MOBILE PLAYFUL LEARNING ENVIRONMENTS: CONCEPTUAL FOUNDATIONS FOR INFORMAL LEARNING ENVIRONMENTS IN THE DIGITAL AGE

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GLOSSARY

Digital Literacy Digital literacy is a term used to describe the ability to use information technologies with ease and competence such as to locate, filter, compare and judge digital information, as well as skills in data analysis (Gallardo-Echenique et al., 2015)

Digital Natives People who are grown up with digital technology and naturally drawn to social networks, search engines or instant messaging systems to access, communicate and share information (Prensky, 2001; Tapscott, 2008)

FBM Fogg's Behavioral Model, Fogg (2009) proposes a model to design systems that impact the user on an affective level based on motivation, ability and triggers

Formal Learning Learning that happens within a formal learning setting like a classroom and leads to some sort of certifcation. Goals and objectives are defined and planned by the instructor (Malcolm et al., 2003)

Informal Learning Learning that is unstructured and takes place outside traditional, formal learning settings (like a classroom). Informal learning is usually the result of an unplanned or an unexpected event. There are no clear goals defined. It is often self-directed by the learner (Malcolm et al., 2003)

Learning Analytics Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs (Duval, 2011)

Lifelong Learning A a form of self-initiated education that is focused on personal development and covers the whole range of types of learning, including: formal, informal and non-formal learning (Laal & Salamati, 2012)

LMS Learning Management System, a learning environment which facilitates the distribution and management of course related resources (Mott & Wiley, 2009)

MPLE Mobile Playful Learning Environment, a reference model to guide the creation of informal learning environments

Non-Formal Learning An hybrid form of formal and informal learning, often exemplified by school trips where the teaching instance provides room to the students to define their own rules and strategies to accomplish a goal (Malcolm et al., 2003)

OLN Open Learning Network, a software tool that connects to informal and formal learning spaces with the help of plugins and combines the concepts of LMS and PLE (Mott & Wiley, 2009)

Persuasive Technology Persuasive technology is broadly defined as technology that is designed to change attitudes or behaviors of the users through persuasion and social influence (Fogg, 2002)

Playful Learning Environment A learning environment that combines learning activities with information and communication technologies both in the classroom and in outdoor spaces (Kangas, 2010)

Playfulness Playfulness can be seen as a type of interaction with learning material that involves fun and enjoyment to facilitate engagement and motivation in the learning process (Nicholson, 2015)

PLE Attwell (2007), Vassileva and Sun (2008) proposed the model of Personal Learning Environments (PLE) in which learners draw connections from a growing matrix of resources and tools (search engines, bookmarking, blogging, social networks) that they select and organize to construct their own understanding

TELE Technology Enhanced Learning Environment

UX User Experience

Abstract

In practice, most learning is done in a classroom environment including face to face instruction and training. This type of learning is called formal learning. Classroom-based learning and teaching has several advantages but frequently also faces difficulties. It might be difficult to gain attention from everyone in a large class and motivate all learners due to the "one-size fits everybody" approach usually applied. On the other hand, there is the ever-widening accumulation and access to information technologies. In theory, this could lead to a world where no boundaries to knowledge construction exist anymore. With a tap on a smartphone or a computer, people are able to search for relevant facts on any topic. The hyperlink structure of digital information spaces makes it possible to interactively explore related content. Search results can generate insights which in turn result in associations for new queries, creating infinite trails of information and knowledge. A new generation of learners is growing up who seems to navigate these complex information environments with ease. In the literature, they are called Digital Natives, Generation Y or Net Generation. They immerse in digital technologies, not only to be entertained but also to develop a collective understanding of politics, culture and society. When this is done voluntarily, the learning is much more driven by personal goals and interests. Opposed to formal school learning, this type of learning, also called informal learning, is not centered around the examination of educational goals and does not lead to a certification. It is an important part of lifelong learning which is the "ongoing, voluntary, and self-motivated" pursuit of knowledge for either personal or professional reasons. This type of learning could mitigate some of the disadvantages of classroom-based learning and offer tailored learning experiences to every student. Based on personal interests and learning aims students could access information autonomously and self-directed.

While independent and informal learning is an admirable aspiration, many learners will still need guidance in their informal learning process. Especially, youngsters (often called digital native learners) have an ambivalent relationship with the overabundance of information and tools available. Research has shown that on the one hand they are used to a wide range of information technologies in their daily life, but on the other hand they seem to miss the necessary information literacy skills to deal with this amount of information. Leaving them entirely alone in learning activities can result in a loss of motivation or even a cynical attitude towards learning in general and increased dropout rates. The current Corona crisis has confirmed this. Even within the context of formal learning and with the guidance of the school and teachers, at lot of youngsters have a hard time to adapt to the online learning situation and to stay motivated. Without guidance, it would only become worse.

Therefore, and in the same vein as formal learning makes use of Learning Management Systems, we argue that informal learning can benefit from the support of some form of digital learning environment. Such a learning environment should provide ways and guidance for people to explore interests and exploit them for future opportunities. It should also show ways to integrate informal learning practices with the (digital) classroom in order to mitigate the digital divide which still exists between classroom-based learning and informal learning. Providing a conceptual framework for such a learning environment is the subject of this dissertation. The goal was to develop a reference model for such a type of learning environment. To develop this model, we first investigated the major requirements for such an environment. For this, we formulated different research questions and performed an extensive literature study to provide answers to these questions.

Based on all the findings, we defined and motivated the main features of our model and explained how the different components interact with each other to achieve the main goal, i.e. supporting youngsters in informal learning, as well as other types of learning. In this way, we reached our research objective: a reference model for creating digital envi-

ronments that offer opportunities for lifelong learning and support for informal as well as formal learning activities, and which are suitable for digital natives, more in particular for youngsters. We called our model the Mobile Playful Learning Environment (MPLE) model because the mobile aspect and the playfulness turned out to be main features in our model. Based on the defined MPLE model and as a proof of concept of such an environment, we developed TICKLE, a platform for mobile playful learning environments for youngsters.

Our research followed the Design Science approach which means that we generated scientific knowledge through cycles of sketching and evaluating different versions of our model with the means of a proof-of-concept application (TICKLE). Theoretical findings from literature and practical insights from user studies were incorporated into the design of the model and indirectly tested by means of the proof-of-concept application with a number of user evaluations.

TICKLE itself is developed using a User Experience (UX) design methodology, which addresses more than just the functionality and usability — it also considers how users feel about a product. Starting from the "Why", the needs and emotions of the user are clarified and then used to specify the so-called Be-and Do-Goals, where Be-goals capture a person's emotion and attitude about using a particular software and the Do-goals refer to the pure functionality. TICKLE has been evaluated in different contexts, including different purposes, and shows to be promising.

The contributions of the thesis are: (1) a clarification of the conceptual foundations for digital learning environments to support informal learning and lifelong learning; (2) the identification of fundamental features for such digital learning environment; (3) the definition of the Mobile Playful Learning Environment (MPLE) model, being a reference model that can be used as a starting point for developing digital learning environments aiming to support informal learning or lifelong learning; (4) TICKLE, a proof of concept application for the MPLE model, developed as a generic mobile playful platform suitable for supporting different activities, for different users, and in different domains.

CHAPTER 1
INTRODUCTION

Generally, a classroom environment with face-to-face teaching is the traditional way of learning. With this type of learning, the teacher or the instructor can explicitly observe the real-time interaction and participation of the learners. The advantage is that the instructor can provide the appropriate intervention immediately. However, in classic classroom learning one may also face some difficulties. For example, in a large classroom the instructor may find it difficult to gain attention from everyone or motivate everybody due to the "one-size-fits-all" approach usually applied, and the use of specific teaching methods, such as flipped classroom, problem-based learning, or active learning, can be challenging with a large class size (Asada & Harris, 2020). On the other hand, in an ideal world, the ever-widening accumulation and access to information facilitated by modern communication technologies could lead to a situation of no boundaries to knowledge construction. Indeed, we can just take the smartphone out of our pocket and follow up the infinite trails of information. This type of learning could be used to complement classroom-based learning and mitigate some of the issues. In addition, this way of knowledge construction could also be important in Lifelong Learning which is the "ongoing, voluntary, and self-motivated" pursuit of knowledge for either personal or professional reasons (Sharples, 2000).

However, in practice, most people are often overwhelmed by the sheer amount of information faced in the digital world. They do not always possess the skills to make sense of all of it (Bawden & Robinson, 2009; Schmitt et al., 2018). In particular, digital literacy skills (Ng, 2012), i.e. the ability to locate, filter, compare and judge digital information, as well as skills in data analysis become increasingly important for this kind of learning (Gallardo-Echenique et al., 2015). At the same time, the current generation of learners seems to navigate complex information environments with ease (Koutropoulos, 2011). In the lit-

erature, they are called *Digital Natives*, *Generation Y* or *Net Generation*, grown up with digital technologies and naturally drawn to social networks, search engines or instant messaging systems to access, communicate and share information (Prensky, 2001; Tapscott, 2008). They immerse in digital technologies, not only to be entertained but also to develop a collective understanding of politics, culture and society (Ito et al., 2013). This knowledge acquisition is mostly driven by personal goals and interests. Often knowledge is co-created within an online community as means to follow up a certain hobby or interest. Opposed to Formal Learning, this type of learning, also called Informal Learning (Maarschalk, 1988a; Tamir, 1991), is not centered around the examination of educational goals and does not lead to a certification. However, it is an important part of Lifelong Learning, which is learning that can no longer be dichotomized into a place and time to *acquire* knowledge (school) and a place and time to *apply* knowledge (the workplace) (Fischer, 2000).

In formal education, *Learning Management Systems* (LMS) are the main tools to provide structure and support for traditional forms of learning. A LMS allows teachers to quickly distribute course content, assignments and announcements. Students can submit assignments to the LMS through digital dropboxes and teachers can grade their work and return feedback within the system. Traditional LMSs are teacher or institution centric because the course structure and content are created by the teacher. Student-initiated activities and interactions are mostly limited to content consumption. LMSs help to make teaching processes more efficient by streamlining content management, delivery, grading and analytics. Attwell (2007) and Vassileva and Sun (2008) also observed that modern learners have different patterns of information access, attention, and learning preferences which could not be satisfied by traditional LMSs in these days. Therefore, they proposed the concept of *Personal Learning Environment* (PLE) in which learners utilize a collection of resources and tools (search engines, bookmarking, blogging, social networks) that they manage to take control over their own learning. To bridge, at that time, the the gap between a PLE and a LMS, *Open Learning Networks* (OLN) (Mott & Wiley, 2009) were introduced, which

combined the best elements of each approach. They consisted of a series of modules that leverage the open architecture of the Web. Existing LMSs were connected with web-based tools, applications, content stores, and a service layer that allowed them all to function together seamlessly. Until now, not many implementations of OLNs have been realized. In (Wilson et al., 2009) an extension of the Moodle LMS using the W3C Widget and the Google Wave technology that enabled the user to use informal learning functionality inside Moodle, is presented. Unfortunately, Google Wave was discontinued in 2012. In (Conde et al., 2013) a service-based framework to facilitate interoperability between a OLN and a LMS is presented. In this way, OLN remains mainly a theoretical concept and has not been widely adopted by schools or universities. There are several reasons for this. First, LMSs often lack interoperability functionality to classify and track learner data in other platforms. Second, the distributed nature of informal learning makes it hard to validate and represent learning activities meaningfully in the OLN. Often, the user is not aware in which situations she or he is learning. To gain awareness, the user should have means to reflect about what he or she has done and then find a way to classify and publish the knowledge gained (Conde & Hernández-Garcıa, 2019). Third, students are rarely willing to use an additional tool to support their learning because they might be already using a set of tools as PLE, or are sceptical about institutional IT solutions – they find them boring to use because they do not have engaging ways to interact with content (Judd, 2018). In addition, and similar to PLEs, using an OLN requires skills in dealing with complex information tasks. Not everybody has the courage, self-discipline, knowledge, or motivation to engage in these activities (Throuvala et al., 2020; Wakefield & Frawley, 2020; Wu & Cheng, 2019). Even for highly motivated users who have strong skills in information management, an OLN can be complex and overwhelming. With a steady stream of information and tools available, it is likely to miss out important information. Moreover, when information is scattered across different tools, it is hard for users to create a mental model of the complete learning environment. Especially digital native learners have an ambivalent relationship with this

overabundance of information and tools (Selwyn, 2009). On the one hand, they are used to a wide range of information technologies in their daily life: "They use search engines and social networks as a first port of call for knowledge unlike older generations who were used to printed press, radio and television" (Helsper & Eynon, 2010). Information is received really fast and activities are frequently switched. High visual content, animation and interactivity is preferred over static textual content (Dresang, 2005; Prensky, 2001). Digital native learners expect information to give answers as well as to be engaging (Radford et al., 2007). However, the apparent familiarity and competence with computers disguises some worrying problems in information literacy (Judd, 2018; Y. Li & Ranieri, 2010; Pettenati et al., 2009; Thompson, 2015a). Fast switching between activities often results in a superficial view rather than an in-depth understanding of information. The speed of young people's information seeking suggests that little time is spent in evaluating information, either for relevance, accuracy or authority (Bowler et al., 2018; Selwyn, 2009). Due to the sheer amount of information available nowadays, digital learners have a poor understanding of their information needs which makes it difficult to access information target oriented.

While independent learning is an admirable aspiration, many learners will still need guidance in their learning process. Leaving them entirely alone in learning activities can result in a loss of motivation or a cynical attitude towards learning in general (Ferrando et al., 2012) and increased school dropout rates. Therefore, we argue that even for informal learning, a learning environment could provide added value. Such a learning environment should provide ways and guidance to explore interests and exploit them for future opportunities from a personal, professional or educational perspective. A conceptual framework for such learning environments is the subject of this thesis.

In the following sections, we discuss the research objectives of the thesis, the research methodology used, and the structure of the thesis.

1.1 Research Objectives

As already mentioned, many learners will continue to require guidance in the learning process, even for informal learning. Moreover, students do not learn all at the same speed nor have all the same learning style or habits (Jonassen & Grabowski, 2012). An good learning environment should consider students' background, needs, characteristics and guide them accordingly. It should provide ways to allow users to explore interests and hobbies in a self-regulated way and exploit them for future opportunities. Our work aims to contribute to the design and development of such learning environments. The focus is on learning environments that can stimulate the intrinsic motivation for informal as well as formal learning while mitigating the problems of PLEs and OLNs (as mentioned above). Note that intrinsic motivation drives an individual to perform an activity for personal satisfying reasons rather than for obtaining some external reward as with extrinsic motivation.

Our main research objective is **to design a reference model for creating digital environments that offer opportunities for lifelong learning and can support informal as well as formal learning activities, and which are suitable for digital natives, more in particular youngsters**. According to (Shields & Rangarajan, 2013) a reference model can be seen as an abstract framework for understanding significant relationships among the entities of a particular domain. The aim is to develop a consistent standards or specifications to support this domain. A reference model is based on a small number of unifying concepts and may be used as a basis for education and explaining standards to a non-specialist. Such a model is not directly tied to any standard or technologies, it tries to provide common semantics that can be used unambiguously between different implementations.

The first research question that we need to answer is as follows:

- **RQ1: How to empower the learner to realize that learning is not only a way to succeed in a formal school context but also a way to improve other areas of personal and social life from a lifelong learning perspective?**

We need to investigate this because of our focus on intrinsic motivation for informal learning. Reflection seems to be essential for learning (Boud et al., 2013). Reflecting on past experiences can lead to new insights and changes in behavior. Lately, interest emerged on how technology can support human reflection to increase self-knowledge and inform actions to change behavior (Rowanne Fleck, 2010). Therefore, a special emphasis will be put on supporting self-reflection related to areas of personal and social life for the purpose of learning.

On the other hand, guiding and motivating the learner in a more extrinsic way is also important for successful learning (Knowles, 1975). To realize this, the following research question needs to be answered:

- **RQ2: How can we guide the learner in the learning process and persuade him to be active while maintaining the openness and non-committal character of informal learning?**

To answer this question, we look into *persuasive technology* (Fogg, 2002). Persuasive technology can help to reduce the cognitive effort to embark on learning activities through the use of social influence principles (Müller et al., 2012). As one of the first, JB Fogg studied the concept of persuasive technology (Fogg, 2002) and how we can design systems that impact the user on an affective level. He proposed the Fogg's Behavior Model (FBM) (Fogg, 2009) that provides the factors that can induce a certain behavior (Muntean, 2011). Note that so-called reflective technology such as Blogs, Wikis or Multimedia (digital stories, podcasts) can also help to facilitate reflection.

Applying persuasive technology and reflective technology for answering RQ1 and RQ2 yields the following additional research questions:

- **RQ3: What is the role of reflection in the persuasion process and what techniques are available to facilitate reflection?**

- **RQ4: Which aspects of existing persuasive and reflective technology can be applied?**

Information visualization techniques have been proven to be a powerful means to enable reflection, persuasion and decision making in various domains such as business or scientific research (Liu et al., 2014; Medler & Magerko, 2011). Building on our human perceptual capabilities, information visualization makes use of computer-supported, interactive, visual representations to understand the meaning of large amounts of abstract data without overburden human cognition (Card et al., 1999). However, most practitioners have approach information visualization from a technical and analytical perspective: visualizations were, for instance, used to gain insight in customer data to maximize profits or to support analysis of scientific experiments. More recently, visualizations for reflection and decision making have been applied in learning. Learning analytics platforms have shown that through tracking, analyzing and visualizing learner-related data, the student's performance can be improved. For instance, (Charleer et al., 2013) improved awareness and reflection through collaborative, interactive visualizations of badges, and the Blackboard LMS offers tools that allow students to monitor their level of online course engagement to reinforce learning behavior ("Blackboard Data & Analytics", n.d.). In this context, visual accounts can help to raise awareness about personal strengths and shortcomings, which can help to set up learning goals and improve learner development (Duval, 2011). However, Learning Analytics tools are often embedded in a course context (Verbert et al., 2013). They do not necessarily establish a link to informal learning. Often, they rely on data collected by an LMS, such as the total time spent on the course, the average time spent on a document, or the number of documents used. To apply visualization techniques to our solution, the following research questions need to be answered:

- **RQ5: Which visualization techniques are suitable for self-monitoring in the context of informal learning?**

- **RQ6: What kind of data can be accumulated in the learning process and how can this data be transformed into a meaningful visualization?**

Note that developing applications for informal and formal learning is a broad topic that cannot be captured in its entirety in a single thesis. Therefore, our research will focus on key aspects of informal learning activities in terms of discovery of activities and reflective practices. We will also explore ways to interoperate with traditional LMSs.

1.2 Research Methodology and Outline

1.2.1 Research Methodology

Design deals with creating a new artifact that does not exist yet. If the knowledge required for creating such an artifact is not known yet then the design is innovative, otherwise it is routine work. Innovative design may call for the use of design science research to fill the knowledge gaps and may result in research publications or patents (A. Hevner & Chatterjee, 2010). Design science research is an approach to research with a goal to construct a new reality (i.e. solve problems) instead of explaining an existing reality, or helping to make sense of it. Design science research looks to develop valid and reliable knowledge for designing solutions (A. R. Hevner et al., 2004). Horváth et al. (2007) states that design science research has to utilize the gained knowledge to solve problems, create change or improve existing solutions and generate new knowledge, insights and theoretical explanations. Design research is a diverse activity because it synthesizes knowledge from many sources, but it also generates knowledge on its own, constructs its own understanding of the world by interpreting phenomena in design context, and creates mental models.

Our research will follow the design science approach as our main research objective is to design a new artifact, i.e. a conceptual framework for creating environments that offer opportunities for lifelong learning and can support informal as well as formal learning activities, and which are suitable for digital natives. In this context, we will generate scientific

knowledge through cycles of sketching and evaluating different versions of our conceptual framework with the means of a proof-of-concept application, which is a reference implementation of our framework (Offermann et al., 2009). Using a design science methodology means that we follow the six steps of the methodology: (1) problem identification and motivation, (2) definition of the objectives for a solution, (3) design and development, (4) demonstration, (5) evaluation, and (6) communication.

1.2.2 Research Outline

In this section, we explain how we applied the design science research methodology to our research project. We do not give an overview of the different chapters. This is done in section 1.5. Rather, we provide an overview of our research method and steps taken in order to answer the research questions and reach our research objective.

Figure 1.1 shows an overview of our research steps. In step 1 we identify the problem and motivate our solution which also sets the scope of literature we had to studied, which was done in step 2. The results from the background literature informed the conceptualization of the reference model that we called *Mobile Playful Learning Environment MPLE model* (step 3), and which answered RQ1 to RQ4. The identified concepts of the MPLE model such as self-monitoring, playfulness, and persuasion, also functioned as categories to consider related applications and frameworks and compare them with our work (step 4). The results from step 3 and the insight we gained in step 4 guided the design of TICKLE as a proof of concept for the MPLE model (step 5). It is a platform that provides an infrastructure to create MLPEs for different but similar use cases in the education domain (shown with Prototype 1, Prototype 2, and Prototype 3). In the context of this platform, RQ5 and RQ6 have been answered. By performing user studies with our proof-of-concept prototypes, we have indirectly tested whether our reference framework succeeds in its objectives (and our research objective), i.e. providing guidance in creating a learning environment that focus on facilitating informal and Non-Formal Learning.

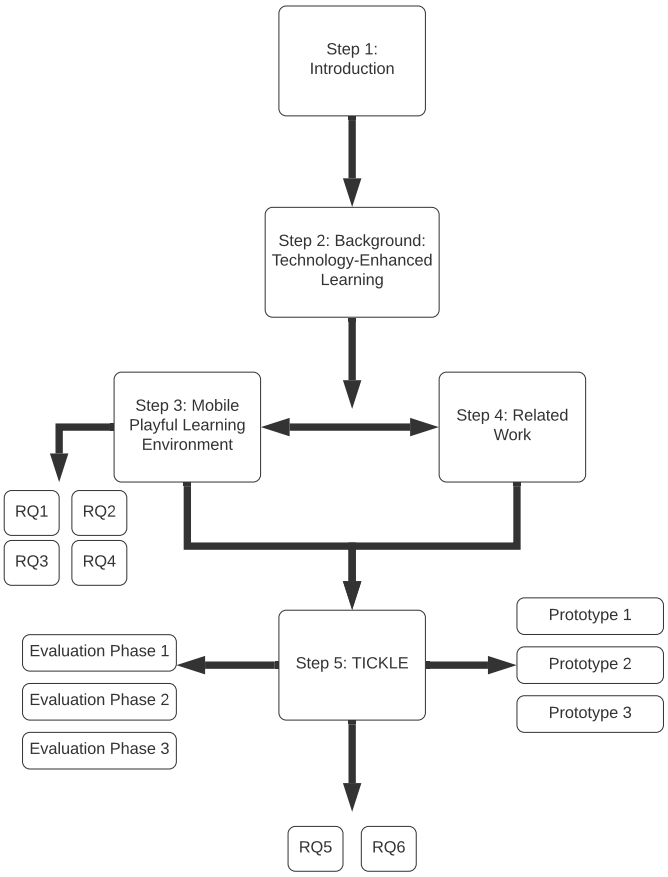

Figure 1.1: Graphical depiction of our research

In step 5, next to the theoretical findings from literature (step 3) and related work (step 4), practical insights from our user studies were incorporated into the design of TICKLE in an iterative way. TICKLE was developed using a User Experience (UX) design methodology which addresses more than just the functionality and usability — it also considers how users feel about a product (Hassenzahl, 2013). Starting from the Why question, UX design clarifies the needs and emotions involved in an activity by specifying Be- and Do-Goals. The first type of goals refers to the perceived ability to support the achievement of a task, whereas the second denotes non-functional aspects such as being autonomous, competent, related to others, stimulated, and popular (Hassenzahl, 2008). Only then, it determines the functionality to provide the experience and how it can be realized. In the past, this UX design methodology has been used for different user-oriented systems (Hassenzahl, 2013;

Hassenzahl et al., 2010), but rarely in an Information Visualization design context, which focuses too often on low-level analysis tasks such as information retrieval, filtering or sorting. However, the personal dimension, i.e. why the user wants to obtain a certain insight and how we can stimulate the motivation to do so, as was needed in our case, is equally important in the design process (Brehmer & Munzner, 2013).

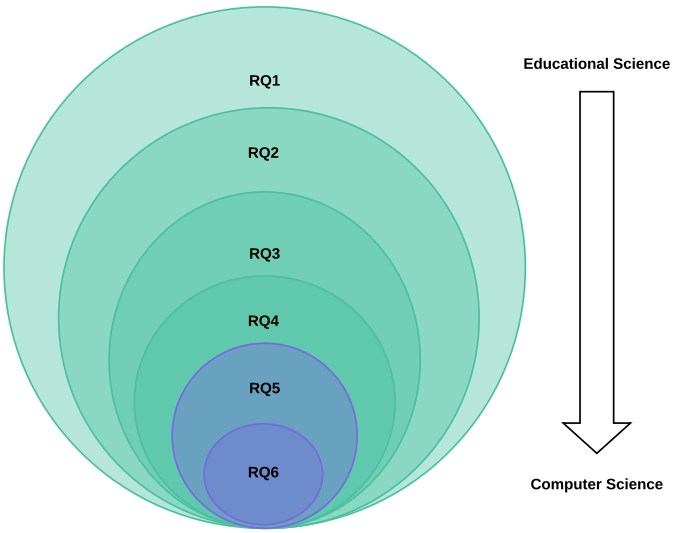

Figure 1.2: Overview of the research questions

Figure 1.2 shows an overview of the generality of the research questions and the degree of Educational Science and Computer Science involved in answering them. RQ1 (How to empower the learner to realize that learning is not only a way to succeed in a formal school context but also a way to improve other areas of personal and social life from a lifelong learning perspective?) is the most high-level question and is embedded to a high degree in educational science. This question has set the field for the other questions, which have an increasing degree of computer science involved in answering them. RQ2 (How can we guide the learner in the learning process and persuade him to be active while maintaining the openness and non-committal character of informal learning?) is targeting software-oriented techniques to simplify the process of convincing youngsters to be active in learning. In this regard, the sub-question RQ3 (What is the role of reflection in the persuasion process and what techniques are available to facilitate reflection?) focus on

a key aspect of learning and persuasion called reflection, and the related concept of self-monitoring. This research question can be positioned in the domain of human computer interaction (Dix et al., 2003) but also has links to the field of psychology and cognitive science. Sub-question RQ4 (Which aspects of existing persuasive and reflective technology can be applied?) calls for methods and techniques that can be applied from existing technology to facilitate persuasion and reflection. The scope of RQ4 is not limited to the analysis of existing persuasive and reflective technology candidates but also incorporates techniques from information visualization and learning analytics, which are also captured in RQ5 (Which visualization techniques are suitable for self-monitoring in the context of informal learning?). Last but not least, RQ6 (What kind of data can be accumulated in the learning process and how can this data be transformed into a meaningful visualization?) is concerned with the type and format of the data that can be accumulated in the learning process and can be transformed into a meaningful visualization. This research question is situated fully in the information visualization domain. We can conclude that although some of the research questions have strong links to the educational domain or related fields such as psychology and cognitive science, the focus is on answering them in the context of computer science. Therefore, only knowledge from these other domains is not sufficient to answer the questions; the knowledge must be embedded in a solid foundation of computer science methods such as human computer interaction models including persuasive/reflective technology and information visualization techniques.

1.3 Contributions

Our contributions can be summarized as follows:

- First of all, we clarified **the conceptual foundations for digital learning environments for informal learning** by reviewing paradigms for lifelong learning as well as other relevant types of learning. Next, we analyzed existing digital learning environment constructs, i.e. Learning Management Systems, Personal Learning Environ-

ments, Open Learning Networks, Playful Learning Environments, and Smart Learning Environments, from the viewpoint of supporting informal and lifelong learning to find the shortcomings of these environments in this respect, as well as **fundamental features for such digital learning environments**. This is the subject of Chapter 2.

- Based on the concepts and features derived from the investigation, we defined **the Mobile Playful Learning Environment (MPLE) model**. This is a reference model, meaning that it is an abstract framework consisting of a set of clearly defined concepts and the relationships between the concepts. This model can be used as a starting point for developing digital learning environments aiming to support informal learning or lifelong learning. This model does not only describe fundamental conceptual features to be included in such an environment and how they should interact, it also presents a set of functional components needed to support the realization of those features. This model is unique in the sense that it targets the sweet spot between a conceptual framework which normally gives only high level account of concepts (e.g. information visualization, persuasion, playfulness), a data pipeline to show the flow of data and dependencies between components, and design guidelines to apply such concepts to provide a positive user experience. The Mobile Playful Learning Environment model is described in chapter 3.

- We designed and implemented **a proof of concept application, called TICKLE**, to demonstrate and evaluate the potential of our MPLE reference model. On the one hand, TICKLE shows that a technical implementation of our model is feasible, but on the other hand it is also used to indirectly evaluate the model by evaluation the proof of concept application with real users. Furthermore, TICKLE proved to be **a generic mobile playful platform suitable for supporting different activities, for different users, and in different domains**. For example:

  - TICKLE was used as a reactivation tool for youngsters in the context of school

dropout, as shown in this thesis

  - TICKLE can be used as a civic engagement for elderly people, as shown in (Lindberg et al., 2019)
  - Other opportunities can be found in adult learning, in advertising employment opportunities, in marketing of physical shops, for takeaway restaurants, in tourism, to inventory particular organizations and institutes, ...

TICKLE is presented and discussed in Chapter 5.

1.4 Related Publications

- Maushagen, J. & De Troyer, O. "A Reference Model For Mobile Playful Learning Environments" Proceedings of the 17th International Conference Mobile Learning. 2021. (accepted for publication)
  - My contribution was the creation of the MPLE model and the writing of the paper.
- De Troyer, O., Maushagen, J., Lindberg, R., & Breckx, D. (2020). Playful Learning with a Location-Based Digital Card Environment: A Promising Tool for Informal, Non-Formal, and Formal Learning. Information 2020, 11(3), 157 (Special Issue Advances in Mobile Gaming and Games-based Leaning)
  - The main content of the paper is based on the design and development of TICKLE, which was completely part of the PhD work. My contribution to the writing was mainly concerned with the technical aspects such as the implementation of the TICKLE tool.
- De Troyer, O., Maushagen, J., Lindberg, R., Muls, J., Signer, B. & Lombaerts, K. (2019). A Playful Mobile Digital Environment to Tackle School Burnout using Micro Learning, Persuasion & Gamification: Design Approach & Architecture. In: 2019

IEEE 19th International Conference on Advanced Learning Technologies (ICALT). IEEE Computer Society, p. 81-83

  - My contribution to the writing was mainly concerned with the technical aspects of the TICKLE tool.

- Lindberg, R.S.N., Maushagen, J., & De Troyer, O.. (2019). Combining a Gamified Civic Engagement Platform with a Digital Game in a Loosely Way to Increase Retention. In Proceedings of the 21st International Conference on Information Integration and Web-based Applications Services (iiWAS2019). Association for Computing Machinery, New York, NY, USA, 679–683.

  - The platform presented in this paper is based on the TICKLE platform, which was developed in the context of my PhD work. My contribution to the writing was mainly concerned with the technical integration of two loosely coupled platforms.

1.5 Structure of the thesis

Next to this introduction, the thesis consists of five chapters:

- Background: Technology Enhanced Learning
- Mobile Playful Learning Environment Model
- Related Work
- Proof of Concept Application: The TICKLE Case
- Conclusions, Limitations and Future Work.

Their role and content is as follows:

Background: Technology Enhanced Learning

This chapters reports on step 2 of our research outline. By performing a literature review, we will gain a first insight into how a MPLE solution can be realized. Different types of lifelong learning will be analyzed and popular and relevant learning paradigms will be reviewed. Subsequently, information/learning needs, and literacy of digital native learners will be discussed in terms of problems faced when these digital natives engage in learning activities. We also provide an overview of technology-enhanced learning environments and investigate shortcomings as well as fundamental features in the context of informal and lifelong learning. We conclude the chapter with an overview of the findings. These findings will serve as the theoretical foundation for our solution (i.e. our Mobile Playful Learning Environment Model).

Mobile Playful Learning Environment (MPLE) Model

In this chapter, we define our reference model for Mobile Playful Learning Environments (step 3). We motivate the main features of the model and also present its learning pipeline to indicate how these main features interact with each other. The motivation for the model's features builds upon already known work in the domain of Human Computer Interaction (HCI), namely Reflection Models, Information Visualization, and Persuasive Technology. This chapter is based on the following publication:

- Maushagen, J. & De Troyer, O. "A Reference Model For Mobile Playful Learning Environments" Proceedings of the 17th International Conference Mobile Learning. 2021

Related Work

In this chapter, we report on the work done in step 4 by describing the related work in detail. Therefore we compare existing technology enhanced learning environments from three different perspectives, i.e. systems supporting different forms of lifelong learning, systems with capability for self-reflection, and systems providing persuasive strategies and playful techniques. Next, we also review existing models and frameworks in the domain. Parts of this chapter is based on the following publication:

- Maushagen, J. & De Troyer, O. "A Reference Model For Mobile Playful Learning Environments" Proceedings of the 17th International Conference Mobile Learning. 2021

Proof of Concept Application: The TICKLE Case

In this chapter, we describe the proof-of-concept application developed for our MPLE model, called TICKLE, in step 5. TICKLE aims to empower learners to perform and reflect on informal/formal learning activities. We describe and motivate the principles used, the main modules of the environment, as well as its iterative development by means of cycles of creating and evaluating different prototypes. The goal was to verify:

- Whether we can create a learning environment that combines informal and formal learning practices based on principles established in the Mobile Playful Learning Environment Model;

- Whether such an environment would be used by youngsters and whether it can spark interest in reflection and self-monitoring.

Parts of this chapter are based on the following publications:

- De Troyer, O., Maushagen, J., Lindberg, R., Muls, J., Signer, B. & Lombaerts, K. (2019). A Playful Mobile Digital Environment to Tackle School Burnout using Micro

Learning, Persuasion & Gamification: Design Approach & Architecture. In: 2019 IEEE 19th International Conference on Advanced Learning Technologies (ICALT). IEEE Computer Society, p. 81-83

- De Troyer, O., Maushagen, J., Lindberg, R., & Breckx, D. (2020). Playful Learning with a Location-Based Digital Card Environment: A Promising Tool for Informal, Non-Formal, and Formal Learning. Information 2020, 11(3), 157 (Special Issue Advances in Mobile Gaming and Games-based Leaning)

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Conclusion, Limitations and Future Work

In this chapter, we provide a summary of our work and we reflect on the contributions of the thesis. We also discuss limitations and possible directions for future work.

CHAPTER 2
BACKGROUND: TECHNOLOGY-ENHANCED LEARNING

In this chapter we provide theories, knowledge and systems related to our research. The focus is on technology-enhanced learning for lifelong learning. Because lifelong learning covers a whole range of types of learning, including informal learning, we describe relevant types of learning and paradigms for lifelong learning (section 2.1 and 2.2). We also discuss how learners access digital information today in terms of their digital literacy, their information needs and their information seeking behavior (section 2.3). Furthermore, we consider different types of current technology enhanced learning environments and analyze them according to aspects of lifelong learning (section 2.4). This chapter prepares for the definition and specification of the Mobile Playful Learning Environment model later in chapter 3.

2.1 Relevant Types of Learning for Lifelong Learning

The knowledge-based economy, the growing speed of technological changes and globalization demand that people acquire skills, knowledge and competences throughout their lifetime to meet constantly changing information needs and to enhance inclusion and employability in our society and labor market. It has become increasingly common for people to undertake so-called *lifelong learning* which is a form of self-initiated education that is focused on personal development and covers the whole range of types of learning, including: formal, informal and non-formal learning (Laal & Salamati, 2012). In (Huffaker & Calvert, 2003), it is argued that forms of learning such as mobile learning, playful learning, and blended learning are likely to occur in interaction with complex social and technological environments where students take control of their own learning experiences by monitoring the mastery of skills, comprehension and implementing strategies to improve their

learning (meta cognition). In Figure 2.1, we have visualized the relationship between these concepts. Where the distinction between informal, non-formal and formal learning refers to the degree of formality of the context in which the learning takes place, blended learning, mobile learning and playful learning refer more to the principles used for the learning. Blended learning is often used in a formal context whereas mobile and playful learning are situated in the informal learning and non-formal contexts. Ubiquitous leaning takes advantage of digital content, physical surroundings, mobile devices, pervasive components, and wireless communication to deliver teaching–learning experiences to users at anytime, anywhere, and anyway (Cárdenas-Robledo & Peña-Ayala, 2018). Therefore, it can be used in formal, non-formal and informal learning. In the following subsections, we will describe each concept in detail and give examples where and how they take place.

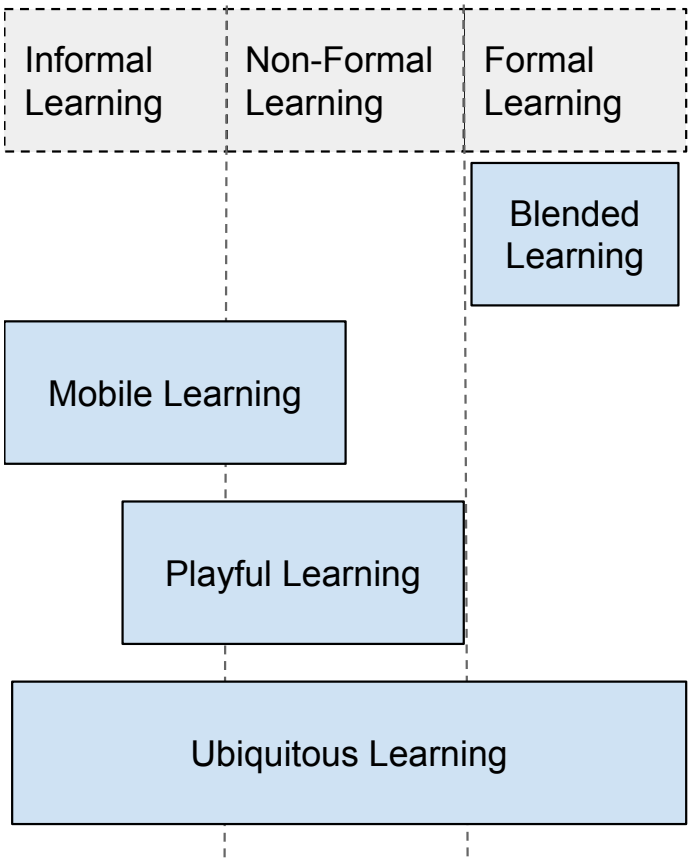

Figure 2.1: Overlap of learning types according to informal, non-formal and formal Learning

2.1.1 Informal Learning

Informal Learning takes place outside formal learning institutions, with friends, family or peers. From the learners perspective, the learning is not deliberately organized around learning goals or learning outcomes. Informal learning applies to situations throughout life that arise spontaneously; for example learning a foreign language while living in the country where that language is spoken through conversations with a friend or family member or movies, songs and using the Web, is a form of informal learning (Marsick & Watkins, 2001). Informal learning is distinguished from formal and non-formal learning by having no authority figure or mediator. The learner is motivated intrinsically and determines the path taken to acquire the desired knowledge, skill, or abilities. Informal learning takes place outside formal learning environments and it is often unintentional, i.e. it can happen as a byproduct of some other activity related to leisure or work such as surfing on the Web to pass time. The learner is often not aware that she or he actually gains knowledge. Therefore, it is often unstructured in terms of learning objectives, time, and learning support (that normally does not exist). (Callanan et al., 2011; Marsick & Watkins, 2001) identified five dimensions of how informal learning is presented in literature:

- learning as the result of self-regulation and integration into daily routines;
- learning as inductive process of reflection and action;
- learning as embedded in a meaningful and personalized activity;
- learning initiated by the learner's interest or incidental;
- learning in the absence of external assessment as open-ended activity.

