

**“Location – Based Design Project:**

**A set of guidelines for the design of Location-Based applications for educational purposes targeting children.”**

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A research Paper submitted to the University of Dublin, in partial fulfilment of the requirements for the degree of Master of Science Interactive Digital Media

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## Summary

The aim of this research paper is to suggest a set of design guidelines that can help designers, pedagogues and developers to design, build and develop location-based applications, aimed at being used inside as teaching tools during in-class activities. For this purpose, the first step was a cross-analysis between the prevalent pedagogical theories, so that a specific age group could be defined and constitute the basic target group of the research. As a next step, a cross-analysis between the most popular User Interface elements used in location-based and educational applications, as well as between the current evaluation processes takes place, in order to determine specific research parameters such as the most practical and comprehensive User Interface elements that are more appropriate for children, as well as the evaluation process that is to be followed. According to the aforementioned parameters, a set of guidelines will be formed and followed during the redesign of already existing location-based applications to fit the needs of children in an educational concept. These wireframes will be heuristically evaluated so that their utility is tested. During this evaluation process questions regarding their validity will arise and will constitute the basic questionnaire of the interviews with experts in both design and pedagogy, so that any lacks regarding their accuracy can be pointed out. Finally, the set of guidelines will be revised in order to include any corrections stressed during the interview process. It is the aspiration of this research paper to provide a point of reference for developers, designers and future researchers regarding the incorporation of location-based applications in education.

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## Abbreviations

UI.....User Interface

App.....application

US.....United States

UX.....User Experience

PhET.....Physics Education Technology

# 1. Introduction

## 1.1 The importance of this research paper

Have you ever thought instant navigation on the palm of your hand was possible? Or what about getting instant feedback on wherever you visit within the relevant time frame you need? This is definitely not science fiction anymore. Many applications use navigation systems nowadays as part of their essential functionality, with varying functionality from application to application. The most common element of navigation systems used in such applications is the map, which is being implemented even more frequently in everyday applications, either as a side or main function element.

This massive expansion of the use of maps has affected their very nature from a functional point of view. The design of maps has changed dramatically over the past few years, especially how they are used and read. Nowadays, maps are used as part of running applications on smartphones. This vast expansion of their use has raised questions regarding the way they are implemented and the redesign of the applications including them to better serve the needs of their users.

One of the fields this applies to is the educational sector. Especially in the pedagogical field, studying map implementation lacks breadth, although it is a highly promising area that involves practical use and interactivity, which is appealing and appropriate for use in this area. One way to achieve the incorporation of maps in education is through the use of location-based applications. Their current scope is confined within the spectrum of entertainment or navigation. Since the nature of the map itself, and the way (for instance, the axis) a map can be read and interpreted, has changed the traditional method of studying and interpreting them, their incorporation in widely available applications requires detailed insights and analysis of the design of the user interface (UI) to be more user friendly and better applied to the prevalent pedagogical norms. Thus, the following question arises:

## 1.2. Definition of the Research Question

*What attributes should the user interface of an application have in order to follow basic pedagogical guidelines, while remaining appealing and user friendly to young learners?*

This question constitutes the main core around which this research paper will develop. As stated above, the incorporation of location-based applications in the educational sector can serve as a

valuable tool for the way education is conceived in general. To answer the research question and taking the lack of time as the most important factor into consideration, the methodology mentioned below will be followed to ensure the most valid results possible. In this stage, it is important to define the parameters around which the research will take place. When referring to learners, the current paper targets children aged 9–11-years old since their developmental stage allows them to handle more complicated and sophisticated application features.

### 1.3 Methodology

To discover the necessary user interface attributes of a location-based app so it serves as an educational tool, a set of design guidelines must exist for designers and developers to adhere to, to create more useful and functional educational apps. Considering the given time frame for the completion of this research paper, the most reliable method to produce the best possible valid design guidelines is a literature review. Thus, by revising the existing, relatively limited, literature and comparing the current norms and suggestions found, a more compact and global set of guidelines will be created to cover most issues arising when two separate fields like user interface design and education come together. The literature review is presented in Chapter 2, where the first version of the set of guidelines will be established.

In Chapter 3, this set of guidelines will be put into practice by serving as a base for producing wireframes of already existing location-based applications redesigned to fit the educational norms. The applications chosen for the purpose of this research paper are Pokémon Go and Foursquare, since they constitute some of the most popular choices for entertainment and navigation, according to statistics. Pokémon Go has been the most popular mobile game in the US, according to Forbes (Kain, 2016). Due to its concept – chasing and catching Pokémon – its core mechanic of catching Pokémon and collecting information could easily be manipulated to fit the needs of teaching a school subject. Foursquare was the first application to seamlessly introduce the concept of checking-in at a location, which is a very important location-based feature. Although after its first implementation, the check-in concept was adopted by numerous other applications, the actual innovation of the idea was established by Foursquare. The implementation of Foursquare has been enriched by the provision of extra information about user locations and their surroundings (Hern, 2014). Thus, Foursquare constitutes one of the basic applications to introduce location-based driven concepts and it was included in the wireframes for that reason.

As a next step in Chapter 4, these wireframes will be evaluated using Nielsen's usability heuristics, as they are considered the most valuable and popular in both industry and academia. It is important to state that since the spectrum of the set of guidelines produced extends in two different fields – User Experience Design and Pedagogy – an analytical examination of its accuracy from both aspects is necessary to obtain a more global opinion of the set's strengths and weaknesses.

After the aforementioned evaluation, a clearer view of the guidelines' validity will have been formed. The most important part of this first evaluation stage is the questions raised regarding the clarity and the necessary tweaks the guidelines require to better fit the needs of designers, pedagogues and, most importantly, children. At this stage of the evaluation, and taking into consideration the resulting questions, a more in-depth analysis is necessary to further clarify the strengths and weaknesses of the existing guidelines. To obtain such an in-depth view of the issues that arise, the creation of a mixed focus group of experts on both user experience and pedagogical field is essential. In this way, a more experienced view regarding further development, enhancement or correction of the existing set of guidelines will be obtained. The results of the interviews with the focus group are presented in Chapter 5. Due to time constraints, an extensive correction and re-evaluation of the guidelines is not possible. Rather, as a conclusion of this paper, the results of the interview will be presented and analysed and the final outcome regarding the advantages, disadvantages and any limitations observed in the set of guidelines will be examined and presented for future research.

#### 1.3.1 Limitations:

A shortage of time and word limits were the main constraints, especially regarding the evaluation process. Thus, one mixed focus group of designers and pedagogues was formed instead of two so that the interview could be kept short in terms of time and data volume. Another issue that has to be stressed is the very procedure of the evaluation using Nielsen's heuristics, whereby, in order to obtain more solid results after an evaluation procedure, a wider team of evaluators, around three or five members at least, as he states, should be formed to test the interface in the same heuristics (Nielsen, 1995b). In this paper, due to lack of time, the evaluation procedure was conducted once by one person, the researcher, and then the questions raised were handed to a

focus group of designers and pedagogues for a more in-depth analysis of the guidelines' strengths and weaknesses.

#### 1.4 Target audience

Taking into consideration the very nature of this paper, its target group includes experts in user interface/user experience (UI/UX) design and pedagogues to design and develop educational location-based apps that fit the needs of children. It also constitutes a suggestion for specific guidelines that location-based apps should follow and a point of reference for teachers on how to better use such apps. Furthermore, this is also available for further development and improvement.

## 2. Literature Review

### 2.1. Introduction

To cover the broad spectrum of the appropriate guidelines for location-based applications for educational purposes targeting children, the literature review is structured into five main thematic categories: child development; interface design for location-based applications; interface design for education; interface design for location-based educational applications specifically for children; and how interface design is evaluated. Each section constitutes a cross-analysis of currently existing methods and theories to find the common axis that best suffices children's needs in educational location-based applications.

### 2.2. Child Development

In order to produce a set of design guidelines for location-based applications that is appropriate for children, an important factor that should be taken into consideration is the distinctiveness in terms of their development and the mental and emotional competence each age is characterised by. Thus, an in-depth study of the different developmental characteristics and achievements of each age is necessary to define a common axis of the general attributes for each age group. This common axis will serve as the point of reference, according to which certain emotional, cognitive and mental abilities of children will be defined. Based on these general developmental competences, certain user interface elements can be considered appropriate for children depending on whether they adhere to the common axis mentioned above or not. Research for this particular topic was based on books and papers regarding child development and child-computer interactions. The structure of the current section has been based on the equivalent sections of Hourcade's two books regarding child-computer interaction, "Child-Computer Interaction" (Hourcade, 2015) and "Interaction Design and Children" (Hourcade, 2008).

#### 2.2.1. Behaviour, cognitive skills and intelligence

The most prevalent theories regarding child development were formulated by Jean Piaget (1973), Seymour Papert (1991) and Lev Vygotsky (1978). While Vygotsky focused more on the socio-cultural background and how it can affect child development, Piaget, as well as his successor, Papert, focused on how children construct knowledge through a process he called adaptation, which includes the senses of maturation, experience, social and emotional aspects in children's development which influence the developmental stages children go through as they develop as a consequence (Hourcade, 2015).

Based on the concept of adaptation, Piaget introduced the idea of *constructivism*, which, as the term itself implies, refers to the construction of knowledge by children through their experiences with the world. One experience can affect each child in different ways based on their backgrounds, thus rendering children active and critical towards new stimuli. Papert enhanced the aforementioned theory by stressing that Piaget's theory could be proven to its full potential when children "consciously engage with something that captivates their interest and they work towards a common public entity" (Papert & Harel, 1991). He thus introduced the idea of *constructionism*. The aforementioned theories focus their success on keeping children's interests alive, considering it as the most valid way with which children can actually evaluate their surroundings and extract some form of knowledge. This constitutes a base for the design functionality guidelines produced in this paper.

An additional theory that has been taken into consideration for the construction of the guidelines is the Piagetian developmental stages. This theory is considered to be the most controversial that Piaget has put forward in terms of validity. It suggests that each child has to go through four stages of development and that these stages must be experienced by each child in the correct order, although the point and the amount of time they reach and spend in each stage varies significantly (Piaget, 1973; Piaget & Inhelder, 1969). More specifically, the four stages consist of the sensory-motor stage (0-2 year olds), the preoperational stage (2-7 year olds), the concrete operations stage (7-11 year olds), and the formal operations stage (11-16 year olds). Piaget describes each stage as follows:

-Sensory Motor Stage: During this developmental stage, young children learn basically through using their senses and manipulating objects. Thus, at this very early stage of development, children enhance their intelligence by acquiring mostly sensory and motor experiences. By learning how to differentiate objects as individual items, children are subsequently able to associate those objects with names, and generally structured speech.

-Preoperational stage: Children in this stage are egocentric and have difficulty viewing the world from a different perspective than theirs. They also cannot concentrate on more than one object of interest at a time, thus not being able to fully understand hierarchies, which renders them difficult for designing new technologies (Guha, et al., 2004).



-Concrete operational stage: Children at this age are able to understand hierarchies and reverse actions in their head, which enables them to use a greater variety of technologies and software (Piaget, 1995). They experience difficulties in grasping more abstract and theoretical ideas. They also become less egocentric and begin to think about other people's perspective. Children in this stage also start realising that their views and thoughts are personal and others don't necessarily perceive external stimuli in the same way.

-Formal Operational Stage: The final stage of Piaget's theory involves an increase in logic, in the ability to use deductive reasoning and in understanding abstract ideas. At this point, children develop a more complex way of thinking and thus start coming up with more elaborate and sophisticated solutions in assigned problems, adopting a more scientific perception about the world around them.

As mentioned above, many have been opposed to Piaget's theory. One of the main ideas that opposes this concept is that the developmental stage the child is in only produces a likelihood of a certain behaviour pattern the child might follow in certain circumstances (Flavell, et al., 2002). Factors that affect children's behaviour in a task are also the amount of data used, social support and instructions (Hourcade, 2015). Another area that Piaget's theory fails to cover is the impact of socio-cultural background and its effects on children, an aspect that is analysed further below.

Although the theory itself has been criticised for its accuracy, it provides a good point of reference for the general types of behaviour anticipated by children around certain ages, and their general level of intellectual, emotional and cognitive competence (Hourcade, 2015). For the purposes of this paper, the age group of concrete operational developmental stage was chosen, since, according to the developmental stages theory, children have acquired the general skills to use and function around technology, and have the competence to understand hierarchies and more complex contexts, making them a good target group for the use of multifaceted location-based applications.

#### 2.2.2. Socio-cultural background and its effects

The most influential person who supported this approach in child development and learning was Lev Vygotsky (Vygotsky, 1978). He viewed language, plays and tools as important factors in child development. He also saw writing and the use of external tools and signs as ways of augmenting human cognition, stressing social support as important for children's development

(Vygotsky, 1978). As a consequence, he suggested that children learn and extract knowledge from performing new tasks by instruction or help from older children or adults and by mimicking their behaviour, a concept known as *scaffolding* (Wood, et al., 1976). Once they internalise the process, they can perform it themselves. The time during which children can perform a task with scaffolding but cannot perform it individually is called the *zone of proximal development* (Vygotsky, 1978). According to Vygotsky, this zone is the most appropriate one for children to extract and internalise more knowledge.

There have been many researchers that have based their work on Vygotsky's findings, enriching what are today known as socio-cultural approaches to learning. The basic idea behind this approach is that learning and cognitive development are not formed much in an individual but rather at a social level while interacting with the rest of the world. The general structure of society has the most definite impact on a child's development. Two levels of socio-cultural context can be studied. The first level refers to the role society in general plays in development and how it influences it. The second level has a more personal sense and refers to the influence the child's circle of immediate family and friends has on them. Both these factors can influence cognitive development differently. Another important aspect that falls into the second level of socio-cultural context but is yet worth mentioning is the literacy levels of the immediate circle of a child.

The basic contradicting view towards the theories about socio-cultural approaches is that the more technology and computers enter education, the fewer and less crucial the social interactions children have with their environment, since technology enhances uniformity (Hourcade, 2008).

Socio-cultural approaches, particularly Vygotsky's theory about scaffolding and the zone of proximal development, can constitute a very important design factor for the guidelines, regarding the textual content of labelling, if any.

