Uniqueness Profile of Mobile Applications for Learning

Yuval Shafriri[1] and Dalit Levy[2](✉)

[1] Tel Aviv University, Tel Aviv, Israel
Yuval.shafriri@gmail.com
[2] Zefat Academic College, Zefat, Israel
dalitl@zefat.ac.il

Abstract. This paper presents findings from a study designed to explore the unique affordances of mobile technologies for learning. The overall aim was to focus on learning experiences that are possible only when using mobile applications (apps), and to develop an overarching profile of uniqueness to describe such educational apps. Throughout the inductive analytic process, five themes of uniqueness have emerged. Common to all is the experience of learning in blended spaces, identified in this study as a primary pedagogical principle for designing unique learning opportunities with the aid of mobile apps. Additional principles have been recognized such as embodied cognition, the device as a discovery machine, open playful design, and mobile system thinking. Based on the analysis, the paper formulates the uniqueness profile of educational mobile apps, and discusses a few implications for designers, teachers, and learners.

Keywords: Blended spaces · Mobile learning affordances
Embodied cognition

1 Introduction

In recent years, much research has been conducted on mobile learning and on integrating mobile apps into educational settings [1, 2]. The educational use of mobile computing devices and mobile applications is thought to have significant learning potential and to increase opportunities for learners and teachers alike. Smartphones are already massively embedded in daily life, but integrating mobile technologies within learning environments is a complex and challenging mission which requires innovative pedagogical thinking and strategic changes [3]. In addition, while many educational initiatives take advantage of the unique affordances of mobile technologies when creating new learning opportunities, others tend to merely implement ‘traditional’ e-learning methods with the aid of mobile devices. As a result, the task of identifying the unique features and learning affordances of mobile technologies has been a complex one.

While many studies focus on learning with mobile applications as part of using a broader technology-enhanced learning toolbox, our research sought to focus solely on those learning processes and learning outcomes that are made possible only when using unique features of mobile devices, and to identify those unique and exclusive affordances.

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The range of mobile learning affordances stems from specific context-sensing capabilities as well as from the ability to embed universal affordances in a tiny mobile device [4]. The Advanced Distributed Learning initiative [5] suggests eight general affordances for mobile learning: augmenting, capturing (audio, imagery, video), communicating, contextualizing, eReading, media playing, notifications/remainders, and supporting memory and performance. Although the very basic capabilities of most current mobile devices are indeed enablers of those affordances, not all are exclusive to mobile learning. Another list [6] describes unique features of mobile devices such as embodiment and internal sensors but also includes general affordances like connectivity, media playing, and memory.

This study has therefore defined a *unique mobile application* as an application with potential added value when integrated into a learning environment. Such benefits would not be feasible using non-mobile desktop systems and are also unattainable in traditional outdoor or indoor learning environments, when no digital technologies are involved. The main research question has been *what are the learning characteristics of unique mobile technologies affordances, that support their informed integration in learning environments?*

The next section details the method for defining unique educational mobile applications and for classifying them into five themes of uniqueness. Using an emergent inductive analysis, we then formulate the 'uniqueness profile' by extracting the unique learning potential in each theme and by highlighting the educational values in the form of a model based on a fundamental pedagogical principle attached by additional four principles. Finally, implications for designing mobile educational apps and challenges for integrating mobile learning experiences are discussed.

2 Method

The study started with examining more than two hundred mobile applications for learning. As a starting point, a distinction was made between unique and universal educational mobile apps, such as gaming apps, quizzes, or social media. Due to their lack of uniqueness with regard to mobile learning, such applications were excluded from the analysis in later phases. Section 2.1 provides details on how we define unique mobile apps and on the selection criterion; Sect. 2.2 details the qualitative analysis conducted with ~60 unique mobile apps selected for further analysis; and Sect. 2.3 describes how these unique apps were classified.

2.1 Defining Unique Educational Mobile Apps

Based on the literature dealing with the premises of mobile learning [7, 8] the selection criterion was formulated as follows: unique educational mobile apps are those located at the intersection of three key areas – Mobility (physical and mental), Ubiquitous learning, and Contextual awareness. Using the first letter in the name of each key area, we suggest the abbreviation MUC to label these distinctive learning apps (see Fig. 1).