Informal learning has the potential to bring wide benefits to young people who are struggling in school. Finding opportunities in informal learning practices that happen outside of school can lead to a huge confidence boost, which is the first step towards a return to

formal learning or finding a pathway to employment. Different forms of informal learning can be distinguished (West, 2017):

- Incidental learning takes place without any intent to learn. It is an accidental by-product of another activity that occurs outside of the learner's current focus (Marsick & Watkins, 2001).

- Tacit learning – tacit knowledge can only be acquired through practical experience in the relevant context which occurs at the subconscious level based on intuition, personal experience, or emotion (Durrance, 1998).

2.1.2 Non-formal Learning

Non-formal learning is an educational activity which happens alongside the formal education system to meet a variety of learning needs which cannot be satisfied in the school alone. Typically, it takes place during school trips (museum visits, zoos, aquariums) or community settings (sport clubs, music lessons) with educational and training purposes (Maarschalk, 1988b). Opposed to informal learning, non-formal learning is set up by an institution or organization. It consists of learning embedded in planned activities that are not explicitly designed as learning but contain an important learning element. Non-formal learning is intentionally planned with specific goals in mind. This type of learning is typically guided by a teacher or supervisor but it arises usually from the learner's motivation to master a particular activity, skill, or area of knowledge (Eshach, 2007). Students usually participate on a voluntary basis in these activities, and as a result, the learner takes an active role in the learning process. Non-formal education gives students the possibility to develop their values, skills and competences other than the ones developed in the framework of formal education. A related instructional strategy is *self-directed learning* where the students, with guidance from the teacher, decide what and how they will learn. Students take ownership of their learning and initiate their own learning activity including goal setting, resource

identification, strategy selection, and evaluation of outcomes (Knowles, 1975). According to (Steffens, 2006) self-regulation is achieved in cycles consisting of:

- The Forethought phase that consists of task analysis and self-motivation beliefs. Task analysis refers to planning processes such as goal setting and strategic planning. Self-motivational beliefs comprise a student's self-efficacy beliefs, his outcome expectations, intrinsic interest, and goal orientation.

- Performance control describes the strategies which are implemented to monitor the progress of the student. For instance, self-control refers to regulatory processes like self-instruction, imagery, attention focusing, and task strategies.

- In the Self-reflection phase, the student tries to evaluate the outcome of his efforts and construct new knowledge.

2.1.3 Formal Learning

According to the EU Counsel (Eberhard & Harribey, 2002), formal learning is typically provided by teaching institutions such as schools or certified training programs in the workplace. This type of learning is structured in terms of aims, time, and learning support by a teaching facility. It is also intentional in the sense that all activities are centered around learning outcomes and certification. Learning in schools is what immediately comes to mind when people envision formal learning. It is structured and typically led by instructors and trainers and often happen in a classroom setting. Educational systems exist to promote formal learning, which follows a syllabus and is intentional in the sense that learning is the goal of all the activities learners engage in. Learning outcomes are measured by tests and other forms of assessment. In formal learning, learning content is "pushed" to the learners according to a set of needs or predetermined curricula (Eraut, 2000).

2.1.4 Mobile Learning

With the growth of the Internet and a world-wide adoption of mobile devices, people enjoy access to a wide range of information enabling learning everywhere and at all times. Not a single day goes by that does not lead to discovery of new information and knowledge, including skills and competences in various domains. The term mobile refers to the fact that the learning takes place while the learner is on the move. Mobile learners learn across space and time by taking ideas and learning resources gained in one situation and develop them in another. By revisiting knowledge gained in the past and relating them to different contexts they move from topic to topic in a non-linear manner instead of following a single curriculum (Sharples et al., 2009). In a nutshell, mobile learning provides freedom to the learners how, where and with who to access, process and construct learning materials. Mobility is not constrained to the use of mobile technology; other aspects are also essential (Ozdamli & Cavus, 2011): Mobile learning is more spontaneous and impulsive than other learning types. Based on location, time and social context information needs are created and satisfied instantly by turning attention to the mobile device. It is also possible to transfer attention across devices, moving from the laptop to the mobile phone, to the notepad. Mobile learning tools are small and portable. Students can use them everywhere during their learning activities. The location may be used as a backdrop for learning. Students can use mobile tools for homework, projects or other formal learning activities but also to satisfy personal learning needs. With *Blended learning* (see next section), mobile learning can be integrated into classroom-based instruction. Furthermore, mobile technologies support communication between students, teachers and peers to support collaborative learning activities and interactivity.

2.1.5 Ubiquitous Learning

Ubiquitous learning or u-learning is a new learning paradigm that expands on previous learning paradigms as we move from traditional web-based learning to mobile learning.

Context-aware ubiquitous learning is an approach that employs mobile, wireless communication and sensing technologies to enable learners to interact with both the real world and virtual objects in authentic environments (Hasanov et al., 2019; Mikulecký, 2012), where students gain knowledge by applying theories in real world contexts to solve practical problems (Yahya et al., 2010). Ubiquitous learning does no longer restrict the learning to formal learning environments. Learning happens anywhere and at any time without much effort from the learner. Unlike in Mobile Learning, information is pushed to the learner rather than pulled. Digital content is transmitted automatically to the client whenever an information need is detected by the learning environment. Such a ubiquitous approach to information access requires modeling of different learner and environmental dimensions (Kinshuk & Graf, 2012). The learner model typically contains information about individual learners, such as their past behavior, current state, learning styles, cognitive abilities, and performance. The location model includes learner's current location and previous location history received from the various navigation systems, such as GPS or cellular network. The technology model obtains information about the capabilities of the technologies that are available to the learner at certain point in time, such as display capability, audio and video capability, available memory and bandwidth, and characteristics of the operating platform. The context model analyzes the learner's environment in real time, including the learner's current learning goal, the atmosphere in which the learner currently is, and the recent history of a learner's interaction so as to relate the next learning experience with it. Yang et al. (2008) summarize the characteristics of context-aware and ubiquitous learning in the following eight aspects:

- The continuity of computing while learners move from one location to another.
- The identification of learners' locations.
- The interoperable operation between different standards of learning resources, services and platforms.

- The seamless provision of everlasting service sessions under any connection with any device.
- The detection of learners' various situations and scenarios, and the knowledge of what learners are doing with whom at what time and where.
- The awareness of learners' social relationships, including what do they know, and what are they doing at a moment?
- The adjustability of learning materials and services depending on learners' accessibility, preferences, and need at a moment.
- The provision of intuitive and transparent ways of accessing learning materials and services, predicting what learners need before their explicit expressions.

2.1.6 Blended Learning

Blended learning (Graham, 2006) is an approach to education that combines online educational material with traditional forms of teaching to personalize learning across a diverse group of students. Different delivery methods, such as collaboration software, web-based courses and knowledge management tools are used to mix various forms of learning, including face-to-face classrooms, live e-learning, and self-regulated learning. Using blended learning models can have several benefits over pure classroom or distance learning (Watson, 2008):

- The integration of face-to-face and online learning can help to enhance the classroom experience and extend learning through the innovative use of information and communications technology.
- Student engagement can be enhanced through online activities that reduce lecture time.

- A blended learning approach provides flexibility in presenting content. Complex topics can be presented in the classroom, while other subject matter can be available online.

2.1.7 Playful Learning

According to "The Value of Play I: The Definition of Play Gives Insights" (2008) many definitions have explored the concepts surrounding play and its role in society. Play can be seen as a free activity which is not serious and done only for the purpose of amusement without any material interest or profit. It happens within a (physical or imaginary) play space where the rules of the real world do not apply and the mechanisms and experiences of play can emerge. Play is a fundamental part of human experience and learning, providing the opportunity to practice and explore in a safe environment. Play can support spontaneous learning, facilitate social interaction, stimulate imagination, support problem solving, reduce stress, and increase happiness. "The Value of Play I: The Definition of Play Gives Insights" (2008) observed five attributes of play:

- Play is self-chosen and self-directed.
- Play is an activity in which means are more valued than ends.
- Play has structure, or rules, which are not dictated by physical necessity but emanate from the minds of the players.
- Play is imaginative, non-literal, mentally removed in some way from "real" or "serious" life.
- Play involves an active, alert, but non-stressed frame of mind.

In this context, playful learning (Rice, 2009) can be seen as a type of interaction with learning material that involves fun and enjoyment to facilitate engagement and motivation in the learning process, thereby blurring the boundaries between play and learning. It

encourages the development of the learners through the use of toys, games, and play-based teaching approaches. It is not only about using games in the classroom but about designing learning activities that can incrementally introduce concepts in a narrative framework and guide learners towards an end goal within an incentive system that might include game elements (gamification) such as competition, challenges, points or rewards (Plass et al., 2015). In addition, the visual aesthetic design and overall look and feel of the activity is crucial to provide cues and feedback. Unlike game-based learning, which utilizes games explicitly in learning activities, playful learning only introduces aspects of play which can happen without games (Whitton, 2018). For instance, a student can tackle a mathematics exercise with creativity and narration. Then, this interaction can be called playful but it is not a game. According to (Kangas, 2010) playful learning should encompass the following values:

- *Creativity* refers to creative knowledge building and learning creatively by using new technology and designing artifacts.
- *Narration* refers to understanding as a key aspect of meaning-making. It makes sense of experience through the lens of engaging stories.
- *Collaboration* emphasizes knowledge co-creation within shared experiences among peers.
- *Insight* refers to the opportunity to make discoveries and to solve problems.
- *Competence* is when participants feel that they have mastered something well enough to make a difference in the world; when the participant no longer feels able to make a difference, he or she then seeks new ways to increase their competence.
- *Autonomy* is experienced when the actions and behaviors that someone engages in matches their own sense of who they are, and the extent to which someone makes his or her own decisions about behavior.

- *Relatedness* is based upon the connections that an individual feels with other people through their behaviors. Intrinsic motivation is a construct that combines these three concepts of competence, autonomy, and relatedness.

- *Safe spaces* identify that enjoyable learning takes place in spaces where students feel relaxed and comfortable with fellow students, where risk-taking and failure are encouraged within an atmosphere of Playfulness and good-humor.

2.2 Learning Paradigms Relevant for Lifelong Learning

To describe how people learn and how information is absorbed, processed and retained learning theories were created. Commonly used paradigms for technology enhanced learning are (Boghossian, 2006):

- **Behaviorism** assumes that meaning exists in the world separate from personal experience. A learner is essentially a passive being who absorbs instructional presentations and material and uses them to create correct mental models. The instructor is the authority who takes control over the learning process and defines learning outcomes by breaking content into small segments and then sequences them into a hierarchical curriculum ranging from simple to more complex tasks. It is assumed that the student has limited capability for evaluation or reflection within the learning process. Learning is considered to take place when learners manage to reach these expected outcomes through observation and repetition of appropriate activities that help them to demonstrate desired behaviors.

- **Constructivism** is the philosophy that assumes that meaningful learning occurs when people actively try to make sense of the world. Learners create their own knowledge based on interactions with their environment and other people. Rather than viewing learning as a linear process, it is understood to be complex and nonlinear in nature.

Learners continuously adapt hypotheses through an experimentation and interpretation process of reality. Teachers, who use a constructivist theory, concentrate on showing students relevance and meaningfulness of their learning interests and invite them to propose their own creative solutions to problems which are discussed in the classroom.

- **Cognitivism** emphasizes the need to understand mental processes that underlie and can explain many human behaviors. The role of memory and perceptual effects led to many studies that eventually adopted a mental processing model similar to that used in computer science (Nagowah & Nagowah, 2009). Computer scientists who became interested in modeling human cognition developed a discipline typically referred to as cognitive science. The contributions of cognitive scientists have continued to expand how computers can be used to model and support human learning in the form of intelligent tutoring systems and pedagogical agents. The lessons learned from these efforts could inform the planning and implementation of smart learning environments.

In formal schooling, learners are often confronted with behaviorist teaching techniques; they become experts at consuming knowledge rather than creating it. Constructivism is much more used for informal and non-formal learning because it sees learning as an approach to construct knowledge based on personal experience and that reality is determined by the experiences of the learner. One important constructivist learning theory is based on experiences and was created by (D. A. Kolb et al., 2014), called the Experiential Learning Theory. We explain this learning theory in more detail because it will be one of the foundations of our approach. A special focus will be put on the role of reflection and learner identity, two essential concepts in this theory.

2.2.1 Experiential Learning Theory

The theory of experiential learning has been introduced in the 1980s and has been well accepted as an efficient pedagogical model of learning in the digital age (D. A. Kolb, 2014). It defines learning as the process of creating knowledge through the transformation of experience. Knowledge results from the combination of grasping, transforming and reflecting on experience. According to A. Y. Kolb and Kolb (2005), the main principles are:

- Learning is best conceived as a process, not in terms of outcomes. The primary focus should be on engaging students in a process that includes feedback on the effectiveness of their learning efforts.

- All learning is relearning. Learning is best facilitated by a process that draws out the students' beliefs and ideas about a topic so that they can be examined, tested, and integrated with new, more refined ideas.

- Learning requires the resolution of conflicts between facts and ideas of the world. Differences, and disagreements are what drive the learning process. In the process of learning, one is called upon to move back and forth between opposing modes of reflection and action and feeling and thinking.

- Learning is a holistic process of adaptation to the world. Not just the result of cognition, learning involves thinking, feeling, perceiving, and behaving.

- Learning results from transactions between the person and the environment. Learning occurs through calibration of the dialectic processes of assimilating new experiences into existing concepts and accommodating existing concepts to new experiences.

- Learning is the process of creating knowledge. Experiential learning theory proposes a constructivist theory of learning whereby social knowledge is created and recreated

in the personal knowledge of the learner. This stands in contrast to the ”transmission” model of the behaviorist school of education, where existing fixed ideas are transmitted to the learner (A. Y. Kolb & Kolb, 2005).

The experiential learning theory provides clear mechanisms for teaching and designing curricula that are strongly based on the constructivist view on the way people learn. D. A. Kolb (2014) suggests that effective learners should undertake four types of activities:

1. Concrete Experience: a new experience or situation is encountered, or a reinterpretation of existing experience.

2. Reflective Observation of the new experience: analyzing experience based on inconsistencies and understanding.

3. Abstract Conceptualization reflection gives rise to a new idea, or a modification of an existing abstract concept.

4. Active Experimentation: the learners apply their ideas to the world around them to see what happens.

Thus, effective learning is happening when a person progresses through these four stages (see Figure 2.2): (1) having a concrete experience followed by (2) observation of and reflection on that experience which leads to (3) the formation of abstract concepts (analysis) and generalizations (conclusions) which are then (4) used to test a hypothesis in future situations, resulting in new experiences. D. A. Kolb (2014) views the activities as an integrated process with each stage being mutually inclusive of and feeding into the next. It is possible to enter at any stage and follow it through its logical sequence. However, effective learning only occurs when a learner can execute all four stages of the model. Therefore, no stage alone is effective as a learning procedure on its own.

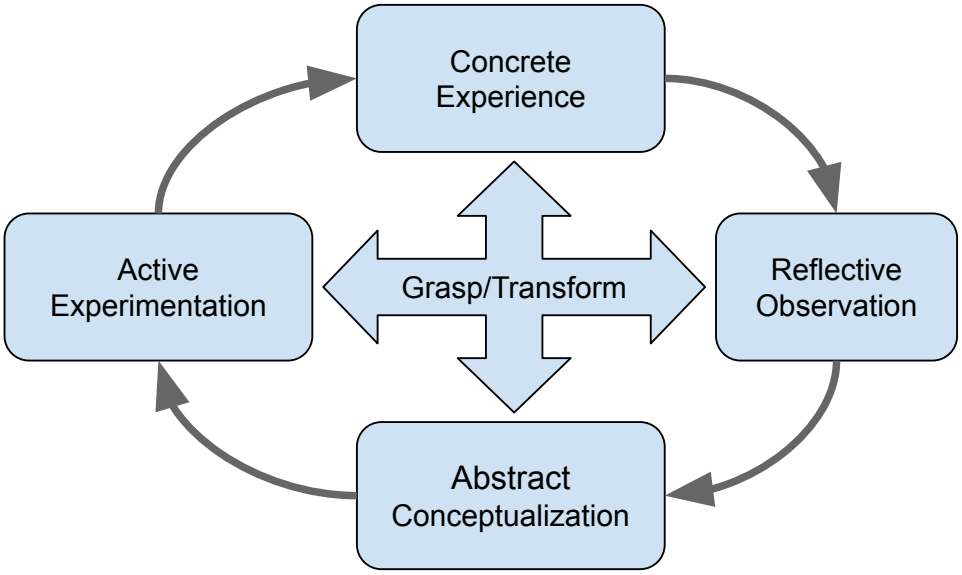

Figure 2.2: The phases of the experiential learning after (A. Kolb & Kolb, 2009)

2.2.2 Learner Identity

Learner Identity (A. Y. Kolb & Kolb, 2012) is defined as the process of becoming and being a learner. In essence, it is about enabling students to review themselves as learners and to foster their understanding of how their actions, emotions, thoughts and motives about themselves in learning are interconnected. People with a learning identity see themselves as learners, seek and engage life experiences with a learning attitude and believe in their ability to learn. Having a learning identity is not an either-or proposition. A learning identity develops over time from tentatively adopting a learning stance toward life experience, to a more confident learning orientation, to a learning self that is specific to certain contexts, and ultimately to a learning self-identity that permeates deeply into all aspects of the way one lives their life. This progression is sustained and nurtured through growth-producing relationships in one's life (A. Y. Kolb & Kolb, 2012). Becoming a learner is not accomplished overnight. One's self-identity is shaped by experiences that support and contradict it. Learner identity is a mix of fixed and learning beliefs. For instance, a learner feels that they are good at learning some things such as sports and not good at others such as mathematics. Every success or failure can trigger a reconfiguration of one's learning identity.

Self-identifying as a learner means trusting one's ability to learn from experiences, seeking new experiences and challenges that reinforce learning (A. Kolb & Kolb, 2009). Figure 2.3 compares a negative fixed self with a positive learner identity. It shows how a negative fixed self can hamper the learning ability and how a positive learner identity can mitigate these risks.

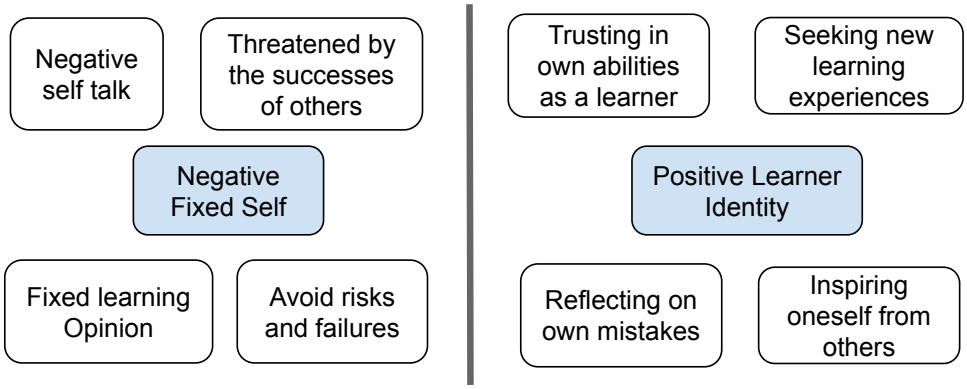

Figure 2.3: Negative fixed self versus positive learner identity. Adapted from (A. Kolb & Kolb, 2009)

When we reflect, we recollect an experience that we might otherwise not have given much attention to. Reflection is concerned with consciously looking at and thinking about our experiences, actions, feelings, and responses, and then interpreting or analyzing them in order to learn from them. From the perspective of the experiential learning approach, reflection is the key process through which individuals distill knowledge from their concrete experience. In general, reflection is defined as a cycle of inquiry for the purpose of understanding or finding solutions for a troubling situation or question (D. A. Kolb, 2014). Learning stimuli such as actions, ideas, or feelings are either cognitively reorganized to form a better understanding, or already learned material is reconsidered to expand existing knowledge.

According to (Boud & Middleton, 2003), reflection is a form of response of the learner to experience. In his model there are three main components namely Action, Idea or Feeling, Evaluating Experience and New Knowledge (shown in Figure 2.4): the experience and the reflective activity based upon that experience. Experience consists of the total

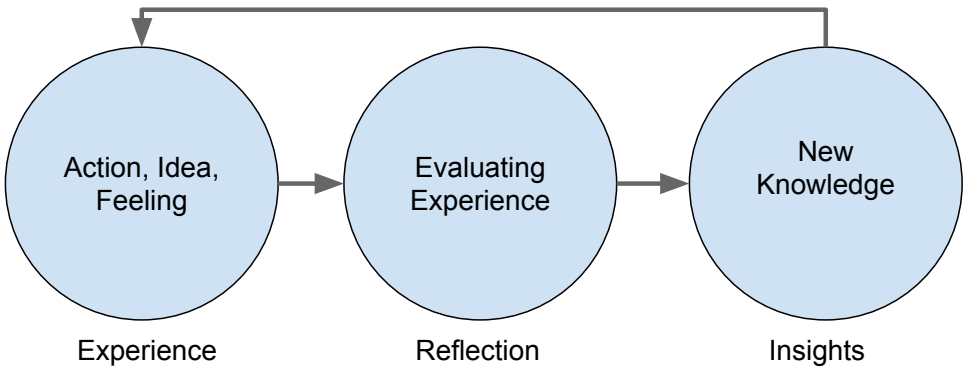

Figure 2.4: Reflection Model after (Boud & Middleton, 2003)

response of a person to a situation or event: what he or she thinks, feels, does and concludes at the time and immediately thereafter. The situation or event could be part of a formal course, e.g. a workshop, a field trip, a lecture; or it could be more informal – an event arising from a personal study project or from the actions of a community group, or a totally unplanned occurrence in daily life. (Schoen, 1992) organized when reflection can happen into two main categories namely reflection-on-action and reflection-in-action (Moon, 2013). Reflection-on-action refers to the retrospective contemplation of practice undertaken in order to uncover the knowledge used in practical situations, by analyzing and interpreting the information recalled. Reflection-in-action on the other hand refers to thinking about the learning process while performing it and the unexpected resulting feedback called ”backtalk” (Schoen, 1992). When a youngster “talks back” they undermine and change directions of future actions and therefore influence the learning outcome. Backtalk presents the learner with puzzles and surprises that need to be overcome to find an overall solution to a learning problem. It is typically stimulated by surprise, by something which puzzled the learner. The resulting insight gives the practitioner a chance to redesign the learning process while doing it.

2.3 Digital Learners' Access to Information

Through the explosive growth of Internet-related technologies, students must not only learn how to use resources to find information, they must also learn how to make sense of information and decide which sources are useful and reliable. Today, learners are expected to understand complex issues and apply them to real world phenomena and be able to connect learning topics to wider contexts and observing them from different perspectives (Perkins, 1991). Learners are also expected to know how to collaborate, to examine and elaborate different alternatives together and to construct knowledge together. Because our solution is focusing on modern, digital learners, we discuss the following:

- The characteristics of modern learners and how they see themselves (digital literacy and digital natives)
- How they access information (Information needs and Information Seeking)
- How they extract knowledge from it (Experiential Learning, Reflective Learning).

2.3.1 Digital Literacy of Digital Natives

Digital Literacy is a term used to describe the ability to use information technologies with ease and competence (Gilster & Glister, 1997). There are many concepts that describe this phenomena, for example Computer Literacy, Information Technology literacy, Digital Competence, etc. but Computer Fluency is the best fit to describe well the differences between digital natives and digital immigrants. The latter are people who are not born with information technologies and are not used to the usage. They have to learn practices to handle these technologies properly. Digital Fluency goes beyond just using computers for simple tasks. It can be defined as: "ability to reformulate knowledge to express oneself creatively and appropriately, and to produce and generate information rather than simply to comprehend it" (Wang et al., 2012). It means to realize one's ambition to become an

independent learner who discovers and shapes information online. A new generation of learners came about who appear to be familiar with all the tools, services and interfaces the digital revolution has brought us. They are called Digital Natives, Generation Y or Net Generation, born after the 1980's and naturally drawn to social networks, search engines, instant messaging systems and online games as tools to direct their life (Judd, 2018; Prensky, 2001; Tapscott, 2008). However, not everybody has the courage, self-discipline, knowledge, or motivation to engage in these activities. Even for highly motivated users who have strong skills in Information Management, the Web can be messy and overwhelming. With a steady stream of information and tools available, it is likely to miss out important information. Moreover, when information is scattered across different tools, users, websites and devices, it is hard for users to create a complete mental model of the learning environment. Especially digital native learners have an ambivalent relationship with this overabundance of information and tools. On the one hand, they are used to a wide range of information technologies in their daily life. "They use search engines and social networks as a first port of call for knowledge unlike older generations who were used to printed press, radio and television" (Helsper & Eynon, 2010). Information is received really fast and activities are frequently switched. High visual content, animation and interactivity is preferred over static textual content (Dresang, 2005; Prensky, 2001; Thompson, 2015b). Digital learners expect information to give answers as well as to be engaging (Radford et al., 2007). However, the apparent familiarity and competency with computers disguises some worrying problems in information literacy (Pettenati et al., 2009). Fast switching between activities often results in a superficial view, rather than an in-depth understanding of information. The speed of young people's information seeking suggests that little time is spent in evaluating information, either for relevance, accuracy or authority. Over 18 months, the Stanford History Education Group has been testing the ability of 7.800 Digital Natives to judge the credibility of online information. They found that students often could not distinguish between a news story and an advertisement. Faced with long search

results they find it difficult to assess the relevance of information and often skim through pages with no more than a perfunctory glance (Rowlands et al., 2008). Due to the sheer amount of information available nowadays, digital learners have a poor understanding of their information needs which makes it difficult to access information target oriented. Too often they get lost in hyperspace.

2.3.2 Information Needs and Information Seeking

Searching for information on the Web is a fundamental task undertaken daily by millions of people. Computer usage is expanding into more and more aspects of everyday life; people increasingly turn to the Web as an immediate source to support learning activities by looking up background information, definitions, or finding distractions from work. Information sources range from practical information about health and money, information to support academic achievement, information that helps with relationships, and the development of identity and place in society. Therefore, information need is a person's recognition of information that marks the beginning of the process of finding it. An information need can originate from the following mental processes (Moon, 2013):

- development of a need to resolve something;
- clarification of the issue;
- review and recollection;
- review of the emotional state;
- processing of knowledge and ideas;
- eventual resolution and possible action and transformation.

The application of skills in finding and using information is critical to youngsters' development as learners. Information seeking research aims to better understand how people search

for, access, and make sense of information resources, with the goal to build better information systems. It does not only emphasize professional contexts, but also information practices in everyday life, for instance the value of serendipitous discoveries on pleasure and positive emotions (Dörk, 2012). Today's youngsters are exposed to information from more sources and in more formats than ever before. They constantly seek, consume and share information with their peers, not only to be entertained but also to develop a collective understanding and critical stance towards topics in the media. Moreover, they also use the Internet and related technologies to work out issues of identity construction. For instance, (Ito et al., 2013) describe the case of Clarissa who is a 17-year-old aspiring fantasy screenwriter. Through friends she discovered an online role-playing site that involved writing fiction interactively. Online, she found a community of like-minded peers who shared her interests, and who collaboratively wrote stories and critiqued each other's work. As one can see, information access in these spaces is much more driven by personal goals, interests and information needs (often shaped by online communities) and developed throughout the whole life. Information seeking is one of the most popular online activities for teenagers (Shenton & Dixon, 2004) and can provide them with an additional information channel to enhance informal and formal learning activities. Everyday life information seeking can be defined as "the acquisition of various informational elements which people employ to orient themselves in daily life or solve problems not directly connected with the performance of occupational tasks" (Savolainen, 1995).

2.4 Technology-Enhanced Learning Environments

First of all, learning environments refer to the diverse physical and digital locations and contexts in which students learn. Traditional examples are classrooms, workplaces, labs, museums, natural sites, or home. These environments can be enhanced with technology to transform the learning experience from being physically present in the classroom to distance education in which the students can participate wherever they find it appropriate. In

general, these so-called *Technology-Enhanced Learning Environments* (TELEs) refer to the use of socio-technical applications to support and enhance learning practices of both individuals and organizations (Goodyear & Retalis, 2010). They provide access to a range of materials, learning tools, and communication facilities to enable students to become more actively involved in learning. This application domain generally covers technologies that support all forms of teaching and learning activities through which students acquire skills or knowledge. Different types of TELEs can be distinguished. (Koper, 2014) identified five cases on how digital devices can be used to support and enhance learning practices of both individuals and organizations:

- *Zero case*: there are no relevant physical or digital relevant stimuli in the environment of a person.
- *Digital case*: when the physical environment includes digital learning devices, but does not provide relevant non-digital stimuli to the user, for instance in a quiet study room when using a simulation program.
- *Embedded case*: the physical environment provides relevant stimuli to the user and the digital devices are adding, augmenting information to enrich the cognitive representation.
- *Side-by-side case*: the digital devices are added to a physical environment to support additional learning functions such as information, support, tests and feedback, but the digital devices are ignorant of the actual physical environment.
- *Classical case*: the physical environment provides relevant stimuli, and there are no additional digital relevant signals.

Mobile devices and ubiquitous technology have enabled major changes in where and how learning can take place, and how TELEs can look like. Today, more and more TELEs

can be situated in the embedded or digital case. In the first case, they are capable of scanning the physical environment for context-aware information to enrich the learning process. In the second case, they fully transform the learning process to the digital domain by simulating all kinds of affordances from the physical domain such as learning guidance by the teacher or social awareness of peer activity. Nonetheless, TELEs often exist side by side with the physical environment and do not take into account rich context-aware information. Especially in schools or universities they often mirror formal learning but fail to connect to informal learning spaces. In the following sections, we will take a closer look on different types of TELEs and their benefits and drawbacks regarding different forms of learning. In particular we will discuss:

- Traditional Learning Management Systems for formal learning
- Personal Learning environments for informal learning
- Open Learning Networks and Smart Learning Environments for informal, non-formal and formal learning

2.4.1 Learning Management Systems

One of the most significant and recent developments in the use of information technology has been the adoption of learning management systems (LMSs) to facilitate teaching and learning (Coates et al., 2005). LMSs are usually implemented across an entire university, faculty, or school, and then used by teachers to facilitate course management tasks in terms of:

- processing, storing and disseminating educational material;
- supporting administration and communication associated with teaching and learning.

According to (Chatti et al., 2010), LMSs have always been focused on delivery of learning objects and a standardization of the learning experience. Most LMSs today are designed to

statically package online courses and modules, following the pattern of course modularization and the isolation of learning into discrete units such as lessons supported with online exercises. Therefore, the core functionalities are:

- *Content Management*: store, manage and author assets such as text, video or learning objects;
- *Analytics*: track the user's learning behavior and performance;
- *User Management*: organize users into course units and assign them learning objects;
- *Certification support*: allow to issue reports on users learning performance and grant access to learning modules.

A LMS is an online portal where students can confidently search and obtain information regarding their courses, but it also has some drawbacks. The learning experience in a LMS is different from traditional face to face instruction because it is not based on physical presence in a classroom. In a physical classroom, learners interact directly with teachers and other learners. In a digital environment, learners often struggle to understand whether their work is of the same level as that of their peers or whether their work is in-line with the expectation of the teacher. For instance, passive listening or observing classmates is a common strategy in a traditional classroom but can lead to isolation in an online context where active participation in form of note taking or online discussions are needed to succeed. Although current students are generally digitally literate, and thus able to manage basic computer tasks well, they might find it difficult to exploit the whole functionality of a LMS. Often, forums, wikis or chat rooms are part of a LMS but neglected in practice. Time management is a difficult task for learners, as online courses require a lot of time and intensive work. Whereas mostly adults prefer the asynchronicity of online-based learning programs for their place and time flexibility, youngsters might lack guidance on what, when and how to learn.

Self-motivation is an essential requirement for learning with a LMS. However, many online learners lack it. After enrolling in distance learning courses, many learners fall behind and are at risk of giving up. Students need to find the motivation to follow the new educational trends and also properly equip themselves for future challenges in their education and careers.

There is room for LMSs to improve student engagement and motivation, for instance by integrating game-based concepts, which are familiar to the students such as gaining points and rewards for learning activities, leader boards, or avatars, (gamification) (Blohm & Leimeister, 2013). Gamification could make an application more fun to use, encourage users to interact with it voluntarily and repeatedly come back to it. Recently, more and more gamification elements have been adopted in open source LMSs, such as Moodle or Sakai, or as well as in commercial software, such as Blackboard or Canvas. For example, Moodle uses a badge system to reward the accomplishment of learning activities and motivate the development of a learner identity by including them in a so-called grade book.

2.4.2 Personal Learning Environments

Formal education systems have problems to prepare students for a world that requires networked learning experiences, an understanding of digital citizenship, and a way to navigate and organize a stream of information and resources from a variety of different sources (Adams Becker et al., 2017; Ash, 2013). Being a professional in this networked field of work requires capabilities for lifelong learning, managing distributed expertise and learning across sites, participation and effective communication in environments mediated by technology (Laakkonen, 2015). (Attwell, 2007; Vassileva & Sun, 2008) acknowledge that modern learners have different patterns of information access, attention, and learning preferences which cannot be satisfied by traditional learning platforms that consider the learner as a bare consumer of information predefined by some supervisor or teacher. To target this new generation of learners, as well as the concept of informal learning, they proposed the

model of *Personal Learning Environments* (PLE) in which learners draw connections from a growing matrix of resources and tools (search engines, bookmarking, blogging, social networks) that they select and organize to construct their own understanding. By definition, in such a PLE, the learner is in charge of identifying what needs to be learned (setting learning goals) and how it can be done (manage learning, both content and process). A typical PLE might, for example, incorporate Twitter where learners follow like-minded people and draw inspiration from their tweets to come up with a set of keywords to initiate a google search from. The retrieved results are translated into blog posts that may reflect personal insight. In this sense, the purpose of PLEs is to provide pointers to access the "right stuff" with respect to the characteristics of the learner, the learner's own context, such as task, nationality, language, or mood, and the external context such as time, location or educational mission (Vassileva & Sun, 2008).

PLEs have been invented to capture how learners organize their own learning spaces. The idea of a PLE is that with the advent of so many free tools such as search engines, social media, bookmarking software and others that are not formally controlled by an institution, people were constructing a set of tools that helped to structure their informal, everyday learning. A PLE may also include course resources, such as information from the lectures and assignments that happen in the classroom, but it is individualized to the needs and interests of the learner. PLEs blur the lines between formal and informal learning. Because they are individualized to the needs and interests of the learner, each PLE can look completely different. Nonetheless, there are four main activities comprised in a PLE[1]:

- *Connect*: The act of connecting to information can happen as reading from a favorite news site, listening to certain podcasts, or talking to particular people. But it also can entail the manner in which one searches for information. One can decide to find information using a single web search engine, or multiple, or none at all. One can use libraries, social media or conferences.

[1] https://iteachu.uaf.edu/personal-learning-environments/

- *Collect*: The practice of collecting information is common among learners, as in general, they cannot remember where they came into contact with information.

- *Reflect*: People seek information because it is useful, it helps us grow intellectually, it challenges us. Reflection deals with questions such as: If one only momentarily glances at a data source how is it evaluated in terms of already acquired knowledge? How can it be improved? Does it contradict something else already known? How can it be improved? Should it be refuted in whole or part?

- *Share*: Sharing knowledge is part of being human, it is part of giving back to a community, and in some cases it is part of one's job function.

However, for users, it is often challenging to create and maintain their own PLE because a much deeper level of learning is required to find and customize content, choose a tool to use, and then use that tool to support their learning.

2.4.3 Open Learning Networks

According to Mott and Wiley (2009), a LMS reinforces the status quo and hinders substantial teaching and learning innovation in education. It may impose artificial time limits on learner access to course content as a LMS is mostly consulted with a desktop or laptop computer (only recently LMS apps for smartphones became available). It privileges the role of the instructor at the expense of the learner, and limits the power of the network effect in the learning process. An *open learning network* (OLN) is a hybrid of the LMS and the PLE. They are similar to PLEs in the sense that they emphasize that peers and other people are essential for the learning process. Peer networks do not only provide a means of disseminating and finding resources, they also provide a space of discussing ideas and connecting with peers. For instance, you may have a well-developed network of peers in Twitter that helps inform your work. This model suggests that the "core set of functionality" remains in the learning institution. With the help of plugins, interfaces or data import/export mech-

anisms an OLN can integrate well with the institutional LMS. Figure 2.5 shows a typical OLN. One can see that tools which are crucial for grading and reporting remain in the LMS, whereas content acquisition for sharing and collaboration happens in the cloud. Using an OLN requires skills in complex information tasks, such as the one given in (Mott & Wiley, 2009):

- *Personal Information Management* for collecting and curating relevant resources into a meaningful structure to support learning.
- *Social interaction and collaboration* for using social media to find informal learning communities around topics of interest and understanding one's place in it.
- *Reflection*, which is concerned with consciously looking on learning experiences, and analyzing them in order to extend knowledge, generate new learning goals or perspectives.
- *Personal Knowledge Management* for synthesis and representation of learning material and knowledge in a general form to support future learning activities.