### 2.2.3. Motor skills

Motor skills, especially hand movements, experience a vast wave of development after the age of five or six. The manipulation of objects using hands, an important prerequisite for writing, starts developing around that age. This age is considered one of the turning points when children's grips start to imitate those of adults more (Rosenbloom & Horton, 1971). However, according to another study, for the majority of children, their grip becomes equivalent to this of

adults by the age of seven, reaching movements, such as aiming and pointing, and opening the way for the accurate use of a computer mouse (Hourcade, et al., 2004). Movement and cognitive operations like these open the way for a more complex UI, establishing the use of typical technological operations when it comes to computers, such as drag and drop, mouse-clicking or the use of buttons and more delicate UI elements.

2.2.4. *Physical, intellectual, emotional and moral safety issues for protecting children's integrity*  
The applications targeting children should address physical, intellectual, emotional and moral issues, so that they safeguard children's health and integrity. All designers should be aware of the physical risks children can be put through when dealing with harmful tools or devices, especially when it comes to hardware. Reading skills, intellectual integrity, emotional and moral issues should be taken into consideration as well, since the exposure of children to violence or disturbing content can lead to potential emotional imbalances with tremendous consequences for their emotional and mental health (Hourcade, 2015).

### 2.3 Interface design for location-based applications

In order to structure valid guidelines regarding children and their interaction with location-based apps for educational purposes, an analytical review of the general interface elements suggested that are already used in existing applications was essential. The sum of the most popular and functional elements used in location-based apps' UIs will constitute the final scope from which the suggested design attributes that satisfy the needs of each children's developmental group will be chosen. For this section of the research paper, a review of existing papers and articles analysing and comparing different UI elements used in location-based applications was conducted.

#### 2.3.1. User Interface (UI) elements for location-based applications

The popularity in UI elements used in location-based applications depends on the level of UI elements the user interacts with (Meier, et al., 2014). By referring to levels of UI elements, we mean the level of interaction the user needs to have with the application to understand certain UI elements of the app's layout. The elements the user first comes in contact with are considered first level UI elements and the elements the user needs more app interactions with are considered second level UI elements.

After a comparison of many location-based applications taken place in the aforementioned paper, five patterns could finally be analysed: *search slots*, *categories*, *result lists*, *maps* and *filters*. At the first level of UI elements, map, search, category and lists were the most popular UI items the user would encounter. At the second level of UI elements, categories, filters and lists were among the most popular. Both first and second level final results showed the map and list elements as the important. The popularity of the UI elements also depends on the scenario the user has to follow each time they use an application. For tasks when a destination is near the current position of the user, they tend to use the map more, whereas for tasks farther away from their current point of reference involved existing search tools, like filters or lists.

The next question that will define in detail the final UI elements used in location-based applications is how certain tasks are mapped to significant UI elements according to their importance (C. Rinner 1, n.d.). Checkboxes, Radiobuttons, ListBoxes, ComboBoxes and DateTime controls were more appropriate for filtering information while Edit controls, Up/Down controls and labels were better for handling text and/or display information. By combining the results of the two research papers together, we end up with the following combinations:

For the use of filters, result lists and categories, Checkboxes, Radiobuttons, ListBoxes, ComboBoxes and DateTime controls are the most appropriate UI elements, whereas for search-slot Edit controls, Up/Down controls could be more appropriate.

### 2.3.2. User Interface variants and personalisation

According to research undertaken in the field of human-computer interactions, simplicity and clarity are necessary when targeting small screens like mobiles or PDAs (Chincholle, 2002). There are three major challenges to overcome when designing for smaller screen sizes (C. Rinner 1, n.d.):

- People use mobile devices in distracting environments without dedicating the necessary attention to navigate through more complex menus and perform more difficult tasks (Pascoe, 2000).
- Input devices often lack precision and practicality.
- Since the screen size of mobile devices is small, information cannot be displayed as clearly or in as much detail as desktop screens.

Another major field that is important in terms of representation is cartography, especially in location-based applications when dealing with small resolutions. The resolutions of hand-held devices are usually 400%-1200% less than a desktop computer (~~Urquhart et al., 2004~~) (Urquhart, et al., 2004). Simple and precise maps that don't require much of the user's attention to present data correctly are thus vitally important. There are many ways to enhance the display of a map. A choropleth map for example could show scores visually. However, the colours could be hard to interpret when superimposed over a road heavy area or at a small enough scale. Similarly, proportional symbol maps would allow for users to quickly interpret scores, but the size of the symbols could potentially clutter the map, making it hard to determine the exact location of the point of interest if the symbols obscure roads (C. Rinner 1, n.d.).

As a result, the general design of the interface of location-based applications should be as simple as possible, especially for children, since they perform better in learning when engaging with activities that hold their interest (Papert & Harrel, 1991: 166). Thus, a simplistic, intuitive and elaborate UI environment is necessary.

#### 2.4. Interface design for education

The basic question answered here concerns the most popular UI attributes that can fulfil the educational purposes of an application. The main purpose of this section is to filter the total variation of different UI attributes and create a focus specification regarding the appropriate attributes to serve an educational concept. Such attributes should be accessible and easy to use for children belonging to the developmental group chosen, while preserving their interest when using the application. In order to narrow down the specifications of UI elements used in education applications, I compared different papers, articles, and current books about child-computer interaction in general, thus defining certain interface attributes that can satisfy the educational purposes of applications.

##### 2.4.1. Intuitive controls (click-and-drag interface, grabbable objects, etc.)

According to the Physics Education Technology (-PhET) interviews, there are certain kinds of controls that are more appealing and easier for students to use. Their functionality and appeal are more related to the students being more familiar with specific types of controls. If such controls are used, then there is probably no need for any 'help' simulation.

More specifically, grabbable objects and click-and-drag interfaces are more appealing to students since they are more familiar with the motion, while it instinctively comes to them as more natural (PhET Interviews, 2008). Their pointing and dragging motions become more precise, especially after the age of seven (Hourcade, 2015), making these interface choices more popular.

Sliders, Radio Buttons and Checkboxes are good choices as well, especially regarding the application of filters, since students are very familiar with their functionality already (PhET Interviews, 2008).

#### 2.4.2. Representations and visual models of the education process

In applications that include some kind of real-world simulation, attention should be paid to the way representations and visual models are used (PhET Interviews, 2008). They should look familiar in terms of representation, especially when depicting everyday objects, as they encourage children to better understand the range of topics presented to them (Hourcade, 2008). Realism in any form of real-life representation is thus encouraged. Duration and consistency are also factors that play a very important role (Adams, et al., 2008). Children tend to push simulation environments to their limits by exploring any possible aspect and they tend to observe a simulation environment as a whole when uncertain what the general purpose is or what to do next (PhET Interviews, 2008, p. 20). The mode of object representation in an environment that is based on real-life simulation is critical, since differences in representation can lead children to misinterpret the importance or the meaning of that object in the application. Thus, general coherence in terms of colour and representation should be followed (Adams, et al., 2008).

#### 2.4.3. Layout

Finally, more specific UI design areas are worth mentioning since they can eliminate confusion and keep children focused on their tasks. For any application control panels, limiting the number of tools/controls and correct and efficient thematic arrangement helps students engage even more with the application's environment. Text is advised to be limited in the control panel area, with an ideal length of one to three words, as children tend to read the parts of text attached to a specific control and ignore abbreviations (PhET Interviews, 2008, p. 25).

Play areas should be distinct from the control panel both in look and functionality, and objects in the play area are advised to be grabbable. In order for this area not to be overlooked, some tools are advised to be present (PhET Interviews, 2008, p. 27).

Backgrounds should not be distracting so that they help children focus on the main objects of importance. Any other control elements of importance should be noticeable in terms of size, colour and explanatory text, so that children are easily aware of its role in the general environment of the app (PhET Interviews, 2008, p. 29). Finally, the Help function needs to remain on screen as a continual reference while the user explores; it should be clear and consistent but not so prominent that it functions as a distraction (PhET Interviews, 2008, p. 33).

## 2.5 Interface design for location-based educational applications for children

This section is the common axis between the last three sections. It functions as a combination between the developmental characteristics of children defined in the first section, the UI attributes of location-based applications defined in the second section and the UI attributes for educational purposes defined in the third section. It subsequently specifies the UI attributes of location-based applications that serve the needs of children in terms of mental, cognitive and motor development and the specifications of educational applications. It thus serves as the main base for structuring the set of design guidelines this paper focuses on.

### 2.5.1. Implementation of intuitive controls according to the children's motion capabilities on the interface variants and elements of location-based apps

As mentioned above, children in the concrete operational stage have established the basic coordination between cognition and motion. Their pointing movements and ability to grasp are as accurate as those of adults. Thus, more delicate UI controls, such as the ones mentioned in section 2.4.1 are appropriate.

### 2.5.2. Implementation of visual models according to the children's cognitive and behavioural capabilities on the interface variants and elements of location-based apps

Since the cognitive and behavioural development of children in the concrete operational stage has matured enough for them to understand hierarchies and perceive environments as a whole entity with a common goal, more generic representations with less abstract representations can be used to simulate and render real-life concepts in an application environment.

### 2.5.3. Implementation of the layout in the children's developmental background on interface elements of location-based apps

Summing up the two aforementioned sections, the maturity and motor and cognitive competence of children in the concrete operational stage allows for the manipulation of more delicate and sophisticated UI elements.

## 2.6 How interface design is evaluated

The evaluation procedure, as mentioned in the introduction, will take place in two different steps. The first step refers to the evaluation of the wireframes using the previously suggested heuristics by Nielsen (Nielsen, 1995a), where the validity of the wireframes will be viewed from a design and a pedagogical perspective. The second step of the evaluation process will focus on gathering and filtering information regarding the functionality of the wireframes, and thus the validity of the guidelines, through performing interviews with a mixed focus group. Obviously, for the last part of the evaluation, there was no particular area to research, since the procedure to be followed was already straightforward. However, a more in-depth analysis of the first two steps – design of wireframe design and Nielsen’s heuristics evaluation procedure – is needed to obtain more analytical and comprehensive results. Thus, this part of the literature review focuses on the correct selection of wireframes that will suffice the needs of this paper, as well as an on-point implementation of the currently available heuristics, so that the procedure results in a more concrete conclusion regarding the accuracy of the guidelines.

### 2.6.1 Types of wireframes designed

To decide the most appropriate type of wireframes for the purpose of this paper, a more complete analysis regarding their nature and their distinguishing attributes is needed. Basing my research on Markopoulos’ work (Markopoulos, et al., 2008), I follow the distinction he makes to describe the nature and use of wireframes and prototypes during the evaluation process. More specifically, he mentions four basic concepts that define them and their use: the medium used, the scope, fitting in the lifecycle and, finally, the purpose (Markopoulos, et al., 2008, p. 50). More analytically, the medium used refers to the nature of prototypes/wireframes used to mirror the hardware and the software used in the applications tested. According to Markopoulos, paper prototypes are a valid option when dealing with children, since they allow for an actual interaction with the application’s environment.

The second concept he analyses is the scope of the wireframes. Markopoulos distinguishes two main kinds of wireframes/prototypes: horizontal and vertical prototypes. The horizontal prototypes depict a static representation of the final UI of the application, providing a detailed description of the main controls used and navigation between the main screens. Vertical prototypes provide a less detailed structure of the main elements and navigation of the app, yet they support full functionality and constitute a more accurate evaluation medium.



In the third concept of fit with the lifecycle, Markopoulos refers to the amount of time one version of a prototype is valid for and states that it can be considerably short in comparison to the general lifecycle of the product itself. Finally, Markopoulos refers to the purpose of the wireframes. Depending on the nature and the anticipated result of the evaluation, designers can choose from a variety of prototype kinds. Graphical prototypes can be divided into three categories, according to their design, their functionality and their role (Houde & Hill, 1997). Markopoulos enhances this concept further by distinguishing three main categories: the product role, which refers to understanding the functionality of the designed artefact and foreseeing what usage motif will result; the user performance, focusing more on testing usability and efficiency in terms of functionality of the application; and the user experience, focusing on the user without being accurate when it comes to functionality issues.

#### 2.6.2 Usability heuristics: Comparison of the available heuristics

In order to test the accuracy and validity of the guidelines, and taking into account the limited time available, the method of heuristic evaluation was chosen, since it required less time and complexity. The next important step was to evaluate the set of heuristics for producing the wireframes based on the set of guidelines. There are plenty of options available, the most widespread of those being Jakob Nielsen's Ten Usability Heuristics (Nielsen, 1995a), Bruce Tognazzini's first principles of Interaction Design (Tognazzini, 2014), Fitts's Law (Goktürk, 2016) and the design principles suggested by Donald Norman (Norman, 1988). By comparing these principles, we find the following differences. Fitts's Law mostly refers to the topography of an object within a site, and its topographical association with its size and selection time, taking into account the user's starting and ending point. More simply, it's faster to hit larger targets closer to you than to hit smaller targets further away from you (Fitts, 1954). Although Fitts's Law constitutes a fundamental aspect of user experience design, it is rather used as a guideline throughout the design procedure than the evaluation. Bruce Tognazzini's First Principles include Fitts's Law to a great extent as well, however they tend to overly extend their analysis. As a result, Tognazzini's first principles tend to overstretch subjects like simplicity, aesthetics and discoverability that could be incorporated into one thematic area. The same applies to Norman's heuristics. Thus, taking into consideration the shortage of time and the precision of Nielsen's heuristics, they were proven to be the most appropriate choice.

### 2.6.3 Usability heuristics: Distinction between the pedagogical and the design aspect

As stated above, since the set of guidelines combines the two different fields of design and pedagogy together, a more global view of how both aspects are incorporated is essential. Since, as stated in the methodology section, a mixed focus group constituting of experts in both fields will be formed, the questions that will arise after the first round of the evaluation need to thematically cover the issues that concern both designers and pedagogues.

In order to achieve this more generic view and examine the issue from both aspects, I used Nielsen's heuristics for performing the heuristic evaluation from a design point of view. To cover the pedagogical side of the evaluation, I based my research and evaluation process on Squires' cross-checking, regarding Nielsen's usability heuristics related to socio-constructivist criteria for learning (Squires & Preece, 1999).