While both the "M" (mobility) and the "U" (ubiquity) imply independent learning anytime and anywhere, the "C" (context) suggests some dependency on the decisions

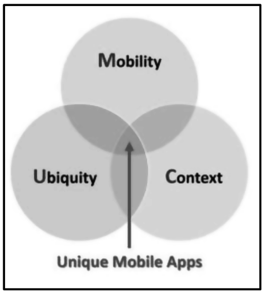

Fig. 1. MUCs - unique mobile apps selected for the study

and actions of the instructional designer and/or the learner. These actions might be related to a specific content and/or environmental conditions while using features of the mobile app in response to those conditions, like triggering instructions in specific location, or operating an object recognition feature through AR technology. The distinctiveness of the selected MUCs thus lies in their ability to be deployed at any time and in any location, while nevertheless being sensitive to the context - the environment, the user, and the learning activity. This combination is what makes mobile apps unique for learning purposes; our aim has been to characterize this uniqueness.

2.2 The Analytic Procedure

In a previous paper [9], the overall research procedure was presented in detail. Figure 2 briefly illustrates the three-phases analytic process conducted in order to construct the uniqueness profile of mobile apps for learning and to answer the research question.

As part of the overall process outlined in Fig. 2 and following the emergence of the five themes of uniqueness in Phase II-b, in Phase III we characterized the learning potential of the sixty selected MUCs with respect to each theme. These benefits were summarized throughout a gradual process, as shown in Fig. 3.

For example, in the Little Digits app[1], one of the twenty-five apps selected for analysis in Phase II, the learner multi-touches the mobile device touch screen with an appropriate number of fingers. The affordances include multi-touch representation of numbers, vocal feedback, and recording data, and the learning potential derives from acquiring the concept through real-time sensory feedback from the mobile app. The key theme of uniqueness apparent in this mobile app was recognized as *interaction* with the mobile device, which is one of two themes in the micro level (see Fig. 4 below). Another example is Traces, a mobile app producing place-based multimedia messages.[2] The key theme of uniqueness in this example is *location-based* learning, one of two themes in the intermediate level. In this case, the learning potential derives from the combination of message and location for the creation of new meaning. Additionally, there is apparent potential for creating personal and social relations with

[1] http://www.cowlyowl.com/apps/little-digits.

[2] http://traces.io/#about.

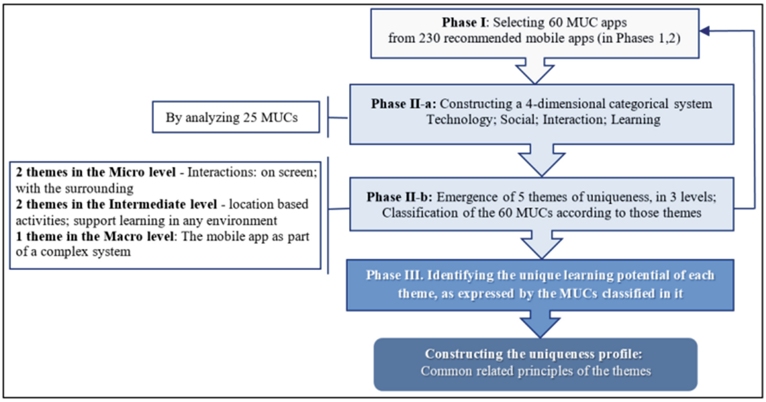

Fig. 2. Three-phase analytic process

Fig. 3. The process of recognizing the learning potential of a mobile app (and theme)

the content, the location, and/or other users, which might enhance personal involvement and therefore help in promoting understanding.

As has been briefly exemplified above, through our analysis a general profile of uniqueness was developed, constructed of five themes which embrace the common unique educational affordances and values identified in the analyzed MUCs. The resulting profile is detailed further in the third section of this paper. But before turning to the profile, Sect. 2.3 explains how the five themes of uniqueness have emerged.