2.4.4 Playful Learning Environments

(Kangas, 2010) coined the term *Playful Learning Environment*, which describes a novel, learning environment that combines learning activities with information and communication technologies both in the classroom and in outdoor spaces. Learning in such an environment takes the form of content creation and engagement in physical games to increase collaborative physical activity in the context of educational tasks. The playful learning environment offers possibilities for children to learn curriculum-based topics by playing on the outdoor playground and provides more opportunities to use physical and bodily activities during the school day. Last but not least, a playful learning environment makes it possible for children and teachers to create their own (curriculum-based) games and contents for

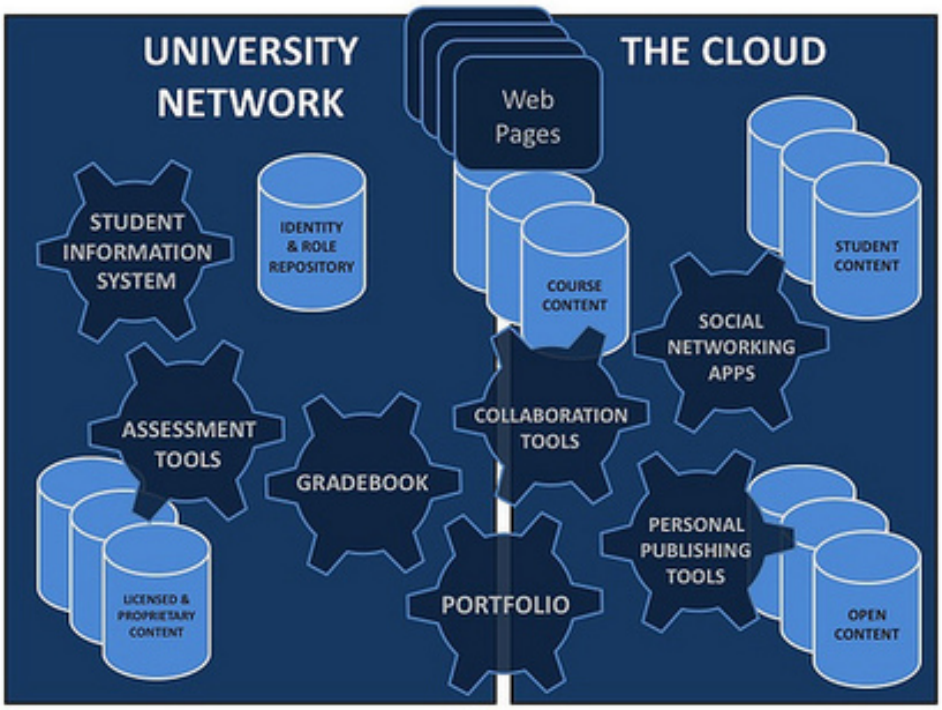

Figure 2.5: Example Open Learning Environment taken from (Mott & Wiley, 2009)

the playground and its game applications via classroom computers (Kangas et al., 2007). Social collaboration and playfulness are crucial activities on the playground.Social collaboration emphasizes knowledge co-creation and collaborative design and play processes. Collaboration with peers encourages motivation, cognitive engagement and requires the participants' commitment to the task during a learning and play process. Moreover, it involves working with others both inside and outside of the classroom to obtain information, to share and discuss ideas, to exchange data and interpretations, and to receive feedback of one's work. Opportunities for collaboration in the playful learning environment context are provided in the form of working in small groups with peers during learning processes when using technology and creating artifacts. Places and spaces for collaboration can emerge almost anywhere in the playful learning setting. Playfulness encompasses learning activities that are based on curriculum and on physical game playing. During the learning process, active gameplay takes place on the playground where students reflect on the games and improve them by commenting and giving advice to the instructor throughout the play process.

A PLE should offer ways for children to design their own game content, create their understanding and find a meaningful way to take part in their learning activities. According to (Caillois, 2001; Kangas et al., 2007) playful activities can be divided into 4 groups namely:

- *Agon*, or competition. It is the form of play in which players compete among each other;
- *Alea*, which denotes chance- and luck-based games;
- *Mimicry*, denoting games based on imitation and simulation;
- *Ilnix*, which stands for vertigo- and physical achievement-based games.

Learning outcomes in playful learning environments are multifaceted. They contribute to academic achievement, thinking skills, physical skills, participation skills, media skills, and knowledge co-creation skills. The following qualities of learning outcomes are important in playful learning environments.

- *Narration* refers to a mode of thinking and understanding by organizing real-world phenomena into a (sequential) structure that unfolds its meaning when the elements are revisited in the given order. One way to create a narrative structure is to embed learning activities in stories with plots that are created and acted out in play and games with problem-solving tasks.
- *Physical embodiment and the use of the whole body in learning activities* can create an involvement and activeness in learning that passive listening or watching does not. This increases levels of motivation and an interest in the activity or learning context. High levels of engagement can in turn affect the cognitive interaction of the learner, in terms of their attention, inquisitiveness and reflection.
- *Creativity* refers to the process of developing and refining imagination and creativity through emotions and by designing artifacts, games or media products. Knowledge

is built by making discoveries, solving problems, using imagination and possibility thinking. New technology and its affordances are essential in the playful learning environment such as Virtual Reality or Augmented Reality, which can be applied in a variety of ways in creative and playful learning to support knowledge creation.

For example, the Space Treasure game concept (Kangas et al., 2007) encompasses the central elements of a playful learning environment. The game is based on children's embodiment, with physical activities enhancing mathematical calculations on the outdoor playground device. Playful learning in this case requires physical body movements and logical thinking, and a plot for a treasure hunt in space (Kangas et al., 2007). Other examples are so-called Escape Rooms where a team of players cooperatively discover clues, solve puzzles, and accomplish tasks to progress and accomplish a specific goal in a closed space (Nicholson, 2018). Figure 2.6 showcases a playful learning environment with its integration of technology and the environment.

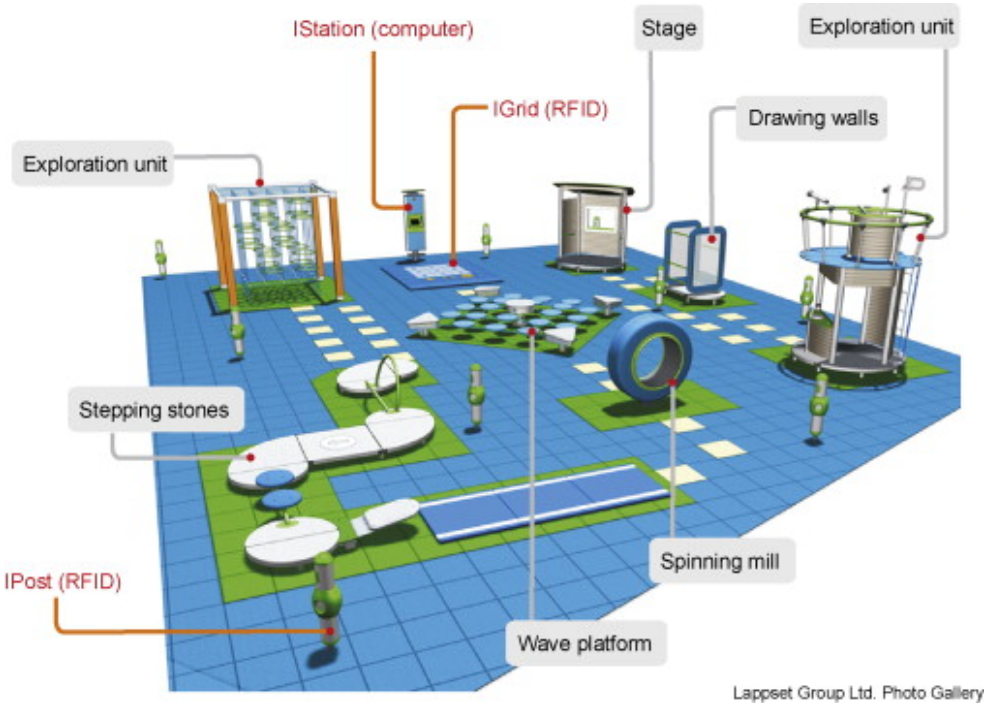

Figure 2.6: Smart-Us Playful Learning Environment (Kangas et al., 2007)

2.4.5 Smart Learning Environments

As another part of the lifelong learning initiative and similar to ubiquitous learning (Hasanov et al., 2019), Smart Learning integrates formal/informal learning and frees the learner from the space and time limitations of the traditional classroom (Temdee, 2020). Smart Learning focuses on the adaptability of learning content and presentation techniques based on the user's context which does not only include current location but also preferences, deficits and learning objectives to support self-regulated learning. Learning environments that support this type of learning are called Smart Learning Environments (SLE) in (Gros, 2016; Hwang, 2014; Spector, 2014). The 3Es meta-model (Spector, 2014) already highlighted the importance to promote engagement, i.e. the SLE must be capable of motivating and sustaining continuing interest and participation of a variety of learners. Besides providing learning activities to the learner, Koper (2014) argues that the key to engagement is the conditioning of the environment of the learner by providing positive and negative feedback, incentives, and contingencies. This means that there is an important overlap between the features of a SLE and a MPLE. The difference is in the emphasis on mobile and playfulness for MLPE, and a greater focus on the smart aspect in a SLE.

2.5 Summary

In this chapter we have described the foundations and the evolution of digital learning by first accounting relevant types of lifelong learning which we categorized along the dimension of informal, non-formal and formal learning. Playful learning and ubiquitous learning are of special importance because they both move away from traditional distance based learning to a way of learning that can happen anywhere and anytime whenever a minute is available to absorb new information. These new learning paradigms can be used to unite informal and formal learning practices outside the classroom. For instance, with modern technology, learning content can be accessed on the way home from school. In this way

learning is not anymore only concerned with the classroom. Contextual information found in the environment of the learner can be used to enrich learning content and make it more relevant to the individual characteristics of the learner.

Building upon these different learning paradigms we described different types of learning environments that target informal and formal learning. The most known example is the LMS which is used to organize and communicate learning material to the learner. Clearly, the focus is on learner control by analyzing the learner actions in these platforms. In this way, a learner profile can be formed that reflects special characteristics of the learner. Unfortunately, current LMSs are focused on the formal learning context. To our knowledge there are no LMSs that targeted the informal learning context as well and tried to bridge these two opposed learning contexts. Next, we focused on learning environments built for the informal learning context namely PLE and OLN which try to organize the information relevant for personal learning endeavors. These platforms are often composed of several applications. For instance, Twitter is used to find pointers to new information by trusted sources. Then Evernote is used to come up with new ideas and finally a blogging software is used to distill the newly formed knowledge in an article. Dedicated PLE and OLN software try to scaffold this process by helping the user finding relevant information by connecting tools, people and learning resources. Finally, we looked at Playful Learning Environments to integrate playfulness into the learning platform. By "playful" we mean a type of interaction with learning material that involves fun and enjoyment to facilitate engagement and motivation in the learning process thereby blurring the boundaries between play and learning. It encourages the development of the learners through the use of toys, games, and play-based teaching approaches.

The insight we gained by comparing (in)formal learning paradigms and learning environments was crucial for the construction of a dedicated learning environment that organizes learning material for informal learning context. We build especially on the strategies that playful learning environments have shown us to integrate fun and joy with learning.

Moreover, the emergence of playful learning environments is also important to showcase how to integrate personal information which is relevant to the user.

CHAPTER 3

MOBILE PLAYFUL LEARNING ENVIRONMENT

In this chapter we build upon the foundations presented and discussed in Chapter 2 to reach our objectives. In particular, we aim to combine playful elements and physical embodiment from the Playful Learning Environment and pair them with formal and informal learning resources used in the PLE and OLN to create the concept of *Mobile Playful Learning Environment* (MPLE). We start by presenting the main features of a MPLE and explain how they contribute to the goal of a MPLE, how they can be supported, and how they interact with each other (section 3.1). Because the main features are general concepts that can be realized by different theories and techniques from other fields, such as by the Visual Analytics Model, the Fogg Model, the Persuasive Systems Design (PSD) Model and other behavior change models, or more general user experience design models, we briefly discuss these as well. Section 3.2 will discuss models and frameworks from the HCI domain for reflection. Section 3.3 will discuss information visualizations. Section 3.4 will describe various models useful for designing and developing persuasive systems. Section 3.5 will provide the conclusions of the chapter.

3.1 MPLE: Reference Model

We will present the concept of an MPLE by providing the main features of an MPLE, and an overall picture of how these features interact with each other and describe the cognitive tasks involved. In particular for organizing the different cognitive processes, we build upon the work of Rowanne Fleck (2010) who defined a stage-based reflection framework consisting of levels of reflection organized by the cognitive effort they demand. She distinguishes between description (level 0), reflective description (level 1), dialogic reflection (level 2), transformative reflection (level 3), and critical reflection (level 4) as functional-

ities among reflective applications. Level 0 and level 1 deals with revisiting data with or without explanation. Level 2 emphasizes the exploration aspect of reflection, i.e. how can new relationships from already known data be established. On level 3, transformative reflection inspects how reflection can lead to attitude and behavior change. Last but not least, level 4 deals with wider societal consequences of reflection.

Our model consists of seven features grouped into three stages, i.e. the Data Gathering Stage, the Visualization Stage, and the Perceptual Cognitive Space. The stages are described in section 3.1.8. The seven features are:

- *The mobile user context* is defined as the collection of information that characterizes the situation in which the learner is.
- *Data collection and analysis* collects and analyzes learning traces from the user's current context into a structure that can be used to extract meaning.
- *Learner visualization* is used to display the learner's actions in order to revisit learning behavior and to provide structure, awareness and guidance in order to scaffold the self-reflection process.
- *Self-monitoring* is supported by representing the state of interaction via a set of key events to reflect upon past behavior and establish new relationships from already known information.
- *Persuasion* is used to stimulate and positively change learning behavior.
- *Playfulness* becomes a lens through which the users can engage with their surroundings in a fun and explorative way.
- Through *Micro learning* the learning takes place by interacting with small chunks of learning content and flexible technologies enabling easy and "on the move" access from anywhere.

The presented MPLE model is a reference model, meaning that, in practice, it should be used together with suitable theories from other fields such as the Visual Analytics Model, the Fogg Model, the PSD Model and other behavior change models, or more general user experience design models, to realize the features. An in depth look into these models and frameworks can be found later in this chapter from section 3.2 on. In the following sections, we describe the role of the different features in a MPLE and how they can be supported by applications. The last section deals with how the features interact with each other.

3.1.1 Mobile User Context

Nowadays, mobile devices provide a powerful platform for all types of learning where individualization of learning content, as well as anytime and anywhere access is critical. Mobile devices are bound to their owner, they are always on, always there, location aware and personalized. This allows the learner to explore informal and formal learning resources in relation to the learner's current context and environment. The learner's context is defined as the collection of information that characterizes the situation in which the learner is. It comprises the information and assumptions about the learner (such as personal profile, goal, knowledge, interests, preferences, interaction and presentation history) and the information about the environment (such as location, device, time, date and weather) (Zhou & Rechert, 2008). With an Internet enabled mobile device the student is able to connect to the MPLE from everywhere at any time. Information can be associated with locations and a wide field of topic areas such as civics, history, career, culture or sports to extend excursions or informal strollings through the neighborhood with up-to-date content. This includes, for example, information about relevant objects and the current position of the learner, like an interesting point of interest in the public space holding an opportunity to learn. The time limit introduced by playgrounds in the Playful Learning Environment is enlarged in our model to the whole day, as students have their smartphone all the time with them.

3.1.2 Data Collection and Analysis

Data collection involves observing and recording the interaction with the MPLE by means of so-called *learning traces*. Learning traces are granular snapshots of student activity. The most basic kind of learning trace is a page-visit trail in a learning environment where page visits and link clicks are recorded and associated with date information (Clemens et al., 2018). Other learning traces include:

- Moving to a point of interest;
- Performing a learning activity (succeeding or failing);
- Adding an interest to own's profile;
- Logging into the MPLE.

The data collection phase logs these traces and store them for later processing. An activity-based analysis allows to create a historical log of student actions across time. Such an analysis involves selecting and computing one or more higher-level variables, called termed *events*, to represent the current state of interaction with the MPLE. For example, an 'agreement event' might be derived by comparing the problem solving actions of two or more students, or a 'symmetry event' might result from a comparison of participation events (Soller et al., 2005).

3.1.3 Learner Visualization

Information visualization is used to provide structure, awareness and guidance in the learning process. It can be used to present large amounts of information (Keim et al., 2013) and is thus a perfect fit to make various types of contextual information and other learning traces visible. Visualization tools can monitor the interaction state with the MPLE and provide basic support for improving awareness of actions taken on learning resources, for instance along a timeline. Moreover, they can aggregate data into a set of high-level indicators that

are displayed to users such as analyzing participation rates with log in events and message reply delays (Govaerts et al., 2010).

3.1.4 Self-Monitoring

According to (A. Y. Kolb & Kolb, 2009) meta-cognitive aspects such as self-reflection and abstract conceptualization are important for the process of learning and the learner identity. Reflection is a mental process that takes as input knowledge or facts and produces an output of greater understanding that emphasizes personal value and meaning (Baumer, 2015). In this way, reflection can promote a positive self-concept whereby learners are confident and believe in their unique talents to face learning challenges. According to (Lin et al., 1999), many students can efficiently find information and memorize facts but unless appropriate scaffolds are provided, they cannot explain why information is relevant for them. They have problems to identify learning gaps and to recognize the limits of their own knowledge. To combat these problems, it is important that the MPLE offers resources for reflection on own thoughts and feelings associated with events, the learner's context, and peers. One way to do this is by providing *journaling* as a way to support self-monitor actions and gain awareness of learning behavior. This automatizes traditional manual journal keeping by gathering learning traces and augmenting them with additional media that offer advice and guidance for future learning such as highlighting missed learning opportunities or recommending new learning material. In this process, narration refers to a mode of presenting events within the context of stories that provide cognitive structures and framing perceptions of learning content. Many people perceive information as unrelated facts as long as they do not find personal value in them. But when information is placed in the context of a story, it is easier to find connections to personal interest and thereby improve recall, interpretation and synthesis of knowledge. These principles should be combined with an adaptive and personalized approach, meaning that what will be offered, how and when, should be adapted to the needs of the individual learner and be dynamically responsive to

the learner's behavior for achieving the strongest impact and highest learning relevance. Furthermore, because we aim for self-reflection, the use of so-called push technologies where the information is pushed to the user is preferred over the pull approach that demands user initiative and is often applied in regular education. (Lin et al., 1999) identified four types of design features that provide scaffolds for reflective thinking and that can be integrated into an interactive diary:

- *Process displays*: displaying problem-solving and thinking processes;
- *Process prompts*: prompting students' attention to specific aspects of processes while learning is in action;
- *Process models*: displaying experts' thinking processes that students can compare and contrast with their own process in action;
- *Reflective social discourse*: creating community-based discourse to provide multiple perspectives and feedback that can be used for reflection.

3.1.5 Persuasion

To adopt a certain learning behavior, people need to be motivated and this is easier to achieve when people perceive social presence, relatedness, feedback, expertise and are rewarded for their actions (Fogg, 2002). Interactive information technology designed for changing users' attitudes or behavior is known as persuasive technology. Persuasive technology is broadly defined as technology that is designed to change attitudes and behaviors of the users through persuasion and social influence, but not through coercion (Smids, 2012). In this context, persuasion means the communication designed to influence the autonomous judgments and actions of people (Oinas-Kukkonen & Harjumaa, 2009). Mobile technologies create special opportunities for persuasive strategies because they are closer to the human than any other device and used ubiquitously and pervasively throughout our life. People have these devices with them all the time and everywhere. User interaction

with such devices reflects more easily all facets of life than interactions with a desktop computer, which are often constrained to a work context. Mobile platforms have better opportunities to motivate people to achieve personal goals. According to (Fogg, 2002) it can layer information into our moment-by-moment life in a way that changes our behavior. This persuasion power has been shown in many domains, including marketing, healthcare education and environmental sustainability (Thieme et al., 2012). Mobile devices enable access to location, personal photos, movement acceleration, or document access history. By exploiting these capabilities they can use the personal data flows coming from mobile devices to persuade the user to change behavior positively.

3.1.6 Micro Learning

Learning in the MPLE should take place by interacting with small chunks of learning content and flexible technologies enabling easy and "on the move" access from anywhere. This type of interaction is based on Micro learning which assumes that people can learn better and more effectively when the content is broken down into digestible parts (Kovachev et al., 2011). Learning in small steps better fits the way people consume information today on the Web, in terms of small text or status updates (Facebook, Twitter) (Bruck et al., 2012). Web 2.0 offers the necessary features to design learning content in smaller objects and support just-in-time learning. For instance, start screen apps can be used to provide micro-content, notifications, or entertaining quizzes. In this process, the content creator's role is to capture knowledge gaps, understanding them with the help of online resources, creating learning objects and integrating them into small learning activities interwoven into the daily life of the learner. MPLE should deliver learning content in small self-contained learning activities which contain context information and provide users with instant feedback.

3.1.7 Playfulness

Next to the use of persuasion, the integration of game-based concepts that are familiar to youngsters, such as leveling up, obtaining rewards or gaining experience into the system, could be a way to motivate learners to use a learning environment. Through the process known as gamification, some game mechanics can be integrated into environments to scaffold playfulness, for instance:

- Points are used to compare users among each other and can be collected by performing so-called challenges which can be missions or tasks one has to accomplish.
- Teammates are mostly used for Cooperation among the users.
- Badges are issued when one has acquired a certain amount of points or a certain activity.
- Leaderboards are used to compare the performance of users and performance graphs provide statistics regarding the users' performance or/and behavior.
- Avatars are the representation of the users in the environment (e.g., to hide one's own identity).
- Story elements can be used to put the user in coherent narrative to nourish motivation.

However, note that playfulness is not the same as gamification. Adding game elements can make a system more fun but it is by no means sufficient. It is not because one can earn points or badges with a learning activity that the activity will be perceived as fun. Even worse, some people (who do not like competition), may perceive game elements such as points, badges and leaderboards, as annoying or childish. Play is an activity engaged in for enjoyment and is often a voluntary activity. When users are finding fun in learning activities, then there is no need for external gamification techniques, as the players are creating their own fun. It is the play, instead of points or rewards that brings people to

become engaged in the real-world setting. (Nicholson, 2015) described playfulness as a framework consisting of:

- The freedom to explore and fail within boundaries.
- Exposition, which is the process of presenting a narrative layer through game design elements by the development and the presentation of a meaningful narrative element.
- Information that allows users to learn more about the real-world context in terms of why and how phenomena work instead of how many points a certain activity brings you.
- Choice, which gives the user the control of how he or she engages with the system. A person will have a more positive sense of self-being if they have autonomy. In a playful system, this means that the player has meaningful choices to make which have a positive impact on the environment.
- Engagement, which creates opportunities for users to interact with others in meaningful ways. People have a more positive mental well-being when they feel connected to the world around them.
- Reflection that creates opportunities for players to step back and think about their game-based experiences. Users can connect what happened in the system to elements in his or her own life.

Within the process of play, it is important that users can establish and change constraints or parameters of the system to playfully define the limits to their own learning. When something is no longer fun, the players need the ability to change it to make it fun and playful again. Otherwise, they are in danger of self-imposing pressure or too ambitious learning goals, which would render the learning effort as work.

3.1.8 Learning Pipeline of MPLE

In the domain of Information Visualization, pipelines are used to describe the process of data transformation to information and knowledge. Data is usually first processed into some form of analytical abstraction which removes duplicates, cleans data and enriches it with new relationships and metadata. This analytical abstraction is further reduced using a visualization transformation into some form of visual abstraction, which is information content that is visualizable. The purpose of the visualization stage is to empower perception to gain insight and form new knowledge which happens in the Perceptual and Cognitive space (Chen et al., 2009; Ed Huai-Hsin Chi & Riedl, 1998). To show how the user's context can generate learning traces that can be visualized to turn awareness into insight we have constructed a similar pipeline. Figure 3.1 shows this pipeline containing the components of a MPLE (which implement the features of the MPLE model), how they interact with each other and how they contribute to the final goal. The Mobile User Context and Micro Learning components provide all information needed for the extraction of learning traces which happens in the Data Collection and Analysis component. The Learner Visualization component is responsible to make the learning traces visible. For instance, the learner can realize that (s)he crossed each week a famous monument with a long history in the city that can nurture her or his interest in that topic. These events are narrated with the help of journaling techniques that stimulate the perception of the learner in such a way that they can generate awareness of their learning actions. This awareness is needed to trigger the Self-Reflection phase where insight is formed about learning problems and opportunities. The outcome of this phase is to reinforce learning behavior by returning back to the Micro Learning component and perform more learning activities. For example, for our learner mentioned earlier, by revisiting all informal learning activities of the past week (which included several trips to museums of city planning) the learner can realize that (s)he has a deeper interest in the history of architecture. The Persuasion component, which can be used in the Data Gathering, as well as the Visualization stage, can influence the forma-

tion of insight by applying persuasive techniques such as notifications, recommendations, rewarding, investments or tunneling. For instance, it can propose several other trips to related museums or monuments. To increase engagement of the MPLE, the Playfulness component is used to enrich the interaction with the system. For instance, the user can gain points by revisiting all learning activities of the past week or an avatar can strengthen the identification with the system. In the Micro Learning component, the user performs (voluntarily) context aware learning activities which are motivated by the insights gained in the Self Reflection stage, and by the persuasive and playful techniques. While performing these activities, the user generates new learning data that reshape and feed back into the Mobile User Context.

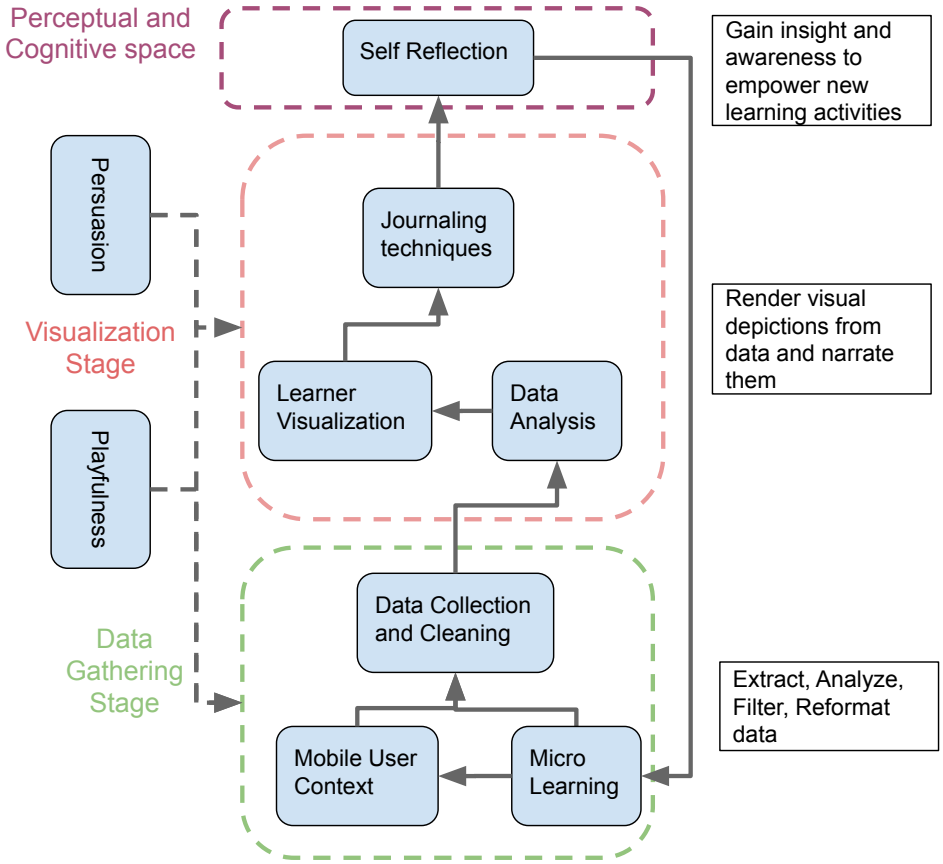

Figure 3.1: Learning Pipeline for the MPLE Model

3.1.9 Summary

In this section we defined our conceptual model for Mobile Playful Learning Environments. This model should guide the design and development of such learning environments, which combine features from personal learning environments (PLE), Playful Learning Environments, Learning Management Systems (LMS) and Smart learning Environment (SLE) to provide a learning experience that is mobile, supports informal as well as formal learning, and acknowledges information access behavior of digital natives. In particular, we tried to combine the openness of PLE/OLN with the guidance and structure of the LMS. Inspired by the emerging concept of SLE, we connected the user's context with Journaling and Visualization techniques to support meta-cognitive aspects such as awareness and self-reflection of learning. To lower the boundary to perform such mentally challenging tasks we apply playful and persuasive techniques that guide the user through the steps of this process. Table 3.1 shows comparison of features of the MPLE with other learning environments highlighting the novelty of our model. One can see that Visualization and the user context have been rarely applied with persuasion and playful techniques in learning environments. The integration of the user context is a more recent development which started with context aware PLE architectures (Alharbi et al., 2012) and was made conceptually sound with the emergence of SLE. Through the holistic perspective of many SLE models, issues of how to represent information meaningfully and guide the interaction process with learning traces have been overlooked. Whereas SLE models cover many different systems including wearables and ambient technologies, our MPLE model targets the mobile applications to visualize and recommend learning activities for the purpose of awareness and self-reflection. In this sense, this model integrates control features from LMS, the collection of learning traces of PLE/OLN and context analysis of SLE.

In the following sections, we discuss existing theories, techniques and frameworks for supporting reflection, information visualization and persuasion.

Learning Environment	Micro Learning	User Context	Visualization	Persuasion	Playfulness
LMS	x		x		
PLE/OLN		(x)			
Playful Learning Environment	x				x
SLE	x	x	(x)		
MPLE	x	x	x	x	x

Table 3.1: Feature Comparison with LMS, PLE/OLN, Playful Learning Environment and SLE

3.2 Reflection in Human- Computer Interaction

In Human-Computer Interaction (HCI) interest emerged on how technology can support human reflection on experience from technology-mediated experiences, events or stories that lead to new understandings or some sort of insight (Baumer et al., 2014). For this purpose, one must synthesize the diverse interpretations of reflection, derive aspects, and adapt them to the specific purpose and domain. The domain of personal informatics develops applications that help people collect, reflect on and explore personal information for the purpose of gaining self- knowledge through the usage of computer assisted algorithms (Rapp & Cena, 2014). These systems provide a better way for self-reflection than simply relying on remembering information about one self because people have limited memory and some behaviors are difficult to keep track of. For instance, monitoring the access of documents as an indicator for learning activity is difficult to do manually. In the following subsections we discuss different models developed to support reflection.

3.2.1 The Stage-Based Model of Personal Informatics Systems

The Stage-Based Model of Personal Informatics Systems (I. Li et al., 2010) devised a five-stage model for Personal Informatics Systems, which are needed for computer systems to scaffold reflection. The model is illustrated in Figure 3.2 and the stages are as follows:

- The Preparation stage occurs before people start collecting personal information.

This stage concerns people's motivation to collect personal information, how they determine what information they will record, and how they will record it.

- The Collection stage happens when people collect information about themselves. People observe different personal information such as their inner thoughts, their behavior, their interactions with people, and their immediate environment.

- Integration is the stage that lies between the Collection and Reflection stages, and where the information collected is prepared, combined, and transformed for the user to reflect on.

- The Reflection stage is when the user reflects on his/her personal information. This stage may involve looking at raw data of collected personal information or interacting with information visualizations.

- In the Action stage, the reflective thought is transformed into behavior. For instance, the learner has realized that his current learning strategy is not efficient. Now, it is on the user perform the reflective thought in practice.

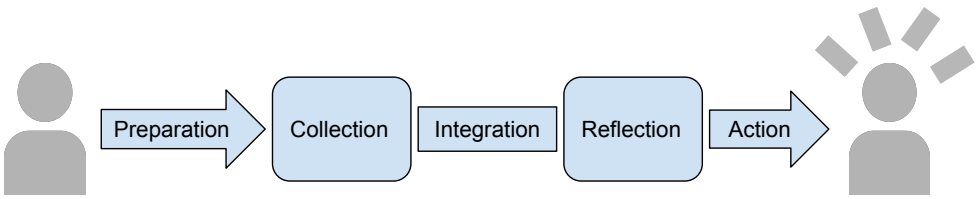

Figure 3.2: The Stage-Based Model of Personal Informatics Systems - Adapted from (I. Li et al., 2011)

3.2.2 Feedback Loop Model of Reflection

(Rivera-Pelayo et al., 2012) present another framework that combines different research areas for the technical support of reflective learning. Three main components are defined to scaffold the reflection process:

- *Tracking cues*: concerns capturing and monitoring raw data as the basis for the reflective learning process. Nowadays, a wide range of sensors is available to design applications that target computer supported data analysis. The following types of data can be considered:
  - *Social data*: Data can be augmented with information from social media. This could be a comparison of one's own performance to that of Facebook friends or a comparison to all users of a system. Sharing in a social context provides additional data to others in expectation to retrieve more data in exchange and ultimately see one's own experiences in relation to other ones. An aggregation of data over multiple users may provide new perspectives on experiences and offer new abstraction levels.
  - *Spatial data*: The location in terms of e.g. city and street can aid reflection by helping the users to understand the relation between place and their behavior. Wearable and mobile sensors are preferred because they accompany the user across different contexts, e.g. rooms and used tools.
  - Temporal data can aid in the reflection process in terms of comparing current events to past ones to see the development of learning performance. Historic data may also help to explore related learning activities from the perspective of a certain point in time.
- *Triggering*: concerns fostering the initiation of reflective processes in the learner either actively or passively based on the analysis of the user's behavior. Active triggering means that the application sends a notification to grab the attention of the user. In order to support active triggering, an application must detect experiences that are suitable for initiating reflection. Passive triggering does not detect experiences for reflection automatically and does not actively contact the user. This type of triggering relies on the intention of the learner to kick off the reflection process by only

presenting the collected data in a basic way.

- *Recalling and revisiting experiences*: concerns supporting learners in recalling and revisiting past experiences through the enrichment and presentation of data. To show important events or parts of the raw data, information visualization techniques are the main means.

Figure 3.3 shows a simplified depiction of the model (Rivera-Pelayo et al., 2012). One can see how the computer powered reflection process is embedded in the process of experiencing the world and decision making.

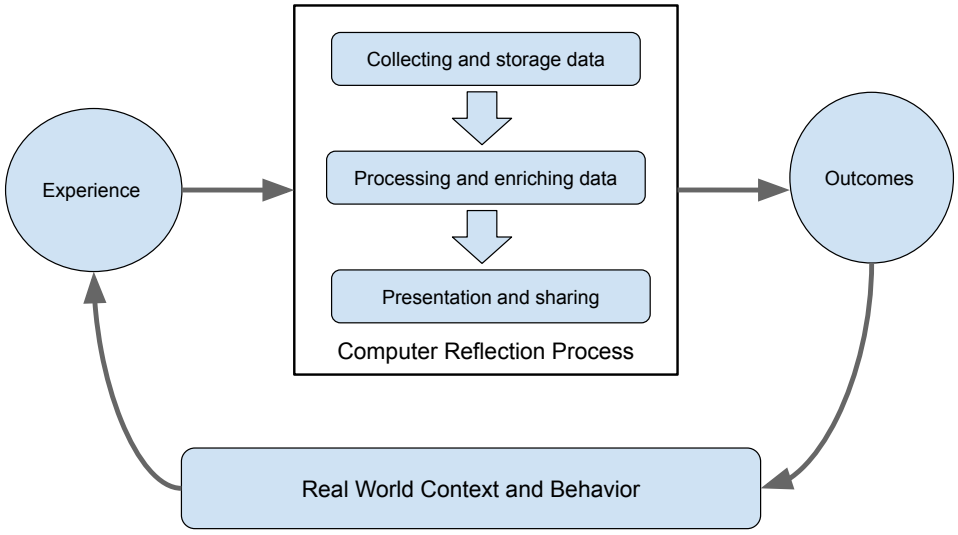

Figure 3.3: Feedback Loop Model of Reflection - Simplified from (Rivera-Pelayo et al., 2012)

3.2.3 Monitoring, Awareness and Reflection in Blended Learning

In (Rodriguez Triana, Prieto Santos, et al., 2017), the authors distinguish the terms monitoring, awareness, and reflection in technology enhanced learning. Monitoring can be

described as tracking learner's activities and outcomes. Learners can monitor themselves (self-monitoring) or learners can be monitored by another person, usually by a teacher or an administrator. Monitoring can be activity-centered (monitoring processes) or outcome-centered (monitoring products) Florian-Gaviria et al., 2013. Monitoring can take place in real time or post hoc. Monitoring learners' performance aims to detect trends, patterns which can be made available to instructors. Monitoring is a prerequisite for awareness and reflection. While monitoring focuses on learner's actions and outcomes, awareness infers the current state of either the learner's understanding or the learning artefacts. Awareness can be seen as a subsequent step from monitoring. For learners, awareness refers to the meta-cognitive process of being aware of one's own state of understanding and progress (self-awareness) as well as teachers' awareness of the state of their students and classes.

3.2.4 Five Stage Model of Reflection and Cognition

Rowanne Fleck (2010) synthesized related literature on Human Computer Interaction into a five-stage framework, consisting of levels of reflection organized by the cognitive effort they demand. Level 0 and level 1 deals with revisiting data with or without explanation. An example is looking back at learning activities and reviewing the mistakes made. Level 2 emphasizes the explorative aspect of reflection, i.e. how can new relationships from already known data be established. One example is to discover new learning activities which are related by a common keyword. In level 3, transformative reflection inspects how reflection can lead to attitude and behavior change. For example, the fact that many mistakes have been made in a particular subject can lead to the insight that one has to improve on that subject. Last but not least, level 4 deals with wider societal consequences of reflection. It involves taking into consideration moral and ethical issues, and wider socio-historical and politico-cultural contexts. This level of reflection is hard to induce by technology alone. It demands a deep cognitive effort by the users themselves and happens often outside technology usage. The levels are illustrated in Figure 3.4.