## 2.7 Conclusion

### 2.7.1. Draft of the guidelines

- 1) Draggable objects/Drag and drop functions: natural to children. They tend to use these with ease when they have to bring a new object in their working space (Adams, et al., 2008). This functionality requires precision and fine vision and motor coordination. It is thus more suitable for children aged 7-11, as their dynamic visual acuity stabilises around that age (Hourcade, 2015).
- 2) Checkboxes/radiobuttons/sliders: children are familiar with their functionality and tend to use them with precision (Adams, et al., 2008). Good for categorising outputs or filtering information (Meier, et al., 2014).
- 3) Presentation of different thematic areas in the same app: use of tabs. Children tend to notice big, clear, colourful tabs. Subtle and more traditional tabs tend to be overlooked (Adams, et al., 2008).
- 4) Representation of the map elements in location-based apps: The use of a more realistic map terrain is important since children tend to make connections between real and realistically represented virtual objects (Hourcade, 2008; Adams, et al., 2008). They thus gain a better understanding of the app and the real-world symbolisations it tries to depict.

5) Buttons: Visual clarity of their functionality in the app: Children tend to overlook their existence but when required to use them, they use them correctly. Bright colours and specific labels relevant to their functionality are suggested (C. Rinner 1, n.d.).

6) Help: The Help function should be available and clearly presented as children tend to follow instructions to complete a task for the first time before they can complete it on their own (Vygotsky, 1978). However, if it is too prominent, it gets followed like a command and children are unlikely to explore the potential of the app on their own (Vygotsky, 1978; Adams, et al., 2008).

7) Backgrounds: These should be subtle in general and main objects of importance should be easily distinguished (Adams, et al., 2008).

8) General coherence in the layout: Important for guiding children through the layout, as they tend to look at all visuals equally when they don't understand the concept (PhET Interviews, 2008). Emphasising certain items of importance and eliminating potential distractions is important as well.

The guidelines and the references on which they were based on are presented in the following design table:

Guidelines	References
1st Guideline	Adams, et al., 2008 Hourcade, 2015
2nd Guideline	Adams, et al., 2008 Meier, et al., 2014
3rd Guideline	Adams, et al., 2008
4th Guideline	Adams, et al., 2008 Hourcade, 2008
5th Guideline	C. Rinner 1, n.d.
6th Guideline	Vygotsky, 1978 Adams, et al., 2008
7th Guideline	Adams, et al., 2008
8th Guideline	PhET Interviews, 2008

Figure 1: Design Table of Guidelines

### 3. Wireframes

After having formed the set of design guidelines, these now need to be put into practise for their utility to be tested. Thus, in this chapter, the main focus is to analyse and redesign existing location-based applications based on the aforementioned guidelines to fit the pedagogical norms and serve as educational tools. As mentioned in the introduction, the main applications chosen for this purpose are Pokémon Go and Foursquare. For each application, a small scenario was conceived, based on which the wireframes and, at a later stage, the prototypes were designed.

#### 3.1 Pokémon Go

##### 3.1.1. General idea and aim

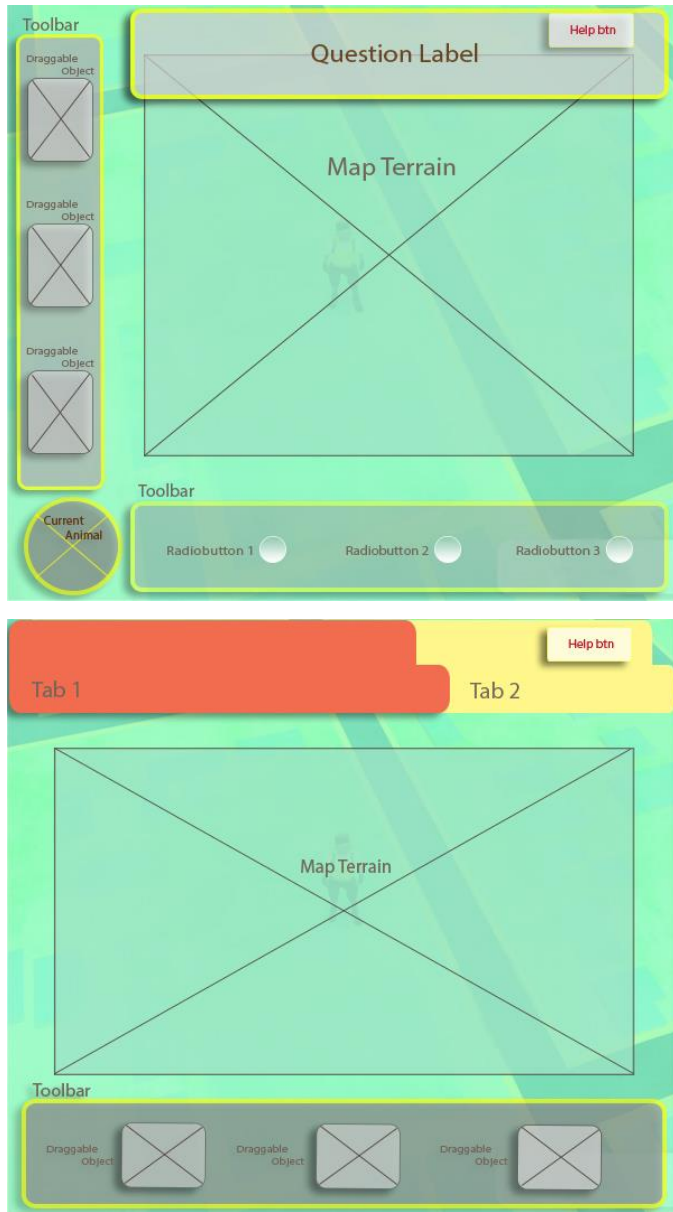
The general idea behind the redesign of Pokémon Go for educational purposes is directed at the animal kingdom. The aim is to educate children about animals and their characteristics. They can find, catch and feed the animals while learning about their nature and special characteristics.

##### 3.1.2 Design implementation

- *Map*: The map of the application is more or less based on the map of the actual game, due to its vividness in colours and its simple yet realistic representation.

- *Bottom toolbar*: The bottom toolbar can contain filters for the category of the animal kingdom presented on the map. For example, if the filter “animals” is selected, only the corresponding creatures will appear on the terrain. The UI elements chosen to represent these filters are radiobuttons, since children are very familiar with their functionality already (2<sup>nd</sup> guideline).
- *Left toolbar*: The left toolbar can contain draggable objects associated with the creatures selected, like choosing the correct kind of food to feed them (by dragging and dropping). Using draggable objects/Drag-and-drop function is natural to children. They tend to use it with ease when they have to bring a new object into their working space (1<sup>st</sup> guideline).
- *“Current Animal” circle*: Inspired by the actual design element used in Pokémon Go depicting the current player, I thought it would be a good idea to use this circle as an element to present the current animal children have to find and focus on. This design choice was made due to layout coherence with the actual Pokémon Go game.
- *Tabs*: Thematic tabs should be vivid in colour and distinguishable from the background (3<sup>rd</sup> guideline). They could be used as filters as well. For example, tabs could contain separate animal kingdoms or different tasks.
- *Help*: The help button is distinguishable, yet follows the general style of the layout, thus not being too distracting (6<sup>th</sup> guideline). The button element has been chosen, since children are very familiar with its functionality already and can easily use it (5<sup>th</sup> guideline).
- *Colour palette*: The colour palette chosen was based on the actual colour palette of Pokémon Go due to design coherence (8<sup>th</sup> guideline).

### 3.1.3 Wireframes



Figures 2 and 3: Pokémon Go wireframes

### 3.1.4. Prototyping and scenarios

As stated above, the time specification of application use is one class. The estimated duration of a class is 45 minutes to an hour. The general aim of the application is that the children can learn the essential biological characteristics of the most basic creatures of the category they are taught in the corresponding lesson or the group of lessons.

*Basic scenario:*

Three basic domesticated mammals are presented: the dog, the cow and the pig. The children need to find out what each current animal is fed, reproduced and how it moves before they can progress to the next one.

*Winning conditions:*

As stated above, they can only progress to the next animal if they have successfully managed to satisfy the needs of the previous one. They can successfully fulfil the general task only if they have correctly satisfied the needs of all the animals presented in the session.

*Technical Specifications:*

**Map:** The map's borders are limited, meaning there is already a predetermined space (for example, the schoolyard) where they have to search for the animals of the task. Children don't previously know the location of the animal they are searching for and have to locate it first and then perform the other parts of the task.

**Medium Used:** The application can preferably run on tablets, since a broader portable screen would better present all the graphic details of the UI.

**Manipulation of toolbars:** Children can filter the results presented on the map by selecting the corresponding radiobutton of the equivalent kingdom (e.g. Animals), thus making their navigation through the map easier.

They can perform the tasks of feeding and choosing the correct reproduction mechanism and movement by dragging and dropping the objects presented on the right toolbar.

Finally, they can see the next animal they have to search for as a small icon on the bottom of the question label.

Prototype:



Figure 4: Pokémon Go prototype

Food icons by Madebyoliver (Madebyoliver, n.d.)

## 3.2. Foursquare

### 3.2.1. General idea and aim

The general idea behind the redesign of Foursquare for educational purposes is directed at the historical buildings of cities. The aim is to educate children about the important buildings in their cities, their history and purpose.

### 3.2.2. Design implementation

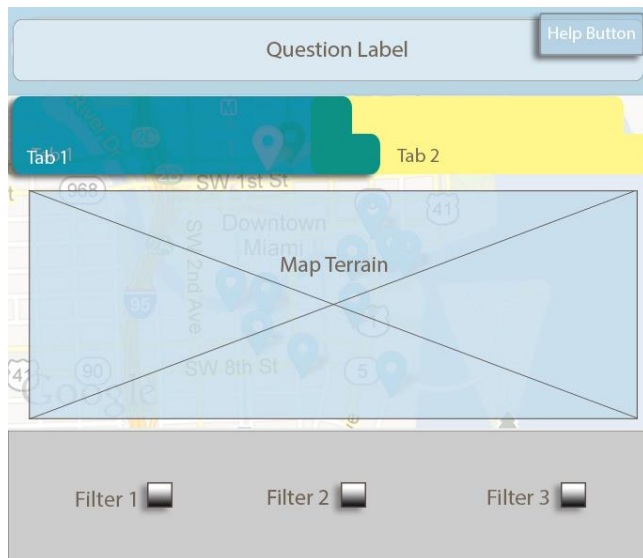
- *Map*: The map of the application is more or less based on the map of the actual app, due to its vividness in colours and its simple yet realistic representation (4<sup>th</sup> guideline).
- *Bottom toolbar*: The bottom toolbar can contain filters that will filtrate the buildings presented on the map. For example, if the filter “museums” is selected,



only the corresponding buildings will appear on the terrain. The UI elements chosen to represent these filters are checkboxes, since children are very familiar with their functionality already (2<sup>nd</sup> guideline).

- *Tabs*: Thematic tabs should be vivid in colour and distinguishable from the background (3<sup>rd</sup> guideline). They could be used as filters as well. For example, tabs could contain buildings of separate purposes or different tasks.
- *Help*: The help button is distinguishable, yet follows the general style of the layout, thus not being too distracting (6<sup>th</sup> guideline). The button element has been chosen, since children are very familiar with its functionality already and can easily use it (5<sup>th</sup> guideline).
- *Colour palette*: The colour palette chosen was based on the actual colour palette of Foursquare due to design coherence (8<sup>th</sup> guideline). More pastel colours have been used so that the contrast is lowered, yet design elements are still clearly distinguishable from the background (7<sup>th</sup> guideline). Thus, children can focus on their tasks rather than the stylistic elements of the application.

### 3.2.3. Wireframes



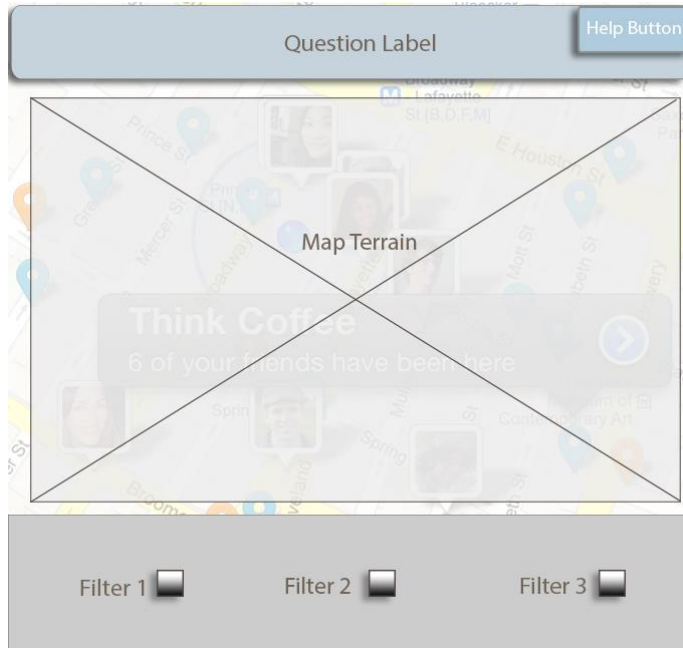


Figure 5 and 6: Foursquare wireframes

### 3.2.4 Prototyping and scenarios

#### *Basic scenario:*

The children need to find all the buildings that fulfil the given question for each task. The pictures of the buildings are presented in Infoboxes by touching the corresponding building icon to help children visually connect the location with the real-world building they see. By selecting all the buildings that correspond to the given question, they can move to the next part (question) of the general task.

#### *Winning conditions:*

As stated above, they can only progress to the next question if they have successfully managed to find all the correct buildings corresponding to the previous one. They can successfully fulfil the general task only if they have correctly answered all the questions presented in the session.

#### *Technical Specifications:*

**Map:** The map's borders are limited, meaning there is already a predetermined space (for example, some squares) where they have to search for the buildings in question. Children don't necessarily know the location of the building they're searching for in advance. They have to locate it first and then select it accordingly.

**Medium Used:** The application can preferably run on tablets, since a broader portable screen would better present all the graphic details of the UI.

**Manipulation of toolbars:** Children can filter the results presented on the map by checking the box of the corresponding group of buildings (e.g. Museums), and thus making their navigation through the map easier.