2.3 Classifying Unique Educational Mobile Apps

As is shown in Fig. 2 above, the first phase of the study resulted in the selection of a group of sixty MUCs, all designed for specific content or a specific context. In the second phase, a thorough examination of about half of the sixty unique apps was performed. The analytic framework combined three approaches: the FRAME model [10] for analyzing mobile learning projects; an approach for surveying educational websites in general [11]; and the TPACK framework, integrating technology, pedagogy and content knowledge [12]. While the first FRAME model regards mobile learning as a process and puts less emphasis on the content, the latter two approaches deal with e-learning for specific content but leave out the situated and contextual mobile affordances. The combination of these three methods enabled analysis of both the context affordances and the content affordances characterizing the selected MUCs. Based on this combination, we developed a four-dimensional framework for characterizing educational mobile apps: (a) the technological dimension; (b) the social-organizational

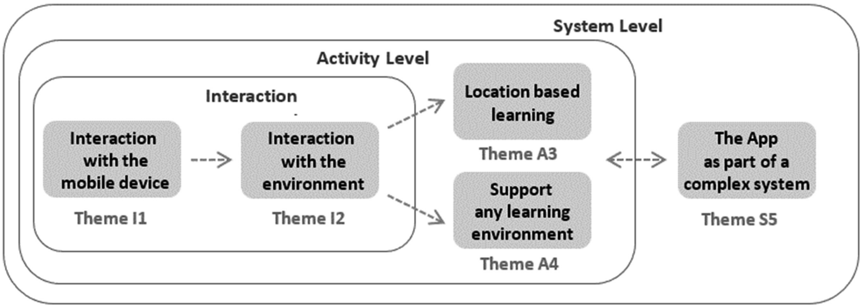

Fig. 4. The emergent categorical system

dimension; (c) the dimension of mobile interaction with the content; and (d) the learning dimension. The combined framework has been applied in classifying the selected MUCs using a thorough inductive analysis [13] and in constructing an emergent categorical system containing five themes of uniqueness, as illustrated in Fig. 4.

The themes of uniqueness are organized into three levels: the micro-level of the interactions between the user and the app (Themes I1, I2); the intermediate level of the activity (Themes A3, A4); and the macro-level of the system context (Theme S5). Table 1 below summarizes the number of MUCs featured in each theme. It should be noted that a specific app can be included in more than one category; consequently, the overall number of apps is greater than the 60 selected for the analysis.

In the last analytic phase, we identified the unique learning potential of each theme and used these emerging themes to characterize all sixty classified MUCs. As a result of the full analytic process, a general profile of uniqueness has been developed, embracing the common unique educational affordances and values identified in the MUCs. The resulting profile is detailed in Sect. 3. Furthermore, following this analysis, we redefined what can be regarded as unique educational mobile application: it is *an application that combines virtual sources on screen with physical, human, and additional digital sources from the surroundings*. Such a combination is not a regular part of learning with desktop environment, nor is it possible in fieldwork without digital support. In other words, unique mobile apps are capable of creating the experience of learning in *blended spaces* [14, 15].

Table 1. Number of MUCs in each category

Uniqueness category	# of apps	Examples*
I1. Interaction with the device	16	Little Digits (A), Motion Math (A), Hopscotch (A), Tynker
I2. Interaction with the environment	20	Star Tracker, Science Journal, Elements 4D (G)
A3. Location based learning	12	TaleBlazer, Treasure-HIT, FreshAiR, Traces, ARIS (A)
A4. Support any learning environment	19	Birdsnap (A), BlippAR, Tonara, Google Translate
S5. The app as part of a complex system	20	Coach's Eye, Geocaching®, Sense-it (G), Google Street View

*Most of the apps are available for both Android and IOS users. (A) designates apps available only in the Apple App Store and (G) designates those available only in Google Play.

3 Formulating the Uniqueness Profile

3.1 Mapping the Unique Affordances of Mobile Apps for Learning

The five themes of uniqueness presented above share some commonalities. Identifying and extracting these common features enabled the formulation of a *uniqueness profile* which characterizes mobile applications for learning. Table 2 summarizes the main characteristics found in each of the five themes of uniqueness, extracts the unique learning potential for mobile apps in each theme, and highlights the educational value in the form of learning principles.