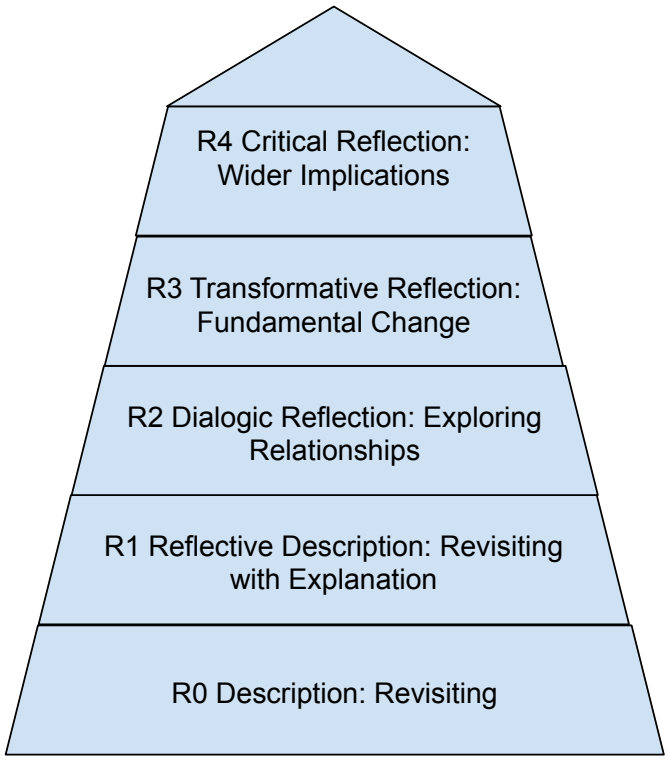

Figure 3.4: Illustration of the different reflection stages of the Five Stage Model of Reflection and Cognition (Rowanne Fleck, 2010)

3.2.5 Conclusion

Self-Reflection as meta-cognitive activity is one of the aims of our MPLE model. Therefore, we discussed in this section several models for reflection relevant for the design and development of reflective applications. Especially the model by (Rivera-Pelayo et al., 2012) and its emphasis on the user's context is relevant for the structure and data flow of the MPLE. The model by (Rowanne Fleck, 2010) will be used in chapter 4 to compare reflective applications and their level of reflection.

3.3 Information Visualization

In the Personal Informatics domain, information visualization has been proven to be a powerful means to enable reflection and decision making. Building on our perceptual capabil-

ities, it makes use of computer-supported, interactive, visual representations to support the understanding of the meaning of large amounts of abstract data without overburden human cognition (Card et al., 1999). However, most practitioners approach information visualization from a technical and analytical perspective: visualizations are, for instance, used to gain insight in customer data to maximize profits or support analysis of scientific experiments. However, in popular media, information visualizations are applied for another purpose, i.e. to persuade, entertain, and to tell stories (Dur, 2014). These visualizations, usually called infographics, can blend serious content with colorful designs to attract a wide audience and to embed the viewer in a playful visual narrative that creates attention, excitement and curiosity. In this way, it may convince people of an opinion, or to take action. In the following we discuss two disciplines that build upon Information Visualization, i.e. Visual Analytics and Learning Analytics, as well as several sub-domains, i.e. Casual Information Visualization, Personal Information , Visualization for Information Seeking, and Playful Information Visualization, which can support the persuasive and playful aspects of our MPLE.

3.3.1 Visual Analytics

As mentioned before, the main aim of Information Visualization is the presentation of data in a visual way in order to equip the user with a tool that allows him or her to make confirmatory analysis, i.e. he or she can validate hypotheses by looking at the presentation. This analysis technique is rather static. The visualization only represents results. The user is not supported in incorporating his or her own thoughts into the automated data analysis process. Visual Analytics integrates visualization techniques and data processing techniques into a highly dynamic approach where the visualization serves as an assistant for the user on his or her way to explore the data (Keim et al., 2010). In Figure 3.5, the visual data exploration is exposed. There, visualizations are used to present the actual selection and model of the data, which is computed by automated data analysis techniques such as

data mining. Then, the user is given the opportunity to reason about the data and to adjust or change the model of the data. Thereafter, data mining is applied, results are visualized and the process starts all over again. As such, the process consists of a feedback loop which is based on interaction between the visualization and the user. "Visualization becomes the medium of a semi-automated analytical process, where humans and machines cooperate their respective, distinct capabilities for the most effective results. The user has to be the ultimate authority in directing the analysis." (Keim et al., 2010)

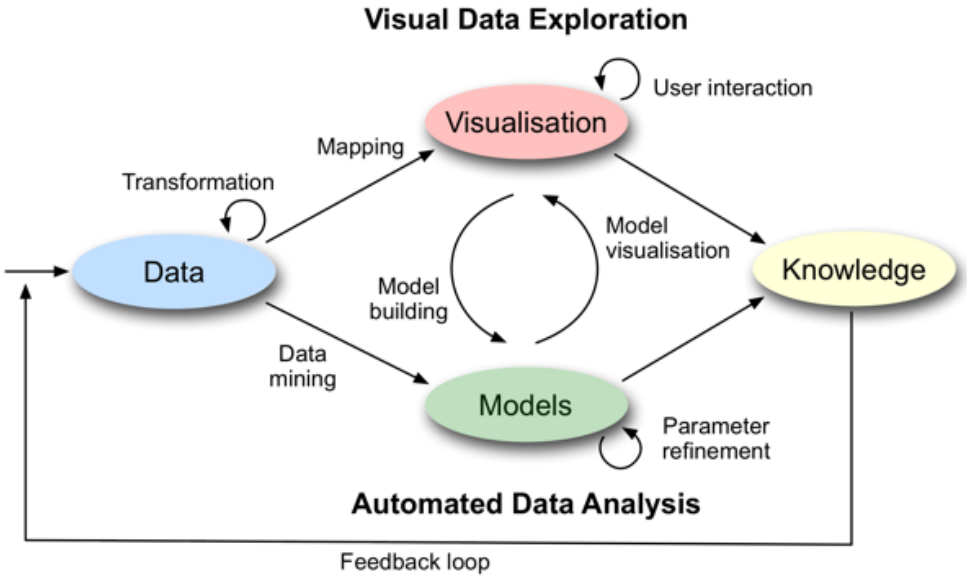

Figure 3.5: Visual Analytics feedback model, taken from (Keim et al., 2010)

3.3.2 Learning Analytics

Visualizations for reflection and decision making have also been applied in learning. Learning Analytics platforms have shown that through tracking, analyzing and visualizing learner-related data, the learner's performance can be improved. Visual accounts can help to raise awareness about personal strengths and shortcomings, which can help to set up learning goals and improve learner development (Duval, 2011). However, Learning Analytics tools are often embedded in a course context (Verbert et al., 2012). They do not necessarily establish a link to a PLE. Often, they rely on data collected by institutional Learning Man-

agement Systems, such as the total time spent on the course, the average time spent on a document or the number of documents used. In some cases they also incorporate more personal data sources such as Twitter streams to assist formal learning (Govaerts et al., 2012).

3.3.3 Casual Information Visualization

Learning Analytics systems often make use of well-known visualization techniques that demand patience, willingness and experience to scan the overall picture for correlations, distributions, outliers and details before one can obtain insight. Originally, these visualization techniques were envisioned for data scientists who are skilled and motivated to dive deep into data analysis. Some of those techniques seem to be too complex for an audience who has little experience or interest in analysis tasks. Pousman et al. (2007) envisioned how interactive data visualizations can be made appropriate for non-expert users and different kinds of insights. They explored edge cases of information visualization and proposed a number of sub-disciplines (bundled as Casual Information Visualization) which focus on different forms of insight and non-expert users. There are several differences between traditional Information Visualization systems and Casual Information Visualization:

- The target audience includes a wide spectrum of users from experts to novices. Users are not necessarily literate in analytic thinking and do not need to be required experts in reading visualizations.
- The usage expands from work or performance to other parts of life such as pass time activities and play.
- The data is personally relevant and not necessarily embedded in a formal context.
- Different kinds of knowledge that go beyond analytical insight are supported. For instance, social awareness is about what is happening with friends or family or reflective insight into personal behavior to change it for the better (see also the section

on Persuasive Technology). Ambient visualization systems often produce awareness insights in data that is either user-selected, or selected by designers to be personally relevant to a community or type of individual.

3.3.4 Personal Information Visualization

Personal Information Visualization and Analytics shift the focus on meaning making of data in personal life. D. Huang et al. (2015) argue that people may look into their data with different goals, backgrounds, and expectations from a personal perspective. They examined what types of insights people draw from their personal data and identified recall, detail, comparison, and value judgement as common types. To include the subjectivity and uncertainty of opinions, beliefs, or memories in personal life, new techniques are developed that give emphasis on local phenomenon and situations. The main research question in Personal Information Visualization is *"How can the power of visualization and Visual Analytics be made appropriate for use in personal contexts — including for people who have little experience with data, visualization, or statistical reasoning?"* (D. Huang et al., 2015). An example can be found in (D. Huang et al., 2014) where the authors extended a traditional calendar view with data streams from household electricity meters and Fitbit devices. Another example is given in (Thudt et al., 2016). In this paper, the authors discuss visual mementos as a particular type of personal visualization for the purpose of reminiscing, and sharing of life experiences. They developed Visits, a tool which relates places the user has visited and time spent there with photos taken to create a visual travel diary.

3.3.5 Visualization for Information Seeking

In the context of everyday information seeking, Dörk (2012) envisioned interactive visualizations as a means to make searching and navigating the Web more high-level, engaging, and exploratory. Building upon the exploratory search paradigm, they proposed Visual Exploration as a model to enable users to explore, overcome uncertainty, and learn with-

out specific questions or tasks in mind. They introduced visualization widgets (VisGets) that integrate graphical summarization with interactive query formulation. In summary, the model looks as follows:

- Information seekers can choose the way they interact with the information space. Interactive visualizations support direct manipulation of graphical elements and underlying data.
- Visualizations summarize meaningful aspects of an information space providing high-level perspectives on the data.
- Visual exploration provides visual and interactive access to data dimensions and a way to navigate the data.
- The searcher can choose how to express an information need using visual and/or textual representations.

3.3.6 Playful Information Visualization

Many casual and personal visualization systems provide insight in a "playful" way to stimulate informal learning but rarely define it as an explicit outcome. By playfulness visualization we mean an interaction which cannot be considered as proper play but features some characteristics of it in terms of:

- Graphics and animation;
- Imagination of an abstract space;
- Providing motivating feedback, often through a storyline where choices matter;
- Spontaneous goal formation to solve problems;
- Browsing information as serendipitous exploration (Bekker et al., 2010).

Furthermore, Medler and Magerko (2011) argue that data analysts and video game players share properties in the way they recombine and manipulate symbols to achieve goals and insights. Analysis tasks are already vital parts of digital games — players are asked to find patterns, manage resources, and work with incomplete information. Moreover, so-called player dossiers make use of statistics and visualizations to enable users to track achievements, analyze past gameplay and share data with in-game friends.

3.3.7 Conclusion

In this section, we reported on several sub-domains of Information Visualization that are of interest for our MPLE Visualization component. Although all these sub-domains are relevant, especially Playful Information Visualization will be important to consider in order to engage the user in a playful way in the Data Analysis process to examine learning traces for the purpose of reflection.

3.4 Persuasive Technology

In general, learners need to be motivated to perform learning activities because they require considerable cognitive effort of the user. Engaging individuals to reflect on information who are not motivated to do so is even more difficult; it may require the use of motivational strategies. One possible strategy to motivate the user to do something is persuasion. Persuasive technology is broadly defined as technology that is designed to change attitudes and behaviors of the users through persuasion and social influence, but not through coercion. Persuasive technologies are now applied in many domains, including healthcare, education and environmental sustainability (Thieme et al., 2012). In the following subsections, we describe the major theories and models developed in the context of persuasion.

3.4.1 The Six Principles of Persuasion

Cialdini (2001) studied the process of persuading people to come into line with the requests and the offers that we make them. He grouped the principles to persuade people into six basic categories which he called the six basic principles of influence. These principles are used ubiquitously in human interactions to influence and to persuade people to do, act, and think the way one wants — even if we do not recognize them as such. Note that influence can be used ethically to nudge people into a positive behavior but it can be also used maliciously. The six principles of influence are as follows:

- **Consensus** describes the fact that people are performing the same behavior when a large group of other people also perform this behavior, because it is considered as appropriate behavior.
- People have the desire to be consistent in what they do. **Consistency** can be used in persuasion by letting people make a (small) commitment to something or someone. Afterwards they will try to be consistent with this commitment in their behavior.
- **Scarcity** describes the fact that people perceive something more valuable when there is a limited availability.
- **Liking** describes the fact that people tend to agree on requests from friends, or people they like.
- **Reciprocity** describes the fact that people tend to return a flavour, gift, or invitation when they have received one from somebody. Most people are feeling obligated to return something.
- **Authority** describes the fact that people tend to comply with the advice of somebody that is presented as an authority.

3.4.2 Fogg Model

Fogg (2009) studied the concept of persuasive technology and how we can design systems that impact the user on an affective level. He proposes a model, called Fogg's Behavior Model (FBM) (Fogg, 2009), which identifies the factors needed to invoke a certain behavior (Muntean, 2011). The model is illustrated in Figure 3.6:

- The Motivation axis describes how motivated the user is to perform the behavior. Fogg gives three types of core motivators: Pleasure/Pain, Hope/Fear, and Social Acceptance/Rejection.
- The Ability axis describes the ability of the user to perform the behavior. It can be described in terms of money, physical effort, and / or brain cycles needed to perform the behavior, as well as in terms of the social deviance of the behavior, or the non-routine character of the behavior.
- In addition to the necessary level of motivation and ability, Triggers are needed to perform the behavior. They describe the elements that could tell the person to perform the behavior. Fogg (2009) distinguishes between Sparks, Facilitators, and Signals.

When technology is used for persuasion, interactive technology has three important functions in behavior change: as a resource, as a media, and as a social actor. The persuasive strategies differ depending on their function:

- As resource: To convinces people to adopt new habits by increasing their possibilities and facilitating the target behavior.
- As media: In this role, convincing technology offers experiences that enable people to practice the intended behavior, creating a loop in learning.
- As social actor: In this role, convincing technology creates a relationship by giving social signals. People respond to social cues of computer systems as they would interact with others, this is an extra strong function.

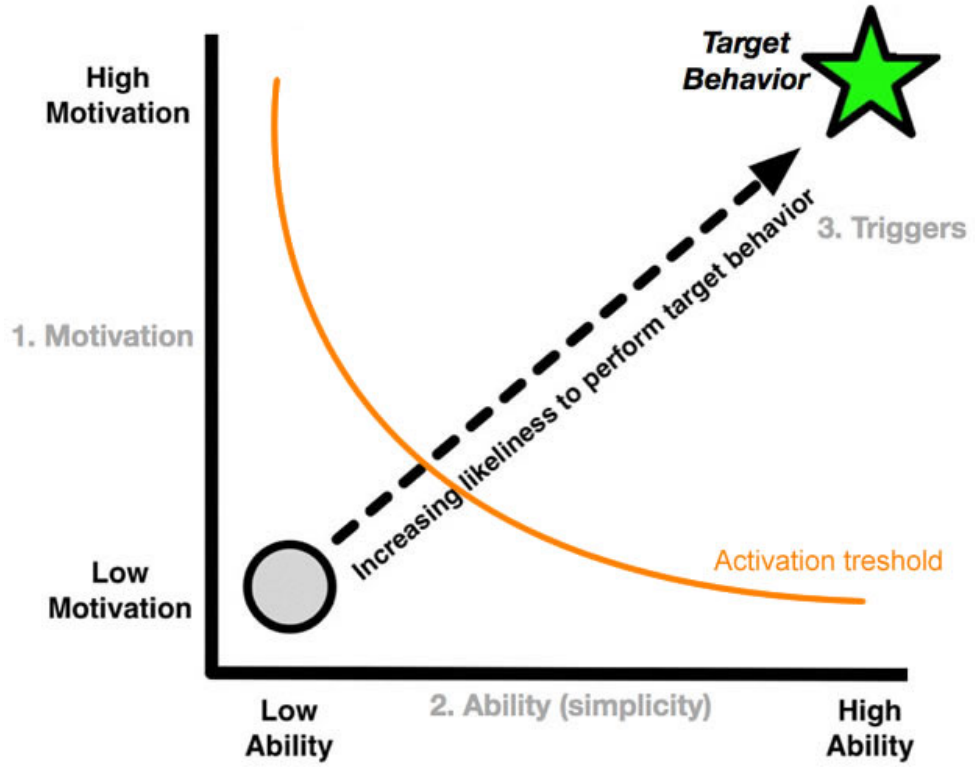

Figure 3.6: Foggs Behavioral Model (Fogg, 2002)

3.4.3 Hook Model

Nir Eyal reverse engineered the principles used by application such as Facebook to hook people to an application in his book "Hooked". His Hook Model explains how a user can be bound to keep on using a product or service, i.e. when it becomes a habit (Eyal, 2014). Habit-forming products are products that people keep using without the need of expensive advertising or aggressive pushing. The aim of the Hook Model is to create a habit of using a certain product. In this way, the Hooked Model can also be used to influence the user's behavior. For a company, the adopted habits can mean more profit. For the user, adopting a new habit means a significant change of mental state. Psychological needs such as belonging, stimulation and social acceptance are directed towards the use of the product. Therefore, the Hook Model proposes a cycle through which the user must repeatedly move to gradually create this new habit. A single cycle is composed of four consecutive steps

(see Figure 3.7). It starts with a trigger that should be followed by an action from the user. In accordance with Fogg, Eyal also argues that an action will only take place if the user possesses sufficient motivation and abilities to perform the action. Therefore, Eyal suggests to make the actions as easy as possible. In this way, the behavior is very likely to be performed. The next phase in the Hook cycle is the reward phase. Rewards are used to increase the likelihood of repeating the action in the next cycle; Eyal advises the use of variable awards. The last phase of the cycle is the investment. This phase is typical for the Hook Model. An investment is everything that a user puts into the system (like time and effort), or supplies to the system (like preferences and content). The more a user invests in a system, the less likely it is that (s)he will stop using the system, as then the investment will be lost. Therefore, when applying the Hook Model, it is necessary to give due consideration to these investments. The goal of repeatedly going through the cycle is to eventually remove the need for an external trigger, which is used in the first step of the cycle, and to replace it by an internal trigger, such as the feeling of boredom or loneliness, or simply curiosity. We discuss the different steps into more detail:

- Triggers can be either internal or external. The behavior often starts with some external trigger (e.g. a push notification on a mobile device). When the cycle is followed repeatedly a habit can be formed in which case the underlying behavior is associated with some internal trigger (e.g. an emotion) and the external trigger is not needed anymore to call for the behavior. Emails are also an example of an external trigger. Seeing your name and subject line in your inbox is an external trigger. However, the motivation for checking emails can also be triggered internally through boredom, curiosity, fear, or some other driver. In that case, reading emails has become a habit.

- Responding to the trigger should be possible by performing a simple action (e.g. pushing a button). Because of the simplicity of the action, the user should have a high ability to perform it, and therefore (based on Fogg's Model) it will be more likely that the action is performed. For example, in the case of email marketing, the email

sender wants readers to perform a series of simple actions such as open your email, read or scan through it, and click on a link.

- Performing the action should be followed by receiving a variable reward. Rewards are used to increase the likelihood of repeating the action in the next cycle. Eyal claims that variable rewards work better for humans than fixed rewards. An example of a reward in the email marketing case is to offer a discount or some free points for opening the link in the email. In this way, people will look forward to the emails.

- Investment is important in habit creation, because it gives a sense of ownership and makes it harder to stop using the product. An example are collected points in a web shop, or the photos uploaded or collected in an application such as Pinterest.

Eyal proposed five questions that a designer should ask himself to build effective hooks (Eyal, 2014):

1. What do users really want? What pain is your product relieving? (Internal trigger)

2. What brings users to your service? (external trigger)

3. What is the simplest action users take in anticipation of reward, and how can you simplify your product to make this action easier? (Action)

4. Are users fulfilled by the reward yet left wanting more? (Variable Reward)

5. What bit of work do users invest in your product? Does it load the next trigger and store value to improve the product with use? (Investment)

3.4.4 Persuasive Systems Design (PSD) Model

The Persuasive Systems Design (PSD) model is a conceptual framework for analyzing, designing and evaluating persuasive systems. It builds on theories of behavior change from both psychology and computer science (Fogg, 2002). In the PSD model, the categories for

Figure 3.7: The Hooked Model according to (Eyal, 2014)

persuasive system design principles are Primary task support, Dialogue support, System credibility, and Social support (Oinas-Kukkonen & Harjumaa, 2009). Primary task support features facilitate users' interaction with a system and help track their performance through features such as self-monitoring. Dialogue support features improve dialogue between the user and the system in terms of feedback to better guide the user through the intended behavior change process. Features such as authority, expertise, real-world feel, and verifiability promote the credibility of persuasive systems. Social support features foster user motivation through components such as cooperation, social comparison and social learning. Furthermore, the model is based on seven postulates that highlight some key principles behind each persuasive system (Oinas-Kukkonen & Harjumaa, 2009):

- Persuasive systems are never truly neutral and always influence their users intentionally and unintentionally.

- People prefer that their views are organized and consistent with the world. Systems should support the making of commitments and investments to initiate a target behavior. This is based on the concept of commitment and cognitive consistency (Cialdini, 1993).

- Direct and indirect routes are key persuasion strategies. The first are clear guides in terms of step by step process through information. The second are simple cues to evaluate the information such as tooltips or optional views on information.

- Persuasion is often incremental. It is easier to initiate people into doing a series of actions through incremental suggestions.

- Persuasive systems should also be open in announcing their intentions to influence their users in order to avoid coercion and deception.

- Persuasive systems should aim at unobtrusiveness, meaning they should avoid disturbing users while they are performing their primary tasks with the aid of the system.

- Persuasive systems should aim at being both useful and easy to use. This includes responsiveness, ease of access, lack of errors, convenience, and high information quality, as well as positive user experience and attractiveness.

Figure 3.8 illustrates the development process of a persuasive system using the PSD Model. The first step is to understand the fundamental issues behind persuasive systems. After obtaining a reasonable level of understanding, the system can be analyzed and designed. Therefore, the second step is to analyze the context for the persuasive system. That means recognizing the intent, event, and strategies for the use of a persuasive system. The final step is to design the actual system qualities which lead to a behavior or attitude change.

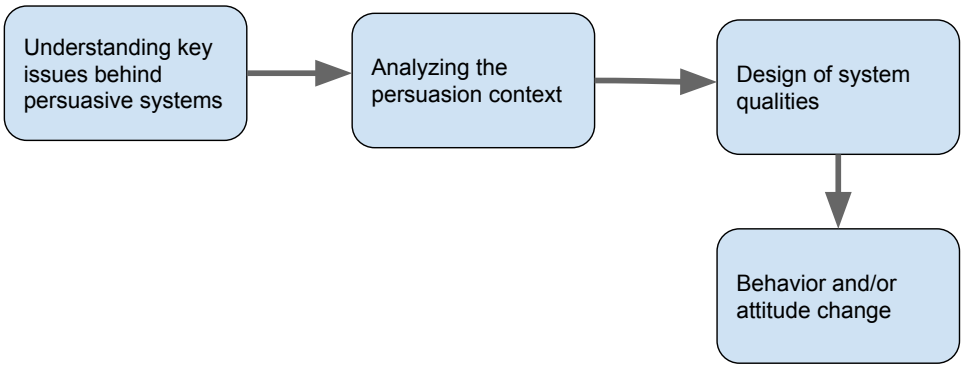

Figure 3.8: The development process with the PSD Model

Overall, the PSD framework is a capable framework for the design and development of Persuasive Technology. It discusses the process of designing and evaluating persuasive systems and describes what kind of content and software functionality may be found in the final product.

3.4.5 Conclusion

In this section we discussed several persuasive technology models for the design and development of such applications. The PSD model provides a framework to analyze the functionality of persuasive applications in terms of task support and context. It will be used in Chapter 5 for the design and development of the proof of concept MPLE application called TICKLE. Furthermore, the Fogg model, as well as the Hook model will be applied in this application.

CHAPTER 4
RELATED WORK

In this chapter we examine related work from a behavioral theory perspective which understand events and situations that drive individual human behavior change with a set of concepts to explain or predict these events or situations. Frameworks describe relationships among fundamental building blocks of a behavioral theory to provide guidance to the design and implementation of behavior change technologies (and help guide the evaluation process). In this context, constructs are the basic determinants or mechanisms that a framework postulates and applications translate these constructs into actual features or functionality to drive individual behavior change (Hekler et al., 2013).

Therefore, we will compare existing TELEs with features of our MPLE model from three different perspectives, i.e. systems supporting different forms of lifelong learning, systems with capability for Self-reflection, and systems providing Persuasive strategies and Playful techniques. For each perspective we will define a set of features that are informed by the literature and map to our research objectives. Second, we will review models and frameworks in the domain of informal and formal learning that not only inform the design of learning environments by defining features and interaction mechanisms but also showcase learning situations that the framework can support.

4.1 Comparison of Related Applications

Here, we compare existing applications that tackle the domain of informal and formal learning. We will discuss these applications from three perspectives, each considering a different dimension of our MPLE model. The first perspective deals with the properties and aspects directly related to achieving the informal and formal learning goals. The second perspective captures the way reflection is handled in these systems. The third perspective looks at

ways to guide the user in the learning process in terms of persuasion and playfulness including gamification. We will analyze resources that describe systems based on properties and attributes that will be identified in the subsections respectively dealing with the three perspectives. To identify related systems, we searched Google Scholar for papers with the following keywords:

- Personal Learning Environment (PLN) [27 papers identified]
- Open Learning Network (OLN) [15 papers identified]
- Informal learning application [5 papers identified]
- Persuasive technology, education [7 papers identified]
- Gamification, informal learning [2 papers identified]

In this way, we obtained 56 systems. It is striking that only a few papers were found dealing explicitly with persuasive technology in the education domain. It seems that the intersection between these two research fields is still an untapped research area. Moreover, only 5 papers were found with the keyword 'Informal learning application'. This is the case because many duplicates were already found using the keywords PLN and OLN. Then, the papers were scanned for references of works facilitating formal and informal learning which resulted in the following systems:

1. *Mindless Change* utilizes learning theories to provide a mobile intervention system to establish healthier habits in terms of food and exercises (Vainio et al., 2014).
2. *Plotmaker* is basically an authoring environment for persuasive learning objects (Behringer et al., 2013).
3. *Chick Clique* is a mobile phone application designed to motivate teenage girls to exercise (Toscos et al., 2006).

4. *RightOnTime* is a mobile application intended as a Behaviour Change Support System for people who want to improve their punctuality and time-keeping skills (Tikka & Oinas-Kukkonen, 2016).

5. *iDetective* is a mobile game that utilizes persuasive techniques to stimulate exercising by offering photo challenges on geo-location (Yoshii et al., 2011).

6. The Canvas Learning Management Platform is a software application for the administration, reporting, and delivery of educational courses ("Canvas", n.d.).

7. *Moodle* is a popular open-source learning management platform that offers a powerful plugin mechanism to tailor learning solutions for a wide range of learning institutions (Conde et al., 2014).

8. *PACARD* (Personalized Adaptive CARD-based interface) is a learning tool that combines several technologies including card-based interface, personalized adaptation, push notifications, and badges (Pham & Chen, 2019).

9. *TalentCards* is a card-based LMS that provides bite-sized learning activities targeted for learning on the job ("TalentCards", 2020).

10. *MGLS* (Mobile Gamification Learning System) is a location-based LMS that was developed and implemented in an elementary school science curriculum to improve student motivation and to help students engage more actively in their learning activities (Su & Cheng, 2015).

11. *Moin* is a mobile application to foster informal learning through face-to-face communication, supported with contextual language learning features and employing gamification as a motivator (Ngan et al., 2016).

12. The *KSMS* project introduces a mobile self-learning system that can be an alternative for school in countries that cannot offer normal education (Abdessettar et al., 2016).

13. *MemReflex* is using flashcards in a mobile LMS environment. It uses the principle of micro learning and the content delivery is adapted by the user's performance (Edge et al., 2012).

14. *Symbaloo Edu* provides methodological support to select and organize information sources, and its use favours collaborative work while helping to develop digital competencies, providing students with an environment that complements formal learning (Biel et al., 2016).

15. (Kolas & Staupe, 2007) presents the *PLExus* prototype, a PLE based on the Semantic technology of topic maps. Semantic-based navigation in e-learning will enable variation, differentiation and individualization, which are important pedagogical factors in the development of a personal learning environment.

16. *Elgg* is an open source social networking engine that provides a robust framework on which to build all kinds of social environments, from a campus wide social network for a university, school or college, or an internal collaborative platform (Conde et al., 2014).

17. The *mEducator* EU funded project developed technologies that enable effective searching and retrieval of learning resources by means of Web 2.0 principles, mashup technologies, semantic linked services and persuasive techniques (Bamidis et al., 2011)

18. *Netvibes* allows the user to customize a personal Dashboard to aggregate resources online such as social networks, news, articles on the topics of interest. It also offers support for digital calendars, to do lists, emails and apps in one place[1]. It offers connectivity with a wide range of tools, and it adds the social element by providing connections ("Widgets") to Facebook, del.icio.us, Flickr and other applications.

[1] https://www.netvibes.com/en

19. *Mahara* is an e-portfolio system that permits to share learning experiences across different tools and devices (Conde et al., 2014).

In the next sections, these works and systems are discussed from the three perspectives mentioned. The approach used for studying the systems, as well as the results, are given for each perspective. A color coding system to denote the different type of system:

- Persuasive application = red
- LMS = blue
- PLE = yellow

4.1.1 Perspective 1: Support for Formal and Informal Learning

As already described before, formal learning is marked by a behaviorist approach of strengthening the association of learning content and behavioral responses to form knowledge. Therefore, the provision of learning material and the control of the learner in terms of how they access information and the observation of learning activity are essential for a formal learning system. In particular such a system needs to support the following features:

- Content Management: store, manage, and author assets such as text, video or learning objects;
- Reporting Analytics to track the user's learning behavior and performance;
- User Management to organize users into course units and assign learning objects.

These three features will be used to compare the systems identified for their capabilities for supporting formal learning. From the theory of informal learning (Callanan et al., 2011; Marsick & Watkins, 2001) and work on technology usage of learners (Dabbagh & Kitsantas, 2012) has resulted into the following features for our comparison of the systems identified for their capabilities for supporting informal learning:

- Self-Monitoring;
- Self-Regulation;
- Personalization;
- Exploration.

Self-Monitoring refers to the capability to inspect on past activities and to trigger a reflective process. Self-regulation links to the incidental quality of informal learning which can happen as a byproduct of some other activity and is not instructed by a learning authority such as a teacher (Pintrich, 1995). In informal learning, personalization refers to the freedom to choose the tools for learning which are deemed appropriate; no LMS or other tools are prescribed. The learners are free to configure their environment for learning and use it how they like. Exploration refers to the open-ended aspect of informal learning. The lack of clearly defined aims results in learning paths which are much more open ended and guided by curiosity instead of tangible learning outcomes (Meyers et al., 2013). Table 4.1 and Table 4.2 compare the systems identified based on the core functionalities (i.e. features) identified above. For the informal learning features, it is obvious that most PLEs score well on self-regulation, personalization, and exploration. Unfortunately, most PLE frameworks neglected self-monitoring as a motor for informal learning. Exceptions are Elgg and ROLE. Elgg supports rudimentary self-monitoring whereas ROLE integrates a complete learning model based on self-reflection. Several applications focus on self-monitoring, notably Mahara which is an e-portfolio application that makes learning achievements visible to peers and employers. Mindless Change, Plotmaker and RightOnTime have also a strong focus on self-monitoring to establish new healthier habits.

As expected, most of the PLE reviewed systems do not score well on formal learning functionalities because they were not created for that purpose. One notable Exception is iPLE which offers an architecture that integrates well with widgets from an institutional

System	Self-Monitoring	Self-Regulation	Personalization	Exploration
1. Mindless Change	x			
2. PlotMaker	x	x	x	
3. Chick Clique	x	x		
4. RightOnTime	x			
5. iDetective		x		
6. Canvas				
7. Moodle				
8. PACARD		x		
9. TalentCards		x	x	
10. MGLS	x	x		x
11. Moin	x	x	x	x
12. KSMS Project				
13. MemReflex		x	x	
14. Symbaloo Edu		x	x	x
15. Plexus		x		x
16. Elgg	x	x	x	x
17. Moodle mEducator		x	x	
18. Netvibes	x	x	x	x
19. Mahara	x	x	x	

Table 4.1: Comparison of learning applications for their informal learning capabilities (Persuasive application = red, LMS = blue, PLE = yellow)

context. On the other hand, Canvas or Moodle, which are LMSs in their own right support sophisticated content and user management. But also TalentCards, which is a flashcard based learning environment, offers user and content management. Last but not least, MGLS is a modern location-based learning environment that offers learning challenges on real physical locations that combine informal learning practices, i.e. self-monitoring, self-regulation and exploration as well as basic formal learning practices such as user and content management.

4.1.2 Perspective 2: Support for Self-Reflection

For this perspective, we utilize the categorization model of (Rowanne Fleck, 2010) which has been described before subsection 3.2.4. The comparison is provided in Table 4.3. Most systems score on ‘Reflective Description’, i.e. they offer ways to inspect past activity for

System	Content Management	Reports and Analytics (grading, performance)	User Management
1. Mindless Change			
2. PlotMaker			
3. Chick Clique			
4. RightOnTime			
5. iDetective			
6. Canvas	x	x	x
7. Moodle	x	x	x
8. PACARD			
9. TalentCards	x		x
10. MGLS	x		x
11. Moin			
12. KSMS Project			
13. MemReflex	x	x	
14. Symbaloo Edu	x		
15. Plexus	x		
16. Elgg	x		
17. Moodle mEducator			
18. Netvibes	x		
19. Mahara			

Table 4.2: Comparison of learning applications for their formal learning capabilities (Persuasive application = red, LMS = blue, PLE = yellow)

instance with a data log. Three exceptions are the Moodle mEducator, PlotMaker, and the user managed PLE. In the first, Moodle mEducator, the focus is on semantifying course documents and make them searchable and explorable instead of tracking user activity. Plotmaker is focused on the creation of learning objects that implement persuasive principles and not on ways to reflect upon these activities. The user managed PLE consists of a manual configuration of tools that are used to support learning activities. For instance, Twitter is used to acquire some opinions on a certain topic. Wikipedia is then consulted to understand some key terms better. The reflective practice can only happen in the user's minds because there is no interface available to show the user's activity among different tools. On the other hand, mEducator offers 'Dialogic Reflection' by the possibility to explore the document corpus with a search facility. Other systems that perform well in 'Dialogic Reflection' are iDetective, Pacard, and Netvibes. iDetective is a location-based game to persuade users unconsciously to have a healthier lifestyle. The user can explore freely a map and discover photo-taking missions. In this process, reflection is supported by persuasion techniques that provide unconscious introspection of the users current behavior through the design of dialogues and conversations that sense the reflection stage of the user with the help of a questionnaire based on a so-called transtheoretical model (Yoshii et al., 2011).

PACARD is a card-based interface that simulates physical flashcards and prompts the user with notification to reflect on past events and future learning opportunities in the tradition of Reflection-On-Action and Reflection-In-Action by Schoen (Moon, 2013). PACARD utilizes badges and push-notifications to trigger these reflective practices. On the other hand, Netvibes is a dashboard that allows the user to combine information from different sources such as social media, favourite websites or apps and monitor them to follow up on interesting topics and trends. Mahara is similar to Netvibes in the sense that one can track different activities from different sources but it is built with the purpose to share one's activities with others as a portfolio. Thereby, one can reach deeper levels of reflection such as to support a change of behavior (Transformative Reflection - level 3). Last but not

System	Reflective Description: Revisiting with Explanation	Dialogic Reflection: Exploring Relationships	Transformative Reflection: Fundamental Change	Critical Reflection: Wider Implications
1. Mindless Change	x	x	x	x
2. PlotMaker	x			
3. Chick Clique	x			
4. RightOnTime	x			
5. iDetective	x	x	x	
6. Canvas	x			
7. Moodle	x			
8. PACARD	x	x		
9. TalentCards			x	
10. MGLS	x		x	
11. Moin	x			
12. KSMS Project	x			
13. MemReflex	x	x		
14. Symbaloo Edu				
15. Plexus	x	x		
16. Elgg	x	x		
17. Moodle mEducator				
18. Netvibes	x	x		
19. Mahara	x	x	x	

Table 4.3: Comparison of learning applications for their reflection capabilities (Persuasive application = red, LMS = blue, PLE = yellow)

least, Mindless Change is the only one who scores on all reflective practices. It is a tool that utilizes the learning theory of Kolb (Moon, 2013) as backbone to change habits for a healthier lifestyle. Mindless change can make the user aware about the consequences of an unhealthy lifestyle not only for the individual but also for society as a whole.

4.1.3 Perspective 3: Support for Persuasive Strategies and Playfulness including Gamification

(Nicholson, 2015) described playfulness as a framework consisting of play, exposition, choice, information, engagement and reflection to create a space where the learner is free to explore and fail within boundaries. Elements of Play can be mapped to gamification techniques to operationalize these elements and make them easier to apply in real-world

context. For instance, gamification elements such as avatars and story elements can be related to the playful element of exposition which create stories for learners that are integrated with the real-world setting. For a more detailed analysis of gamification and playfulness see (Nicholson 2015). Recently, many LMSs integrated gamification elements e.g. (Su & Cheng, 2015) or persuasive techniques (Devincenzi et al., 2017). Table 4.4 and Table 4.5 show which systems deal with these strategies. The following, typical gamification elements are selected for the comparison based on their visibility to the user as proposed in (Sailor et al., 2017) and the impact they have on motivation:

- Points
- Challenges
- Cooperation
- Badges
- Leaderboards / Performance Graphs
- Avatars
- Story elements

Most systems we reviewed implement at least one gamification element, most often the triad of points, badges, and leaderboards, but PLEs rarely implement gamification elements to guide the informal learning. These systems guarantee users a maximum of independence to organize their environment, which comes with some disadvantages with respect to user control and management. Other playful elements such as Story elements are rarely realized, probably because of the effort it takes to implement it in a generic way. For comparing the systems for the persuasive capabilities (see Table 4.5), relevant persuasive techniques were selected based on our review of Fogg's design principles (Fogg, 2002) and the Hooked Model by Nir Eyal (Eyal, 2014). From the work of Fogg and Eyal, we selected four major techniques for our comparison of the systems:

- Trigger (Suggestion)
- Tailoring
- Commitment (Tunneling),
- Social Comparison
- Reward (Conditioning)

Although Fogg's design principles and the Hook model share a common component (a trigger), they capture different levels in the analysis of an application. The design principles consider higher level concepts of ability and motivation integrated in an application, whereas the Hook model provides guidelines to design specific features (Filippou et al., 2016). Therefore, we map the components of the Hook model to the corresponding design principles by Fogg, 2002 to yield a set of categories that capture the functionality of a wide range of different persuasive applications. Suggestion or Triggers refer to the right moment when an application intervenes with the current behavior of the user to spark a target behavior which is called action in the Hook Model. As already said, they exist in both models. For instance, push notifications can be used to remind a user about a product they have accessed some time ago and spark an acquisition.

