified a framework mainly considering the educational approach while lacking the technological side and focused on PK-12. This paper created a framework for higher

education while providing a technological approach. Compared to the framework of Cherner et al. (2014) there are two main differences in the classification framework. The first difference is in the core of the classification. Cherner et al. (2014) used skill-, content-, and function-based application as the first classifier for the apps. This paper suggests organization, social, creation, and practice as the first order of selection. Second, the stance in regards to applications spanning multiple categories is different. In the proposed classification, hybrid applications are natively supported and encouraged, whereas Cherner et al. (2014) did not touch upon the possibility of overlap in some subcategories. The most notable example of this is the Subject Area from the content-based applications includes sub-subcategories for languages, math, science, and social studies. This while skill-based applications already had subsections for literacy, numeracy, science, and social studies.

However, even without this example, the lack of support for hybrids is clear from the definition used for function-based applications. Cherner et al. (2014) defined function-based applications not to allow any form of assessment or contain content for the course. This perception is in contrast to Tang and Hew (2017), who found six specific uses for Twitter in an educational setting. Notably: a) capture and representation, which falls by definition under function-based, and f) assessment, categorized into skill-based applications, are educational use-cases within Twitter, making it a hybrid application.

4 Limitations

For this research, 37 papers were taken into account when creating the framework. It is, however, likely that these papers do not cover all applications. In addition, some applications cater to specific needs. This allows for hybrid versions not currently described within the papers. Thus, at this point, specific categories may be incomplete.

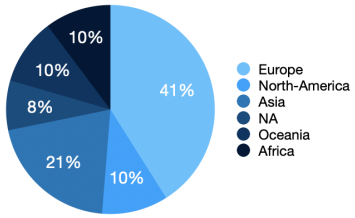


Figure 8: Percentage of papers per continent.

The papers found were mainly from Europe (41%) and Asia (21%), as is visible from figure 8. On the other hand, only a small percentage came from Oceania (10%), North America (10%) and Africa (10%). Finally, there was no representation for South America. This distribution means that it is still required to look into South-American countries for a complete overview and look for applications used in the other mentioned Continents.

5 Conclusion

This paper sets out to find different types of mobile (learning) applications for teaching and learning in HE while also trying to provide a pedagogically and technologically sound framework to classify these apps.

First, eleven different app types (LMS, SLN, conference, SNS, office, note-taking, presentation, modeling, virtual, SRS, and Game) were identified and sorted into four categories (Organization, Social, Practice, and Creation). However, not all applications fit into these separate categories. Instead, some applications contribute to multiple categories at once. Therefore, overlapping categories were included to provide for this need. Several applications apply for this, with one app (office) being distributed into all four categories.

The papers were checked on: the instructional approach, pedagogical design, platform for the applications, and features provided to provide a pedagogically and technologically sound framework. The pedagogical design consists of skill, content, and function-based application, defined for which level of higher-order thinking the learning activity requires, in line with Bloom's revised taxonomy.

The instructional approaches provide insight into the common principles used for providing education to the students. This insight shows the open nature of LMS and SNS. This open nature allows for the educator to choose the style most fit to them. Creation applications provide a basis for learning by doing, including active learning and direct instruction as the most common approach. Finally, practice applications have their nature in games.

The use of technology differs somewhat in the applications. Most applications both support native- and web-based versions of the app, making it so-called hybrid applications. Hybrid applications are mainly content- and function-based, native apps are mainly skill- and content-based, and web-based applications are solely skill-based.

The platform chosen for the application dictates the affordance of integrating several features, and adopting a web-based application limits the available features to organization, sharing, and accessibility. In addition, different style features could be available. However, it has not been found in the literature.

Native and hybrid applications share the most amount of features which it could include. The main difference here is the power of the platform itself. Native applications allow easy access to the sensors and actors on the device. On the other hand, hybrid applications allow more commonly for downloading and searching through content.

Within the final framework, all four categories of applications can be separated into skill, content, or function-based pedagogical designs, with most applications supporting both native- and web-based versions.