*Prototype:*

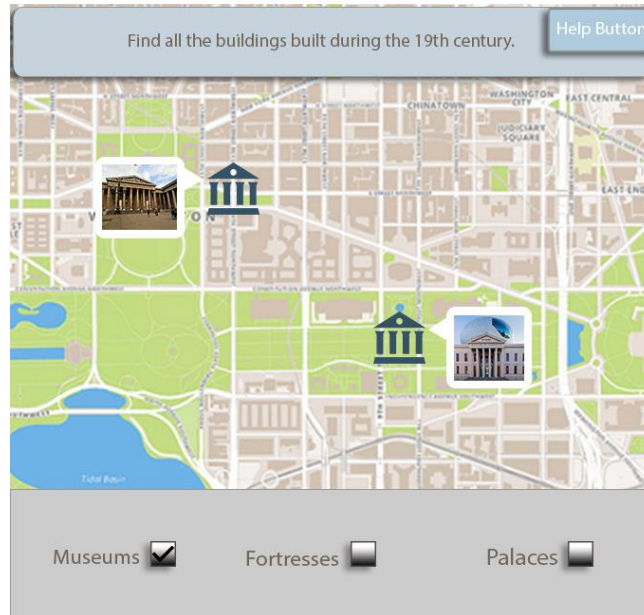


Figure 7: Foursquare prototype  
“Checked” icon by Eleanor Wang (Wang, n.d.)  
“Museum” icon by Icomoon (Icomoon, n.d.)

## 4. Evaluation

### 4.1. Evaluation following Nielsen’s heuristics

The guidelines designed consider two different scientific fields: Pedagogy and User Experience Design. Thus, they need to be evaluated focusing in both fields, so that a more accurate view of their potential is formed.

Nielsen’s Ten Heuristics will be used in order to validate the guidelines from a designer’s perspective. These heuristics, revised from a socio-constructivist view (Squires & Preece, 1999), will be used to evaluate the guidelines from a pedagogical point of view. As shown in Figure 8 below, Squires has divided the interaction of the ten heuristics into five concepts, belonging both in Cognitive and Contextual authenticity. Both notions spring from the concept of socio-constructivism. Based on this concept, Squires defines the two notions and their breadth as follows.

Cognitive authenticity refers to the learner extracting knowledge from learning experiences and personally absorbing it according to their personal criteria and traits, thus expressing one of the very basic beliefs of constructivism. Squires distinguishes three aspects of Cognitive Authenticity, Credibility (how credible and trustworthy a User Interface is), Complexity (how complex a UI is) and Ownership (what kind of rights are practised in a UI and who owns them). Contextual authenticity on the other hand refers to the way learner’s knowledge experience gets affected by its surroundings, in other words, its context. It thus deviates from constructionism’s tenet in the sense that acquiring knowledge should be a personalized procedure related to real experiences. Squires distinguishes Contextual Authenticity in two main aspects: Collaboration (collaboration between learners) and Curriculum (the curriculum taught). The table below presents a more accurate association between the aforementioned notions and Nielsen’s heuristics.

**Table 1**  
The relationship between usability and learning evaluation heuristics

	Cognitive authenticity			Contextual authenticity	
	Credibility	Complexity	Ownership	Collaboration	Curriculum
System status visibility	Feedback and designer/learner models	Navigation			
Match system/world	Cosmetic authenticity	Representations of the real world			
User control			Learner control	Shared responsibility	
Consistency		Symbolic representation		Consistent protocols	Subject content
Error prevention		Peripheral cognitive errors			
Recognition	Representational forms				
Flexibility	Multiple views/representations		Tailoring the interface		Teacher customisation
Aesthetic design		Superficial complexity			
Error recovery	Interaction flow	Pedagogical techniques	Metacognition		
Help/documentation		Learners’ support materials			

Figure 8: The relationship between usability and learning evaluation heuristics

Image from: (Squires & Preece, 1999)

The aforementioned validation from both a design and pedagogical aspect will finally form the questions intended for interviews with the equivalent focus groups. These questions are presented in italics below.

#### 4.1.1 Evaluation from a design and pedagogical point of view

##### 1) “Visibility of system status”:

Visibility of system status refers to keeping the user informed of all states the application is in, at all stages, within a correct time frame and synchronisation.

#### **Design:**

The wireframes designed already offer a responsive map that ideally changes its layout in real time, thus providing the user with enough up-to-date information in the correct time frame. The Infoboxes provided constitute a more static source of information, yet are synchronised enough to follow the current time frame the user is on. Thus, the wireframes, following the 4<sup>th</sup> design guideline of the paper, respond to Nielsen’s first heuristic. However, since the current layout and the corresponding guideline target a more pictorial result, questions arise regarding the correct symbolisation and labelling. More specifically:

*Is the pictorial representation of a map element and its markers enough or does it require more precise labelling to convey the general information more accurately?*

It is important to state that if the answer is yes, a future, more accurate revision and maybe additional guidelines should incorporate labelling as well.

#### **Pedagogy:**

The relationship between the first heuristic and learning evaluation lies on the cognitive authenticity, mostly regarding credibility and complexity (Squires & Preece, 1999). In terms of credibility, “feedback and designer/learner models” refers to the system providing sufficient feedback to the user about every current state of the application. In terms of complexity, “navigation” informs the user about their current state/place in the application (Squires & Preece, 1999). The responsiveness stressed by the maps, the draggable objects and the general UI elements used in the interface (guidelines 1, 2 and 4) confirm the first aspect. However, there is no specification regarding the second aspect. The only guideline that includes a sense of navigation up to a point is guideline



Figure 9:  
Pokémon Go wireframe,  
left toolbar

number 3, focusing on the distinction between different thematic areas using tabs. Assuming the apps will have a maximum of one or two main display pages from the existing wireframes, the main navigation will be the tabs.

*Thus, the question is whether a more structured navigation system should be formed in order to serve the needs of children and, if so, how it should be constructed.*

2) *"Match between system and real world":*

This heuristic refers to real connections and conventions made in the design of the user application, so that they constitute easily-perceived references to the real world, and thus convey their message easier.

### **Design:**

Regarding the second heuristic, the 4<sup>th</sup> guideline already demonstrates this idea. According to the aforementioned analysis of Nielsen's first principal, the question lies on whether text labelling would be a necessary addition to the existing form of map and environment representation. Thus, the only question regarding the second design principal of Nielsen is if there are *any further suggestions regarding the 4<sup>th</sup> guideline.*

### **Pedagogy:**

Nielsen's second heuristic is examined from the same aspects mentioned in the pedagogical aspect of the first heuristic: Credibility and Complexity. In terms of credibility, "cosmetic authenticity" refers to the graphic complexity of the existing layout. Since too much complexity can be distracting, especially when it comes to children, the general layout should be simple. This rule is confirmed by guideline 7 regarding subtle backgrounds. In terms of complexity, "representation of the real world" refers to the same necessity of correctly associating a symbolic and graphical representation of an element to its direct interpretation of the outside world. In this case, the map used in location-based apps is the main element to be correlated with its real-world symbolism. Guideline 4 already stresses the necessity of realism in map representation, thus confirming this cognitive aspect.



Figure 10: Foursquare’s prototype map screenshot

### 3) “User control and freedom”:

Supporting Redo/Undo functions as an escape exit from an unwanted situation within the running of the app.

#### **Design:**

The third design heuristic refers to the Undo/Redo function in an app. There are currently no guidelines designed regarding the incorporation of such a function. However, since its provision is critical to the application, it is necessary that the current set of guidelines be revised to include relevant suggestions as well. Thus, a more general question could be formed:

*According to Nielsen’s heuristics, an Undo/Redo function is important, as it provides a user with more control and freedom throughout each app session. How could such a function be incorporated so that it preserves the coherence of the general layout and not be too distracting, especially for children? Any suggestion?*

#### **Pedagogy:**

Squires and Preece (1999) examine the third heuristic from a contextual point of view. Focusing on attributes like Collaboration, Ownership and Curriculum, they distinguish two thematic areas, according to which a UI system should be checked: “learner control and self-directed learning” and “shared responsibility”. The first aspect interpreting ownership refers to learners finding their own way and rhythm when acquiring knowledge. Software that provides students with high levels of self-control can be more successful in providing knowledge. This aspect is partly

confirmed by the existing guidelines that include responsiveness (guidelines 1 and 4); however, there is no mentioning of Undo/Redo functions.

*How could such functions be incorporated to suit children and how could the existing responsiveness potentials be accentuated?*

“Shared responsibility” in terms of Collaboration refers to sharing the control of learning among a group of people, mostly students, thus leading to the question of *how the current guidelines could be further enhanced to include the possibility of children cooperating in different tasks.*

4) *“Consistency and standards”:*

Consistency in representation, signage and labelling to avoid confusion.

### **Design:**

Nielsen’s fourth design heuristic concerns the general consistency of the layout including representation, signage and labelling, thus confirming the 8<sup>th</sup> guideline produced regarding the general schematic representation of an app’s layout. However, if a labelling guideline needs to be added, the fourth design heuristic could result in the design analysis of the representation labelling itself. A good example of this could be the use of monolectic or periphrastic labels.

*How could labelling be used so that it preserves the general consistency of the existing layout and still be appealing to children?*

### **Pedagogy:**

Squires and Preece (1999) combine the two fields of contextual and cognitive authenticity in this heuristic, focusing on the attributes of complexity, collaboration and curriculum. “Subject content” refers to the scope of curriculum covered in an application. This can differ according to what the app targets; for example, if it is one course or multiple ones. “Consistent Protocols” refers to shared documents, artefacts and other pieces of information over a collaborative network of users. “Symbolic representation and terminology”, interpreting complexity, refers to easy correlation between symbols and texts and certain ideas or message conveying. As mentioned already, symbolic and pictorial representations are already preferred in the wireframes produced. Taking into consideration all the three aspects mentioned, and although the guidelines don’t



necessarily target the nature of content presented, *the question is whether a pictorial representation is straightforward enough for children, or if textual addition would be more helpful for correctly conveying the subject's content.*

5) "Error prevention" and 9) "Help users recognise, diagnose, and recover from errors":

Design that prevents the occurrence of errors and avoids complicated language when phrasing errors and promotes on-point solution suggestions and accurate problem description. For the sake of simplicity, the fifth and ninth heuristic regarding error handling and recovery will be combined and examined together to evaluate the existing guidelines.

### **Design:**

The current set of guidelines lacks such specification for the time being, thus the question refers to the necessary tweaks in the layout of the app to prevent such error instances, as well as in the representation of the textual and graphical formulation for the necessary error messages.

*How could the interface be tweaked to prevent errors and how should the corresponding error messages be formulated, so that they are still appealing and not too distracting for children?*

### **Pedagogy:**

Squires and Preece (1999) focus on the cognitive aspect of authenticity regarding this heuristic, stressing all its three attributes (credibility, complexity and ownership).

In terms of credibility, "interaction flow" (that is, a smooth interaction between the sequence of tasks the user has to perform while using an application) is stressed as important. This is covered by guidelines 1, 3, 4 and 8. Interaction flow, particularly in educational applications, also refers to providing users with sufficient feedback, especially for handling errors. In terms of complexity, "peripheral cognitive errors" refer to error prevention and handling, and "pedagogical techniques" focus more on the nature and the amount of feedback, thus contradicting each other from a constructivist point of view. Users need to be protected from the appearance of cognitive errors, while, on the other hand, according to constructivism, feedback is important. In terms of ownership, "metacognition" refers to learners reflecting their own cognition to improve their learning. Combining all these three aspects together, and since there is no specification regarding error prevention and handling in the guidelines, the question is *how*

*an error handling and recovery system could be implemented, so that it provides enough feedback to children regarding error prevention and recovery without being too distracting.*

6) *“Recognition rather than recall”:*

Clear representation of any element used and a careful depiction of its meaning and symbolisation.

**Design:**

The sixth principal states that an app should produce a clean representation of any element used and a careful depiction of its meaning and symbolisation, so that it minimises a user’s memory load. Schematic representation focusing on “recognition rather than recall” has already been stressed through the existing guidelines. More specifically guidelines 2, 3, 5 and 6 regarding the use of checkboxes/radiobuttons, the use of the thematic areas organised with tabs, buttons and help already stress the importance of minimalism and familiarity with the nature of each element’s function in an interface, thus confirming the corresponding heuristic. However, *any design suggestions regarding that matter would be helpful.*

**Pedagogy:**

“Representational forms” is another norm defined by Squires and Preece (1999) in terms of credibility that refers to minimising the complexity of the actual content presented and allocated inside the application, preferably with the use of UI elements users are already familiar with. Guidelines 1, 2 and 5 referring to the preferable UI elements used since children are more familiar with their function are confirmed by this specific rule. The important aspect covered, apart from familiarity, is the level of cognitive demand needed to perform tasks related to these UI elements, which need to be minimised for the sake of simplicity. The aforementioned guidelines stress that already. *However, any suggestions regarding that matter would be useful.*

7) *“Flexibility and efficiency in use”:*

Speed up (using Accelerators) or slow down the interaction of the interface with the user so that it fits the needs of each user separately.

**Design:**

The seventh heuristic refers to the flexibility and efficiency of an app’s use by tailoring frequent interactions between the user and the interface. Guidelines 1 (Draggable objects), 2

(Checkboxes/radiobuttons), 3 (thematic tabs), 4 (map representation) and 5 (buttons) already focus on filtering how the user interacts with the application in an intuitive, yet familiar way, and thus is validated already. However, *any design suggestions regarding that matter would be helpful.*



Figure 11: Pokémon Go wireframe, bottom toolbar

### **Pedagogy:**

Squires and Preece (1999) combine cognitive and contextual authenticity in this heuristic, focusing on credibility, ownership and curriculum. “Multiple views/representation”, interpreting credibility, refers to the flexibility with which multiple thematic areas are represented inside an application. Guideline number 3, focusing on tabs as the UI element organising the thematic areas, covers this aspect already. “Tailoring the interface”, regarding ownership, refers to the flexibility of the software, as users’ capabilities in using interfaces become even more sophisticated. “Teacher customisation”, regarding curriculum, refers to tweaks in the interface to serve the teachers’ needs as well. The existing set of guidelines only covers the interface referring to students in a certain age group. *Any suggestions regarding further additions and tweaks to serve the teachers’ needs that offer further sophistication and flexibility would be valuable.*

### *8) “Aesthetic and minimalist design”:*

Careful filtering of information, reallocated and presented in a minimalistic way, to avoid unnecessary noise and confusion.