Tailoring information to the user needs and characteristics increases the likelihood that an action is taken. For instance, a persuasive diet application can suggest healthy meals based on preferences for certain ingredients. Tunneling is based on guiding users through a process or experience to provide opportunities to persuade along the way. Tunneling is persuasive because of the commitment that people make once they engage in the process. Commitment is also an important step in the Hook Model. The more the user invests time in a product the less likely (s)he stops using it. In this regard, Tunneling places the user in a clearly defined sequence of steps they have to perform within the system based on the principle that the commitment to the first (simple step) will persuade the user to

also perform the following steps; the more the user progresses in the sequence the less likely are they to abort the effort. For instance, a user learned to handle a complicated financial software to organize income taxes. (S)he continues using this software even if better solutions exist because of the effort it takes to re-learn a different software. Social comparison is not an independent component in the Hook Model but it can be used to facilitate commitment when a user is aware of the actions of others. They can guide the user to embark in certain actions and processes. For instance, users might copy the behavior of higher-performing users in order to reach their level Last but not least, variable rewards are used to condition the users for certain actions. They can be external such as real money or based on some virtual currency. The goal of rewards is to stimulate continued usage of the system. Note that rewards are also used in gamification. Because it serves the same principle and is the same technique, we only mentioned it under persuasive techniques.

On the application front, the picture is two-faced. On the one hand, the portfolio applications (Mahara, Netvibes) and the LMSs (Moodle and Canvas) do not target specifically persuasive strategies. However, with the latest updates Moodle and Canvas integrated gamification strategies such as Leaderboards, Badges and Avatars. On the other hand, Mindless Change, PlotMaker, KSMS Project, RightOnTime, Moin and iDetective are dedicated persuasive applications. They integrate a wide range of persuasive design principles such as Trigger, Commitment, Tailoring, and Social comparison. Besides those dedicated persuasive applications, PACARD and TalentCards are digital flashcard-based systems for learning that also score well on gamification. MGLS, a location-based LMS that allows the creation of missions on geo-locations, has also good gamification support but lacks integration of persuasive techniques.

4.1.4 Conclusions

Here, we recapitulate the comparison of related applications in terms of informal, formal learning on the one hand and reflective and playful capabilities on the other hand. Common

System	Points	Chall.	Coop.	Badges	Leaderb. Perf. Graph	Avatars	Story Elem.
1. Mindless Change							
2. PlotMaker				x			
3. Chick Clique	x						
4. RightOnTime				x			
5. iDetective		x					
6. Canvas							
7. Moodle	x	x		x	x	x	
8. PACARD	x	x	x	x	x	x	x
9. TalentCards	x	x		x	x		
10. MGLS	x	x		x	x		
11. KSMS Project							
12. Moin	x	x	x	x	x		
13. MemReflex	x	x	x	x	x		
14. Symbaloo Edu							
15. Plexus	x	x					
16. Elgg							
17. Moodle mEducator							
18. Netvibes							
19. Mahara	x			x	x	x	

Table 4.4: Comparison of learning applications for playful capabilities (Persuasive application = red, LMS = blue, PLE = yellow)

among applications that score high on informal learning is the fact that they also support a wide range of reflective capabilities. Due to the focus on the informal learning domain, it's obvious that PLEs have a rather large support of informal learning features. They also support at least reflective description and dialogic reflection except for applications that have a narrow focus such as Evernote and Symbaloo Edu. In general, LMS' rather focus on formal learning with the support of user and content management. It is striking that two LMS applications (TalentCards and MGLS) can trigger transformative reflection by providing relevant information to the user needs and characteristics at the right moment to change attitudes and behavior. To certain extent, transformative reflection can be seen as a technique to persuade because it can change the perspective and opinion on information provided by the application. Persuasive applications draw a complicated picture in terms of reflection. On the one hand, Mindless Change supports all categories of reflection by

System	Tailoring	Commitment (Tunneling)	Social Comparison	Suggestion (Trigger)
1. Mindless Change	x	x	x	x
2. PlotMaker	x	x	x	x
3. Chick Clique	x		x	
4. RightOnTime		x	x	x
5. iDetective	x	x	x	x
6. Canvas				
7. Moodle			x	x
8. PACARD	x	x	x	x
9. TalentCards			x	x
10. MGLS				
11. KSMS Project	x	x	x	x
12. Moin				
13. MemReflex	x	x	x	x
14. Symbaloo Edu				
15. Plexus	x	x		
16. Elgg		x	x	x
17. Moodle mEducator				
18. Netvibes				
19. Mahara				

Table 4.5: Comparison of learning applications for their persuasive capabilities (Persuasive application = red, LMS = blue, PLE = yellow)

intervening unhealthy food habits with notifications to establish a healthier life style. On the other hand, the remainder of persuasive applications mainly focus on reflective description based on self-monitoring. The other phases of reflection are not stated explicitly in the design of the application. Regarding playful capabilities of the reviewed applications, it can be highlighted that the adoption of gamification techniques is quite advanced in the field of LMS. Persuasive applications often do not directly mention playful techniques as design features. Nonetheless, points and badges are often integrated as functionality. But this is only the case because points and badges can be seen as a form of internal reward which is part of persuasion techniques. To some extent, PLEs support playful capabilities as seen in Moin, MemReflex or Mahara. Nonetheless, the other applications do not incorporate playfulness as design drivers. The lack of support of playfulness or gamification is an untapped research area to come up with novel approaches to incorporate these techniques in the PLE domain.

4.2 Comparison of Related Models/Frameworks

In this section, we review existing models and frameworks in the domain of TELE. The selection of resources is limited to articles which contain conceptual and architectural frameworks or models and metamodels. A model is an abstract or simplified representation of some aspects of an organizational structure, the purpose of which is to communicate those aspects of the system to one or more stakeholders.

In the terminology of behavior theory, meta-models describe organizational structures that encompass multiple levels of influence on individual behavior (Hekler et al., 2013). A meta-model is therefore a model of the constructs and rules needed to build specific models, it provides rules, constraints and a vocabulary to govern how a domain of interest will be modeled. For practitioners, they offer multiple perspectives on how a system can be evaluated (Gonzalez-Perez & Henderson-Sellers, 2008). In this way, novel approaches can be unearthed to highlight gaps in existing research without destroying the established world

view of the meta-model. On the other hand, conceptual and architectural frameworks provide one perspective on how a system can be constructed and decomposed. They describe fundamental building blocks and their relationships to provide more specific guidance for the analysis of technologies (Hekler et al., 2013). On the lowest level of granularity, there are design guidelines which make theoretical or practical findings applicable in a clear defined context but cannot be easily generalized to other contexts of use. To deal with the fact that selected resources do not use the same terminology we will resort to three broad categories (Dialogue support, Context of use, and Support of learning activities) to make a comparison between related but distinct systems possible. The selection of these categories is inspired by the design elements of behavior change systems formulated by (Oinas-Kukkonen & Harjumaa, 2009) and defined as follows:

- **Dialogue Support** are the techniques which the system uses to interface with the user. This does not only include the graphical depiction of the user interface but also ways to tailor, personalize, simplify, and gamify information to persuade the user and spark a learning action. Moreover, it also covers different ways to access information (push or pull) and to present learning traces (visualization). We use two sub-categories to compare dialogue support: **User interaction Scaffolding** and **Engagement techniques**:
  - **User Interaction Scaffolding** includes all techniques to simplify the interaction with resources provided by the system for the purpose of learning. These are:
    - **Reduction and Tunneling** can be used to guide the user through a complex set of tasks. People can interact with information better and more effectively when the content is broken down into digestible parts; learning thus takes the form of small steps.
    - **Tailoring and Personalization** of information can be used to meet the information needs of the learner.

        * **Structure, share and annotate resources** can be used to provide more structure to the learner and allow to to build a mental model of the resources.
        * **Information tracking** can be used to observe and record learning behavior (i.e., actions, thoughts and emotions).
        * **Visualization support** can be used to scaffold the presentation of learning behavior.
        * **Information access**. The user can decide about the opportune moment to access information (pull of information) or it can be the responsibility of the system (push of information).
    - **Engagement techniques** are used to increase the motivation for using the system.**Recommendation**, **Feedback**, **Cooperation**, **Competition**, **Rewarding**, and **Story elements** can be used as engagement techniques.

- **Context of Use** is the set of different data dimensions the system collects from its user and environment. Typical examples are location, learning styles and technology used, such as desktop computers, mobile devices, or ubiquitous technology. We distinguish the following dimensions:

    - The **personal context** contains information about past learning behavior, current progress in learning activities, learning styles, cognitive abilities, and learning goals.
    - The **location context** includes learner's current location and previous location history. This includes formal learning spaces such as the traditional classroom, informal learning spaces such as home, public transport and other mobile contexts, and blended learning spaces where informal and formal learning spaces are combined.
    - The **social context** includes information about peers in learning communities.

  - The **technology context** obtains information about type of technologies (mobile, desktop or wearables) and their capabilities (sensor range, GPS precision, touch input, screen size).

- **Support of Learning Activities** are the range of cognitive tasks promoted by the system to achieve learning goals. We distinguish between **cognitive tasks** and **meta-cognitive tasks**:

  - **Cognitive tasks** require a person to mentally process new information and allow them to recall, retrieve it from memory and to use it at a later time in similar but different situations (Kester & Kirschner, 2012). Typical examples are critical thinking, content production, and (collaborative) problem solving.

  - **Meta-cognitive tasks** refer to ways of framing, re-contextualizing and comparing cognitive processes for the purpose of gaining new knowledge and self-regulating future actions. Typical examples are awareness, self-monitoring, goal-setting, reframing, and self-reflection.

In order to find related work on models and frameworks in the domain of TELE we constructed our literature search as follows. We started with the general term of Technology Enhanced Learning Environment (TELE) and extended it with keywords along three dimensions to retrieve more specific work:

- Components of the MPLE namely Persuasion, Playfulness, Micro-Learning, Self-Monitoring, and Visualization

- Related learning environments which are more specific, namely LMS, PLE, SLE, and OLN, and Mobile Learning Environment

- Type of system including meta-model, architectural and conceptual framework and design guidelines

In this way we obtained 20 resources containing 20 works. Among these systems, there are 8 frameworks (mostly conceptual frameworks and one architectural framework) and 12 models including 3 meta-models. After a more thorough scan we removed 5 works because they were more concerned about the technical integration of PLEs into LMS than conceptually guiding the design and development. The following works were considered for the comparison:

1. (Nordin et al., 2010) propose a **conceptual framework for mobile learning applications** that provides systematic support for mobile lifelong learning experience design. It considers four perspectives: generic mobile environment issues, learning contexts, learning experiences, and learning objectives.

2. (Motiwalla, 2007) explored the extension of e-learning into wireless/ handheld (W/H) computing devices with the help of a **m-learning framework**. This framework provides the requirements to develop m-learning applications that can be used to complement classroom or distance learning.

3. (Bruck et al., 2012) presents the micro-learning approach, **Micro-Mobile Learning Framework**, and the KnowledgePulse system that delivers micro-content on mobile devices and allows learning anytime, anyplace and any pace.

4. (Churchill et al., 2016) propose the **RASE learning design framework** as a key strategy for utilizing multiple affordances of mobile learning technology. This learning design framework includes and integrate at least four core components, namely: Resources, Activity, Support, and Evaluation

5. (Alharbi et al., 2012) present a proactive context-aware architecture for PLE, i.e. the **Context-aware PLE architecture**, supporting two major objectives: lifelong access and learner-centric study.

6. (Sumadyo et al., 2018) propose a component model that focuses on adaptive services on improving students' meta-cognitive abilities. Components in **SLE-metacognitive** are arranged in the form of modules connecting students with awareness activities of self-knowledge and ability for self-learning.

7. (Freigang et al., 2018) deal with the design of Smart Learning Environments (SLEs). Over and above that, it is about the interconnection between SLEs and the Internet of things, i.e. **Conceptual SLE Framework**.

8. (Spector, 2014) combined philosophical, psychological and technological approaches to develop a platform for planning and implementing SLEs. In the author's view, smart learning environments have to achieve sustainable educational work at the levels Engagement, Effectiveness and Efficiency, hence the name **3Es model**.

9. (Hwang, 2014) transparently deconstructs and compares the terms "smart learning", "ubiquitous learning", and "adaptive learning" to define characteristics of a dynamic SLE system in the **SLE u-learning framework**.

10. (Koper, 2014) has developed the **Human Learning Interface Model** that shapes the design of a SLE by defining in and outputs to define the learning process. Three core interfaces must be supported to initiate a learning activity: identification, socialization, and creation. For better and faster learning to happen, two meta interfaces must be supported: practice and reflection (Hoel & Mason, 2018; Kop & Fournier, 2014).

11. (R. Huang et al., 2013) propose the **TRACE3 Functional Model** for SLEs as the learning place or an activity space that can sense learning scenarios, identify the characteristics of learners, provide appropriate learning resources and convenient interactive tools, automatically record the learning process and evaluate learning outcomes in order to promote the effective learning.

12. **PLEF** is a framework for mashing up personal learning environments. The primary

aim of PLEF is to help learners create custom learning mashups using a wide variety of digital media and data (Chatti et al., 2010).

13. **Customized xLearning Environment** is a theoretical model where all the learning and e-learning elements are present and where the student is the focus and the one who decides what should be included in this learning environment (Mesquita et al., 2017).

14. (Conde et al., 2014) have defined a service-based framework, **PLE-LMS Framework**, which facilitates the definition of a PLE with activities that returns information to the LMS.

15. (Milligan et al., 2006) report on initial work to create a Reference Model for a Personal Learning Environment, the **Personal Information Toolkit**, where the emphasis is on facilitating learning in contrast to traditional Virtual Learning Environments which exist primarily to manage the learning process.

Table 4.6 shows a high-level comparison of the selected works. Colors are used to indicate the main domain of the work: yellow = PLE, green = mobile learning, blue = SLE. The following scale is used to rate how a system meets the features mentioned earlier for a category:

- **low**, at most one feature of a category is used/supported. For instance, a system that only supports personalization, scores low on User Interaction Scaffolding (Dialogue Support)

- **partial**, at most half of the features of one category are used/supported. For instance, a system that considers the location of the learner and personal context scores partially on Context of Use.

- **high**, more than half of the features of one category are used/supported. For instance,

a system that supports both cognitive and meta-cognitive tasks scores high on cognitive tasks.

In the following sub-sections, we will describe each work further and explain which characteristics led to the final rating for the different categories.

Work	User Interaction Scaffolding	Engagement Techniques	Context (learner, location, social)	Cognitive Tasks
1. TRACE3 Functional Model	low	low	partial	partial
2. PLE-LMS Framework	low	-	partial	-
3. PLEF	high	-	partial	-
4. Customized xLearning Environment	-	-	partial	partial
5. Personal Information Toolkit	partial	-	low	partial
6. Context-aware PLE architecture	low	-	partial	partial
7. m-learning Framework	high	low	low	low
8. RASE Learning Design Framework	partial	high	low	low
9. Conceptual Framework for Mobile Learning Apps	high	high	partial	high
10. Micro-Mobile-Framework	partial	partial	partial	partial
11. SLE-Metacognitive	partial	-	partial	high
12 Conceptual SLE Framework	low	low	high	low
13. 3Es Model	high	high	partial	high
14. SLE u-learning Framework	partial	-	high	-
15. Human Learning Interface Model	low	high	high	high

Table 4.6: High-level comparison of the selected works (yellow = PLE, green = mobile learning, blue = SLE)

4.2.1 Dialogue Support (User Interaction and Engagement Techniques)

As already explained before, our category Dialogue Support covers techniques from User Interaction Scaffolding as well as Engagement Techniques. It is quite remarkable that the

works in the context of PLE (i.e. TRACE3 Functional Framework, PLE-LMS Framework, PLEF, Customised xLearning Environment, Personal Information Toolkit and Context Aware PLE Architecture) score rather low on techniques to simplify interaction with the user interface and resources. With one exception, PLEF, these works highlight interoperability issues between LMS and PLE and how the communication can be done smoothly but they often neglect issues of the application layer, namely how to meaningfully present information that learning can aid (Visualization). The PLEF Framework does not only highlight the utility of content personalization based on the user's needs and problems but also ways to personalize and unite the set of tools the user uses for learning. Persuasive Techniques such as Tunneling or Reduction and visualization techniques are rarely present in these works which is strange because most of the PLE systems track learning traces of the user, and tracking data allows for visualization and persuasion techniques. The second batch of systems consists of Mobile learning models and frameworks (i.e. Micro-Mobile Framework, m-learning Framework, Conceptual Framework for Mobile learning apps, RASE Learning Design Framework). They do not only support mobile devices, they also integrate micro-learning elements that permit to decompose large learning resources into small digestible chunks which do not require a high attention span. Furthermore, they offer personalizing learning algorithms that track learner responses and update the learner profile dynamically. Unlike PLE systems, mobile learning systems often rely on the push mechanism to transmit information to the user. They do not wait for the user to initiate the access of information. Instead, Mobile Learning systems push information via notifications or SMS to the user. The Conceptual Framework for Learning Apps does also support engagement elements such as enjoyment, user satisfaction, and motivation. Activities that draw on conflict and possess competitive elements might be more interesting to the learners. Indirectly, this inserts a playful element into the user interaction cycle (Nordin et al., 2010). On the other hand, SLE systems (i.e. SLE metacognitive, SLE u-learning Framework, Human Learning Interface Model, 3Es Model, Conceptual SLE Framework) also

stress the importance of personalization from a more dynamic perspective. In this view, the system makes automatic adjustments when the user is facing problems and updates the user profile accordingly. The Human Learning Interface Model and the 3Es Model go one step further and offer "Conditioning" of the environment of the learner, i.e. they provide positive and negative feedback by applying gamification techniques through points and batches thereby hoping to build associative stimuli with learning.

4.2.2 Context of Use

As one might expect, good coverage of context of Use (learner, location, social, and technology context) is often yielded by SLE models and frameworks. A smart learning environment is context-aware in the sense that the learner's situation of the real-world environment in which the learner is located are sensed, implying that the system is able to provide learning support based on the learner's online and real-world status. This does not only include learning styles, preferences, and learning performance but also social relationships to peers and learning supervisors. The most complete models are the Human Learning Interface Model, Conceptual SLE Framework, and the SLE u-learning framework, which take into account the learner, location, social and technology context of the learner. The Human Learning Interface Model sheds a special emphasis on the context of use. It defines a series of systems including Identification and Socialization interface that observe learning behavior and intervene learning by providing tasks, giving feedback and conditioning the user. In the Socialization Interface, learning is seen as a way to represent the social norms, values, customs and ideologies of social institutions and learning the skills and habits. This enables the learner to behave within the social institutions, including the dissemination of norms and values to others including family, peer groups, religion, economic system, language, and legal system (Koper, 2014). In the Identification Interface the real-world status of the learner is represented by situations, events, and learning activities how to react upon it. On the other hand, the SLE u-learning Framework is defined to be minimally context-aware,

adaptive and personalized. Only the online and real-world states of learners are considered as the context of learning. The adaptivity with respect to emotional states, cognitive capacity, motivation, and socio-economic factors are not considered. Personalization is limited to content selection; pedagogy-oriented guidance to shape the way how information is accessed is not supported.

On the PLE side, with the exception of Context Aware PLE Architecture, most work focus on the learner and social context by collecting learning traces from applications that deal with informal learning, i.e. social networks, note-taking apps, word-processors. The Context Aware PLE architecture integrates a provider layer of various tools and independent service providers including physical sensors, such as a camera or thermometer, to capture information about its local environment. Unfortunately, it is not described how physical sensors contribute to improving formal/informal learning in (Alharbi et al., 2012). The green batch of the works (m-learning framework, RASE learning Design Framework, Conceptual Framework for Mobile Learning Apps, Micro-Mobile Framework) which combines mobile technology with micro-learning approaches generally integrates rather conservatively the users context with learning activities. In all works, there is some sort of personalization based on user profiles and past behavior, but the location and social context are handled only rudimentary meaning that they have a rather limited support of location awareness or social relationships in the learning process. The Micro-Mobile-Framework mentions the location context and deeper integration of collaboration as an important aspect for future work. The RASE Learning Design Framework highlights connectivity, social interactivity and context sensitivity as important aspects of mobile devices but does not provide detailed instructions how to integrate these affordances into mobile applications.

4.2.3 Support of Learning Activities

Whereas models and frameworks of PLE systems often focus on informal and blended learning types (including formal learning), they rarely specify what kind of cognitive pro-

cesses they actually target. This is not the case for Micro-Learning works (m-learning framework, RASE learning Design Framework, Conceptual Framework for Mobile Learning Apps, Micro-Mobile Framework). Their inherent focus on small digestible chunks of information leads to the support of the repetition of learning content and frequent feedback in form of assessment before the user can progress to the next unit. Also, the content is organized in a manner such that the systematic seeking of information is permitted to provide as few barriers to instant learning as possible. Regarding meta-cognitive tasks (i.e. self-monitoring, reflection, reframing), Micro-Learning works are less specific. (Churchill et al., 2016) often write about gaining awareness through self-monitoring but which results in terms of learning outcomes are produced through this process is often vague. In general, SLE systems are more specific about the cognitive and meta-cognitive tasks. For instance, (Sumadyo et al., 2018) provides an architectural expansion that specifies components to infer information that can be used as feedback or recommendation to foster meta-cognitive skills which solve problems of self-awareness including planning and scheduling task solving processes. (Koper, 2014) gives a detailed overview of SLE functionality in terms of interfaces, i.e. a set of learning related interaction mechanisms that humans exposed to the outside world to control, stimulate and facilitate their learning processes. These interfaces include support for the following learning activities:

- exploration, recognition, differentiation and generalization of stimuli
- labeling groups of stimuli
- building knowledge about the behaviors of the unknown stimuli
- creating mental maps of the environment.

Furthermore, the Human Interface Model also includes features to create representations of knowledge and change future behaviors in form of meta-cognitive tasks, i.e. reflection, reframing of the problem and solution, evaluation of results, decision making, strategy development, and self-regulation.

4.2.4 Conclusion

Overall, one can say that the reviewed works can be divided by time and technological advances. In the early 2010, with the emergence of the Web 2.0 researchers looked frequently into ways to exploit the manifold ways users interact with information on the Internet for informal learning. As a reaction, the concept of PLE was born whose focus was solely on the learner and the services they use from a static perspective, i.e. desktop computers were the starting point to analyze and improve digital learning. Only with the shift to mobile devices and applications the peculiarities of this platform were integrated into learning tools, exemplified by micro-learning models and frameworks. They took into account the changed habits of Digital Natives to access information spontaneously and impulsively from changing locations. This resulted in learning activities that are sliced in small digestible chunks which are pushed to the user at opportune moments and do not overburden the attention span of the digital learner. Around 2012, the concept of SLE was developed which introduces a holistic, big-picture view of education as a whole to reveal the opportunities and possibilities inherent in digital technologies, particularly as personalized learning processes emerge (Freigang et al., 2018). In this view the learner's situation or the contexts of the real-world environment in which the learner is located are sensed, implying that the system is able to provide learning support based on the learner's online and real-world status.

As one of the most complete models the Human Interface model scored high on most categories (Engagement Techniques, Context, Cognitive Tasks) except on User Interaction Scaffolding. It provides theoretical foundations for different incarnations of SLE systems. It subdivides the design space into five ideal typical applications called Human Learning Interfaces (HLI) each targeting a different learning goal (identification HLI, socialization HLI, creation HLI, practice HLI, and reflection HLI) thereby providing sound conceptual guidelines for the development of SLE systems. Due to the general purpose of this model, only general help is provided for Dialogue Support including User Interaction Scaffolding and Engagement Techniques. To simplify the interaction with information provided by the

system, the Human Learning Interface Model argues that a SLE has to represent knowledge faster and better by including representations of performance targets and future incentives. To achieve this, (Koper, 2014)) mentions techniques to condition and engage the user, such as the use of batches and rankings, but it neglects techniques to streamline the interaction with information through visualization and persuasive techniques . Our MPLE model tries to fill this gap by providing a set visual interactions with data (overview, selection, filtering) with persuasive techniques (tailoring, reduction, tunneling) and playful concepts (rankings, points, badges).

CHAPTER 5

PROOF OF CONCEPT APPLICATION: THE TICKLE CASE

The objective of this chapter is to provide a proof of concept for our MPLE model. We will describe the design, development and evaluation of a MPLE solution, i.e. a persuasive mobile and playful system that empowers learners to perform and reflect on informal/formal learning activities. The original context of the application was the TICKLE project[1] that aimed to deal with the need to tackle school burnout in the Brussels region. School burnout refers to exhaustion at school, a cynical and detached attitude, and feelings of inadequacy as a student (Salmela-Aro & Tynkkynen, 2012). School burnout often precedes school dropout, also named Early School Leave (ESL), which results in young people leaving education with only lower secondary education or less. Early school leavers have lower job opportunities and only qualify for jobs with lower earnings, which has a great impact on their further life. Therefore, the issue is high on the political agenda. Europe 2020 aims for a reduction of ESL to less than 10% (Vlieghe & De Troyer, 2016b). Although different programs exist to prevent school burnout and ESL, ranging from offering customized training projects and individual coaching time-out trajectories aiming to bring the student back into the classroom, these projects and programs have in common that they are very labor-intensive (Vlieghe & De Troyer, 2016b). To come to a less labor-intensive solution, in particular to deal with school burnout, our objective was to complement the existing programs with an ICT solution. The goal was to re-activate and re-motivate youngsters for learning through the recognition of non-formal learning opportunities.

The solution developed, called TICKLE, is based on the MPLE model as we believe that the features of MPLE will allow us to reach the objectives of the ICT solution. Playfulness and persuasiveness can improve engagement in learning within a non-game context.

[1] https://wise.vub.ac.be/tickle

In particular, we will adopt the design values for playfulness given by (Bekker et al., 2010) (including motivating feedback, supporting spontaneous goal formation, and creating competitive or collaborative relationships) as well as the design values for persuasiveness given by (Oinas-kukkonen, 2010) (including tailoring, personalization, reduction, and tunneling from the PSD model). Narrative techniques are used to provide guidance in the reflective process. Data traces will be interwoven with a personal profile of the learner to produce a compelling story that allows learners to look back on their activities and learn more about themselves, their interests, behavior and shortcomings, but also provide access to cultures, norms, communities and academic opportunities which are outside their own (Figueiras, 2014). Examples of learning opportunities that can be provided to the learner are:

- Civics. For instance, where is the town hall and what can I do there? Where can I find information about finding a job?
- History. For instance, what does the statue of the soldier next to my house tell me about war?
- Social engagement. For instance, how can I help my neighbors?
- Career. For instance, what kinds of training are offered in my neighbourhood and how can they improve my career?

For the design and development, we applied cycles of prototyping, testing and analyzing the results to refine the functionality and quality gradually.

The remainder of the chapter is structured as follows. We first explore why and how the Fogg model, the Hook model, and a personalized approach can be applied in the solution (respectively in section 5.1, section 5.2, section 5.3) before we specify the requirements in section 5.4. Thereafter, we present the main modules of our design in terms of a frontend and backend architecture (section 5.5). This section is followed by details on the implementation (section 5.6). Next the different evaluations and demonstrations are discussed (section 5.7). The chapter ends with a summary (section 5.8).

5.1 Applying the Fogg Model

Re-activating youngsters with school burnout implies a behavior change. Therefore, we applied the principles of the Behavioral Model of Fogg (Fogg, 2002), which offers factors to determine whether a person will perform a certain behavior or not. For a detailed explanation of this model see subsection 3.4.2. Studies have shown that motivation and ability are crucial requirements for behavioral change (e.g., (Lo et al., 2007)). According to Fogg, motivation in the context of behavior can be distilled to three pairs of core motivators: pleasure and pain; hope and fear as well as social acceptance and social rejection. These are aspects that could be taken into consideration in the development of the environment. For instance, our objective to make learning a pleasant activity is implemented by applying playful techniques such as avatars and playful visualizations, as well as game elements such as mini games and rewards in the form of badges. We prefer to call TICKLE a playful learning environment instead of a game-based environment because the overall interaction scheme is based on learning, play and exploration instead of on pure gaming which is a means for itself. However, social acceptance and social rejection are also usable in our solution in the form of a leaderboard. The ability in Fogg's model relates to available resources. Fogg (2002) uses the term ability in a broad sense, i.e., available time and/or money; required physical effort and/or cognitive effort; social deviance caused by the behavior; and the familiarity with the behavior. For a behavior to happen, the ability should be high enough. To take this into account, we should carefully adapt the activities to the abilities of a youngster. The trigger in Fogg's model is the element that sparks, facilitates, or signals the target behavior. Triggers are most effective when they are provided at the right place and time (Fogg, 1998). This is an argument in favor of keeping track of the youngsters' performance and activities within the environment in order to be able to give the trigger at the right place and time. However, the type of trigger used, as well as the content of the trigger, also seems to be important. If an app keeps sending notifications that

are not considered useful by the receiver, this might be annoying, and (s)he will start to ignore them (Eyal, 2014). Furthermore, what will trigger one person to perform an action may not trigger another person. This is because different users have different preferences and characteristics (Smiderle et al., 2020) which is an argument for using an elaborated user profile in order to also personalize the triggers (see also section 5.3).

5.2 Applying the Hook Model

Next to applying the Behavioral Model of Fogg to re-activating youngsters with school burnout, we also followed the Hook Model, as this model provides a practical approach to create new habits or behavior. According to Eyal (Eyal, 2014), a new behavior becomes a habit when the behavior becomes an automatic response to a situational cue or trigger. Unfortunately, turning a new behavior into a habit is hard since, according to Eyal, old habits die hard, while new habits quickly dissipate. In accordance with Fogg, Eyal also argues that an action will only take place if the user possesses sufficient motivation and ability to perform the action. Therefore, Eyal suggests making the actions as easy as possible, e.g., clicking on a link. In this way, the behavior is more likely to be performed. Variable rewards are used to increase the likelihood of repeating an action in the model. An important phase of the cycle is the investment. The more a user invests in a system, the less likely it is that (s)he will stop using the system, as then the investment would be lost. The triggers in both the Behavior Model of Fogg and the Hook Model of Eyal aim to persuade the user to perform a certain behavior (Fogg) or an action (Eyal).

5.3 Personalized Approach

Next to applying a personal approach to learning, which we do by adapting the content to the abilities and preferences of the user, it is also important to use a personal approach for persuasion. Research has shown that the "one size-fits-all" approach is not working to persuade all users in an effective manner (Bray & McClaskey, 2010). This is because

different users have different preferences and characteristics. According to (Berkovsky et al., 2012), there are opportunities in using personalization in persuasive systems by:

- Monitoring and presenting information about aspects of importance to the user.
- Tailoring the content and the look-and-feel of the information in order to meet the user's communication preferences.
- Responding to a user's susceptibility to various persuasive techniques and methods.

Different taxonomies exist to categorise individuals based on personality traits such as the Five-Factor Model, the Bartle Model, or HeXad (B. Braun et al., 2016; Hamari & Koivisto, 2014; Tondello et al., 2016). These ones are those most often used in technology for the purpose of personalization. Some of these personality trait models, e.g. Bartle and HeXad, have their source in a gaming context; nevertheless, they are also useful in a broaden context like TICKLE and their relationship with persuasion is also studied nowadays. The HeXad model maps well to the domain of our MPLE. Especially, the focus on achieving and mastering challenges suits the learning activities promoted by TICKLE. The HeXad model describes six gamer types:

- **Philanthropists** are motivated by purpose, meaning that these people are motivated by putting effort in the system without expecting a reward for it.
- **Socialisers** are motivated by relatedness, meaning that these people want to interact with other people within the system and create relationships.
- **Free Spirits** are motivated by autonomy. They want to have the freedom to express themselves within the system without external control.
- **Achievers** are motivated by mastery. They want to progress within the system by completing challenges, they also want to prove themselves by performing difficult challenges.

- **Players** are motivated by extrinsic rewards. They will do whatever they need to do to earn a reward within the system.

- **Disruptors** are motivated by the triggering of change. They like to disrupt the system and find the system's boundaries.

Another model for describing the personalities of humans is the Five-Factor Model (Digman, 1990). With this model it is possible to characterise humans giving five categories based on their personality traits. The Five-Factor Model uses the following categories:

- **Extraversion**: These people tend to be more communicative, easy making social contact with others, and being more assertive.

- **Neuroticism**: These people tend to be more anxious, more frustrated, and in a depressed mood.

- **Openness to experience**: These people tend to be more curious, insightful and they have a wide range of interests.

- **Conscientiousness**: These people tend to be more organised, efficient, hardworking, and more careful.

- **Agreeableness**: These people tend to be kind, sympathetic, and cooperative.

In terms of persuasion, research has shown that three of the five types in the Five-Factor Model are more vulnerable for source persuasiveness: Extraversion, Neuroticism, and Openness to Experience. Within the two remaining types, Conscientious and Agreeableness, there is no clear relation between personality and persuasiveness (Oreg & Sverdlik, 2014).

Furthermore, as already mentioned, also what is offered (i.e. content), when (time-wise) and how (medium) should be personalised to make the solution as effective as possible (see also section 5.4 for a more detailed motivation)

5.4 Requirements Engineering

The first step in a software engineering process is requirements engineering. It is concerned with the goals, functionalities, and constraints of the software. Based on (Räisänen et al., 2010), the following core requirements engineering activities were performed:

- Eliciting requirements;
- Modeling and analyzing requirements;
- Communicating requirements, agreeing requirements and evolving requirements.

The first activity, the elicitation of requirements aims at identifying all the stakeholders —such as customers, developers and users — as well as the objectives and tasks of the users. Hassenzahl (2013) proposes a simple User Experience (UX) method to understand the needs of all stakeholders involved by specifying so-called Be- and Do-Goals. Be-Goals capture a person's emotions and attitudes about using a particular software whereas Do-Goals refer to the pure functionality, i.e. what can the user achieve with a software. The starting point for the specification (i.e. modeling; the second phase) of requirements in terms of Be- and Do Goals is always the motive, i.e. what does the user want to represent with using the software. The designer tries to comprehend these Be-Goals in order to be able to envision the overall experience and to foresee the functionality. Communicating and agreeing on requirements is more concerned with the collaboration between the designer and the stakeholders. Once the requirements are modeled they need to be communicated and discussed to the stakeholders in order to evolve them when they do not completely meet the stakeholders' expectations.

The remainder of this section mostly deals with the first two steps, i.e. eliciting and modeling requirements but the specified requirements were also presented and discussed with all stakeholders. We mentioned this in subsection 5.4.3. The presented requirements are the final ones.

5.4.1 Eliciting Requirements based on Literature

To come to the requirements, an in-depth understanding of the main users, namely youngsters, was needed. Therefore, the TICKLE project started with a number of literature studies. To be able to make a grounded decision for the requirements and the technology to be used, the results of the major studies on computer and media use among youngsters were analyzed. The focus was on Flanders and Brussels, as youngsters in Brussels were initially the target users of TICKLE. Because this was not part of the PhD work, we only provide a summary of the findings that are relevant for the design of our solution. The complete report is available online (Vlieghe & De Troyer, 2016a). Youngsters appear to have more experience in media usage than the average Belgian or Flemish citizen. They seem to have ample experience performing basic operations and handling office applications like a word processor. A similar trend is visible in relation to youngsters' experience with Internet related activities. Youngsters have more experience than the average citizen with the various kinds of activities like creating a Web page or changing the safety settings on their browser. In terms of perceptions, the results indicate that youngsters recognize the importance of using computers and their potential to make learning at school more interesting. At the same time, youngsters also indicate that they are only moderately interested in using computers in their own learning endeavors. They are also in strong disagreement about the potential of computers to increase learning enjoyment. Even though youngsters recognize the importance of computers, they appear to remain sceptical about the advantages of using computers in their own learning practices.

With regard to the Web for gathering information, searching for information about goods and services is the most popular activity, followed by reading news messages. Searching for information about job and training offers, and consulting Wikis and other Internet resources to learn new things are two activities which youngsters seem to perform more frequently than the average citizen. Many youngsters report about performing communication activities with the help of social media. The popularity of pass time activities is

reflected in the list of most frequently used applications. Facebook and Instagram appear to be most successful in inducing heavy use (i.e. more than one hour per day). Other popular applications among youngsters are a wide variety of games. These also inspire heavy use, as one in four people play games daily and one in eight play games more than one hour a day.

The actual media usage clearly shows that information seeking and learning activities are equally as important as, if not more important than, pass time and communication activities. The latter two activity types do seem to invite more frequent or heavy use (i.e. daily or even multiple hours a day). This trend is present among youngsters, but also among the population as a whole. As a consequence, it is hard to attribute these results to theories that offer simplified and stereotyping explanations of the theory of Digital Natives.

Youngsters appear to have good general computer skills and experience with the Web. They also regularly share their own material online. They have a preference for smartphones and are using them daily; tablets are used less. Smartphones seem to fit best with their lifestyle, i.e., they have often limited financial resources and spend a large part of their time outside. Therefore, **we decided to adopt smartphones for our solution**. The Internet is well spread and most youngsters do have access to the Internet. Moreover, the availability of the Internet is only increasing: free Wi-Fi becomes available in public spaces and a lot of youngsters have mobile broadband on their smartphone. Therefore, **we opted for an Internet-based application**. To keep all options open, we decided to go in the first place for a browser application rather than a native app. In addition, this allowed for having the application immediately available on different types of smartphones. Furthermore, the majority of mobile operating systems can provide a Web application as an "app" on the start screen. At a later stage, a limited version of the application was turned into a true (native) app.