As can be seen in the rightmost column of the table, the five themes of uniqueness have some educational benefits in common. These are labeled as *learning principles*, since they can be used beyond the particular mobile technology to guide instructional design in general. Overall, five principles have been recognized:

1. Blended Space Experience, identified as significant in all the themes.
2. Embodied Cognition, identified as significant in three of the five themes.
3. Inquiry/Discovery Machine, also found significant in three themes.
4. Playful Personal Design in four themes.
5. Mobile Complex Thinking, found as significant in the intermediate and the system level themes.

These learning principles are interrelated in such a way that each one enables the others. Together, they can create a unique learning experience, what is regarded in our study as the uniqueness profile of MUCs. It should be noted that only the most unique principles have been emphasized; there may be additional universal principles, like authentic learning or PBL in general, that are not exclusive to unique mobile apps such as those analyzed in our study and have therefore not been regarded as part of the uniqueness profile.

Table 2. Themes, unique affordances and learning potential

Theme	Unique affordances	Unique learning potential	Learning Principles
I1. Interaction with the device	Embodied interaction Direct manipulation & control Open interaction mode Minimal & open-ended playful design 'Here and now' interaction design	• Embodied cognition as a learning strategy • Learners can use direct & open gestures and thus engage in learning by design • Learners can design their own gesture interactions	Embodied Cognition; Blended Space Experience; Playful Personal Design;
I2. Interaction with the environment	Context sensing, documenting, and processing environmental data Sharing artifacts during the experiential inquiry process Embodied recognition tools and processes Augmented Reality (AR)	• Cognitive tools for smart learning with and from the environment • Reviling invisible parts of daily life • Support discovery learning • Contextual learning – learners engage in authentic, situational and playful activities • Employ of 'the world as a lab' idea/use environment as a library or as an artifact • Empowering environment with AR	Inquiry/Discovery Machine; Blended Space Experience; Embodied Cognition; Playful Personal Design;
A3. Location based learning	Movement and activity programming Mobile Augmented Reality (mAR) Embodiment in the environment Location based games, hyper-contextual activities Creating blended spaces artifacts by learners Mobile -collaboration of blended spaces artifacts	• Discovery learning approach • Message + place = meaning • Applying learning by design (of blended space artifacts) • Cognitive and spatial dissonance as a learning strategy • The world as a construction kit	Blended Space Experience; Embodied Cognition; Playful Personal Design; Mobile Complex Thinking;
A4. Support any learning environment	Object recognition smart tools Outsourcing of cognitive skills Training and on-the-job support	• Cognitive tools for supporting recognition tasks • Knowledge support in AR blended spaces • Just-in-time (JIT) learning – here and now • Learners can become context sensors (with an appropriate design approach)	Inquiry/Discovery Machine; Mobile Complex Thinking; Blended Space Experience;
S5. The app as part of a complex system	The app as end unit/actor in the system Smart learning using the apps/actors as context-sensors Blended spaces of multi systems: Multi devices, screens, spaces & Contexts (Hyper-context)	• Creativity and problem solving in blended spaces • Device + Learners as context sensors • Mobile collaboration using crowd sourcing • Serendipity learning	Mobile Complex Thinking; Inquiry/Discovery Machine; Playful Personal Design; Hyper-Contextual Blended Space Experience;

3.2 The Learning Principles and Their Role in the Uniqueness Profile

Blended Space - Here and Now. First and foremost, the learning principle titled *Blended Space Experience* has been dominant in each and every theme of uniqueness. Using the conceptual framework suggested by Benyon [16], the title of this unique learning principle has been rephrased to emphasize its being ready to be deployed *Here and Now*. In addition to its manifestation in all the themes, this powerful idea also enables and supports the other four learning principles recognized in the study. We therefore suggest seeing *Blended Space – Here and Now* both as a new medium and as a powerful idea in mobile learning. Blended spaces interweave unique mobile apps with users and their learning experiences. In other words, every interaction in a unique mobile app simultaneously merges the personal, physical, and social environments/contexts with the app's digital content and virtual space. In addition, this merging happens within a situated 'here and now' activity, which might lead to an even more meaningful learning experience. This unique mobile experience forms the ground for both the challenges and for the pedagogical potential inherent in mobile learning. An important implication of this learning principle is the potential for creativity entailed in construction of such spaces by learners themselves [17], that calls for a 'learning by design' approach, where learners must acquire deep understanding of both virtual and environmental properties, thus applying the idea of the world as a construction kit [18]. The challenges include cognitive and spatial dissonance and disruption from the merged experience.