### **Design:**

The eighth heuristic refers to the general aesthetics an interface adheres to. Nielsen (1995) suggests that minimalism is the preferable style to choose in terms of design. Guidelines 7 (subtle backgrounds) and 8 (general coherence in the layout) already comply with this heuristic. However, *any design suggestions regarding that matter would be helpful.*

### **Pedagogy:**

Squires and Preece's (1999) "superficial complexity" refers to the complexity of the general layout and media used in an interface. For example, poorly structured use of audiovisual media can be confusing and distracting for users, especially for children. Thus, simplicity is the key for a flowing application. Guideline 7 already confirms this statement.

10) "Help and documentation":

Ideally, a system should be so straightforward in terms of design that any provision of help and supporting documentation would be unnecessary. However, if such a function needs to be present, it should be easy to search and correctly organised.

**Design:**

The tenth and final heuristic refers to providing help to the user while they use an interface. This could be done by actually providing such a function in the interface or by supporting documentation (manual). Guideline 6 already covers the incorporated help function in the interface.

**Pedagogy:**

Squires and Preece (1999) refer to "learner's support material", which is the provision of help and guidance when using the application (as a UI element inside the app or as any form of supporting documentation). The current set of guidelines already mentions this as an important factor.

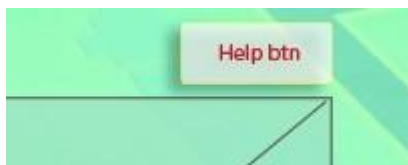


Figure 12: Pokémon Go wireframe, Help button

4.1.2. Formation of questions targeting the focus group

Summing up the questions above, the final outcome are two main sets of questions for the designers and the pedagogues of the focus group equivalently. Since many questions tend to converge in terms of meaning, they were reconstructed and combined, so that they include all the viable information while avoiding repetition.

## Focus Group Questions

- 1) *Is the pictorial representation of a map element and its markers enough or does it require more precise labelling to convey the general information more accurately?*
- 2) *According to Nielsen's heuristics, an Undo/Redo function is important, as it allows the user to have more control and freedom throughout each app session. How could such a function be incorporated so that it preserves the coherence of the general layout and not be too distracting, especially for children? Any suggestion?*
- 4) *How could the interface be tweaked in order to prevent errors and how should the corresponding error messages be formulated, so that they still be appealing and not too distracting for children? What kind of feedback would be more appropriate in this case?*
- 5) *How the current guidelines could be further enhanced to include the possibility of children cooperating in different tasks?*
- 6) *Any suggestions regarding further additions and tweaks to serve the teachers' needs to offer further sophistication and flexibility would be valuable?*
- 7) *Any suggestions regarding the 2<sup>nd</sup>, 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> heuristic and how those are covered by the current set of guidelines would be helpful.*

## 4.2 Conclusion

Overall, the current set of guidelines managed to sufficiently cover several goals regarding Nielsen's heuristics, both from a design and pedagogical perspective. More specifically, the guidelines and the wireframes produced successfully included good pictorial representation, both from a design and pedagogical point of view. There were good connections drawn between the real world and its representation inside the app's environment. Nielsen's sixth guideline "recognition rather than recall" is confirmed from both a pedagogical and design aspect stressing the use of effective UI elements. The general design is characterised by flexibility and minimalism, thus confirming Nielsen's seventh and eighth heuristics. Finally a Help provision, Nielsen's tenth heuristic, was sufficient in terms of design and pedagogy.

However, there were still some important weaknesses to be stated in terms of design and pedagogy. There were no guidelines for navigation or error prevention/handling. Furthermore, there was no implementation of Undo/Redo functions. Thus, Nielsen's heuristics number 1, 3, 5

and 9, the latter just from a pedagogical aspect, were violated. There are questions regarding sufficient and accurate labelling as well. From a pedagogical point of view, there is ambiguity in design regarding the possibility of student cooperation in group tasks and supporting teachers' needs. The issues mentioned above can be left open for future research.

Schematically, the guidelines fitting into the heuristics suggested above from both aspects can be summed up in the following table:

Nielsen's Heuristics	Guidelines evaluated from a Design point of view	Guidelines evaluated from a Pedagogical point of view
1st Heuristic	Guideline 4	Navigation: Guideline 3 Feedback and designer/learner models: Guidelines 1, 2, 4
2nd Heuristic	Guideline 4	Cosmetic Authenticity: Guideline 7 Representation of the real world: Guideline 4
3rd Heuristic	No specification	No specification
4th Heuristic	Guideline 8	No specification
5th and 9th Heuristic	No specification	Interaction Flow: Guidelines 1, 3, 4, 8 Peripheral Cognitive Errors: No specification Metacognition: No specification
6th Heuristic	Guidelines 2, 3, 5, 6	Representational Forms: Guidelines 1, 2, 5
7th Heuristic	Guidelines 1, 2, 3, 4, 5	Multiple views/representations: Guideline 3 Tailoring the Interface: Guideline 8 Teacher Customization: No specification
8th Heuristic	Guidelines 7, 8	Superficial Complexity: Guideline 7
10th Heuristic	Guideline 6	Learner's support material: Guideline 6

Figure 13: Evaluation Table

## 5. Results from the focus group interview and analysis

### 5.1. Results from the interviews with the focus groups

The focus group consisted of one designer and one pedagogue, both working as researchers in the Learnovate Centre, Dublin, Ireland. The two experts were contacted via the email provided on the centre's website and they agreed to participate in the interview process. Due to some bureaucratic inconveniences regarding the Ethics Application, the interview was arranged in advance. Based on the application's approval, the results would be included in the research paper as an additional chapter. As a result, the interview took place in the Learnovate Centre on the 28<sup>th</sup> of April, 2017. The whole process lasted around 45 minutes. The procedure constituted of

going through the prototypes of the redesigned applications and examining the design choices made, according to the given scenarios and winning conditions of the prototypes. It should be stated that a small document containing the guidelines, wireframes, prototypes and the scenarios they adhere to (the structure followed was based on Chapter 3) was submitted to the two interviewees beforehand so they could familiarise themselves with the general subject. The conversations were recorded for later analysis. With the application's approval, the interview results and their analysis are presented below.

#### 5.1.1. Results from the interviews presented

Taking into account the questions formed above, both experts focused on five main areas of the prototypes. These areas are the Undo/Redo possibility, the error prevention/handling, any necessary redesign for teachers, any redesign for cooperation between children and, finally, the map.

##### *Undo/Redo possibility*

The first comment the UI designer made regarding this issue was that young children, especially during their first years entering the cognitive operation stage, have difficulties grasping whole concepts. Thus, as they suggested, a more appropriate and intuitive way to incorporate this function into such an application would be a navigation system that would allow children either to redirect back to the home screen and restart the procedure (in the case of the redesign of Pokémon Go) or reset the application (in the case of Foursquare), depending on the app's context. As a result, the aforementioned redesign process can affect labelling, as the higher cognitive functions required in the Undo/Redo procedures entail more elaborate and sophisticated textual contents.

##### *Redesign of the application for teachers' needs*

The two views acquired from the UI designer and the pedagogue related to this matter focussed on two phenomenally different approaches that still shared a common denominator. More specifically, the designer focused on the prototype based on Pokémon Go, pointing out that the current design choices serve the purpose of the application sufficiently, since the scenarios are aimed at being executed in in-class activities. The presence of the teacher offers the possibility of direct clarification regarding any questions arising from use of the UI. In case of a stand-alone

application, he suggested that more explanatory pictorial representation could be incorporated, especially in the bottom toolbar filtering the living kingdoms, thus adding more independence for use of the application. The pedagogue agreed with the previous comments adding that, in the case of the remake of Foursquare, the redesign of the app would be more administrative in nature, for example, filtering how many buildings are in the system that the children can work with. She also stressed the necessity of the app's UI to be easy for children to grasp, with the least dependence on the teacher possible, especially because some children struggle with learning difficulties like dyslexia.

### *Error handling/preventing*

The UI designer mentioned relevant research indicating that children tend to overlook long text. Thus, error messages should be less textual and focus more on pictorial representation, for example, funny icons. A good solution to error handling was, according to his view, the provision of navigation back to the home screen and then the possibility of reopening the application, instead of providing more complex error messages. The pedagogue at that point added that children tend to push an application to its limits, for example, by extensive tapping. In general, they tend to prefer exploring beyond the limits of the task they are assigned. Thus, the pedagogue's suggestion was to make any educational application targeting children as least responsive as possible since over-interaction can result in errors, and this will adhere to the concept of simplicity as much as possible.

### *Cooperation between children*

Both experts were negative towards this concept, since they predicted the result would be unclear, causing confusion and lack of discipline, especially within the concept of an in-class activity.

### *Map*

The main point both experts focused on was the resizability of the map. Especially in the context of a more complex map like the one used in the Foursquare prototypes, resizability can distract children from the assigned task. A form of solution suggested by the designer was the implementation of a bouncing animation whenever the user goes off the map's limits. Both



experts stressed again the importance of simplicity in this case, and the lack of excessive responsiveness, especially when the areas responsive don't necessarily contribute to fulfilment of the task. According to their point of view, simplicity prevents unnecessary distraction from the main task. It is also interesting to state that the pedagogue expressed her preference towards the more comic-looking adaptation of the map used in the Pokémon Go prototypes, especially because of the necessity of simplicity stated above.

### *General comments*

Both experts agreed that the UI elements chosen and the choice of background and stylistic coherence could efficiently suffice the needs of children. The only comments received in this stage concerned labelling and its relation to the attribute it defines. The designer stated that it is important for both elements to have the same functionality, as users, especially children, tend to tap on the label rather than the actual attribute to select it. Some additional comments regarding the 'Help' function were made by both experts, stating that its implementation should focus on navigation and usability issues, rather than issues relating to the assigned tasks.

#### 5.1.2. Analysis and revision of guidelines

By analysing the results of the interview, two main areas of interest emerge. The first area derives directly from the evaluation process based on Nielsen's heuristics and thus answers the questions raised after the aforementioned process was completed. The second area concerns the guidelines themselves and how they could be revised and enhanced to constitute a more complete and accurate point of reference.

The first area deduced by the questions from the heuristic evaluation mainly covers the incorporation of Undo/Redo functions, the redesign of the application for teachers' use, any error prevention and handling, and the possibility for cooperation between children during the execution of the task. The Undo/Redo functions are more complicated and sophisticated concepts for children to grasp at such a young age. It needs to be stated that the cognitive and motor competence of the age group chosen varies between these children in comparison to children of older ages. Thus, children aged eleven could be familiar with the aforementioned concept, while children aged seven might struggle to grasp it completely. This diversity requires some form of compromise for an application to respond to the needs of a broader audience. Such compromise could be met by resetting or navigating to a previous and more generic state of the application,

such as the Homepage, bypassing the necessity for the incorporation of such a function. However, if such incorporation is inevitable, it subsequently requires more sophisticated and detailed labelling for its functionality to be clarified.

Redesigning an educational location-based application to meet the teachers' needs depends on the portability of the application. More specifically, if an application is designed for stand-alone distribution targeting children, more pictorial representation is essential, as the interface of the application requires more in-depth clarification regarding its use. However, if an application is aimed for in-class use, then the possibility of the clarification can be provided in real time by the teacher, thus eliminating any necessity for incorporating additional explanatory information in the interface. It is important to state any form of additional, mainly pictorial, information incorporated should still adhere to the rule of simplicity since, as the pedagogue stated, simplicity provides independence, which is an important interface trait in applications used inside and outside of class.

Error handling and prevention should rely on pictorial rather than textual elements. As the UI designer stated, children tend not to read text blocks, thus the traditional method of informing the user about an error occurrence and its possible solution may not be as appropriate. A more effective approach to this issue could be the implementation of navigation to reopen the task. A more interesting addition is the elimination of any unnecessary responsiveness irrelevant of completing the corresponding task. This concept mostly applies to the implementation of maps, especially regarding maps' resizing, as children tend to disorient themselves and tap or navigate to places irrelevant to the task's context. Thus, simplicity in design and responsiveness again constitutes the rule of thumb in this case, as it both prevents errors and keeps children focused.

Lastly, cooperation between tasks should preferably be avoided, as it can again lead to unnecessary confusion and disorganisation in the class. Yet, if such cooperation is proven to be necessary, the nature of the task itself should alter, rather than the app's UI.

The second area emerging from the analysis of the interview results concerns the existing set of guidelines. As mentioned before, the UI elements chosen were approved by both experts, thus indicating the utility of guidelines 1, 2, 3, and 5. Both experts also confirmed the validity of guidelines 7 and 8, stressing that the general coherence in design and the design of subtle

backgrounds are important aspects in a user-friendly application targeting children and were successfully implemented in the wireframes. The importance of labelling was again stressed regarding its relation to the attribute it defines. Users, especially children, tend to take both labels and the attributes they specify as a whole. Thus, when they tap on the corresponding element, they tend to perceive its label as part of the element itself and as a result, they only tap on the label to select the object they need. Therefore, one important design aspect to incorporate is unifying common elements, probably in the same `div`<sup>1</sup> tag, so that they don't cause confusion during use. Finally, guideline 5 regarding the provision of help was confirmed as well, although its content required more specification in terms of being more pragmatic, focusing on the navigation and the practical use of the application, rather than the description of the application's goal or the corresponding task.

As a final result, the current set of guidelines can be updated to include the observations regarding the guidelines themselves and any omissions regarding Nielsen's heuristics. What follows are the updated guidelines:

- 1) Draggable objects/Drag-and-drop function: Natural to children. They tend to use this with ease when they have to bring a new object into their working space. This functionality requires precision, fine vision and motor coordination. It is thus more suitable to children aged 7-11, as their dynamic visual acuity stabilises around that age (Hourcade, 2015).
- 2) Checkboxes/radiobuttons/sliders: Children are familiar with their functionality and tend to use them with precision. Good for categorising outputs or filtering information.
- 3) Presentation of different thematic areas in the same app: Use of tabs. Children tend to notice big, clear, colourful tabs. Subtle and more traditional tabs tend to be overlooked.
- 4) Representation of the map elements in location-based apps: The use of a more comic map terrain that represents all the main geographical attributes of the area of interest is important, since children tend to make connections between real and realistically represented virtual objects. They thus gain a better understanding of the app and the real-world symbolisations it tries to

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<sup>1</sup> Referring to the `<div>...</div>` tags of HTML.

depict. However, simplicity should be the most important rule applied in design and responsiveness for the sake of error prevention.