The initial problem that we wanted to address was school burnout in order to avoid ESL, so studies related to these topics were investigated as well in the TICKLE project. The com-

plete report is available online (Vlieghe & De Troyer, 2016b). Also this work was not part of the PhD work but the results were important for are solution. In summary, it was found that a large variety of factors can play a role: factors from the youngsters' environment, as well as individual characteristics, but none of these factors seems to be conclusive. Therefore, it is recommended in the investigated literature that prevention programmes should rely on a wide body of information related to multiple influencing factors, to provide a more complete picture of the youngster. For this reason, **we added the requirement of an elaborated user profile** that should be used to personalize the environment and the presented content towards the situation and characteristics of the youngsters.

5.4.2 Formative Evaluation to Inform Requirements Specification

In order to have clear picture of the user specific characteristics, stakeholders (supervisors, content creators) and the derived requirements we decided to do a formative evaluation. The objective of this evaluation is twofold:

- To explore processes as they develop and emerge, and thus to inform the design process for the application under study (i.e., the TICKLE environment) in parallel with that process so that the application design can be improved as it progresses (Kaplan & Maxwell, 2005). In other words, we want to provide a formative evaluation that is aimed at improving the TICKLE environment under development, rather than just assessing an existing one and speaking of outcomes or impacts. Therefore, we developed early prototypes which showcased sketches of functionality in the form of screenshots, user profile sketches, ready-made components such as Google Maps or login/registration blueprints.

- To understand and demonstrate how main users (i.e., youngsters with school burnout, and their supervisors and the organizations concerned with school burnout and dropout) perceive and evaluate the TICKLE environment and what meanings the system has for them. More specifically, we want to gain insight in how people think or feel about

the TICKLE environment and why they think that way, what their perspectives and situations are and how those influence what is happening (Kaplan & Maxwell, 2005).

Since we want to examine the dynamics of the TICKLE environment as an ongoing process rather than its static characteristics, qualitative research methods are more useful than solely quantitative ones (Kaplan & Maxwell, 2005). According to Kaplan and Maxwell (2005) qualitative methods can be used throughout the entire systems development and implementation process as they can help identifying potential problems as they are forming, thereby providing opportunities to improve the system as it develops. This way "the evaluator can play an active role in the project, offering evaluations as the project progresses (formative evaluations) instead of having to wait until the project is completed (summative evaluations). Furthermore, evaluators can serve as a bridge between the interests of systems developers and systems users" (Kaplan & Maxwell, 2005). Next, the users' perspectives are generally not known in advance. By allowing researchers to study users' perspectives in depth, "qualitative methods can contribute to the explanation of users' behavior with respect to the system, and thus to the system's successes and failures and even of what is considered a "success" or "failure"" (Kaplan & Maxwell, 2005). In sum, by providing evaluation findings that connect more directly with these individuals' perspectives, qualitative methods can increase the credibility and usefulness of evaluations for decision makers (Kaplan & Maxwell, 2005).

In order to meet the dual evaluation objective, a phased approach was used. We first wanted to receive suggestions and recommendations from supervisors and organizations concerned with school burnout and dropout about our solution (phase 1), Next, we aimed at gaining feedback and/or input on specific topics concerning the TICKLE environment (e.g., attractiveness, usability, and feasibility) and setting up try-out environments with potential users (phase 2 and 3). Furthermore, we follow a user-centered development: (1) to ensure that the research performed and products developed remain relevant in practice, but also (2) to ensure access to a sample of potential end-users (i.e., youngsters with school burnout

and their supervisors) and (3) to identify the so-called lead users who are prepared to apply the results in an early stage, and can act as advocates for driving the necessary positive attitude towards the application and approach. Therefore, at the same time attention was also paid to awareness creation to inform people that the information/product/service exists and is useful within a given context.

The main question which all of the chosen evaluative strategies were supposed to answer is as follows: **Is the TICKLE environment, as an adaptive mobile tool with persuasive strategies, able to encourage youngsters to explore the city and to increase the intrinsic motivation and learning capacity of youngsters, and to prevent school burnout and dropout?**

Feedback and suggestions of related organizations and supervisors

We wanted to receive suggestions and recommendations from supervisors and organizations concerned with school burnout and dropout for the further and continuous (re)design and improvement of the TICKLE environment when it comes to feasibility, attractiveness and the roles and guidance by coaches and organizations. Next to that, we also wanted to create awareness about the project within the field, by informing the organizations (both on specific as well as more broadly related issues) and inviting them for a feedback moment. Computer systems (here: a playful location-based learning environment) do not exist in a vacuum, but their implementation, use, and success or failure occur in a social, cultural and organizational context that shapes what happens when that system is introduced (Kaplan & Maxwell, 2005). Therefore, it is important to treat the "context" as intrinsically part of the object of study rather than as external to the information system. Qualitative methods are useful for discovering and understanding these influences (Kaplan & Maxwell, 2005). Therefore, through discussions with the organizations and supervisors, we wanted to get to know these important contextual influences. In terms of data collection, we used open (duo) interviews with organizations and supervisors/coaches working with youngsters who

are at risk of school burnout and/or already dropped out. This included the organizations already running programs related to school burnout and dropout. From these meetings with small groups and individual contacts with the organizations, we aimed at gaining feedback and/or input on specific topics concerning the TICKLE environment (e.g., attractiveness, usability, and feasibility) and setting up try-out environments (Phase 2 and 3).

Regarding the procedure of the meetings, after a short introduction round of all parties, the researchers explained the aim, design, and features of the TICKLE environment, after which a demo version of the environment was presented. Based on this the TICKLE environment was discussed. The following questions served as a guide for the interview conversations:

- What do you think about the environment?
- What were the positive things for you about the environment?
- What were the negative things for you about the environment?
- Is there anything you would like to add to the environment?
- Do you foresee any (technological) barriers with the equipment / set-up / operation or the environment in general?
- How do you think about the reward system? Do you think of other ways the youngsters can be rewarded?
- How do you consider the role of the supervisor?
- What do you consider feasible as a supervisor?
- To what extent / in what way do you think it is feasible to use the environment to tackle school burn out?
- What are important aspects to take into consideration when TICKLE would be used as supportive tool?

- Do you think TICKLE can be supportive in encouraging youngsters to explore the city / to learn new things / to start learning again/ to be engaged in their city?

In this way, we presented the initial requirement ideas to relevant organizations namely Groep intro, Jeugdienst, Abrusco, Steunpunt, Don Bosco, Kans and Tracé. These interviews provided important feedback and several proposals for our design:

- Potential value of TICKLE for exploring the youngster's environment: The organizations we consulted pointed out that a lot of youngsters, among whom those that (eventually may) dropout, hold on strongly to the boundaries of their own quarters, in this way missing opportunities to broader their interests. Through its location-based service and on-the-go approach, the organizations did see merit in TICKLE in allowing young people to go out and step outside their own direct neighborhoods, enabling them to explore new parts of their neighborhood and the city in general. By offering youngsters different challenges and activities, the application could bring them to locations and places they have not been before and stimulate them to explore activities they did not participate in before.

- Potential value of TICKLE for engaging youngsters: The coaches and supervisors from the consulted organizations recommended that the offer in terms of cards, activities, and challenges should be very diverse, so that all youngsters could find something of their interest. Themes mentioned were sports (e.g., dance and boxing) and music, but also media. Next to our intention to start from the youngsters' own interest, the gamification element within TICKLE was considered a positive and appealing way to motivate youngsters to explore more. Based on this feedback, and in order to allow the youngsters to broaden their interests, we decided to provide links to "related" cards on (the back side of) a card.

- Potential value of TICKLE for informal learning: Within the environment, the youngster is able to track the cards already opened and collected, the themes discovered,

and his/her own growth. It was indicated that this could offer a means of self-reflection. Furthermore, it also provides ownership over one's own learning process. Another idea that was dropped, and added to the system, was to include soft skills next to topics of interest, and allow the labeling of cards with soft skill labels too, e.g., responsibility, team spirit. In this way, the youngsters can (possibly unconsciously) practice these soft skills and also collect points for them. Furthermore, it was indicated that it would be valuable to guide the youngsters around within the educational, social (-cultural) support and service landscape. This has been taken up by providing a specific card environment dedicated to this. In this card environment, each relevant organization is described by a card, which is positioned on the map by means of a dedicated icon (see also subsection 5.7.4).

- Other suggestions: It was suggested that the app could support geocaching ("Geocaching", 2020). Although TICKLE is not explicitly tailored towards geocaching, it is possible to support it by means of the open challenges. In the future, we will investigate how it can be supported in a more explicit way. Another aspect that was mentioned was the importance of allowing youngsters to connect with each other with and within the TICKLE environment. The organizations gave several reasons why this would be good to have: to communicate and connect, to inspire and trigger each other, to collaborate and meet in real life, to help and learn from each other. This valuable suggestion would be implemented later. It was also suggested that the app should provide a help button that the youngster could use when (s)he would be stuck on a challenge. There are different possibilities to implement such a help-functionality. It will be considered in future work. Another suggestion was to introduce leaderboards. This was considered later as part of the persuasive strategy.

For the data-analysis, the interviews were audio-recorded, transcribed ad verbatim and read through repeatedly. The interviews were coded and analyzed in MAXQDA software package through an iterative process that combined elements of both content and thematic anal-

yses (Bowen, 2009), including various cycles of coding and discussing the data (V. Braun & Clarke, 2006). Content analysis is the process of organizing information into categories related to the central questions of the research. It entails a first-pass document review, in which meaningful and relevant passages of the text are identified. "Thematic analysis is a form of pattern recognition within the data, where emerging themes become the categories for analysis" (Fereday & Muir-Cochrane, 2006). The analysis process involves a careful, more focused re-reading and review of the data.

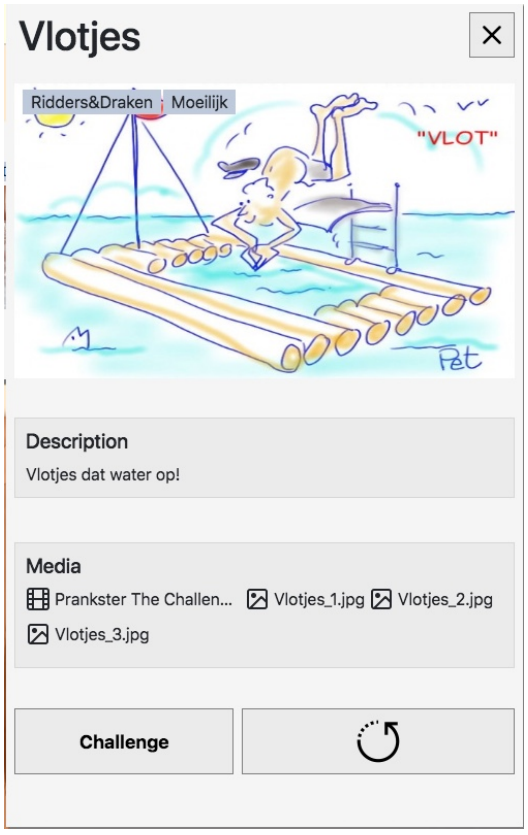

Figure 5.1: Sample card (cards are in Dutch)

5.4.3 Specification of the Requirements

In this section we present the requirements formulated for the TICKLE App based on the objectives and design decisions discussed in the previous section. The final requirements were formulated based on informal conversations and questionnaires given to the partic-

ipants at the end of the evaluation period. Then, the requirements were categorised into the functional and nonfunctional requirements representing Do-and Be goals. The following terminology is used: *youngsters* use the TICKLE environment to detect and perform learning activities; *supervisors* are the persons responsible for youngsters; they will use the system to follow the progress of their youngsters and manage their learning activities. *content creators* are the persons that create the learning activities.

Do-Goals

- The youngster is able to explore his/her surrounding (neighborhood) and learn more about opportunities in terms of hobbies, career possibilities, history, social engagement, and civics:
  - The youngster is able to explore learning activities related to an environment.
  - The youngster can collect and gain points from learning activities to have sense of progress in fields of interest.
  - The youngster can choose from a set of learning activities.
  - The youngster is able to inspect his/her activity in terms of performed learning activities, discovered topics and own interests.
- The youngster is able to reflect on past learning activities with a digital diary:
  - They can discover related learning activities based on interests or already performed activities.
  - They should gain insight into their interests and deficits by a visual overview of all past learning activities.
  - They should gain insight into location-based information, i.e. walked distance, discovered points of interests and neighborhoods.

- The content creator is able to create learning activities which includes choosing a mini-game, and providing background information and media (video, sound) about a learning activity.
- The supervisor can manage the youngster's profile:
  - The supervisor can consult the persuasion profile of a particular youngster.
  - The supervisor can consult the events log of a particular youngster.
  - The supervisor can enter the results of the personality questionnaires (i.e. BigFive, HeXad) of a youngster in the youngster's profile.
  - The supervisor can define the block off time span for notifications for a youngster, meaning that in that time span no notifications should be send to the youngster.
  - The supervisor can define the preferred notification medium for a youngster (push or email); the preferred notification medium must be suitable for the device of the youngster (e.g. the device should allow push notifications).
- The youngster can manage his/her notifications:
  - The youngster can view his/her notifications.
  - The youngster can remove notifications.
  - The youngster can navigate from a notification to a related card.
- The system should be able to send notifications:
  - The system should be able to send emails to youngsters.
  - The system should be able to send push notifications to youngsters.
  - The system should be able to present the notifications as a popup and/or in the notifications panel to the youngster.

  - The system should not send notifications in the block off time of a youngster.
  - The system should be able to send personalised messages based on the persuasive profile of the youngster.
  - The system should be able to send non-personalised messages when the youngster does not have a persuasive profile.

Be-Goals

After defining the Do-Goals for the different types of users and the system, we will also present the Be-Goals by means of user experience, legality and compatibility requirements.

User Experience

- The youngster should be empowered to self-regulate informal learning experiences in their neighborhood of residence or other environments as a part of pass time activities:
  - They should be notified about learning opportunities while on the move to the school, job or while meeting friends.
  - The notification about opportunities should be as non-intrusive as possible and coupled with activities of play to make learning pleasant activity.
- The youngster should be enabled to establish a gradually more positive self-view through the usage of rewards and feedback in order to develop a more positive learning identity.
- The youngster should be able to showcase achievements in TICKLE to peers and supervisors as a means to improve the learner identity.
- Youngsters should be able to collaborate with other users to perform learning activities.

- Exploration should be sparked through usage of location-based learning activities and gamification
- Persuasive techniques should be embedded in the interaction scheme.

Legality

- The system must follow the guidelines of the GDPR. The user's persuasion profiles should be deleted upon request, as well as all other information collected about the user. Also an unsubscribe link must be included in the emails. Users should give their consent for collecting data and tracking their location while using the system.
- To receive push notifications, users first must give their consent.

Compatibility

- The user needs a recent web browser to use the application.
- An email account is required to receive emails.
- A mobile device or compatible desktop browser is required to receive push notifications.

5.5 Design

TICKLE is designed as a MPLE to stimulate youngsters to explore their environment in a meaningful and playful way. TICKLE allows youngsters to collect digital cards by performing associated challenges in their surroundings. The challenges are small activities intended to reactivate the youngster for learning. The main component of TICKLE is the playful environment. This is a mobile location-based application composed of a *Card Interface* and a *Card Diary*. The Card Interface module displays a (geographical) map on which cards are marked, which the youngster can collect by performing the associated challenges

when (s)he is nearby. Note that in the beginning and depending on the characteristics of the youngster, the challenges can be quite simple (e.g. taking a picture) in order to not demotivate the youngster, but more advanced activities are possible, like performing a quiz or a small game. By collecting cards, the youngsters can gather points that can be used to obtain rewards (variable). In the Card Diary, the youngster can see his/her achievements and compare them with the achievements of peers (persuasive principle of social comparison) (if allowed).

The final design of TICKLE is composed of a *Frontend* and a *Backend* (see Figure 5.2). The frontend is the actual learning environment and is intended to be used by the youngsters. The backend contains the *Authoring Environment*, which allows the content creators to create the actual content, i.e. cards, for the environment, as well as a supervisor module to create and maintain the profiles of the youngsters, i.e. the *Profile Editor*, and to link cards to youngsters, which is needed for the personalized approach. This module also provides the *Learner Analytics* module. All information related to learning activities is stored in the *ChallengeCardStore*, whereas the learners' activity and profiles are stored in the *Learner Profile Store* and the *Activity Record Store*. Through the use of these multiple data collections the frontend and backend can communicate and separation of concerns is preserved.

Table 5.1 shows how the persuasive design principles, adapted from the PSD Model (Oinas-Kukkonen & Harjumaa, 2009), are used in the TICKLE environment. One can see that we put emphasis on the Primary Task and Dialogue support categories from the PSD Model whereas System Credibility plays a minor role. For instance, for Customization we give the user the ability to create their own challenge cards at one point. Moreover, the user can also customize their character in TICKLE with an avatar, and include unique interests that are used for personalization. For rewards, the user is rewarded with a variable amount of points for performed learning activities. These points can be used to obtain real tangible rewards, such as a visit to the cinema (variable), or for virtual badges.

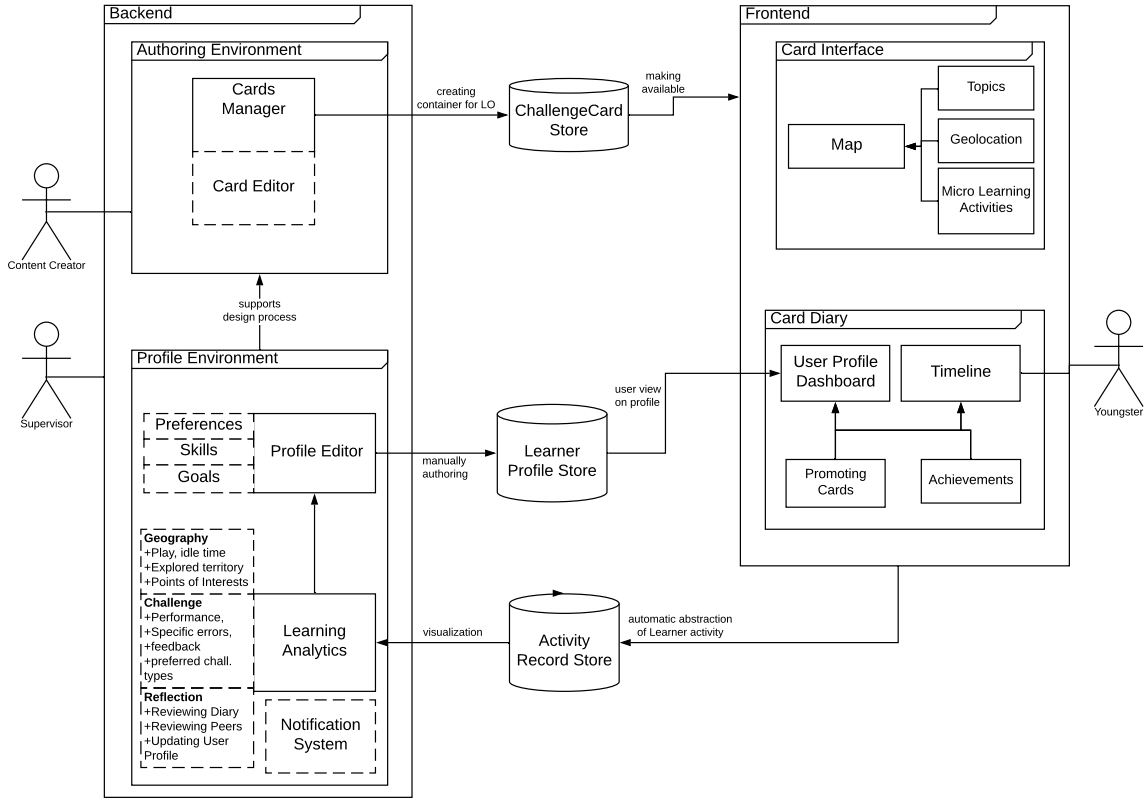

Figure 5.2: Diagram depicting the architecture, main modules and users of the TICKLE environment

The following two sub sections describe in detail respectively the frontend and backend. We conclude this Design section with a summary and an overview on how TICKLE can be used.

5.5.1 Frontend

In this section we describe in more detail each component of TICKLE's frontend and how they interact with each other. The main components are the Card Interface and Card Diary. They communicate to the backend by the use of database collections, which include the Activity Record Store that is populated by an event system that keeps track of the user's activity in the frontend. We will first describe the Card Interface which includes the *Map View* and the *Topic View*. They serve as navigational cues to explore and discover learning

activities. Next the Card Diary is described.

Strategy	Description	Use Case for TICKLE
Customization	Giving the user the ability to customize the environment to their needs or preferences	The user can create their own cards add and customize the avatar
Self-Monitoring and Feedback	Provide the user's performance	The Diary reflects the user's performance and provides feedback
Suggestion	Give suggestions to the users regarding their behaviors	Recommendations of learning activities are given based on interests, behavior and geolocation
Personalization	Provide personalized content to the user	With the concept of environment, user groups have personalized access to a specific set of learning activities
Praise	Applauds the user when performing the target behavior	The user is praise at several occasions, e.g. when he logged in multiple times in a row
Reward	Reward users for target behavior	Points are given for successfully performing a learning activity. These can be used to obtain rewards
Comparison	Comparing the user's performance against other users	The leaderboard in Tickle provides the ability to compare the performance against others
Competition	Compete against other users	An integrated leaderboard shows the collected points of the user
Cooperation	Cooperate with other users to achieve a target behavior	Allowing to help another user with a particular challenge.
Reminders	Remind the user of target behavior	TICKLE can send reminders to the user
Tailoring	Information provided by the system tailored to the interests of the users.	Challenges in Tickle can be based on the user's interest and background

Table 5.1: Persuasive Strategies implemented in TICKLE

Card Interface

Micro Learning Activities (LA) are the core unit of interaction to provide playful learning experiences in the Card Interface. They are formed around the idea of new media (text, voice, music, graphics, photos, video) and situated in the personal context and interests of

the youngster. The youngster's mobile context (i.e. location, time and the social network) play an important role. For instance, based on a youngster's personal interest in racing cars and current location, the platform could recommend a LA which can take place in a museum nearby. The LA could utilize augmented reality to better exemplify the workings of an engine of a racing car. In principle, learning activities can be located anywhere and performed anytime and they are explicitly not bound to a school context. In line with (Sharples et al., 2010), youngsters can perform learning activities across physical and digital information spaces by taking ideas gained in one activity and applying or relating it to another activity. Ideally, the accomplishment of LAs should lead to new insights. Each LA is pervasive in the sense that it accesses information placed in the surroundings where it should take place. The LAs do not exist in isolation, they are interwoven in a web of links of related LAs. They provide navigational cues to move from one LA to another. LAs can be members of certain sets and refer to other LAs. In this way, it is possible to create extensive storylines or themes that offer guidance through an overall information space. Similar to the influential Hypercard software (Bowers & Tsai, 1990), LAs are visually presented as cards, called *ChallengeCards*. These cards provide an intuitive way to provide and access background information (pointers to multimedia resources) needed to successfully perform the LA (called the *Challenge*). ChallengeCards can be presented either purely digital (on a mobile device) or in mixed reality. For instance, the virtual card can be accessed by a youngster on his/her mobile device while standing relatively close to the physical location associated with the ChallengeCard. Or a real physical card (e.g. made out of cardboard) can be placed on a physical location and the attached QR code can be scanned to reveal the corresponding ChallengeCard on the mobile device. Overall, the cards serve three functions:

- Being a visual metaphor to ease recognition of LAs and present them as fun challenges and not as work or duty.
- They also constitute the reward system. The cards are collectible (by performing the

associated LA successfully) and various cards can form sets and themes. When completed, they reveal rewards to the youngster, like unlocking new content, or setting apart the user from their peers, or providing a material reward (like a free hamburger).

- By using cards, the boundary between producer and consumer can be blurred. ChallengeCards consist of small building blocks such as description, location, media and the actual challenge (i.e. the learning activity) which can be easily created and combined to form new cards. In this way, youngsters can produce new LAs for their peers. This process of card creation is a main part of the reactivation process because it demands creativity and imagination which are important skills for learning and for youngsters' self-esteem.

- Cards allows to achieve playfulness by a combination of gamification techniques and story elements. LAs can include mini-games which need to be succeeded in order to collect the ChallengeCard. In the current version of TICKLE, we embedded the following mini challenges (see Figure 5.3 for examples):

  - Photo Challenge: the user has to find a certain artifact and make a photo of it;
  - Hangman: the user has to guess letters of a word. When too many mistakes are made a hangman is shown on the screen;
  - Quiz: a multiple choice question-answer game.

However the generic architecture of TICKLE also allows the integration of third-party activities such as BookWidgets[2], which offers a wide range of different learning activities from timelines to gap texts:

Moreover, each ChallengeCard is associated with a number of topics and is given a certain amount of points per topic. These so-called *Experience Points* (XP) are earned when the challenge is successfully performed. The XPs are saved in a so-called *Wallet*

[2]https://www.bookwidgets.com/

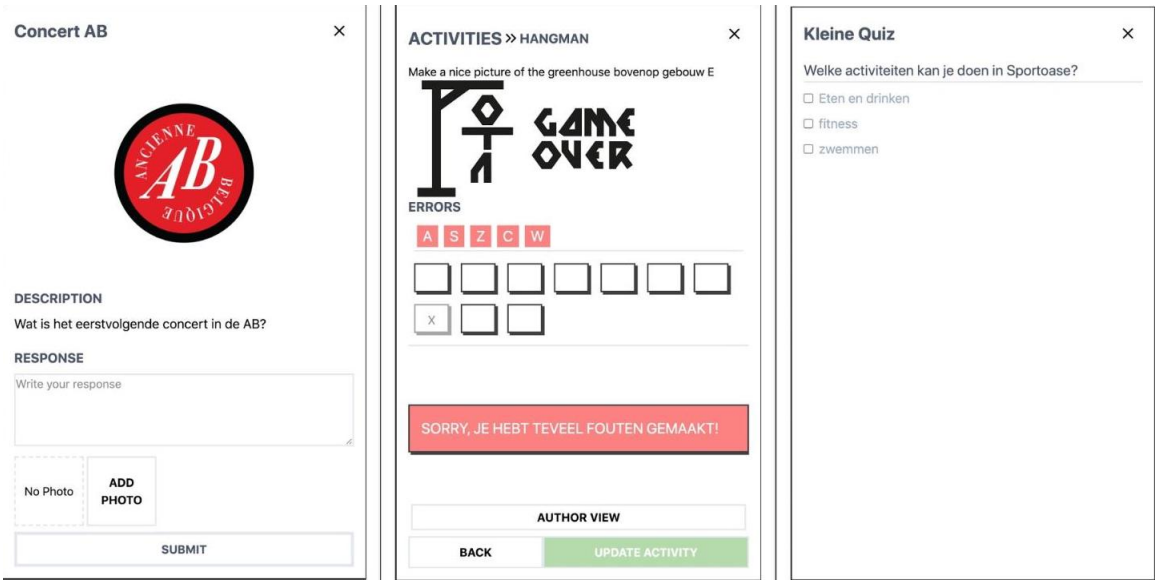

Figure 5.3: Currently supported Mini-Challenges in TICKLE

that can be used to buy (internal or external) rewards. Internal rewards can unlock more content for TICKLE. For instance, with a certain amount of XPs new sets of cards can be made available, or when the user reaches a threshold of XPs a badge is issued to denote that the user is experienced in a certain topic. External rewards, on the other hand, can be freely chosen by the supervisor of the learner(s). For instance, they can range from cinema tickets to coupons for reduction of products. Figure 5.4 (left) shows the front side of an example ChallengeCard. The challenge is revealed when the user clicks on the CHALLENGE button. The back side of a card shows basic information about the author, related cards which are linked by category and comments by users.

Map and Topic View

The Map View is the main navigational facility of the TICKLE environment. Challenge-Cards are placed on locations in a map, ready to be discovered by the youngsters. Figure 5.5 (left) shows an example (geographical) map where the user is currently exploring the neighborhood; the position of the user is indicated by the avatar symbol. The radius of the user denotes the range within which hidden ChallengeCards can be discovered. The slideshow

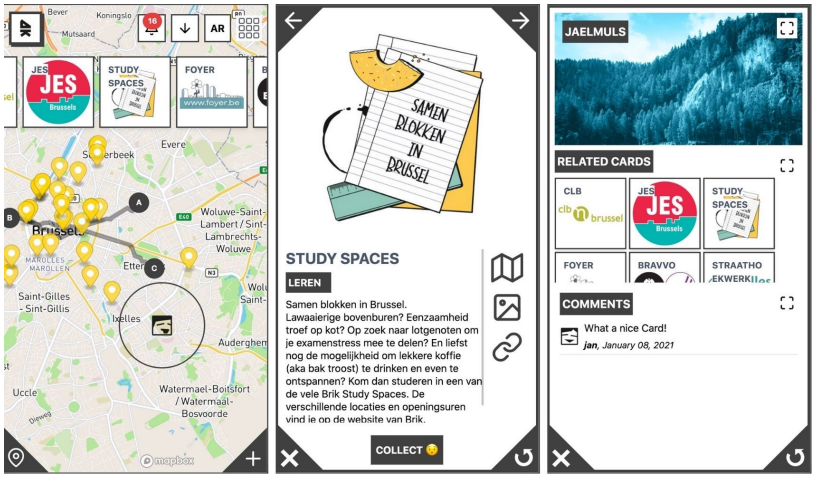

Figure 5.4: Left: Map View of the TICKLE app; Center: Front side of a ChallengeCard; Right: Back side of a ChallengeCard

of cards in the top of the screen shows current cards available in the view. Moreover ChallengeCards can be found via the topics for each card that can be associated to ChallengeCards. In this topic view, the user can access cards more interest oriented (see Figure 5.5 (right)).

Card Diary

Each collected ChallengeCard is moved to the youngster's Card Diary to track the youngster's progress. It interweaves past TICKLE events in a coherent user story to foster reflection and promote future learning activities. The diary is presented in a visual format to facilitate revisiting collected ChallengeCards and exploring related ChallengeCards, or to perform the challenges not done yet. To create a coherent user story, the diary couples the presentation of the in-app events, such as the performed challenges or important milestones (completion a card set), with personal data. For instance, GPS data is used to determine visited places or participation in social events such as concerts or museum visits. The supervisor of the youngster can make use of this data to notify the youngster about interesting activities or interesting pointers to information.

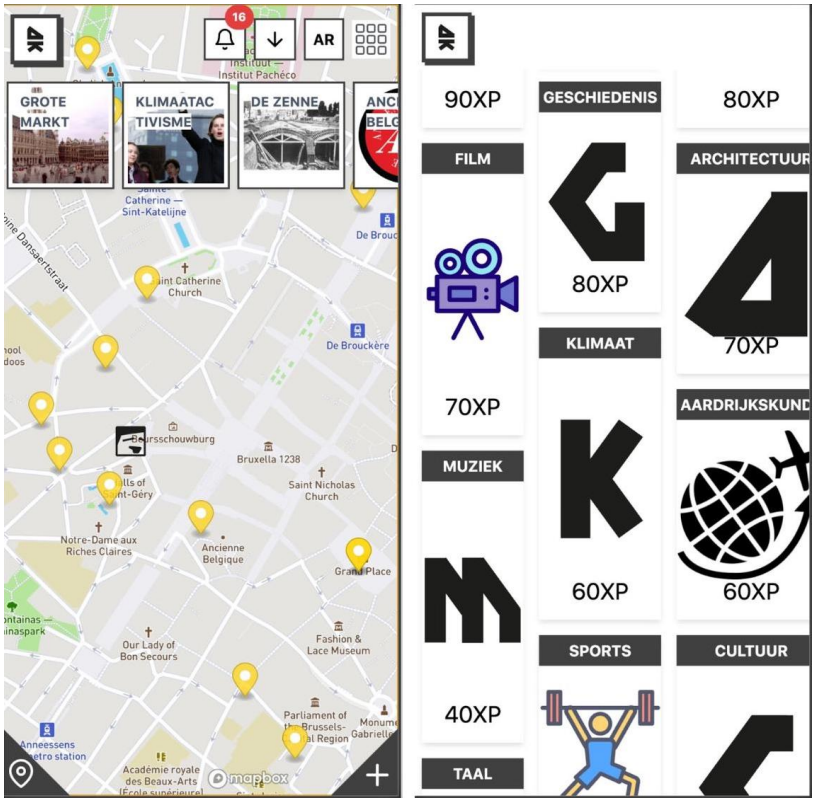

Figure 5.5: The Main View of the TICKLE App to discover cards by location (left) or topic (right)

At certain moments, for instance at the end of the day, users are encouraged to slow down and contemplate on the activity of the past day in terms of acquired ChallengeCards, walked distance, and discovered points of interests. This is done with the precise scheduling of notifications provided by our Rule Engine. However, self-monitoring is not the only function of the visualizations, they are also a means to demonstrate one's accomplishments to others. For instance, a big stack of collected ChallengeCards in a category like art or football can impress others and can strengthen self-esteem. Showing one's personal stack of ChallengeCards to others can help to form a (learning) identity and motivate peers to keep going on. Youngsters may draw inspiration from the actions and behavior of their peers to plan their future activities. However, this functionality is in an early stage and cannot be yet exported to other media such as Facebook or Twitter to showcase achievements.

Figure 5.6 shows four important parts of the TICKLE Diary (from left to right):

- Collected XPs are visualized in form of bar charts to give the youngster an overview of his/her strengths and weaknesses.
- The next visualization shows nearby ChallengeCards by their distance to the youngster's location in a radial visualization.
- The topics associated with the ChallengeCards are visualized with the help of a visualization technique called Bubble Sets (Collins et al., 2009).
- The Timeline view shows ChallengeCards based on the point in time when they have been collected. By opening a context menu the user can access related ChallengeCards.

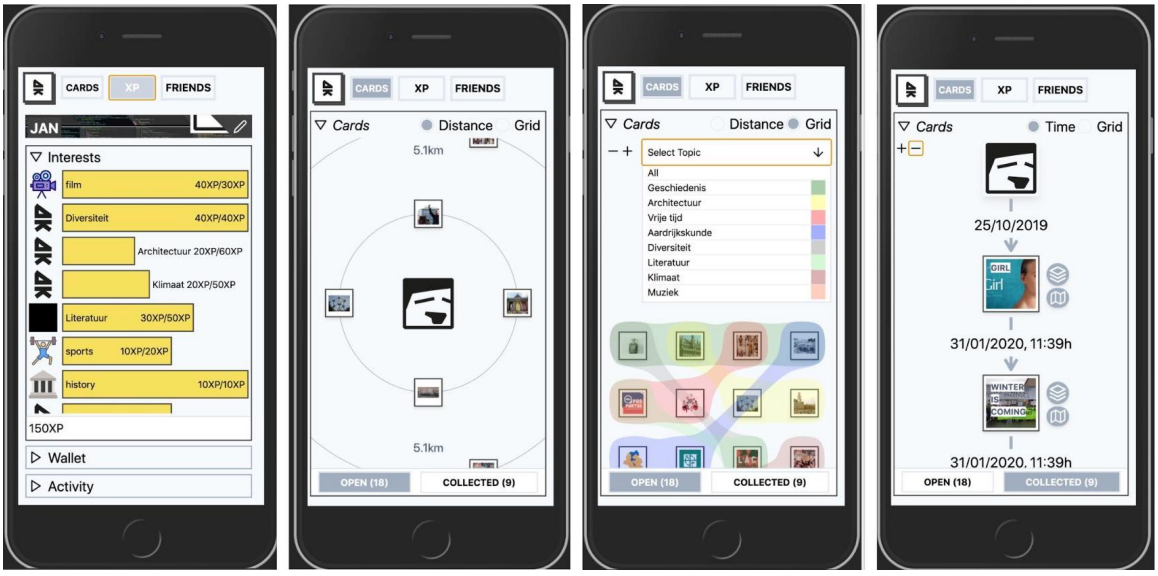

Figure 5.6: Screenshots of four important functionalities of the TICKLE Diary

5.5.2 Backend

The backend consists of an Authoring Environment for creating ChallengeCards and challenges and a Supervisor Module for creating and maintaining the profiles of the youngsters, to link ChallengeCards to youngsters, to manage the sending of notifications, and to

inspect the progress of the youngsters. The users of the Authoring Environment are (learning) content creators, and the users of Supervisor Module are professionals who want to use TICKLE in their institute or organization. These can be teachers, or professionals supervising youngsters with school burnout, or members of an organization or institute that want to use a TICKLE environment for some purpose, e.g., a teambuilding event, a city game, training. We first describe the Authoring Environment, then the Supervisor Module. Both include sub-modules, namely the *Cards Manager*, *Profile Editor* and the *Learning Analytics*. As shown in the architecture (Figure 5.2), these modules communicate with ChallengeCard store, Learner Profile store and Activity Record Store.

Content Creator: Authoring Environment

The Content Creator user role has limited access to the Authoring Environment where (s)he can create ChallengeCards by means of the Card Editor (part of the Cards Manager). The creation of card environments which contain groups of cards assigned to particular users is not permitted to the Content Creator. A ChallengeCard consists of a number of fields, such as Image, Title, Description, Links, Videos, Topics, and Time-period. The author can choose which ones to include in the card and then provides the content for those fields as shown in Figure 5.7. Giving the location of the ChallengeCard on the (geographical) map is mandatory, as well as the information on when and where the ChallengeCard should be visible. The visibility of a ChallengeCard can be limited to a certain range, i.e., 50, 200, or 500 m, meaning that the ChallengeCard will only become visible when the user is physically within this range of the location associated with the ChallengeCard. The alternative is that a ChallengeCard is visible wherever the user is located. The duration of the visibility can be limited by providing a starting date and time and end date and time, for instance when the ChallengeCard is about an event or a temporary exhibition. If such a time period is not given, the ChallengeCard will stay visible (until explicitly removed). It is also possible to indicate that a ChallengeCard should not be visible on the

map after it was collected (or the user failed to collect it). To speed up the creation of similar ChallengeCards, templates can be created and used.