Embodied Cognition. The second pedagogical principle stems from the fundamental, powerful idea of *Blended Space – Here and Now*, and was found to be dominant in the first three themes of uniqueness. This principle promotes the use of mobile sensors for gestures, movement tracking, and spatial embodiment as a learning strategy [19]. It is regarded as significant for immersing in activities designed for constructing abstract concepts such as mathematical proportion (in apps like Motion Math[3]) or the periodic table (in apps like element4D[4]). The principle of embodied cognition is expressed through direct manipulation of objects within the app as well as through taking advantage of the environment as an 'object to learn with'. Technologies such as mAR, mVR, IOT and wearable computing also employ this principle to enhance the learning experience. Together with blended space, the possibility of embodiment enhanced by unique mobile apps can be thought of as an innovative medium blurring the borders between sensory data and mental constructions.

The Device as Inquiry and Discovery Machine. The third principle has been apparent in three themes. The mobile device as an inquiry or 'discovery machine' and as a context sensor [20, 21] enables the use of innovative 'smart' cognitive tools for exploration and investigation, in particular when learners use mobile apps for making the invisible evident with the aid of novel object recognition technologies. The unique educational goal of mobile inquiry itself develops the learner as a context sensor [22,

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[3] https://itunes.apple.com/us/app/motion-math-fractions/id410521340?mt=8.

[4] https://itunes.apple.com/us/app/elements-4d-by-daqri/id782713582?mt=8.

23]. The learning potential inherent in the use of a mobile device as an inquiry machine is further strengthened by combining it with the principle of blended space, when physical interaction is involved in operating the inquiry machine. We can see inquiry machine feature of MUC apps as mobile cognitive tools used for enhancing human knowledge performance, while acting within an authentic environment such as a lab, factory, field, natural setting, indoor or outdoor sport activity, etc. [24]. Applying the third learning principle enables the design of highly authentic learning environments [25] while supporting community sharing and environmental change.

Open, Personal, and Playful Learning. The fourth pedagogical principle denotes the need for designing open and playful learning experiences. The unique mobile apps examined in this study tend to use an open design approach, allowing for spontaneous learning and serendipity in the discovery process, while bringing the role of the actor (e.g. learner) closer to the role of the scientist in the field. Our assumption is that such an approach is crucial for meaningful learning with MUC apps. The unique mobile affordances support learners' discoveries and control and assist in developing personal curiosity by engaging learners in context sensing. Together with the previous 'inquiry machine' principle, learners can develop a sense of competence that encourages their curiosity [26]. It should be noted here that in a more structured pedagogical approach, the sensors might remain at the device level and could create dependency on it, while in the open approach the learners themselves are the sensors and therefore depend mainly upon themselves. In addition, the fourth principle implies that the mobile app should be part of the learner's daily life, as well as being in continuous interaction with both the environment and the actor's body and behavior.

Mobile System Thinking. The fifth and last principle has been titled *Mobile System Thinking*, to denote the emergence of a new metacognitive literacy that requires learners' awareness of multiple contexts, as well as their understanding of their place as actors in complex situations [27]. Blended spaces, by definition, are complex systems, due to the merging of physical and virtual domains. Thus, the highest cognitive skill identified in this study was 'system thinking', and its uniqueness lies in its also being 'mobile thinking' [28, 29]. The idea of 'mobile thinking' refers to the player's awareness of the device's capabilities in the context of ever-changing systematic factors and environmental data. Here, too, the player functions as a context sensor, applying device sensing and recognition affordances. The situation becomes even more complex using crowd-sourcing inquiry applications, and considering spatial actions and data created by multiple actors. Such complexity might carry greater learning potential than the individual actions of the learner per se; this is the rationale for citizen inquiry apps and systems [30]. The need for further development of *Mobile System Thinking* literacy is also related to the issue of dissonance and distraction in mobile apps—an inherent challenge for any mobile learning and blended space experience.