6 Implications

In this paper, a classification was conducted by finding different applications and determining which categories were present using deductive and inductive coding. However, the framework should still be evaluated with a larger sample of applications to make sure it holds up.

Additionally, the presented diagrams still have some overlapping categories which are currently empty. However, it does not mean that hybrid applications for this overlap do not exist. Instead, it means that the hybrid type of application for this overlap has not been specified yet. In future research, other app types may be defined and added to this framework as an extension.

Finally, the exact position of the app types and sizes of the components in the diagram could be improved in the future. Currently, the categories are all overlapping in the center. The current structure does not leave enough room for particular hybrid overlaps in visual form. Extended research on where the app types are located and how the categories interact should therefore be conducted.

Responsible Research

A literature research was performed to answer the research question stated in section 1. The course itself provided the research question at hand, which allowed for a quick start regarding the introduction and background, straight to the methodology. For the methodology, three major decisions had to be made for this paper 1) the databases to be used, 2) The search terms for the paper, and 3) the year range.

Only online databases were selected, not only because online databases allow for more reliable reproducible using the same search terms and year range, but also due to the COVID-19 situation limiting the access to libraries. The three specific databases (IEEE, Scopus, and ScienceDirect) were then chosen for their peer-reviewed submissions, and most of the papers there are accessible via Delft University of Technology.

The search terms were selected for their relevance to the main question. At first, a too specific set of terms was used, limiting the number of papers found. After which, too many restrictions were lifted, resulting in too many references. With the logic operators, some 'trial and error' was then performed to get to a result where most of the literature on the first page were looking decently applicable for the next selection phase.

I wanted to make sure that relevant mobile-learning applications were included for the year range, even if they were a bit older. This choice was also made to see where the applications came from and how they progressed. 2008 was finally chosen as it marked the start of the App Store and Android Market. These stores both allowed for easy downloading of applications which could then be used for education.

The analysis framework was first determined for the coding. Here some issues arrived similar terms being used for various meanings. My research question required a pedagogical approach and a technological sound framework. This required an analysis of pedagogy and technology used for the application. However, when you then find the paper of Cherner et al. (2014), then they do speak of pedagogy. However, it does not include the instructional approaches, which are also seen as pedagogical approaches. The same principle applied to the technology. It could be seen as the feature set used for an app, and it could be seen as the hardware it runs on. It could be seen as how the application is executed. All these different interpretations apply to technology. Therefore, in the end, the selection was made to include pedagogical design and instructional approach for the pedagogical approach and platform the application runs on and the features it has for the technological approach. More than one interpretation would be applied this way, making the final framework more applicable in different citations.

When this was decided, a coding scheme had to be created to analyze the papers. For this, both inductive and deductive coding have been applied to make sure standard codes would be used, but codes that were not yet listed could also be considered. The frameworks which were deductively coded were sometimes the hardest to use. Here it is essential to make sure that the definition of all codes is straightforward to make sure you select the code for the right reasons. However, the inductive codes required an extensive search to make sure you included the right thing and, additionally, make sure you have a singular term to use later on. For example, the app type was coded inductively. A common type of application is the LMS; however, sometimes they are called VLE (virtual learning environment) or CMS (content management system).

While coding the literature, I used a sticky note to make sure I could identify which codes there were at my disposal. When non of the codes applied, a new code was added based on the paper's own suggestion. Additionally, multi-purpose was used for apps that could be used in various ways and NA for any paper that did not specify their use.

When following the same procedure as described above, another researcher should get to roughly the same findings. There will, of course, always be some personal interpretation. Usually, these are covered by independently coding the papers by more than one person. Afterward, the results would then be discussed for a more reliable set. However, due to this paper being individual for CSE3000 Research Project, no other researchers were able to do the same coding. This is, however, something to do in future literature reviews.

A final note to this research is how to keep track of the findings. For the literature coding, a table has been used to fill in the codes with remarks where needed. However, I did not correctly track how many papers were discarded while selecting the papers. They have all been discarded for inclusion/exclusion criteria. However, these were not further kept track of. This is something to improve on in the future, to make sure that the selection process is also traceable.

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