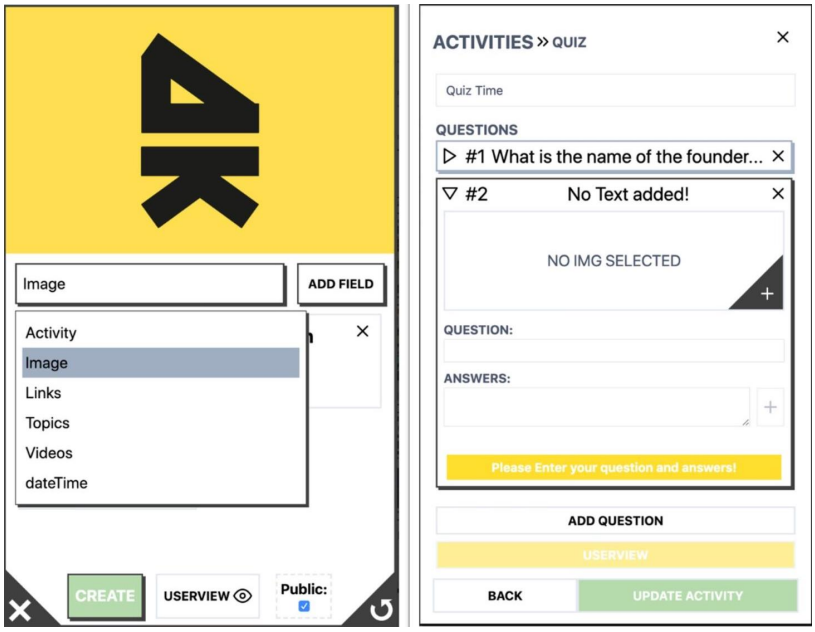

Figure 5.7: (a) Card Editor: Adding an image field; (b) Card Editor: Creating a quiz challenge

Currently, TICKLE supports a limited number of challenge types, i.e., a quiz, an open question, and a hangman game. However, external authoring tools, e.g., BookWidgets ("BookWidgets", n.d.), can be used for creating other types of challenges like timeline exercises, riddles or educational games. Figure 5.7b illustrates the creation of a quiz challenge within TICKLE.

For some types of application it may be useful to help the user to find the ChallengeCards. For this purpose, so-called *waypoints* can be created, which guide the user in the direction of the ChallengeCards. They are especially useful when the ChallengeCards are not visible upfront and need to be discovered by the user. Then, helpful comments can be attached to the waypoints to specify a region of interest for the user. Figure 5.8 shows the creation of these waypoints in the authoring environment.

Cards are grouped in a so-called *Card environments*. A card environment is given a name, a description and an image. It is possible to make the card environment public,

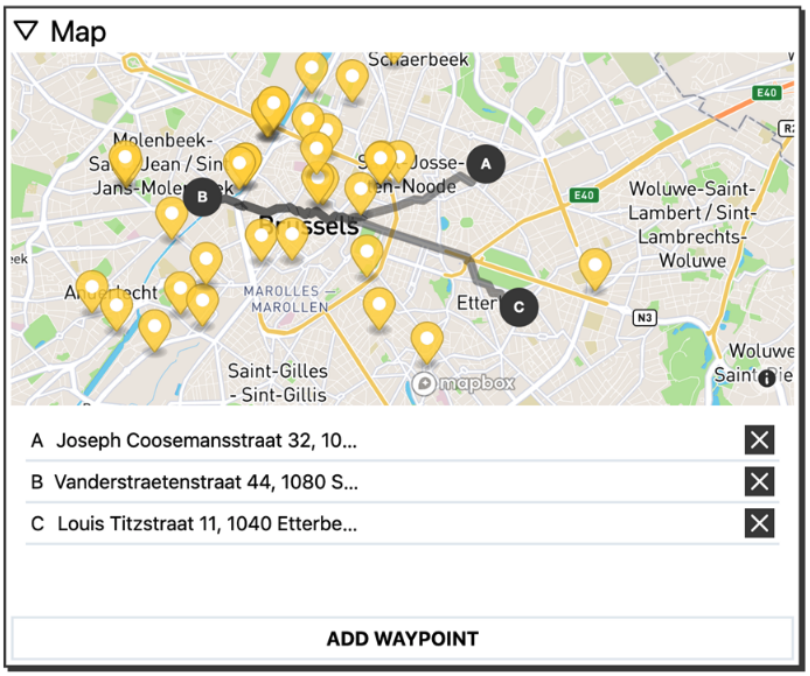

Figure 5.8: Creation of Waypoints in TICKLE

which means that all TICKLE users will be able to use the card environment. Otherwise, the card environment is private and needs to be assigned to a user to allow the user to see the environment. This is done in the Supervisor module. Note that a user can have access to multiple card environments. In Figure 5.9, we see the start screen of a user who has access to multiple card environments.

Supervisor: Authoring and Profile Environment

In the Profile Environment module, accounts for youngsters can be created and youngsters can be given access to card environments by the supervisors. The information about a user (youngster) is maintained in a user profile. The user profile includes personal information (such as the name and email address of the youngster and his/her interests), and also information to steer the sending of notifications (such as the block off time, i.e., time period(s) in which no notifications should be send to the user), as well as the persuasion profile of the user that contains personality information (e.g., the values for the Five-Factor Model) that is used by the system to select the appropriate persuasion techniques for the user (see

Figure 5.9: Start screen for a user who has access to multiple card environments.

subsection Notification System for more details). User profiles are created and maintained by means of the Profile Editor.

The supervisor can also inspect the performance of his/her users, i.e.,the points collected, the cards collected, failed, or started, and their activities in TICKLE by means of the Learner Analytics Module. Note that a supervisor can only manage his own users. A supervisor has also access to the Authoring Environment where (s)he can manage card environments. For a card environment, (s)he can add and remove cards, add and remove users. To ensure that the challenges are adapted to the abilities and the interests of the user, (s)he can add or remove individual cards for a user. (S)he can also inspect who could collect a particular card, and who could not (see Figure 5.7a for an illustration of this last functionality). For the challenges that cannot be assessed automatically (like open questions), the supervisor should inspect the answers given and assess them (see Figure 5.7b).

Furthermore, the Cards Manager allows adding rewards to a card environment.

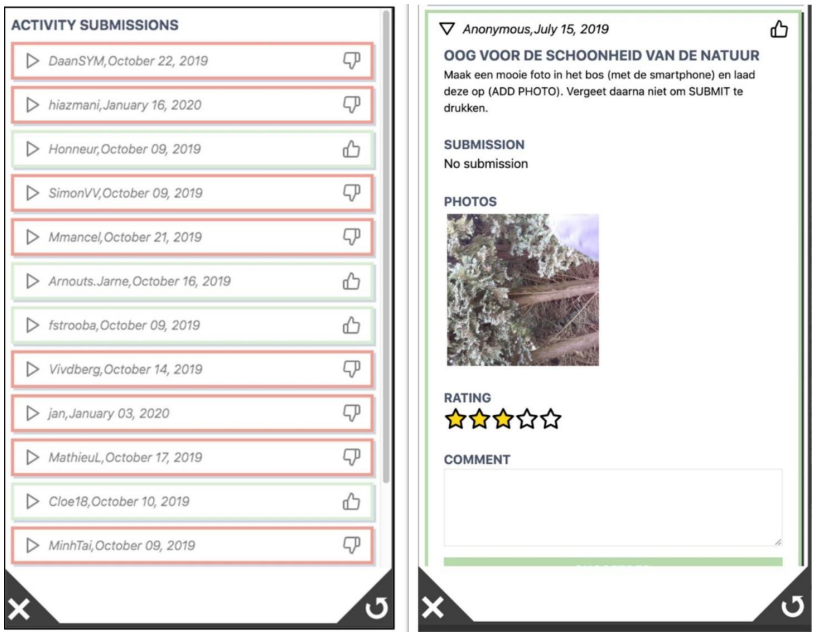

Figure 5.10: (a) Interface in the supervisor module for inspecting who could collect the ChallengeCard and who could not; (b) Interface for rating an open question

Learning Analytics

In TICKLE, the results of the learning activities that are presented to the youngsters need to be stored. Therefore choices will have to be made on how and where to store these results. To keep track of all learning related activities that happen within TICKLE and to be able to store the relevant ones in a Learning Record Store (see subsection 5.6.4), events are used. The learning analytics system in Tickle is based on these events. An event occurs when the user performs an activity. Below, in Table 5.2, one finds a selection of the most important events. To keep it short, the term ChallengeCard is replaced by card in this table.

Event	Description	Insights
Card created	Triggered when there is a new card created.	Card is created in a particular Environment
User invited	Triggered when the user is invited by the admin.	Possibility that a new user will use the system
User registered	Triggered when the user is registered after being invited by the admin.	A new user that wants to try/use the system, Interests of this new user
User deleted	Triggered when the user is deleted.	An existing user that no longer wants to use the system, Feedback of the user who stops to use the system
User became inactive	Triggered when the user is inactive for a certain period, e.g. 7 days not logged in.	An existing user who loses interest in the system; Feedback, why the user loses interest in the system
User started the challenge of the card	Triggered when the user started the challenge of a particular card	Which user started, which card in which environment
User asked for help on the challenge of a card	Triggered when the user asks for help to perform the challenge of a particular card.	Which user asked for help on which card in which environment
User wanted to help another user	Triggered when a user wants to help another user with a particular challenge of a particular card.	Which user responded to help with which challenge for which user
User submitted the challenge of the card	Triggered when the user submitted the challenge of a particular card.	Which user, Which card, Which environment; Points earned by submitting the challenge on the card; Time elapsed to submit the challenge; Challenge succeed or failed; BookWidget result; Whether the user got help or not; Which user helped the user with the particular challenge
User collected a card	Triggered when the user collect the card by performing the associated challenge of the card	Number of collected cards of the user

Table 5.2: Event types of TICKLE and their corresponding insights

In the Card Diary, each user has an Activity tab when inspected in detail. There, one can see a list of events sorted by time. This is illustrated in Figure 5.11

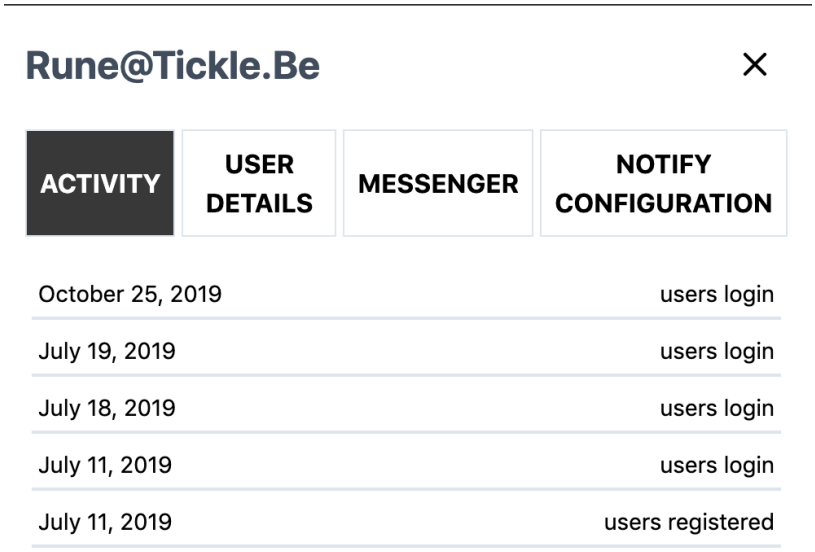

Figure 5.11: Activity Tab of a specific user showing latest events

Notification System

In this section we discuss the design decisions taken for the personalized/persuasive notifications. In general, notifications are used to inform users about an event or to add interactivity to software applications. According to the Hook model (see subsection 3.4.3) external triggers are an essential part to build habit-forming products. Notifications are such triggers that can be used to build a habit-forming product. Each trigger should be followed by an action to make it easier for the user to perform the target behavior. We will use this in our notifications to make it easier for the user to go to the TICKLE environment or to the relevant ChallengeCard. For TICKLE, we decided to use two types of notifications: internal and external notifications. Internal notifications are shown inside the TICKLE environment, this means that the user must be using the application to see these notifications. They are useful to notify the availability of ChallengeCards when the user moves in the surroundings. However, this may not be sufficient to trigger a youngster to

use TICKLE. Therefore, we decided to also foresee external notifications that are sent to the user without the need that they are using the TICKLE app. Examples of external notifications are emails and push notifications. Figure 5.12 shows an example of an internal notification message given when the youngster failed to perform the challenge correctly. It is a supportive message tailored towards the personality of the youngster and depending of the number of attempts already made.

Figure 5.12: Example Notification in the TICKLE App

As discussed before, one of the objectives of TICKLE was to motivate youngsters by using persuasive techniques. These persuasive techniques are used in our notification system in a personalized way. Therefore, the user profile was extended with a persuasion profile. To build the persuasion profile we opted for the *Five-Factor Model* and *HeXad* (explained in section 5.3). Figure 5.13 shows a part of the persuasion profile as seen by the supervisor. In this example the values for the Big Five still need to be entered. One can see that learning deficits, interests, sensitive content and personality traits can be specified for a particular user.

The notification system will respond to events that occurred in the system. However, when an event occurred, the system must take action only when specific conditions are met. Therefore, a simple rule engine is used. Rules are used to specify when specific actions should be taken. The system will check the input event against the conditions formulated in the rule(s) and when these are satisfied the corresponding action is taken as output. To

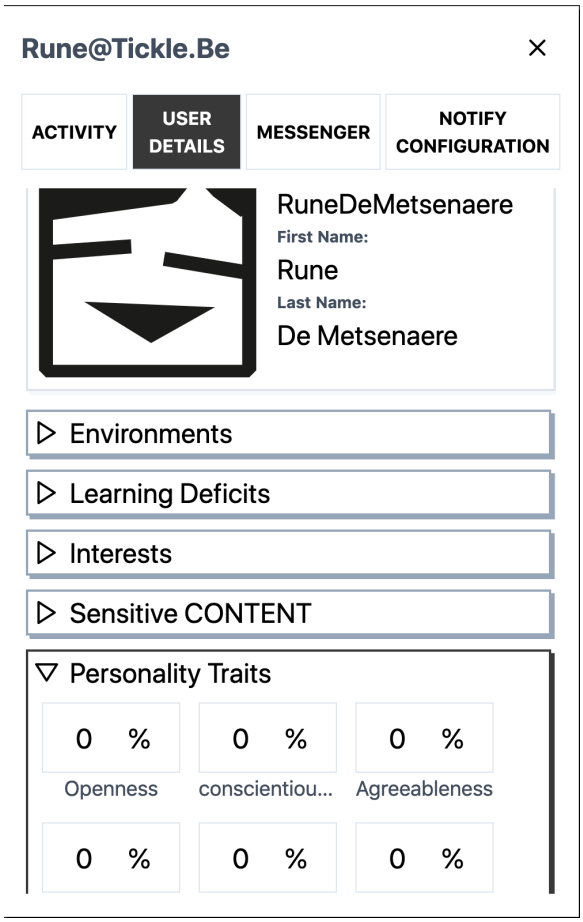

Figure 5.13: Persuasion profile of a particular user

enable personalization when using the notification system, the youngsters (i.e. users) have the ability to choose the preferred medium for the external notifications, e.g. email. We also decided to allow the user to indicate some time span where (s)he does not want to receive notifications to avoid disturbing the end user too much.

5.5.3 Summary

In this section we have explained the design of TICKLE, a MPLE application. Next to the principles formulated for a MPLE, the guiding principle in the design of the TICKLE environment was the Hook Model (Eyal, 2014) and the PSD Model (Oinas-Kukkonen, 2013). Both models were used to connect the different facets of the MPLE into a coherent application. The Hook model is a methodology to bind users to a product or service and

provides the general structure of the user interaction process whereas the PSD model was used for strategies to perform the required actions in each phase of the Hook Model. Starting with the trigger phase, TICKLE takes the hand of the youngster by providing guided tours and notifications that are customized and personalized based on their characteristics using the PSD Model. For instance, when the youngster opens the app, all suitable ChallengeCards in proximity of the youngster's location are presented and possible rewards are teased with suitable visualization in the Card Diary. To make it easy to access learning activities, TICKLE also allows to provide exact routing how to find the physical location of ChallengeCards. By collecting ChallengeCards and exploring areas of interest the youngster makes progress in the app. As a result, TICKLE becomes more open ended and the youngster is notified about new ChallengeCards in the domain of interest. The notifications use persuasive messages tailored towards the personality of the youngster. For the moment, the Big Five trait taxonomy (Jia et al., 2016) and HeXad (Tondello et al., 2017) are used for this purpose. In a second stage, when the youngster has collected a fair amount of ChallengeCards, (s)he also gains access to the card authoring system. From then on, the youngster is not a bare consumer of information anymore, (s)he is also encouraged (using persuasive techniques) to become a producer of ChallengeCards.

An important strategy for a MPLE is the ability to self-monitor progress and receive feedback. Therefore, we included an extensive Diary component into TICKLE that is not only used to recapitulate learning content based on time and topic, but it is also used to allow the youngsters to discover new related learning content based on their interest. For instance, when the youngster has performed a couple of learning activities based on sports, then, TICKLE can use this to recommend further sports activities. With the help of the leaderboard, youngster can compare their performance to others, which is also important for the self-monitoring of their progress.

5.6 Implementation

In this section, we discuss important aspects of the implementation, i.e. the client and server architecture and data model including our Learning Record Store implementation. Overall, the implementation of TICKLE follows the Progressive Web App (PWA) paradigm which mimics the user experience of native mobile applications on the Web platform ("Progressive Web Apps", n.d.). A PWA is required to be reliable, i.e. load instantly, provide limited offline functionality, and also to be fast and engaging.

5.6.1 Client Side Architecture

To separate business logic from implementation internals we chose to follow the Redux architecture as a model ("Redux - A Predictable State Container for JS Apps", n.d.). It centralizes the state of the application in one place and provides a unidirectional data flow which makes it easy to test complex user interaction procedures. Whenever the user interacts with the UI to read from the database for instance, an action is triggered which updates the state of the application and the view again. Figure 5.14 depicts in a graphical way the process flows in the application. For the view, we chose React.js [3] as framework which provides a declarative way to author HTML components in JavaScript. Moreover, it has its own notion of state which helps further to separate business logic and pure user interaction.

5.6.2 Plugin System

As we described in subsubsection 5.5.1, learning activities can hold a wide range of different data, such as media, geo-location or challenges including various mini-games. To make this possible all data fields of a ChallengeCard are stored and described through key-value pairs in the database. In this way, learning activities in the TICKLE app can be suited to all kinds of use cases ranging from school dropout prevention and school field trips to formal learning. As we will see, the storage in the database is quite simple. On the other hand, on

[3] https://reactjs.org/

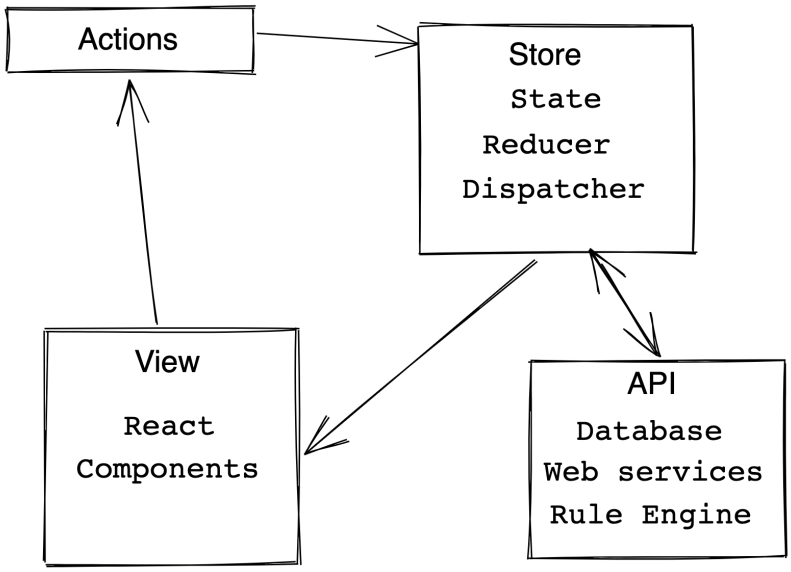

Figure 5.14: The process flow in the TICKLE App

the client side we needed to create some sort of interface to define how a data field from a ChallengeCard is visualized in different contexts (i.e. Card Interface, Authoring environment). Therefore, we keep a global object in the store that defines for each key a number of React components which are needed to realize this. Figure 5.15 shows this global object which assigns to each data field of a ChallengeCard a component object which holds a number of components to be visualized in different context of the applications state.

```
export const fieldComps: { [key: string]: Object } = {
  [Title.key]: Title,
  [Description.key]: Description,
  [Img.key]: Img,
  [Videos.key]: Videos,
  [Activity.key]: Activity,
  [GeoLocation.key]: GeoLocation,
  [Hyperlinks.key]: Hyperlinks,
  [DateTime.key]: DateTime,
  [Topics.key]: Topics,
  [Canvas.key]: Canvas,
};
```

Figure 5.15: The global store object to define components for different data keys

Figure 5.16 shows a detailed view of the interface for the Videos object mentioned in Figure 5.15. One can see the key definition which is used throughout the application and database to refer to this data field and the different components which are used to show and manipulate the data in different situations. For instance, the `View` component shows a list of videos, whereas `VideoPreview` shows metadata of one single video. The `ModalContent` component embeds the `Videos` component into a modal component. For each data field we define such an interface with the exception of the Activity field which points to another object specifying sub keys for different mini-games (challenges). Currently we have implemented all ChallengeCard fields as plugins:

- Title, a simple header field realized with a bigger font size and font weight.
- Description, a text field holding context information for the corresponding ChallengeCard
- Videos, a component consisting of a list to preview videos and a detail view to watch a video
- Activity, an object pointing to another object specifying components for different mini games. Currently we support Hangman, PhotoChallenge and Quiz
- Geolocation, a component to show the latitude and longitude for the ChallengeCard
- Hyperlinks, a list component to show a number of associated hyperlinks.
- DateTime, a field to specify the time range a particular ChallengeCard is visible
- Topics, a list of keywords to categorize a ChallengeCard
- Canvas, an integration with the CANVAS LMS. With this plugin, course units from CANVAS can be represented as ChallengeCards in TICKLE

```
import React from 'react';
import { VideoField } from '~/constants/cardFields';
import { ModalProps } from '~/components/utils/Modal';
export declare const key = "videos";
export declare const label = "Videos";
export declare type Video = {
    id: string;
    thumbnail: string;
    title: string;
    descr: string;
    url: string;
    onClick: Function;
};
export declare const VideoPreview: React.FC<Video>;
export declare const ModalContent: React.FC<{
    modalProps: ModalProps;
    disabled: boolean;
    videos: VideoField;
    onChange: Function;
}>;
export declare const Preview: React.FC<{
    onClick: Function;
    videos: VideoField;
}>;
export declare const View: React.FC<{
    onClose: Function;
    videos: VideoField;
}>;
```

Figure 5.16: Components of the Videos object

5.6.3 Server Side Architecture

The API or server layer is provided by Firebase[4], including a schema-less document database, i.e. Firestore and Firebase's Cloud functions. The rule engine is used to process user events (login, challenge submitted, location change) and schedule (when, what, how) user notifications based on the persuasion profile of the user. Every time a new event is stored in the database, this newly created event is passed to the rule engine (this is achieved by using a Cloud Firestore *onCreate* function trigger). The rule engine will then evaluate all the rules based on the data from the newly created event. When all conditions of a particular rule

[4]https://firebase.google.com/

evaluate to true, the corresponding action will be taken. The Firebase Cloud messaging service is used to send the resulting notifications to the clients. Figure 5.17 shows the process of the rule engine.

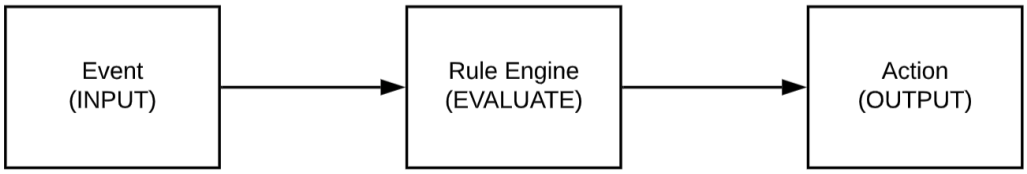

Figure 5.17: Basic process flow of the Rule Engine

Figure 5.18 presents a conceptual overview of the classes that model the structural elements in the TICKLE. It is presented by means of a UML class diagram, i.e. it is not the complete model implemented in TICKLE; it contains only high-level classes and details (non-relevant attributes, operators) are omitted. The structure and how this data is used is as follows:

An event instance represents a particular event that occurred in the system, e.g. a user that logged in, a new card that became available. An event is used as input for the rule engine as explained before. The events are linked to users and notifications. A user instance represents a particular user of the system. The following information about a user is captured: basic contact information about the user, i.e. first name, last name, email, and username. This information will be used in the message body of the notifications to address the user personally. The notification system will make use of this service to send push notifications. Note that this can only be used if the user has a device that is able to receive push notifications. Furthermore, the Big Five characteristics are stored for a user. This information is used to determine the content of the persuasive messages to be send to the user.

A Card instance represents a particular ChallengeCard of a particular card environment. Any information about the card, i.e. topic, description, videos or learning activity is saved as key-value pairs. A learning activity is a generic and abstract class for several types of

learning activities. To this date, we implemented a simple PhotoChallenge, a Hangman game, a Quiz, and a BookWidget integration, which are sub classes of the class Learning Activity. In this way, a card is a generic container which can hold a wide range of different data that can be easily extended by creating a new unique key-value pair. A card instance also refers to instances of ActivitySubmission that keep track of the response the user has given to certain learning activity. Instances of the Reward class are related to Card instances through the XP (Experience Points) class. Whenever a card is collected the user is rewarded with XPs. XPs are kept in a so called Wallet the user has access to. The user can use XPs to acquire rewards. An Environment instance represents a particular card environment. Some basic information about the environment, i.e. name and image, is stored. As the name suggests, an environment contains a number of cards and is associated to a number of users to create different user groups.

5.6.4 Learning Analytics Implementation

The Learning Analytics module is implemented by means of a Learning Record Store[5] based on the Experience API standard (xAPI)[6]. The basic idea of xAPI is quite simple: people learn by interacting with text, video, e-content, other people. Therefore, the aim of this new standard is to provide a means of recording such learning interactions and store them in a so-called Learning Record Store (LRS). Every interaction is stored by sending a secure statement to the LRS in the form of "Noun, verb, object" ("I did this"). An example of such a statement could be: "Pascal finished exercise 5". All of these data can be accessed, within or outside an LMS. In Figure 5.19 an example of such a statement is given.

LRSs can also share their data with each other. This standard uses a whole new philosophy about learning. Learning is no longer limited to working your way through a pre-made learning object, but literally 'everything' can be recorded as a 'learning activity': watching a video, attending a conference, following a step-by-step tutorial on the Web, reading a

[5]https://xapi.com/learning-record-store/
[6]https://xapi.com/

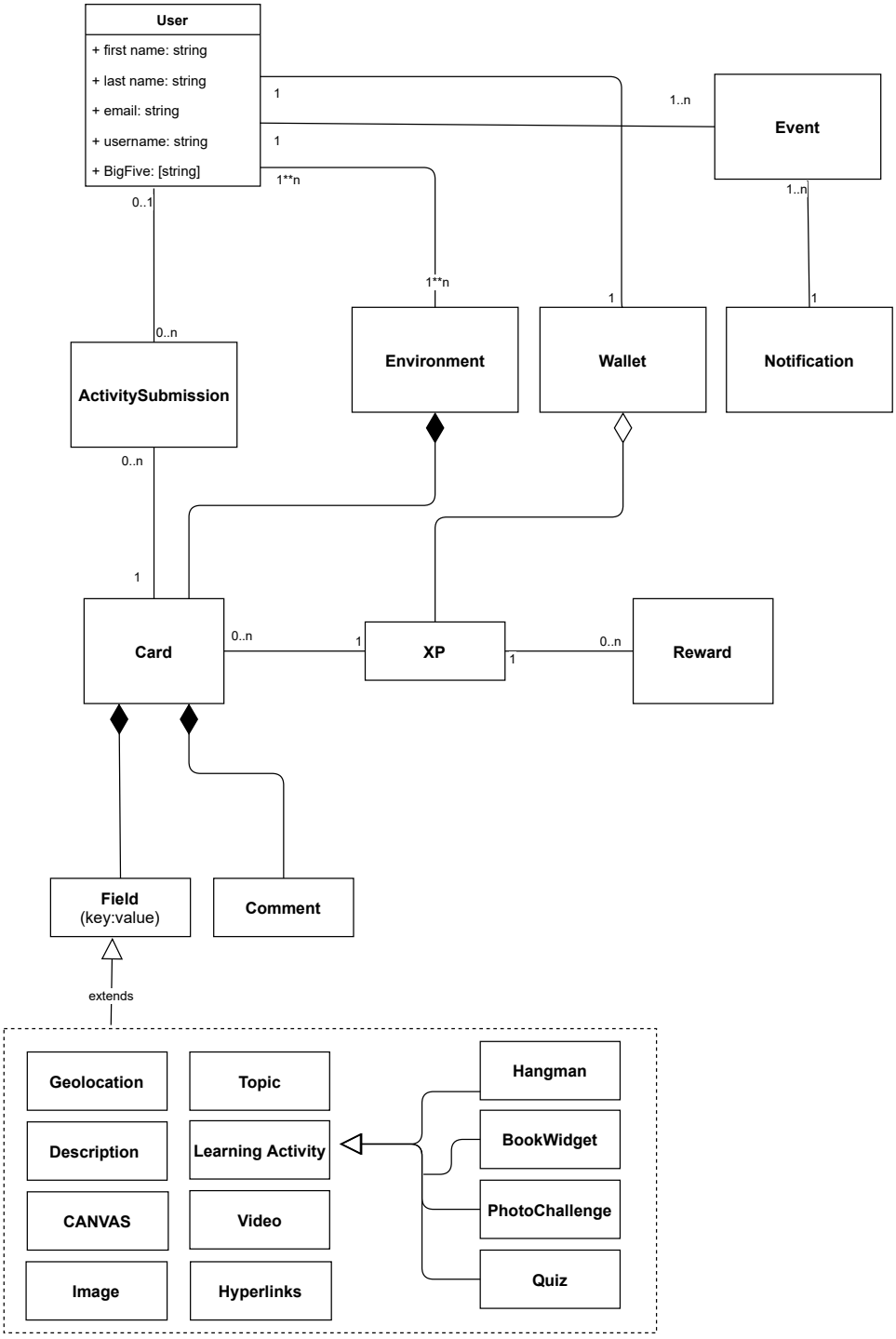

Figure 5.18: Conceptual UML class diagram for the TICKLE App

book, writing a paper, since activities are recorded in the form of short sentences. Furthermore, a learner is no longer bound to the limits of a browser and an LMS to register his/her

```
{
  "actor": {
    "name": "Sally Glider",
    "mbox": "mailto:sally@example.com"
  },
  "verb": {
    "id": "http://adlnet.gov/expapi/verbs/experienced",
    "display": { "en-US": "experienced" }
  },
  "object": {
    "id": "http://example.com/activities/solo-hang-gliding",
    "definition": {
      "name": { "en-US": "Solo Hang Gliding" }
    }
  }
}
```

Figure 5.19: Example statement in the grammar of the Learning Record Store. Taken from ("xAPI Statements", 2021)

learning activities. No Internet connection needs to be established to record an interaction, it can be done afterwards. The xAPI protocol is used to send statements to the LRS. Afterwards they can be retrieved to perform analytics. xAPI defines how statements should look like to be accepted by the LRS. In the simplest form, an xAPI statement is of the form 'Actor Verb Object', e.g. 'Pascal has read "The catcher in the rye"'. All statements of this kind should be sent to the LRS in JSON-format (Berking, 2016), i.e. a number of properties expressed as key/value pairs.

5.7 Evaluations and Demonstrators

As already explained earlier (subsection 5.4.2), during the research and development process, we performed several evaluations. As explained, the evaluations were formative evaluations with the aim to improve the application as its development progresses, and a phased approach was used. After each evaluation phase the app was improved based on the feedback received. Recall that the main questions for this formative evaluation were: *Is the TICKLE environment, as an adaptive mobile tool with persuasive and playful strategies: (1) usable for youngsters, (2) able to engage youngsters, and (3) able to increase the intrinsic motivation and learning capacity of youngsters?*

To see how self-reflection is influenced by TICKLE and the underlying MPLE model, we opted for self-regulation as another evaluation goal which combines important aspects of the MPLE model including self-monitoring and behavior change. Self-regulation is concerned with what people aim to do and how they plan their actions to accomplish their goals. According to (Grant et al., 2002), we can distinguish the following three components of the self-regulation process (see Figure 5.20):

- Set a goal, before users can effectively regulate their behavior, they must select a goal and decide what they intend to do.
- Develop an action plan, Having adopted a goal, users prepare to attain it. They gather information, construct scenarios regarding possible outcomes and engage in behavioral practice (rehearsal). In short, they design and prepare to implement a plan to achieve their goal.
- Cycle of action, monitoring, evaluation and behavior change, in this phase users act according their action plan and monitor their progress which requires self-reflection to observe past behavior and impressions. The outcome of monitoring is the insight (1) whether the action was successful to attain the goals or (2) whether adjustments of the action needs to be done. If (2) is the case the cycle needs to be gone through another time.

This self-regulation model was crucial in the design of different demonstrators and evaluations of the TICKLE environment. For the setup of the different use cases described in the following sections the focus was on (1) exploring learning activities (2) monitoring the progress in the diary and (3) how actions need to be adapted to succeed learning activities through self-reflection. Thereby, a great part of the MPLE model can be evaluated, i.e.:

- The mobile user context
- Data collection analysis

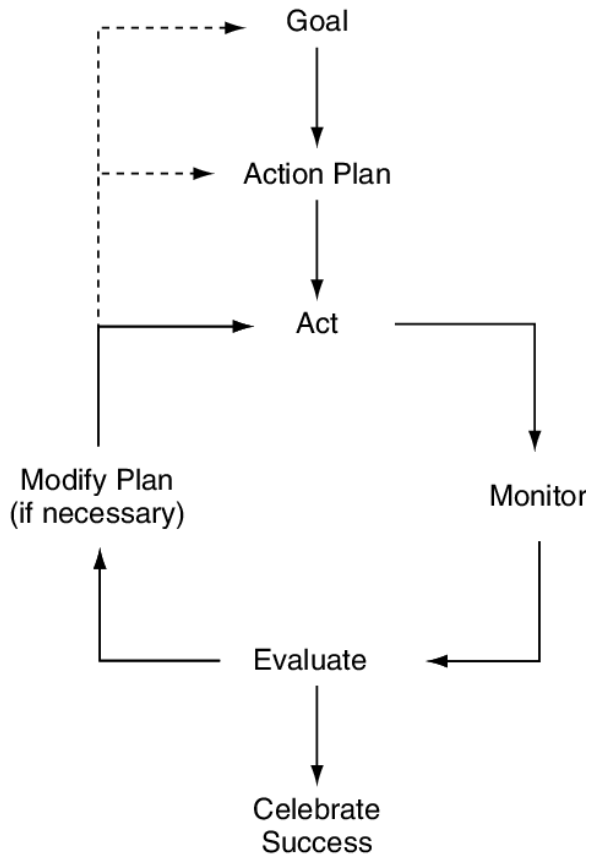

Figure 5.20: Generic model of self-regulation and goal attainment showing role of self-reflection and insight (Grant et al., 2002)

- Learner Visualization
- Self-Monitoring
- Persuasion
- Playfulness
- Micro Learning

For instance, exploration combines aspects of Playfulness, Learner Visualization and Journaling Techniques. Discovering new data points in a visualization means that self-monitoring with Journaling Techniques can be facilitated. In this process, Playfulness and Persuasion can boost the motivation to search for interesting insight in the interactive diary. When curiosity can be triggered by exploring additional information related to learning activities

it is likely that the user will undergo a reflection process where existing knowledge is combined with additional information to create new knowledge. For instance, at the end of a day, the user is confronted with a notification that includes a visualization that recapitulates his/her daily activity and showcases/proposes additional learning activities. When the user actually interacts with the visualization and scans through the recommendations the foundation for reflection is provided. Note however, that it must be the subject of further evaluations to test the longitudinal effects of this process.

For the purpose of the evaluations, different demonstrators were developed, but also demonstrators not related to these evaluations were developed. In this section, we discuss the different evaluation phases and the demonstrators developed. We also provide a discussing on the findings and the limitations of the evaluations.

5.7.1 Evaluation Phase 1

The first phase was situated in the early design phase. We wanted to receive suggestions and recommendations from supervisors and organizations concerned with school burnout and dropout to inform our design process and to ensure that our environment would be usable for our target users. Individual sessions were held with organizations working with youngsters. More information on this phase can be found in subsubsection 5.4.2

5.7.2 Evaluation Phase 2

Within phase 2 a functional tool and infrastructure was piloted and evaluated in realistic settings.

During the summer of 2018 we had several meetings with the *Vlaamse Dienst Speelpleinwerk* (VDS) (translated as the Flemish Service for Playground Working). VDS was looking for a game to improve the cooperation between the animators of the playgrounds and to stimulate their creativity. We found that this need was a good opportunity to evaluate and inform the requirements for our TICKLE app with the help of domain experts who are

used to work with youngsters in a non-formal context. An early working prototype of the TICKLE environment was used for this. This phase consisted of two evaluation, described below.

Evaluation 1 of Phase 2

As already indicated, VDS was looking for a game to improve the cooperation between the animators of the playgrounds and to stimulate their creativity. In order to do so, we proposed them to try out the TICKLE environment. For this evaluation, cards were created with challenges related to the operation of a playground. An example challenge was, for instance, to construct a spaceship together with the children. The cards and challenges were created by experienced instructors from the organization. Figure 5.1 shows a sample challenge given in the form of a card that could be collected to prove that the learner was active. Challenges could be carried out individually, or collaboratively with other animators. The goal for the participants was to carry out the challenge/activity to the best possible standard and to collect as many cards as possible. For this evaluation, the cards were not placed on a physical map but on a fantasy map, i.e., a treasure map (see Figure 5.21), as all challenges were located at the playground's location. All cards were visible and labeled with a topic, as well as with a difficulty degree: easy, medium, or difficult. The participants were animators of the organization. We informed them that they were participating in an evaluation, and they were informed about their rights and agreed to participate.