3.3 From Learning Principles to a General Profile of Uniqueness

Taken together, the above principles draw a uniqueness profile for MUCs that supports deep understanding of the environment in which the unique mobile app operates. As

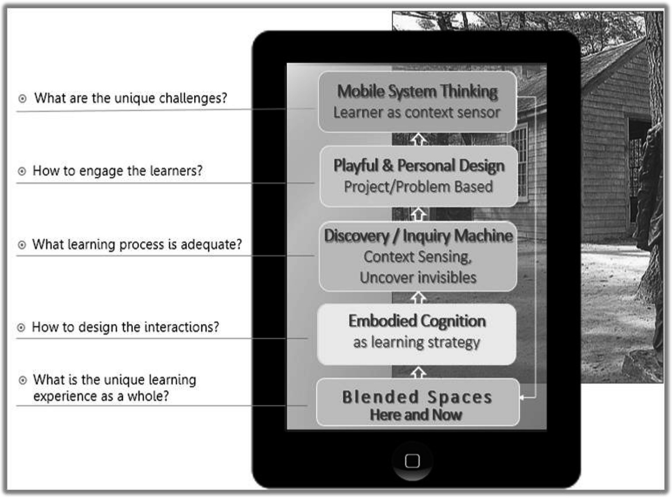

Fig. 5. The Uniqueness Profile of the learning experience with mobile apps

has been noted above, the overall profile stems from the fundamental principle *Blended Space – Here and Now*, while each additional principle has some relationship with this major unique learning principle as well as with the others. Therefore, the fundamental principle is drawn at the bottom of the uniqueness profile (see Fig. 5). In other words, the study suggests that these principles should be treated not just as a list, but as a structure in which the components are placed layer upon layer so that each layer serves as a base for the next, and all are made possible by applying the founding principle. Along with the structure and the flow of the learning principles in the uniqueness profile, Fig. 5 presents the main question that needs to be considered in applying each of these principles.

In summary, the mobile device serves as the context sensor of a *Discovery Machine* in diverse environments, enabling *Embodied Cognition* interactions as a learning strategy using smart learning through sensory affordances. MUC applications and learning activities also enable building *Blended Space* artifacts in context, documenting sensations, and sharing data and messages between near and distant actors in an *Open and Playful approach*. All the above-mentioned principles lead ultimately to *Mobile System Thinking*, which is necessary in multi-device learning situations and within *Blended Space Experiences*.

4 Implications and Challenges

Based on a thorough analysis of sixty unique mobile applications, labeled here MUCs, this paper presented five emergent categories of uniqueness with regard to learning with mobile applications, and proposed an overarching profile characterizing such apps. The

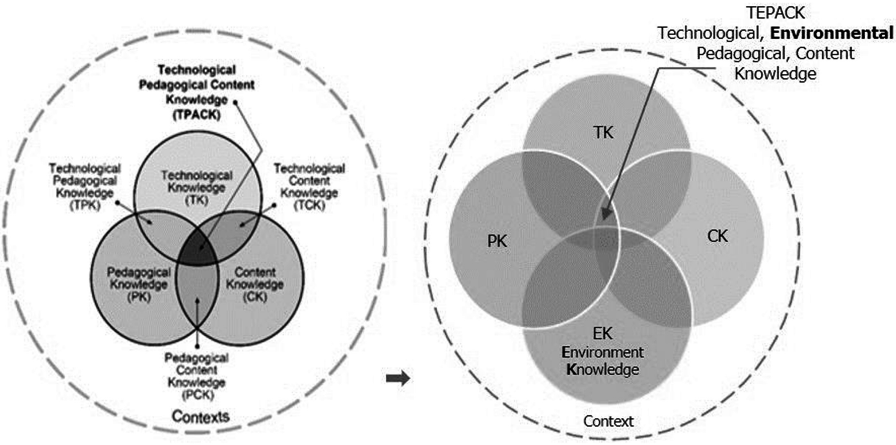

Fig. 6. Adding a fourth dimension to consider when designing or using unique mobile apps

proposed uniqueness profile, together with the detailed account of its learning principles, can serve as an answer to the question that directed our study: *what are the unique affordances of mobile technologies that support their informed integration in learning environments?*