5) Buttons: Visual clarity of their functionality in the app. Children tend to overlook their existence but use them correctly when required. Bright colours and specific labels relevant to their functionality are suggested.

6) Help: Help function should be available and clearly presented as children tend to follow instructions to complete a task before they can complete it on their own (Vygotsky, 1978). Its content should mostly concern usability and navigation, rather than specific instructions regarding the nature of the task. However, if it is too prominent, then it gets followed like a command and children are unlikely to explore the potential of the app on their own (Vygotsky, 1978).

7) Backgrounds: Subtle in general, the main objects of importance should be easily distinguished.

8) General coherence in the layout: Important for guiding children through the layout, as they tend to look at all visuals equally when they don't understand the concept. Emphasising certain items of importance and eliminating potential distractions is important as well.

Four new guidelines can be added as an outcome of the heuristic evaluation and the interviews:

9) Labelling should be specific and unified with the element it refers to. Since users, especially children, tend to perceive labels and their corresponding elements as whole entities, they tend not to distinguish which element to tap. Thus, unifying labels with the elements they refer to are important in terms of usability.

10) Undo/Redo functions can be too complicated for children to grasp. Thus, their incorporation into the app's UI could be bypassed by the use of either navigation or reset, depending on the context of the app. Such implementation will still require more sophisticated labelling, thus it should be carefully assessed.

11) Any redesign for teachers depends on the app's portability. Stand-alone applications require more explanatory UIs than non-portable applications. Any necessary redesign also depends on the nature of the application's scenario as well, as it can vary from just pictorial elements to more administrative additions.

12) Cooperation between children in such applications should be preferably avoided, since it can be messy. However, if it is considered necessary, then any tweaks should be on the nature of the task, rather than the app's UI.

## 6. Conclusion

As mentioned in the introduction, the set of guidelines produced in this paper is of significant importance, especially for pedagogues and designers that wish to take education one step further by incorporating location-based application into the teaching process. As previously stressed in this paper, maps and, to a greater extent, applications that base their core function on them have been of great interest recently to designers, programmers, and users. Such growing popularity has resulted in the expansion of maps and location-based applications to education as well. The incorporation of such applications to this sector is currently in the experimental phase, though vast advances are being made, especially at the research and academic level. Thus, the suggested set of guidelines in the current paper constitutes a point of reference for designers and pedagogues to develop more appropriate location-based applications that respond to children's needs in an educational setting.

Due to time limitations, research regarding the pedagogical aspect and the determination of the most appropriate UI elements that would suffice the needs of children in location-based applications comprised a cross-analysis of the existing pedagogical norms and dominant UI elements in location-based applications. Moreover, the heuristic evaluation should be performed by more experts and should take place more than once, after revising the guidelines accordingly. Thus, the methodology itself reveals one major weakness regarding the existing set of guidelines, which is the lack of breadth and accuracy, taking into consideration the methods followed. Another weakness of the current set of guidelines is that the four new guidelines lack specification and vary in terms of specification, depending on the context of the app. Although this is true, more research regarding these suggestions is required.

As a result, any future work should definitely include more research regarding the pedagogical norms and theories that govern child development before forming the first set of guidelines. Another important field that should be taken into consideration is a more meticulous cross-analysis of the UI elements used in location-based and educational applications, so that the final UI elements chosen as suggestions are more accurate. Finally, as Nielsen states, the heuristic evaluation process should be conducted by a bigger number of experts (Nielsen, 1995b). Further development of the prototypes suggested and performing usability testing are essential steps to obtain more insights into the validity and accuracy of the guidelines.

# Appendix

## Ethics Application

### APPLICATION FORM:

#### School of Computer Science & Statistics Research Ethics Application

#### CHECKLIST

The following documents are required with each application:

1.	• SCSS Ethical <b>Application Form</b>	
2.	• <b>Participant's Information Sheet</b> must include the following: a) Declarations from Part A of the application form; b) Details provided to participants about how they were selected to participate; c) Declaration of all conflicts of interest.	
3.	• <b>Participant's Consent Form</b> must include the following: a) Declarations from Part A of the application form; b) Researchers contact details provided for counter-signature (your participant will keep one copy of the signed consent form and return a copy to you).	
4.	• <b>Research Project Proposal</b> must include the following: a) You must inform the Ethics Committee <b>who</b> your intended participants are i.e. are they your work colleagues, class mates etc. b) How will you recruit the participants i.e. <b>how</b> do you intend asking people to take part in your research? For example, will you stand on Pearse Street asking passers-by? c) If your participants are under the age of 18, you must seek both parental/guardian AND child consent.	
5.	• Intended <b>questionnaire/survey/interview</b> protocol/screen shots/representative materials (as appropriate)	
6.	• <b>URL</b> to intended on-line survey (as appropriate)	

#### Notes on Conflict of Interest

1. If your intended participants are work colleagues, you must declare a potential conflict of interest: you are taking advantage of your existing relationships in order to make progress in your research. It is best to acknowledge this in your invitation to participants.
2. If your research is also intended to direct commercial or other exploitation, this must be declared. For example, *"Please be advised that this research is being conducted by an employee of the company that supplies the product or service which form an object of study within the research."*

#### Notes for questionnaires and interviews

1. If your questionnaire is **paper based**, you must have the following **opt-out** clause on the top of each page of the questionnaire: *"Each question is optional. Feel free to omit a response to any question; however the researcher would be grateful if all questions are responded to."*
2. If your questionnaire is **on-line**, the first page of your questionnaire must repeat the content of the information sheet. This must be followed by the consent form. If the participant does not agree to the consent, they must automatically be exited from the questionnaire.
3. Each question must be **optional**.
4. The participant must have the option to **'not submit, exit without submitting'** at the final submission point on your questionnaire.
5. If you have open-ended questions on your questionnaire you must warn the participant against naming **third parties**: *"Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised."*
6. You must inform your participants regarding **illicit activity**: *"In the extremely unlikely event that illicit activity is reported I will be obliged to report it to appropriate authorities."*



UNIVERSITY OF DUBLIN, TRINITY COLLEGE  
Faculty of Engineering, Mathematics and Science  
*School of Computer Science and Statistics*

**RESEARCH ETHICS PROTOCOL**

**When is Ethical Approval Needed?**

Ethical approval is required before any studies involving human participants can commence. This requirement applies to studies to be undertaken by staff, postgraduate and undergraduate students. In the case of collaborative projects involving researchers from outside the School, ethical approval obtained from an external research ethics body may suffice – evidence of same must be submitted to the SCSS Research Ethics Committee prior to the commencement of the study (see procedures below). In the absence of such external approval, approval must be obtained as per this document. Additional ethical approval may be required if the project involves or is funded by an external body, for example, studies under FP7 automatically require such approval.

For the purpose of this document a “study” may be understood to involve a potentially staged series of different experiments to be conducted over a period of time. If substantive changes are made to a study following receipt of ethical approval, this will constitute a new study for which further ethical approval must be obtained.

**Procedure**

Completed application forms together with supporting documentation should be submitted electronically to [research-ethics@scss.tcd.ie](mailto:research-ethics@scss.tcd.ie). To submit, if the proposal is from an undergraduate or postgraduate students, the **completed** application package must be presented to the academic supervisor who will sign after verifying completeness. These signed originals may be scanned and emailed. Please use TCD e-mail addresses only. When your application has been reviewed and approved by the Ethics committee hardcopies of the application form with original signatures should be submitted to the School of Computer Science & Statistics, Room F37, O'Reilly Institute, Trinity College, Dublin 2.

The Committee will consider each application and normally provide a response within two weeks but not more than one month later. Applications that are considered not to have significant ethical implications may be evaluated by the Committee Chair without reference to the full Committee. Applications will otherwise be considered at a meeting of the SCSS Research Ethics Committee. When approval has been obtained from an external research ethics committee, and School approval is not required, a copy of the external ethical approval must be submitted to the School's Research Unit, prior to commencement of study, for noting by the SCSS Research Ethics Committee.

Please note that in signing the approval form one is making a commitment to review the provisions of the Data Protection Act, like legislation and College Policy on Good Research Practice. Please ensure that your study conforms to the standards of anonymity preservation and data retention set in those documents. Those provisions suggest a default proscription against making digital or photographic recordings of participants. A study which requires such records must include in the research ethics approval application a justification and documentation of the methods by which the statutory provisions and research practise guidelines will be met.

*Note: These procedures may be amended from time-to-time following recommendation by the SCSS Research Ethics Committee and with the approval of the SCSS Research Committee.*

**Before seeking ethical approval researchers should:**

- identify actual and potential ethical issues that might arise;
- reflect on how these will be addressed; and
- formulate procedures to deal with all such issues.

**During the research project researchers should:**

- implement the ethical procedures;
- obtain continuous feedback from participants about ethical issues;
- periodically review the ethical strategy in the light of feedback received; and
- if required, update their ethical procedures;
- retain copies of consent forms signed by the participants.

**Composition of the SCSS Research Ethics Committee**

The Committee will consist of a Chairperson/Convener appointed by the Director of Research and two other experts – a member of the School's academic staff and external advisors. The internal and external members will be selected from a panel approved by the Director of Research from time to time. Members will be selected on a case by case basis by the Chairperson subject to their availability. Researchers will be precluded from the Committee considering ethical approval for their study.



**School of Computer Science and Statistics  
Research Ethical Application Form**

**Part A**

Project Title: .LBDP.....

Name of Lead Researcher (student in case of project work): Eleni Kapsimali .....

Name of Supervisor: .Nina Bresnihan.....


TCD E-mail: Nina.Bresnihan@scss.tcd.ie..... Contact Tel No.: 01-896 2704.....

Course Name and Code (if applicable): .....M.Sc. in Interactive Digital Media .....

Estimated start date of survey/research: .....30/03/2017.....

I confirm that I will (where relevant):

- Familiarize myself with the Data Protection Act and the College Good Research Practice guidelines [http://www.tcd.ie/info\\_compliance/dp/legislation.php](http://www.tcd.ie/info_compliance/dp/legislation.php);
- Tell participants that any recordings, e.g. audio/video/photographs, will not be identifiable unless prior written permission has been given. I will obtain permission for specific reuse (in papers, talks, etc.)
- Provide participants with an information sheet (or web-page for web-based experiments) that describes the main procedures (a copy of the information sheet must be included with this application)
- Obtain informed consent for participation (a copy of the informed consent form must be included with this application)
- Should the research be observational, ask participants for their consent to be observed
- Tell participants that their participation is voluntary
- Tell participants that they may withdraw at any time and for any reason without penalty
- Give participants the option of omitting questions they do not wish to answer if a questionnaire is used
- Tell participants that their data will be treated with full confidentiality and that, if published, it will not be identified as theirs
- On request, debrief participants at the end of their participation (i.e. give them a brief explanation of the study)
- Verify that participants are 18 years or older and competent to supply consent.
- If the study involves participants viewing video displays then I will verify that they understand that if they or anyone in their family has a history of epilepsy then the participant is proceeding at their own risk
- Declare any potential conflict of interest to participants.
- Inform participants that in the extremely unlikely event that illicit activity is reported to me during the study I will be obliged to report it to appropriate authorities.
- Act in accordance with the information provided (i.e. if I tell participants I will not do something, then I will not do it).

Signed:   
Lead Researcher

Date: .....24/03/2017.....

**Part B**

<i>Please answer the following questions.</i>		<b>Yes/No</b>
Has this research application or any application of a similar nature connected to this research project been refused ethical approval by another review committee of the College (or at the institutions of any collaborators)?		No
Will your project involve photographing participants or electronic audio or video recordings?		Yes
Will your project deliberately involve misleading participants in any way?		No
Does this study contain commercially sensitive material?		No
Is there a risk of participants experiencing either physical or psychological distress or discomfort? If yes, give details on a separate sheet and state what you will tell them to do if they should experience any such problems (e.g. who they can contact for help).		No
Does your study involve any of the following?	Children (under 18 years of age)	No
	People with intellectual or communication difficulties	No

SCSS Research Ethics Application Form August 2014

	Patients
<b>School of Computer Science and Statistics Research Ethical Application Form</b>	

Details of the Research Project Proposal must be submitted as a separate document to include the following information:

1. Title of project
2. Purpose of project including academic rationale
3. Brief description of methods and measurements to be used
4. Participants - recruitment methods, number, age, gender, exclusion/inclusion criteria, including statistical justification for numbers of participants
5. Debriefing arrangements
6. A clear concise statement of the ethical considerations raised by the project and how you intend to deal with them
7. Cite any relevant legislation relevant to the project with the method of compliance e.g. Data Protection Act etc.

**Part C**

I confirm that the materials I have submitted provided a complete and accurate account of the research I propose to conduct in this context, including my assessment of the ethical ramifications.

Signed:  Date: .....24/03/2017.....  
Lead Researcher

*There is an obligation on the lead researcher to bring to the attention of the SCSS Research Ethics Committee any issues with ethical implications not clearly covered above.*

**Part D**

If external or other TCD Ethics Committee approval has been received, please complete below.


External/TCD ethical approval has been received and no further ethical approval is required from the School's Research Ethical Committee. I have attached a copy of the external ethical approval for the School's Research Unit.

Signed: ..... Date: .....  
Lead Researcher/student in case of project work

**Part E**

If the research is proposed by an undergraduate or postgraduate student, please have the below section completed.

I confirm, as an academic supervisor of this proposed research that the documents at hand are complete (i.e. each item on the submission checklist is accounted for) and are in a form that is suitable for review by the SCSS Research Ethics Committ

Signed: .....  ..... Date: .....27/03/17.....