As discussed in previous sections and illustrated schematically in Fig. 5 above, the uniqueness profile stems from the fundamental principle *Blended Space – Here and Now*, and the additional four learning principles are interconnected. One implication of this profile is the importance of environmental context (physical, human, and virtual) in the design process. Experience designers (UX), instructional designers, teachers and students alike should understand not just the affordances of the mobile technology, but also the environmental ones, and be able to move through physical, mental and pedagogical (blended) spaces.

The notion of *Blended Space* implies the emergence of a new environment in which digital elements are embedded [14, 16, 19]. What is known as 'learning with the environment' is obviously possible without mobile devices, and in fact has been carried out since the dawn of humanity. Although our study did not address differences between digital and non-digital learning with the environment, this kind of research might constitute a fruitful continuation. Through blended space applications, the environment becomes a *computed* object to learn with, and the activity becomes mobile learning *with* the environment instead of e-learning *about* the environment [31]. The uniqueness profile suggested in this paper offers a framework for analyzing the environment properties in relation to the characteristics of the application and of the player, but those characteristics play a central role even when using a different design model.

In terms of design considerations, in creating blended space learning experiences in which the merging of multiple sources is crucial to knowledge construction, the environment and the context should be regarded as inherent dimensions to consider.

Building upon the TPACK framework [12] we suggest adding the knowledge of the environment to the original framework when designing unique educational mobile apps. As is illustrated in the right side of Fig. 6, the upgraded framework is labeled TEPACK to denote Technological, Environmental, Pedagogical, and Content Knowledge.

For example, when designing STEM learning scenarios that use Geocaching activities [32, 33], one should consider the specific environment affordances and constrains in order to achieve deep and relevant learning experience. In fact, understanding environment learning affordances is the main implication of learning in blended spaces.

Another implication is related to learning environments and applications other than those included in our study. The uniqueness profile indeed stems from analyzing mobile apps defined as unique for learning (MUCs), but it might be applied to more general mobile learning activities using universal mobile apps like Twitter, Instagram, or even a smartphone's 'smart' camera. Other innovative technologies like mobile-AR/VR headsets, mobile apps supplying an interface to wearable devices, IOT-related apps, etc., can be integrated into any learning environment as cognitive tools to support knowledge integration. Furthermore, mobile devices can be incorporated into the learning discourse through conversational applications like Apple's Siri, Google Assistant, Amazon's Echo and chatbots, and thereby become equal players in this discourse.

The challenges related to the status of technology in human-environmental relations arise here as well. The interdependence between the environment and the mobile application has been apparent throughout the phases of this study; from the first phase of considering more than two hundred mobile applications to the last phase of constructing the uniqueness profile, the environment has been recognized as effecting on, as well as being influenced by, almost every mobile app we analyzed. Indeed, cognitive and spatial dissonance often occurs when using mobile apps [34–36]. The interdependence between the external environment and the unique mobile app for learning has been a central insight of our research as well.

Finally, a major challenge is to apply MUC affordances not only as 'context sensor' extensions of the human body and mind, but also as a way for learners themselves to become 'context sensors', curious and aware of their surroundings. This is particularly important with the emerging trend of smart 'things' with novel abilities related to both the cognitive and affective domains [37]. A related pedagogical challenge calls for extending the question 'how to wisely integrate mobile apps in learning?' into enquiring 'how to integrate any learning into daily life?'. This is important especially at a time when mobile apps already serve as a digital interface to the world; when the world itself is increasingly turning digitized; and when objects in our world are becoming more connected and 'smarter'. This fascinating combination generates new objects to think with, new blended spaces to live in, and may also generate new ways of being, experiencing and learning.

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