Supervisor

**Completed application forms together with supporting documentation should be submitted electronically to [research-ethics@scss.tcd.ie](mailto:research-ethics@scss.tcd.ie) Please use TCD e-mail addresses only. When your application has been reviewed and approved by the Ethics committee hardcopies with original signatures should be submitted to the School of Computer Science & Statistics, Room F37, O'Reilly Institute, Trinity College, Dublin 2.**

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QUESTIONNAIRE:

LBDP Focus Group Questions:

*The focus group will ask open-ended questions and follow up on issues raised. The following questions are therefore indicative only.*

Pedagogical Focus Group:

1. What kind of attribute would captivate the interest of children the most in a location-based application, according to your opinion and experience?
2. What would keep that interest focused on that attribute?
3. How would such an interface prevent any unpredictable behaviour in the case of scenario X?
4. How can this interface keep its educational character without being presumed to be a source of fun by children?
5. How could the X guideline be modified so that it better applies to the needs of children?
6. Do you think that the Y sample interface fulfils the requirements of the X guideline?
7. If not, why, and what changes would you make to interface to overcome this gap?

Design Focus Group:

1. How could this design aspect be simplified so it is more easily implemented, while keeping its aesthetics and functionality as intact as possible?
2. From a designer's point of view, what are the compromises you could make when dealing with educational software to achieve maximum functionality and portability?
3. What guidelines would you modify for that reason and why?
4. Which guidelines would you consider as less important and possible to ignore and why?
5. How would you implement the X guideline in a sample interface, so that coherent delivery across devices is achieved?
6. From your experience, how would you introduce a change or update in an existing educational interface so that it is easily recognised and manageable by children?

## INFORMED CONSENT FORM

### TRINITY COLLEGE DUBLIN INFORMED CONSENT FORM

**LEAD RESEARCHERS:** Eleni Kapsimali

**BACKGROUND OF RESEARCH:** My plan is to investigate user interfaces in location-based learning software applications. More specifically, my research question is: What attributes should the User Interface of an application have in order to follow basic pedagogical guidelines, yet being appealing to learners and, at the same time, easy to be used by them? To the best of my knowledge, location-based learning is a field that hasn't been thoroughly examined to this day. It is a relatively recent topic, since maps have started being used in applications for the past decade. Especially in the pedagogical field, studying maps implementations lacks breadth, although it is a highly promising area that involves practical use and interactivity, thus being appealing and appropriate for use in the education sector. The product of this research paper will be a set of guidelines regarding the UI/UX design of location-based software applications. This set of guidelines will be evaluated by design experts and pedagogues for their accuracy, breadth and validity.

**PROCEDURES OF THIS STUDY:** The duration of this project is 14 weeks and divided into three stages.

- The first stage constitutes an extensive research on the currently available pedagogical guidelines regarding the design and development of software applications for educational purposes. Its product will be a revised and enhanced set of pedagogical guidelines that will satisfy the children's needs when it comes to designing educational software applications.
- The second stage will be the first evaluation process where the produced guidelines will be applied to already existing location-based applications, as an attempt to redesign them for educational purposes, thus checking the guidelines' implementation scale, validity and accuracy. Through this process any unforeseen weaknesses or lacks of clarity will be

specified. The outcome of this process will be then collected and restructured in order to be re-evaluated by experts.

- As mentioned above, the third and final stage of the project will be the revision of the produced set of guidelines by experts. The previous will be performed using of focus groups. Since the project's nature is two-sided and combines the two major fields of UI/UX design and pedagogy, two focus groups will be formed accordingly. After the completion of this stage, a complete overview of the lacks of the current set of guidelines produced will be formed. Due to lack of time, no substantial redesign of the guidelines will take place, however the reasons any lacks and misconceptions were detected will be stated in detail, so that they constitute a valid point of reference for further research or implementation.

**PUBLICATION:** The spectrum of this project is for the time being limited to the context of the course and there are no specific plans for publication in the future.

Individual results may be aggregated anonymously and research reported on aggregate results.

**DECLARATION:**

I agree to Trinity College, University of Dublin anonymizing and storing all information that is collected by the researchers in accordance with the Data Protection Act. I agree to the processing of such data for purposes connected with the research project as outlines in the Information Sheet.

- I am 18 years or older and am competent to provide consent.
- I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.

- I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
- I understand that if I make illicit activities known, these will be reported to appropriate authorities.
- I understand that I may stop electronic recordings at any time, and that I may at any time, even subsequent to my participation have such recordings destroyed (except in situations such as above).
- I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded.
- As the research involves materials via a computer monitor, I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.
- I have received a copy of this agreement.
- All my data will be treated with full confidentiality and stored securely so that, in the event that any data is published, my data will not be identified as mine, nor identify my school or students.

**PARTICIPANT'S NAME:**

**PARTICIPANT'S SIGNATURE:**

**Date:**

**Statement of investigator's responsibility:** I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

**RESEARCHERS CONTACT DETAILS:** [elenik@tcd.ie](mailto:elenik@tcd.ie)

**INVESTIGATOR'S SIGNATURE:**

**Date:**



You are invited to participate in the **LBDP** research project. The project is based in the School of Computer Science and Statistics, Trinity College and led by Eleni Kapsimali ([elenik@tcd.ie](mailto:elenik@tcd.ie)), master student of the course “M.Sc. in Interactive Digital Media”.

### **Research Project Overview:**

The overall aim of the project is to analyse the design of the User Interface of location-based learning applications, in order to make it more user friendly and better applied to the prevalent pedagogical norms.

The program, which you are participating in, will take place over a 14-week period. My plan is to select UI/UX design experts and pedagogues in order to evaluate a set of guidelines produced regarding the redesign of location-based applications for educational purposes. In Ireland, Learnovate Research Centre has been invited through a call for participation to this Research Paper written by Eleni Kapsimali, a master student of the course “Interactive Digital Media” in Trinity College Dublin. Those contacted are also encouraged to invite appropriate colleagues they are aware of.

The project will begin with a background research on the existing guidelines regarding the design of applications for educational purposes targeting children. The outcome of this research will be a revised and enhanced set of guidelines that satisfies the needs of the specific group of children aged 9-11 years. Subsequently, the aforementioned guidelines will be used to redesign existing location-based applications for educational purposes using wireframes, and then they will be evaluated using the heuristic suggested by David Squires and Jenny Preece in their paper “Predicting quality in educational software: Evaluating for learning, usability and the synergy between them”. Through this first evaluation process, any weaknesses or ambiguities regarding the guidelines will emerge and will be summed



up and structured. Based on those results, the set of guidelines produced will be re-evaluated by design experts and pedagogues with the formation of focus groups. More specifically, two main focus groups will be formed, one consisting of designers and the other consisting of pedagogues, thus providing an overall, two-sided view on the validity of the guidelines.

### **Research Participation**

In order to demonstrate the validity of the set of guidelines, I will collect information about designers' and pedagogues' opinions regarding the final product of the research at its final stage. You will be invited to (1) join a focus group according to your area of expertise and answer questions regarding the accuracy and the validity of the set of guidelines produced during the research process. Any further addition by expressing your personal opinion or suggesting points for correction, enhancement or extension of the existing guidelines is mostly welcome.

All information that is collected by the researchers will be anonymised and stored in accordance with the Data Protection Act at Trinity College, Dublin. In the extremely unlikely event that illicit activity is reported during the study, the research team will be obliged to report it to appropriate authorities. There may be lectures, Ph.D. theses, conference presentations and peer-reviewed journal articles written as a result of this project, however the participants will not be identified. The voice recordings of the focus group will not be replayed in any public venue, and are constructed solely for transcription purposes for review by the research team.

#### *Voluntary nature*

Participating in this project is voluntary. You may change your mind and stop at any time. You may also choose to not answer a question for any reason.

*Participant's recruitment criteria and obtaining participants' credentials.*

We inform you that your credentials have been obtained through the official Learnovate Centre site. The criteria according to which the participants were chosen are their areas of expertise. The preferred areas confirming the needs of this project are UX/UI designers and Pedagogues.

### *Benefits*

I hope that this project will contribute to the reassessment of the use of location-based technology in learning, as it will provide a useful basis for the UI/UX design of applications of that nature.

### *Risks and discomforts*

Answering questions about one's experiences may be uncomfortable. You can choose not to answer a question at any time. You may withdraw from the study at any time without penalty.

### *Confidentiality*

The results of the study will be reported in a research paper submitted in partial fulfilment of the requirements for the M.Sc. Interactive Digital Media in Trinity College Dublin. The report will not include any information that would identify your personal details, however it will include the name of the Research Centre involved.

If you have any questions in relation to this, please do not hesitate to contact me.

Kind regards,

Eleni Kapsimali

School of Computer Science & Statistics

Trinity College Dublin

Dublin 2

## 1. Purpose of project including academic rationale

The aim of the LBDP (Location – based Design Project) project is to analyse the design of the User Interface of location-based learning applications, in order to make it more user friendly and better applied to the prevalent pedagogical norms. The project will begin with a background investigation on the currently existing pedagogical guidelines regarding the User Interface design of educational technology applications, through which a summarised and, where needed, further developed set of guidelines will be developed. The evaluation procedure will be divided into two stages: the first stage will consist of designing wireframes of existing location-based applications according to the set of guidelines developed and reviewing them according to the heuristics suggested by David Squires and Jenny Preece. The results of this stage will lead to the second stage of evaluation, where the results produced from the first evaluation round will be gathered and organised in the form of unstructured questionnaires. Those questionnaires will be handed out to design experts and pedagogues, so that the final evaluation results have more depth in terms of validity.

The **objectives** of the project are:

1. to offer more well-structured and concrete guidelines to designers regarding the design of location-based applications for educational purposes;

2. to extend the perspective and potential of location-based technology in the pedagogical field, a field that this kind of technology hasn't been taken into serious consideration so far;
3. to broaden the horizons of learning and suggest new approaches to the educational procedure of children;
4. to encourage further research on the integration of location-based technology in education.

## 2. Brief description of methods and measurements to be used

As mentioned above, the project will be divided into three stages. The first stage will contain a literature review regarding the already existing pedagogical guidelines for designing an educational application. The summary and further study and enrichment of these guidelines will result into the construction of new, revised guidelines, more suitable to location-based applications. The second stage of the project will include the graphical construction of wireframes of existing location-based applications, redesigned according to the aforementioned set of guidelines, so that they fulfil their educational purposes. Those wireframes will be evaluated according to the heuristics suggested by David Squires and Jenny Preece in their paper "Predicting quality in educational software: Evaluating for learning, usability and the synergy between them". The outcome of this evaluation will expose any weaknesses or omissions of the set of guidelines produced. Based on those results, the set will be re-evaluated by design experts and pedagogues with the formation of focus groups, so that more validity and insight will be added to the final set of guidelines, as well as leeway for further research and development.

### 2.1 Focus groups:

As mentioned above, in order for the set of guidelines to be evaluated in depth, experts in design and pedagogy will be asked to answer questions

regarding the validity and the accuracy of the guidelines. Such kind of evaluation requires that the experts are guided towards specific subjects, but be given the opportunity to deepen their analysis and express their opinion more freely. Since the project is two-sided with one side regarding design and the other regarding pedagogy, two main focus groups are going to be formed accordingly. Thus, an overall view from professionals on both fields will be formed on where and how the resulted guidelines should be restructured and enhanced.

## **2.2 Data processing:**

After the completion of the process, all results will be gathered and examined, so that a common axis can be found, covering the basic points where the guidelines need to be enhanced on. Those points, as well as the reasons why they lack integrity, will be analytically stated and discussed for further future research.

## **3. Participants:**

### **3.1 Profile:**

Experts in design and pedagogy from Dublin will be selected for the final stage of the project. They will be designers and pedagogues already experienced on relevant projects regarding educational applications. All participants will be over 18. All efforts will be made during recruitment process to ensure a reasonable gender balance in the participants.

### **3.2 Recruitment methods:**

Convenient sampling will be used, targeting designers and pedagogues who fit the profile described above. The average number of participants on each expertise group is estimated to be around three or four participants. In Dublin

a call to Learnovate Research Centre will be made through email. Those contacted will be invited to join the study and encourage other appropriate colleagues they might be aware of.

#### 4. Debriefing arrangements

After the completion of the process, all participants will be given the opportunity to further express their opinions about subjects they consider important and have been omitted. It will be made clear to them that, upon request, they will be informed about the findings of the research after its completion.

#### 5. Concise statement of the ethical considerations

All participants are over the age of 18. It will be made clear to the participants we do not intend to evaluate their technological competency, but rather to assess the effectiveness of the intervention on increasing their confidence levels. It will also be made clear that the results will be used only for our own research purposes. Participants will be informed that they may withdraw from the research at any time. Participant identities will be kept anonymous.



#### 6. Legislation relevant to the project

All information that is collected by the research will be encrypted and stored in accordance with the Data Protection Act at Trinity College, Dublin.

## APPLICATION'S APPROVAL

TCD REC WebApp: The status of 'Location-Based Design Project (LBDP)' (224) has been updated by the Committee Inbox x

rec-app-help  
rec-app-help@tchpc.tcd.ie

 **rec-app-help@tchpc.tcd.ie**  
to me 

28 Apr (7 days ago)   



[Show details](#)

The status of 'Location-Based Design Project (LBDP)' has been updated by the Committee.

Title: 'Location-Based Design Project (LBDP)'  
Applicant Name: Eleni Kapsimali  
Submitted by: Eleni Kapsimali  
Academic Supervisor: Nina Bresnihan  
Application Number: 20170205

Result of the REC Meeting: Approved

The Feedback from the Committee is as follows:  
This project may proceed.

The application can be viewed here:

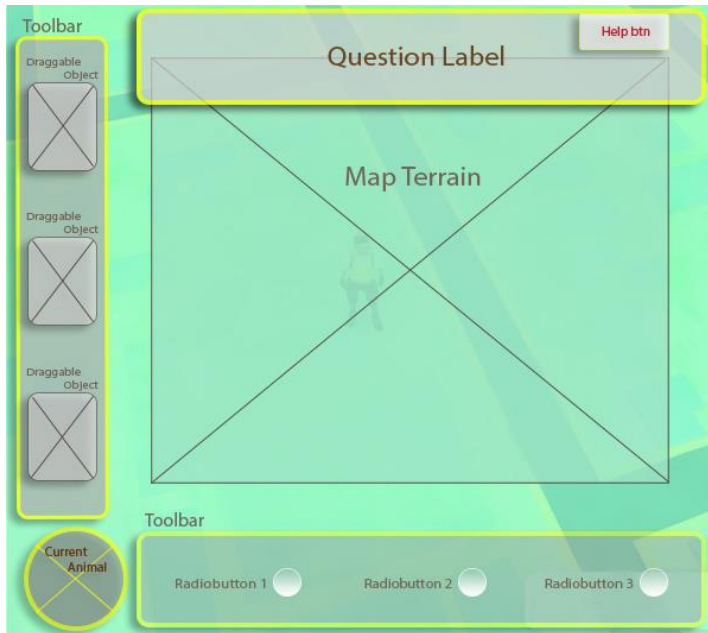
[https://webhost.tchpc.tcd.ie/research\\_ethics/?q=node/224](https://webhost.tchpc.tcd.ie/research_ethics/?q=node/224)

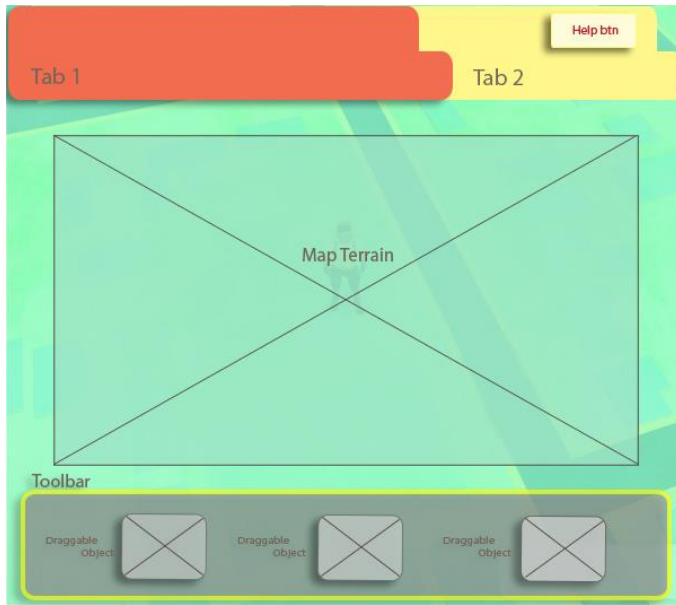
If amendments are required, please use the following link to edit the application and upload the changes:

[https://webhost.tchpc.tcd.ie/research\\_ethics/?q=node/224/edit](https://webhost.tchpc.tcd.ie/research_ethics/?q=node/224/edit)

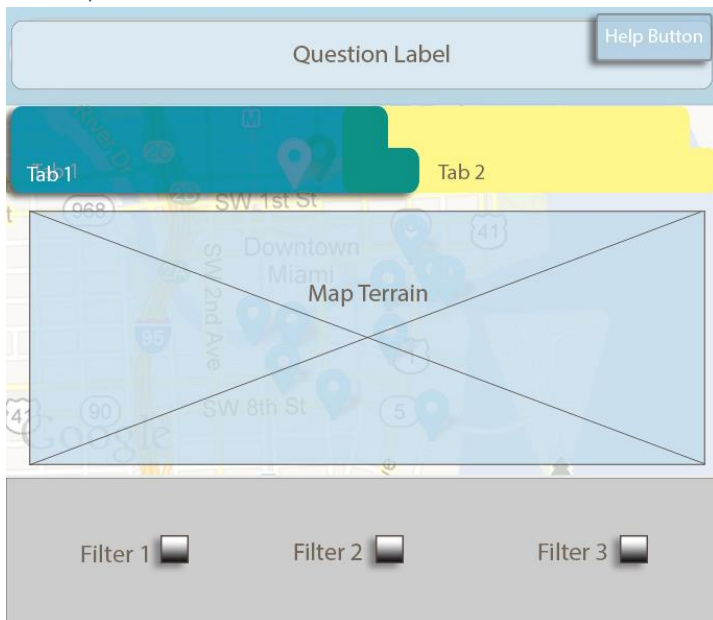
## Wireframes

### Pokémon Go

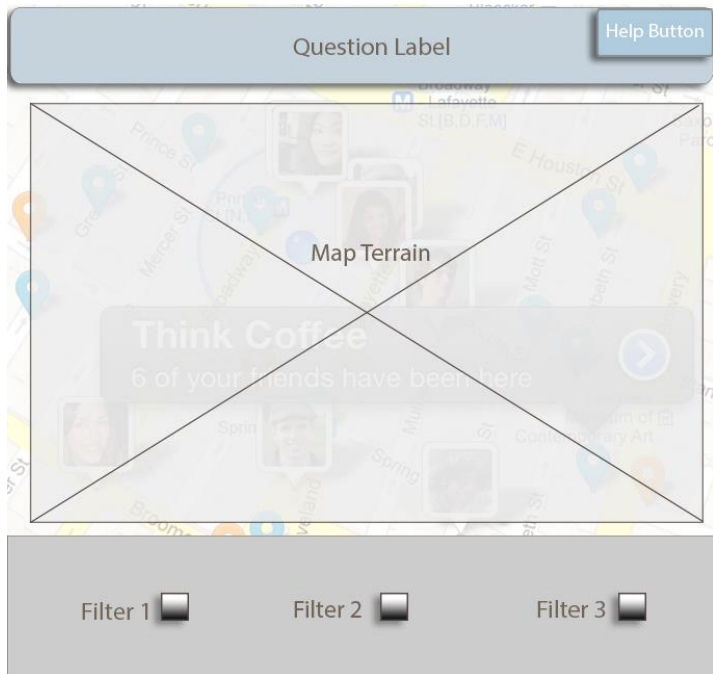




## Foursquare





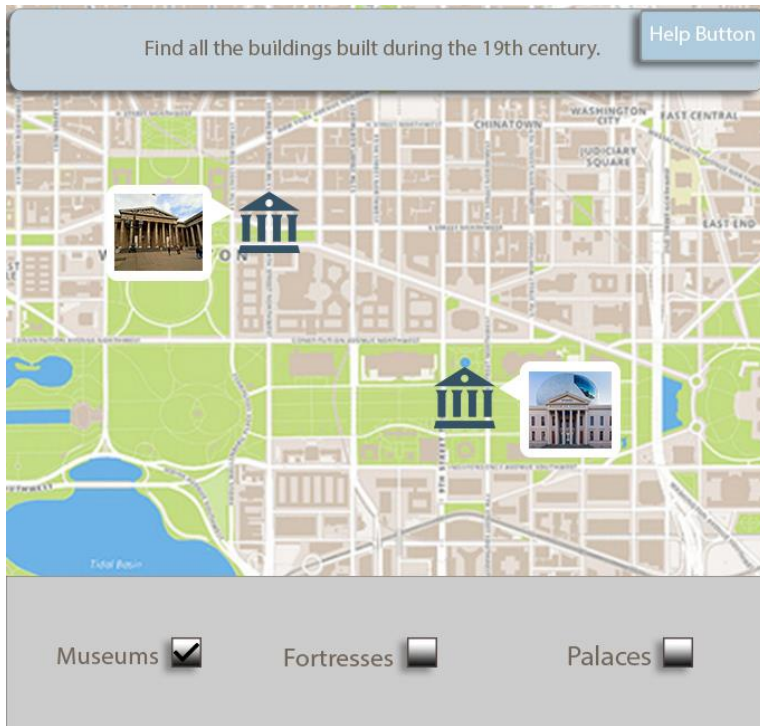


## Prototypes

### Pokémon Go



## Foursquare



## Design Table of Guidelines

Guidelines	References
1st Guideline	Adams, et al., 2008 Hourcade, 2015
2nd Guideline	Adams, et al., 2008 Meier, et al., 2014
3rd Guideline	Adams, et al., 2008
4th Guideline	Adams, et al., 2008 Hourcade, 2008
5th Guideline	C. Rinner 1, n.d.
6th Guideline	Vygotsky, 1978
7th Guideline	Adams, et al., 2008
8th Guideline	PhET Interviews, 2008

## Evaluation Table of Guidelines

Nielsen's Heuristics	Guidelines evaluated from a Design point of view	Guidelines evaluated from a Pedagogical point of view
1st Heuristic	Guideline 4	Navigation: Guideline 3 Feedback and designer/learner models: Guidelines 1, 2, 4
2nd Heuristic	Guideline 4	Cosmetic Authenticity: Guideline 7 Representation of the real world: Guideline 4
3rd Heuristic	No specification	No specification
4th Heuristic	Guideline 8	No specification
5th and 9th Heuristic	No specification	Interaction Flow: Guidelines 1, 3, 4, 8 Peripheral Cognitive Errors: No specification Metacognition: No specification
6th Heuristic	Guidelines 2, 3, 5, 6	Representational Forms: Guidelines 1, 2, 5
7th Heuristic	Guidelines 1, 2, 3, 4, 5	Multiple views/representations: Guideline 3 Tailoring the Interface: Guideline 8 Teacher Customization: No specification
8th Heuristic	Guidelines 7, 8	Superficial Complexity: Guideline 7
10th Heuristic	Guideline 6	Learner's support material: Guideline 6

## Bibliography

Adams, W. et al., 2008. *PhET Look and Feel*, s.l.: s.n.

C. Rinner 1, \*, M. R. 2. B. S. 1., n.d. *USER INTERFACE DESIGN FOR LOCATION-BASED DECISION SERVICES*, s.l.: s.n.

Chincholle, D. E. M. B. A., 2002. Location-Sensitive Services: It's Now Ready for Prime Time On Cellular Phones! . In: *Proceedings of the Conference on Designing Interactive Systems*. s.l.:s.n., pp. 331-334.

Fitts, P. M., 1954. The Information Capacity of the Human Motor System in Controlling the Amplitude of Movemen. *Journal of Experimental Psychology*, 0(47), pp. 381-391.

Flavell, J., Miller, P. & Miller, S., 2002. *Cognitive Development*. 4th ed. Upper Saddle River, New Jersey: Pearson.

Goktürk, M., 2016. *Fitts's Law*. [Online]

Available at: <https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/fitts-s-law>

[Accessed 2017].

Guha, M. et al., 2004. *Proceedings of Interaction Design and Children*. s.l.:ACM Press.

Hern, A., 2014. *Why Foursquare should be on everyone's phone*. [Online]

Available at: <https://www.theguardian.com/technology/2014/may/26/why-foursquare-isnt-just-the-timeline-spammer-you-thought-it-was-and-should-be-on-everyones-phone>

[Accessed 2017].

Houde , S. & Hill, C., 1997. What do prototypes prototype?. In: *Handbook of human-computer interaction*. Amsterdam: Elsevier Science, p. 367–381.

Hourcade, J., Bederson, B. & Druin, A., 2004a. Building KidPad: An Application for Children's Collaborative Storytelling. In: *Software Practice and Experience*. s.l.:s.n., pp. 895-914.

Hourcade, J. P., 2008. *Interaction Design and Children*. Hanover MA: now Publishers Inc. .

Hourcade, J. P., 2015. *Child-Computer Interaction*. s.l.:s.n.

Icomoon, n.d. *Library*. [Art].

Kain, E., 2016. *'Pokémon GO' Is The Biggest Mobile Game In US History - And It's About To Top Snapchat*. [Online]

Available at: <https://www.forbes.com/sites/erikkain/2016/07/13/pokemon-go-is-the-biggest-mobile-game-in-us-history-and-its-about-to-top-snapchat/#411a28995d5c>

[Accessed 20 April 2017].

Madebyoliver, n.d. *Gastronomy set*. [Art].

Markopoulos, P., Read, J., MacFarlane, S. & Höysniemi, J., 2008. Using Prototypes in Evaluation. In: *Evauation Childrn's Interactive Products*. s.l.:Morgan Kaufmann, pp. 41-44.

- Meier, S., Heidmann, F. & Thom, A., 2014. *A Comparison of Location Search UI Patterns on Mobile Devices*, Toronto, Canada: s.n.
- Nielsen, J., 1995a. *10 Usability Heuristics for User Interface Design*. [Online] Available at: <https://www.nngroup.com/articles/ten-usability-heuristics/> [Accessed 2017].
- Nielsen, J., 1995b. *How to conduct a heuristic Evaluation*. [Online] Available at: <https://www.nngroup.com/articles/how-to-conduct-a-heuristic-evaluation/> [Accessed March 2017].
- Norman, D., 1988. *The Design of Everyday Things*. 1st ed. New York: Doubleday.
- Papert, S. & Harel, I., 1991. *Constructionism*. s.l.:Ablex Publishing Corporation.
- Pascoe, J. R. N. a. M. D., 2000. Using While Moving: HCI Issues in Fieldwork Environments. *ACM Transactions on Computer-Human Interaction*, III(7), pp. 417-437.
- PhET Interviews, I. w. s., 2008. *A Study of Educational Simulations Part II – Interface Design* [Interview] 2008.
- Piaget, J., 1973. *The Child and Reality*. New York: Grossman.
- Piaget, J., 1995c. Logic and Psychology. In: *The Essential Piaget*. London: Aronson, pp. 445-447.
- Piaget, J. & Inhelder, B., 1969. *The Psychology of the Child*. H. Weaver ed. New York: Basic Books.
- Rosenbloom, L. & Horton, M., 1971. The maturation of fine prehension in young children.. *Developmental Medicine and Child Neurology*, Issue 13, p. 38.
- Squires, D. & Preece, J., 1999. Predicting quality in educational software: Evaluating for learning, usability and the synergy between them. *Interacting with Computers*, 11(3), pp. 467-483.
- Squires, D. & Preece, J., 1999. Predicting quality in educational software:: Evaluating for learning, usability and the synergy between them. *Interacting with Computers*, 11(5), pp. 479-480.
- Tognazzini, B., 2014. *First Principles of Interaction Design (Revised & Expanded)*. [Online] Available at: <http://asktog.com/atc/principles-of-interaction-design/> [Accessed 2017].
- Urquhart, K. et al., 2004. Exploring the Usefulness of Cartographic Representations for Location-Based Services in an Austrian Context. *Journal of Spatial Science*, 1(49), pp. 71-87.
- Vygotsky, L., 1978. *Mind in society: The development of higher psychological processes*. Cambridge: MA: Harvard University Press.
- Wang, E., n.d. *Checked*. [Art].
- Wood, D., Bruner, J. & Ross, G., 1976. The role of tutoring in problem solving. *Journal of child psychology and psychiatry*, II(17), pp. 89-100.