The evaluation was done in August 2018 at two different playground locations (Bornem and Puurs in Belgium). In principle, all animators of those playground locations could participate. The animators were introduced to the TICKLE environment in small groups by means of an oral presentation and a hands-on demo. They also received a short manual on paper. They could use the environment for three weeks. The youngsters had to use their own smartphones. At that time, only recent Android smartphones were well supported. Youngsters that did not have such a device could use the application on a laptop or desk-

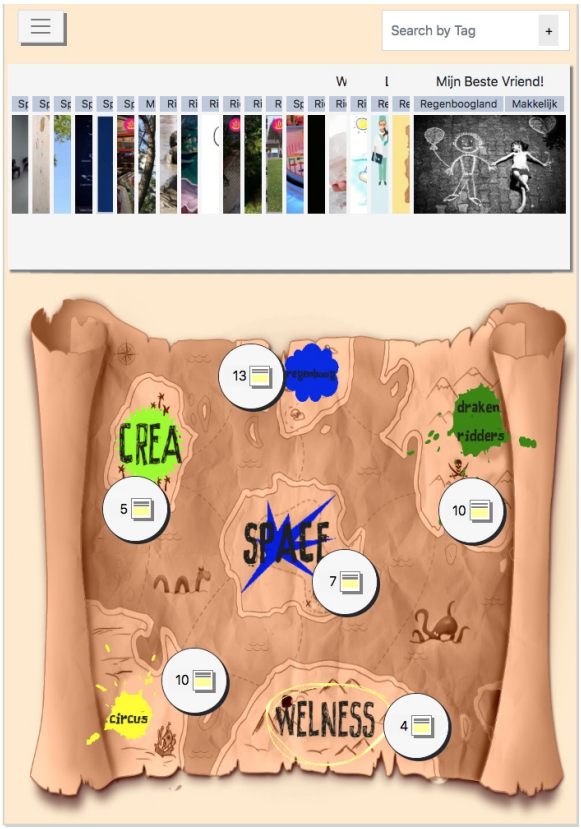

Figure 5.21: TICKLE's treasure map interface for first evaluation with VDS.

top computer through a Web browser. Afterwards, feedback was invited through an online questionnaire. Next to some questions related to the participant (age, background), this questionnaire contained questions from the short version of the User Experience Questionnaire (UEQ) (Rauschenberger et al., 2013), as well as questions for testing whether the participants understood specific features of TICKLE, questions about the look and feel of the cards, the challenges, and about the original goal (i.e., stimulating the cooperation and creativity of the animators). These questions used a Likert scale. The participants could also leave comments and suggestions for improvement.

Results: In total, 20 animators filled out the questionnaire: nine participants were 16 years old; the others were between 17 and 25 years old. Nine participants had no or only one year of experience as animator. Concerning the questions from UEQ, the hedonic quality (stimulation and novelty) scored higher (1,5) than the pragmatic quality (attractive-

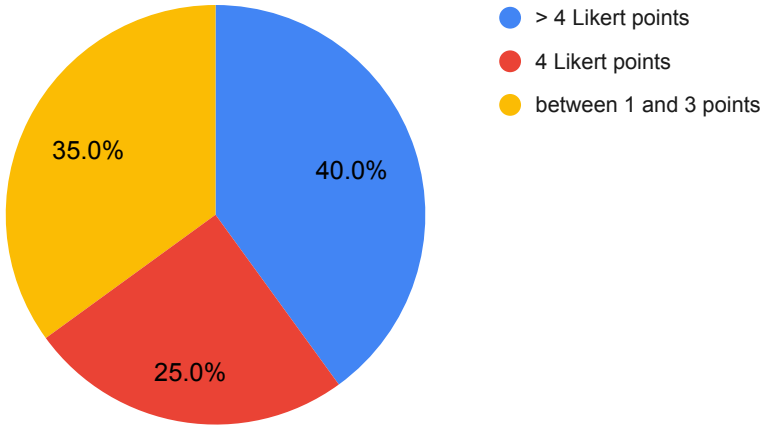

Figure 5.22: Answer distribution of the question whether TICKLE is attractive for the users. Answers based on Likert Scale (where 1 is attractive and 7 not attractive)

ness, efficiency, perspicuity, dependability) (1,00). According to the UEQ handbook, these scores represent a positive evaluation. The results on the questions to test the understanding of specific features, as well as about the look and feel, were mixed, indicating that some improvement would be needed on these aspects: eight of the 20 participants (40%) gave a score higher than 4 for attractiveness (where 1 was attractive and 7 not attractive); five participants (25%) gave a score of 4, while the scores of the other seven participants were between 1 and 3 (Figure 5.22). In general, we received positive results about the challenges. For the fun aspect, all scores were between 1 and 4 (where 1 was fun and 7 boring), with 20% (four participants) for score 1 and 40% (eight participants) for score 2 (see Figure 5.23). All scores for being doable (where 1 was not doable and 7 good doable) were 4 or higher, with 45% (nine participants) for score 5 and 6. The results on the questions related to the original goal were positive: 85% (17 participants) indicated that the challenges were inspiring, the other 15% (three participants) replied “maybe”; 70% (14 participants) indicated that this app could contribute to a better collaboration, the other 30% (six participants) answered “maybe”; everybody agreed that the challenges could contribute to a higher quality of the playground activities. Suggestions and comments were provided. Comments about the challenges provided useful feedback about the type of challenges youngsters are interested in. The other comments and suggestions were about improving the interface, the

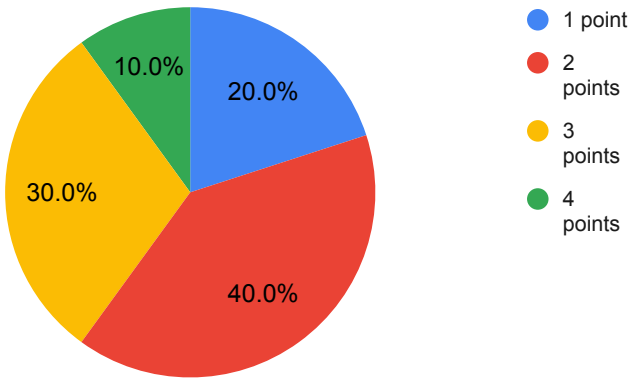

Figure 5.23: Answer distribution of the question whether the TICKLE challenges were fun to perform (where 1 is interesting and 7 boring)

info presented on the cards, and some aspects of the functionalities. Additionally, usability issues with specific smartphones and browsers were mentioned.

Evaluation 2 of Phase 2

For the second evaluation, the app was used for a kind of city game restricted to one long street, in the context of a "start of the year" event of the VDS. On the TICKLE map, cards with challenges were spread along the street (see Figure 5.26 for an illustration). Participants had to find the cards, which only became visible on the map when the participant (i.e., the smartphone) physically came in the vicinity of the location of a card. Each challenge that was well executed yielded points. The aim was to collect as many points as possible. The cards and challenges were created by the organizers of the event. For this evaluation the youngsters had to use their own smartphones. Just as for the previous evaluation, only recent Android smartphones were well supported. However, as the street game was done in small groups and only one smartphone was needed per group, enough suitable smartphones were available. Afterwards, feedback from the participants was invited through an online questionnaire. This questionnaire included the same UEQ questions as the first evaluation, as well as specific questions about the way the street game was set up in TICKLE, about the look and feel of the cards, and about the challenges. These questions also used

a Likert scale (1 to 7). The participants could again leave comments and suggestions for improvement.

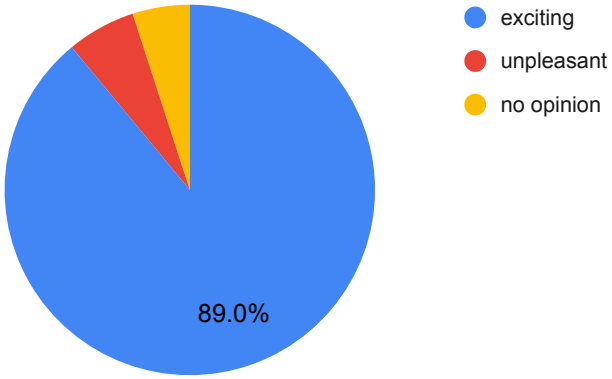

Figure 5.24: Answer distribution of the question whether to hide the location of the cards until the user is in proximity

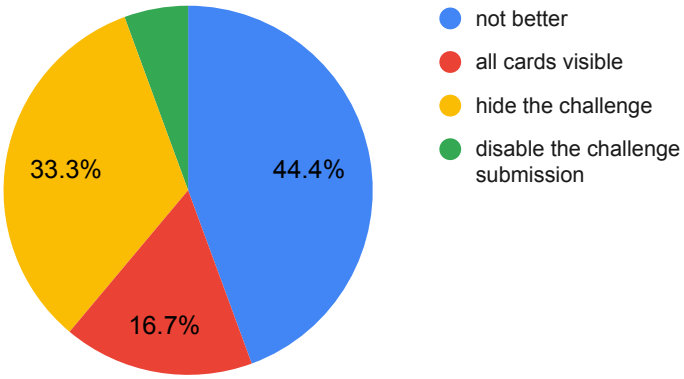

Figure 5.25: Answer distribution of the question whether to make 1) all cards always visible, b) hide the challenge or c) disable the challenge submission

Results: In total, 18 animators filled out the questionnaire. In this evaluation, the participants were young adults: 18 years old or older; one person was older than 26. Concerning the questions from UEQ, the results were in line with the previous evaluation: the hedonic quality (stimulation and novelty) scored higher (1.34) than the pragmatic quality (attractiveness, efficiency, perspicuity, dependability) (1.04). The results on the questions about the design of the game confirmed our setup: 89% (16 participants) agreed that keeping the cards hidden until close to the location made the game exciting (Figure 5.24), but in addi-

tion, 39% (seven participants) would have preferred an alternative to see all the cards right from the start, but keep the challenges hidden, or only provide the functionality to submit them when near the location (Figure 5.25). In this evaluation, the results about the look and feel were mixed (11 of the 18 participants (61.1%) gave a score higher than 4 — where 1 was attractive and 7 not attractive). The ease of entering the answers was also evaluated mixed (nine of the 18 participants (50%) gave a score higher than 4 — where 1 was easy and 7 cumbersome). We received positive results about the challenges. For the fun aspect, all scores were between 1 and 4, with 38.9% for score 2 (where 1 was fun and 7 boring). All scores for being doable (where 1 was not doable and 7 very doable) were 3 or higher, with 50% for score 5. Comments were about the available time for the game (which they found to be too short), the data consumption and the battery consumption (which were both considered too high), and small usability problems and bugs.

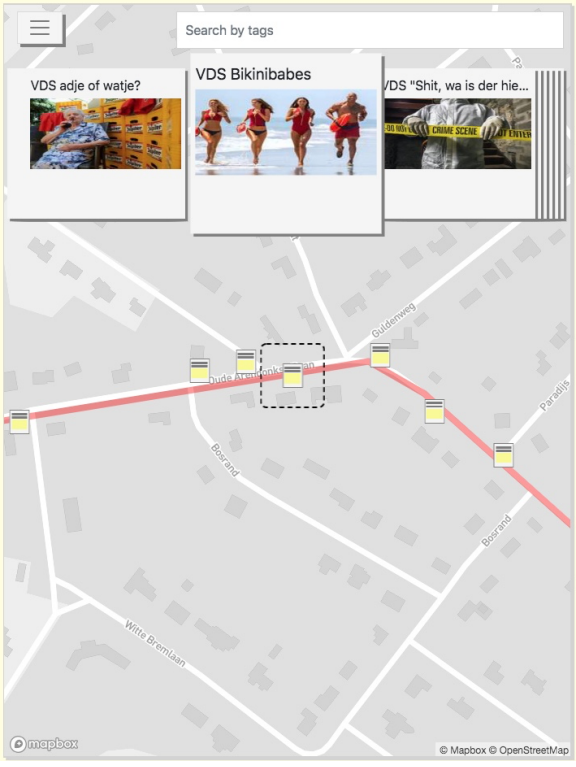

Figure 5.26: TICKLE's Map Interface for second evaluation

5.7.3 Evaluation Phase 3

In this phase, also evaluations in real-life settings were done, but this time the focus was on youngsters in some way related to the issue of school burnout and school dropout. Two evaluations took place, both with an organization dealing with youngsters who are in a problematic situation, i.e., Try-out[7] and CAD Limburg[8]. Try-out offers activities that allow youngsters with school issues to detect their talents and interests, and in this way try to reconnect them with regular school or work, and CAD Limburg offered a Reboot Camp ("Reboot Kamp", n.d.) for young gamers at risk, who often are also at risk for school dropout. In both evaluations, the participants were informed that they were participating in an evaluation, they were informed about their rights, and agreed to participate. Due to the problems experienced with the broad range of smartphones used by youngsters in the evaluation phase two, we decided to provide them with a smartphone to avoid usability problems due to incompatibility issues. The smartphones were Android devices. Sufficient mobile data volumes were provided for the phones, as this was reported as an issue in the previous evaluation phase. We realize that those issues should be resolved in a later stage, but we wanted to avoid that issues with smartphones influenced the results of the evaluations.

Evaluation 1 of Phase 3

This evaluation was done in the context of a day activity organized by the organization Try-out. For this evaluation, a city game was created with TICKLE. The location was the center of Brussels, and the cards and associated challenges had the aim of letting participates explore interesting places in the city and find out more about these places (see Figure 5.27 for a screenshot of the card interface) Variable amounts of points could be collected with the cards. The goal was to collect as many points as possible. There was no predefined

[7] http://alba.be/project/try-out-brussel/
[8] https://www.cadlimburg.be/

route; the participants had to develop their own strategy to collect as many points as possible in the given time (2 hours). They played the game in groups of two to three. Each group was accompanied by a supervisor from the organization. Each participant received a smartphone with a mobile data volume and a short manual on paper (three pages). We had six participants in total.

Figure 5.27: TICKLE's Card interface for the city game in Brussels

Afterwards, the youngsters were asked to fill out an online questionnaire. The questionnaire included questions about their age and interests, as well as questions related to the user experience. This time we did not follow UEQ completely, because the way the questions in this questionnaire were formulated is not suitable for the youngsters who would

participate in the evaluation (see also subsection 5.7.5). Furthermore, questions about the challenges, the look and feel and the information on the cards were asked. In this evaluation, we also measured whether the app was able to engage the youngsters, and if it was able to increase the motivation for learning more about Brussels. All these questions used a Likert scale. In this evaluation, the questions were formulated as statements, and a scale from 1 to 5 was used to indicate the level of agreement with a statement: 1 being "strongly disagree" and 5 being "strongly agree". The participants could again leave comments and suggestions for improvement.

Results: all participants (six) filled out the questionnaire. They were 14 and 15 years old. Given the small number of participants, we did not use statistics to process the results. The results on the user experience were rather neutral. In this evaluation, the participants found the look and feel more attractive (note that after the previous evaluation phase the interface was improved considerable): two participants (33.3%) agreed with the statement that the cards were attractive with a score of 3, three participants (50%) with a score 4, and one participant (16.7%) with a score of 5; two participants (33.3%) respectively agreed with the statement that the cards look nice with a score of 4 and 5. They liked the challenges (four participants (66.7%) confirmed this with a score of 4 and two (33.3%) with a score of 5), found them not difficult to understand (three participants (50%) strongly disagreed (score 1) with the statement that the challenges were difficult to understand, while the other three participants provided a score of 2, 3, and 4 respectively), very doable (three participants agreed with this statement, with a score of 4 (two participants) and 5 (one participant) respectively; two participants were neutral (score 3), and one gave a score of 2), and varied (two participants (33.3%) agreed, with a score of 4, and four (66.7%) gave a score of 5). They appreciated that the challenges addressed a range of areas of interest (50% agreed, with a score of 4, and 50% gave a score of 5). They all found the city-game with TICKLE a nice way to get to know Brussels (four participants (66.7%) agreed with a score of 5, the two other participants gave a score of 3 and 5 respectively); four of the six

participants recognized that they learned new things; and 50% indicated that they would use the app again (with a score of 4), the other 50% gave a score of 3 on this statement. However, the results were mixed concerning the questions to measure a change in their motivation for learning more about Brussels or other domains. Regarding the statement of whether they would like to learn more about Brussels, the distribution of the scores were as follows: one participant gave a 1, two participants gave a 2, two participants gave a 3, and one participant gave a 4. On the statement whether they would like to learn more about other domains, two participants gave a score of 4, and one participant gave a score of 1, 2, 3 and 5 respectively. Few comments were given and were mainly on small usability issues.

Evaluation 2 of Phase 3

This evaluation was done in the context of the Reboot Camp organized by the organization CAD Limburg. The camp lasted one week (5 days). For this evaluation, cards were created for the different activities offered during the camp. In this way, the youngsters could use TICKLE as a kind of agenda. Each day they could see, by means of cards, the activities of the day. The cards only became visible on the day of the activity. The cards contained information about the activity. To collect a card, they had to do a small challenge related to the activity. The challenges were ranging from doing a quiz to writing a small reflection about an activity. In this way, points could be collected. There were also cards with general information, such as a card with a short manual, a card with the rules of the camp, a card about the camp's location, and a card with a link to the questionnaire. See Figure 5.28 for a screenshot of the card interface used for this evaluation. The seven youngsters that participated in the camp received an introduction with a hands-on demo. They each received a smartphone with mobile data. On the request of the organization, we restricted the use of the smartphone to TICKLE, to consult the Web, and to take pictures. Unfortunately, the supervisors of the camp decided that the youngsters could only use the smartphone at certain moments during the day. At the last day of the camp, the participants were supposed

to fill out an online questionnaire, an activity that was also offered through a card. The questionnaire for the participants was similar to the questionnaire for the city game. The questions were formulated as statement and a scale from 1 to 5, used to indicate the level of agreement with the statement: 1 being "strongly disagree" and 5 being "strongly agree". In this evaluation, we also asked questions about the notifications provided in TICKLE. The participants could again leave comments and suggestions for improvement.

Results: Although we explicitly asked the organization to stimulate the youngsters to fill out the online questionnaire at the last day of the camp, only three (of the seven) youngsters filled out the questionnaire. They were respectively 14, 15 and 18 years old. These participants were positive about the app (measured by means of different questions), found it easy to use (two participants agreed with a score of 4, one with a score of 5), and a nice way to detect new things (one score of 3, one score of 4, and one score of 5). They were positive about the use of notifications for letting them know which activities would take place (two scores of 4 and one of 3), but they were divided about the usefulness for informing them about the points collected (one score of 1, one score of 3 and one of 4). The information on the cards and their look and feel was evaluated positively (agreement with a score of 3 (one participant) and 4 (two participants) for the information, and with a score of 4 (three participants) for the look and feel). Also, these participants liked the challenges (one score 4, and two score 5), found them good doable (three scores of 4) and varied (one score of 3, and two scores of 4), but found them in average difficult to understand (one score of 2, one score of 3, and one score of 4). They found TICKLE a nice way to get to know the activities (one score of 3, one score of 4, and one score of 5); recognized that they learned new things (two scores of 4 and one score of 5), and indicated that they would use it again (with different degree of certainty: one score of 3, one score of 4, and one score of 5). For the questions used to measure a change in their motivation for learning more about new areas of interest or activities, the results were mixed: two showed a clear increased motivation (score 5), while one did not (score 2). No comments or suggestions were given.

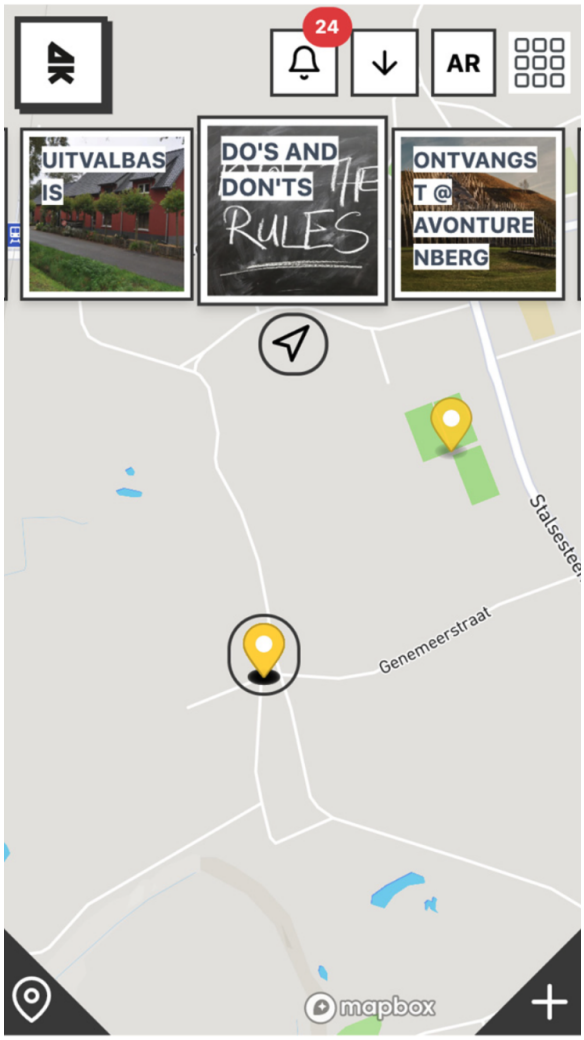

Figure 5.28: TICKLE's Card interface for the Reboot Camp

5.7.4 Demonstrations

In the context of the evaluations, different card environments were created that demonstrate the possibilities of the application. We used TICKLE to create a street game and a city game; for creating a playful environment to stimulate collaboration and creativity of animators; to inform and support reflection during a camp for youngsters at risk of game addiction. These use cases cover informal and non-formal learning.

Next, we used TICKLE in the context of formal learning, i.e., to stimulate the processing of the course material during the semester for one of our university courses, i.e.

the course on Object-Oriented Modeling of the Bachelor of Computer Science (see Figure 5.29). Cards were created about topics in the course (see Figure 5.30 for an example card), and the associated challenges had the aim of letting students test their knowledge about the topic. By collecting cards, the student could collect points. The cards became available during the course of the semester. The students were notified by email when new cards became available. This demonstration was used to test the personalized notification system. We asked the students (on voluntary basis) to fill out an existing online questionnaire in order to determine their personality in terms of the Big Five taxonomy (Tondello et al., 2016), and send us the results. Based on this information, the students received notification messages tailored to their personality.

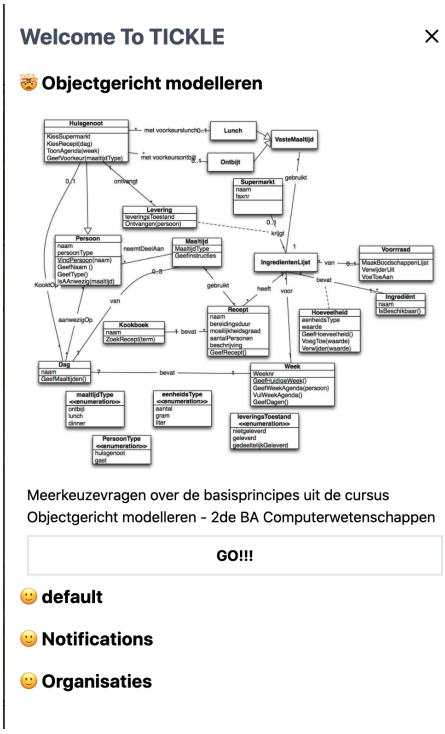

Figure 5.29: TICKLE environment for the Object-Oriented Modeling course

Next to these card environments, we also created an environment that provides an inventory of all organizations related to school burnout or early school leave located in Brussels. This card environment contains 41 cards. There is a card for each location of an organization (some organizations have more than one office in Brussels), and the cards are

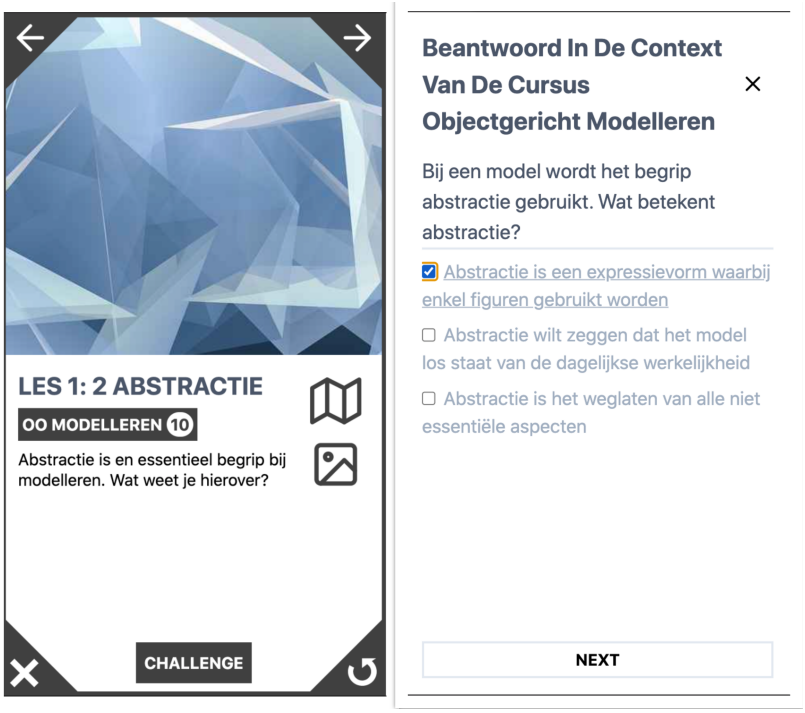

Figure 5.30: Example ChallengeCard of the Object-Oriented Modeling Course: Card front (left); Example Challenge (right)

positioned on the map of Brussels (see Figure 5.31). The card of an organization contains the following information: the name of the organization, a short description, address, a link to the website and Facebook page of the organization, and contact information. These cards could be collected without the need to perform a challenge.

5.7.5 Results

In general, in the context of the formative evaluations, we obtained positive results and received useful feedback to improve and extend the application. Based on the results, we can conclude that in the context of these formal evaluations, the app was usable for the youngsters and able to engage them, and we see indications that it may be able to increase the intrinsic motivation and learning capacity of youngsters. However, the evaluations were limited in the number of participants and the context in which they were performed, and they had a limited goal, i.e., checking the usability of the app for youngsters and the ability to engage them. To confirm the results and to verify whether the app can increase the intrin-

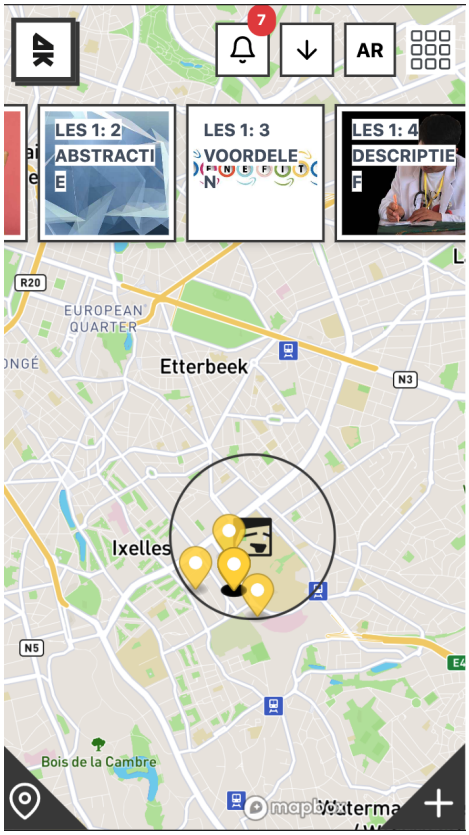

Figure 5.31: Overview of youth organizations located in Brussels

sic motivation and learning capacity of youngsters, summative and longitudinal evaluations are needed. Such evaluations were under preparation but could not be performed yet due to the COVID-19 restrictions.

5.8 Summary

In this chapter we presented TICKLE, a playful learning environment for youngsters. The environment is a mobile location-based smartphone application that offers youngsters an interactive environment with which they can explore their surroundings based on their interests or needs and is based on the MPLE model. The environment offers cards that the youngsters can collect by performing small challenges. In the regular case, the cards are associated with physical locations, and the challenges are related to those locations. In this way, TICKLE promotes the playful exploration and discovery of information in a physical

environment. However, the environment is also usable with a fictive environment, like a treasure map.

We explained how the requirements were derived, justified the decisions made, and presented an overview of the system and its functionalities. The system consists of a frontend that is the actual playful environment, and a backend that offers an authoring environment for creating the content, and a supervisor module for managing and monitoring the performance of the users and the card environments. We also discussed aspects of the implementation. Next, we discussed the evaluations performed. We opted for an elaborated set of formative evaluations to ensure good usability of the app and evaluate, to a certain degree, the impact of our MPLE model to improve self-reflection and informal learning. Note that it is difficult to test the effectiveness of the individual features of the MPLE model because the components implementing them are very related: one particular component depends always on its predecessors and successors. For instance, the Learner Visualization depends on Data Analysis and Collection stages. On the other hand, Learner Visualization enables and facilitates the Journaling techniques to provide an interactive diary of performed learning activities. Moreover, there are also orthogonal features such as Persuasion and Playfulness, which have an influence on several other components. For instance, persuasion techniques are used throughout the Visualization and Data Gathering stages. Moreover, it is difficult to draw conclusions about the effect on self-reflection (the final stage in the MPLE learning pipeline) in formative evaluations, as these formative evaluations have a short time span and cannot show longitudinal effects on behavior change because the ability to self-reflect and improved informal learning ability does not change overnight. For this, one must carefully observe the behavior of the user over a long time span and track behavior and attitude changes by performing summative and longitudinal evaluations. Such evaluations, which should also measure the learning impact, could not be undertaken due to the COVID-19 restriction imposed in 2020.

Notwithstanding that the results of the different formative evaluations were positive,

the feedback received was used to considerably improve the system, and other suggestions were noted for future work. Still to be considered, and planned for future work is:

- Allowing youngsters to connect with each other with and within the TICKLE environment and to collaborate on the collection of cards.
- To provide a help functionality that a youngster could use when (s)he would be stuck on a challenge.
- To allow youngsters to create cards themselves easily. This will contribute to the investments made by the youngsters, but also to the fact that youngsters like to share their own material online. This functionality is already available, but a procedure needs to be added to prevent youngsters from creating cards that are not acceptable.
- Adding an intelligent matching algorithm to suggest cards to youngsters in an automatic way. Currently, this needs to be done manually by the supervisor of a youngster.

Although the environment was developed for dealing with school burnout, the environment is also usable in other contexts and for different purposes. We have demonstrated that TICKLE can be used for a large range of use cases: for team building activities, for information providing, and for non-formal learning activities, as well as in the context of regular education (for formal learning). Although we did not yet test it, we see more possible application domains, e.g., for tourism, for museums, for shopping opportunities in a city, for event announcements, for social engagement, etc.

CHAPTER 6

CONCLUSIONS, LIMITATIONS AND FUTURE WORK

The traditional way of learning usually takes place in a classroom environment. However, classic classroom teaching frequently faces difficulties. On the other hand, modern communication technologies provide a situation of no boundaries to knowledge and thus could facilitate informal learning, which is characterized as learning integrated into daily routines as ongoing, voluntary, and self-motivated pursuit of knowledge. While such independent learning is an admirable aspiration, in practice, most people are often overwhelmed by the sheer amount of information faced in the digital world. Therefore, many learners will require guidance in their informal learning process. Leaving them entirely alone in learning activities can lead to dropout and loss of motivation. Especially youngsters, grown up with digital technology, seem to have problems to deal with this overabundance of information. On the one hand, they are capable of navigating a wide range of different information spaces and technologies, but on the other hand they tend to switch fast between activities which often results in a superficial view rather than an in-depth understanding of information (Bowler et al., 2018; Selwyn, 2009).

Therefore, we argue that for informal learning, a digital learning environment could provide added value. Such a learning environment should provide ways to explore interests freely, but also guidance in doing so, and use them for future opportunities from a personal, professional or educational perspective. In this thesis, we introduced the Mobile Playful Learning Environment (MPLE) model that aims to provide a reference model for such type of digital learning environments.

In the following sections, we first summarize the approach taken in the thesis and discuss the findings in more detail. Next, we provide a discussion, which also gives limitations and future work.

6.1 Summary & Findings

In order to deal with the issues related to informal and lifelong learning introduced in the introduction, including the needs of youngsters, we started by formulating our main research objective and the related research questions. We now give a summary of the work that has been described in this thesis by providing the answers to the research questions and reflecting on the achievement of our research objective. We start by recalling our objective. Next, for each formulated research question we discuss the approach taken and our findings.

Research Objective: To design a conceptual framework for creating digital environments that offer opportunities for lifelong learning and can support informal as well as formal learning activities, and which are suitable for digital natives, more in particular youngsters.

Research Questions:

- RQ1: How to empower the learner to realize that learning is not only a way to succeed in a formal school context but also a way to improve other areas of personal and social lives from a lifelong learning perspective?

In order to answer this research question, we started by looking into different forms of learning with or without support of technology and relevant for lifelong learning (chapter 2). To gain an overview of different learning strategies, we used informal, non-formal, and formal learning as categories to organize different types of learning and investigated their relationship with these types of learning. The purpose was not to only list different strategies and to inspect how they impact the learner in terms of knowledge construction, but also to analyze the components, i.e. which steps are needed to make learning a successful activity in terms of efficiency, efficacy and ease. We especially considered Mobile Learning and Ubiquitous Learning because they focus on the learner seamlessly moving between different contexts and scanning the environment for learning opportunities. Playful Learning was considered because it imposes a fixed set of learning activities within a

clearly defined space by setting up a technology enhanced playground where learners can learn in a play-like fashion.

To recapitulate, the aim was firstly to obtain an overview of how learning is currently supported in a real-world context, but secondly to derive informal learning strategies that can inform the design of our ideal learning environment, i.e. which strategies can empower the learner to realize the importance of learning for personal and social lives. In this regard, Mobile and Playful Learning were deemed of special importance because they can blend aspects of informal and formal learning in a way that blurs the boundaries between these concepts. For instance, mobile technologies can be used in the classroom as additional tool to access teaching materials but they can be also used to access environmental information to enrich the interaction with learning material. Within our ideal learning environment, learning strategies that combine aspects from formal and informal learning are important to provide openness and guidance at the same time, i.e. the learner can freely move within the learning space and discover learning opportunities but is also restricted in the sense that boundaries to the learner are shown to provide guidance and goal orientation.

Next, we reviewed learning paradigms relevant for lifelong learning (section 2.1). In particular, the Experiential Learning theory (D. A. Kolb, 2014), described as a constructivist learning paradigm, was considered important for achieving our goals. D. A. Kolb (2014) observed that reflection is the key step in experiential learning to show the value of information for personal aims and the applicability of knowledge in wider contexts. When reflection succeeds, a so-called learning identity can be formed which is an attitude to embrace the world and its settings as resources for learning. A person with a great learner identity actively seeks for opportunities to learn and gain more knowledge about the world. Therefore, we also discussed the concept of learner identity. The aim of RQ1 was to gain a theoretical understanding of learning as a whole and the role of informal learning in particular, from the perspective of the learner. RQ1 lays out the groundwork for persuasive strategies to motivate for informal learning activities and therefore improve continuous learning

and aspects of personal and social life that are not targeted by school-based learning.

- RQ2: How can we guide the learner in the learning process and persuade him to be active while maintaining the openness and non-committal character of informal learning?

The insight that we gained by studying the work of D. A. Kolb (2014) and the importance of *reflection* serve as the starting point for dealing with RQ2, namely to investigate how we can guide the learner in the learning process and support the phase of reflection while maintaining the sense of openness and non-commitment from informal learning and playful learning. For answering this question, we looked at the field of *persuasive technology*. Persuasive technology has already been applied in contexts such as marketing but rarely found its way in education. It could be used to guide and persuade the learner to be active. Next, persuasive technology also takes behavioral models into account.

Based on the decision to use persuasive and reflective technology to guide the learner, we first continued with answering research questions resulting from the approach taken for answering RQ2:

- RQ3: What is the role of reflection in the persuasion process and what techniques are available to facilitate reflection?

- RQ4: Which aspects of existing persuasive and reflective technology can be applied?

To answer RQ3, we further studied models for supporting reflection in HCI (section 3.2). Already in early 2000, Fogg mentioned self-monitoring as starting point to convince the user to start to reflect on behavior and change it for the better. By taking inspiration from Nir Eyal's Hook model, we propose to embed the reflection process as self-monitoring in a so-called learning pipeline, and to utilize different human-computer interaction techniques to scaffold this process. For this we decided to look at visualization not only to persuade the user for continuous usage but also to provide ways to scaffold the self-reflection process (section 3.3).

Regarding RQ4, we studied existing persuasive technologies in the context of HCI (section 3.4). For the overall process model, we mainly based ourselves on the hook model of Eyal (2014). This process model provides a number of sequences the user has to go through to be hooked to a product, meaning the user is ready to use the product over a longer period of time and come back to it when a need arises that the product solves immediately. In each step of the model's cycle different techniques from psychology are applied. For instance, in the rewarding phase the integration of game-based concepts familiar to youngsters, such as collecting points and obtaining rewards, could be a way to motivate learners to use the environment. In software development, this is known as gamification. Game mechanics, such as points, badges, leaderboards, avatars or stories, can be integrated into the environment to scaffold playfulness. Furthermore, the Six Principles of Persuasion, the Behavioral Model by Fogg (2009), and the Persuasive System Design (Oinas-Kukkonen & Harjumaa, 2009) (PSD) model were selected for use in our solution.

The choice of using visualization techniques to provide ways to scaffold the self-monitoring (to support self-reflection) resulted in the research question RQ5 and RQ6:

- RQ5: Which visualization techniques are suitable for for self-monitoring in the context of informal learning?
- RQ6: What kind of data can be accumulated in the learning process and how can this data be transformed into a meaningful visualization?

These two research questions focused on ways to make self-monitoring more efficient by means of visualization techniques. We started by studying existing information visualization approaches for reflection and decision making to select suitable techniques for integrating meaningful visualization into our solution. One obvious candidate was the so-called timeline to highlight events with a value for learning. Therefore, a classification of events that might have a learning value is needed to recommend learning activities. In our proof of concept application, TICKLE, we designed and implemented such a visualization so-

lution (see subsubsection 5.5.1) and evaluated it with youngsters (see section 5.7). In the evaluation, users used the timeline as fast access to past learning activities and monitor progress.

Besides this, we also investigated visualizations to show different categories of learning content. The technique used in the TICKLE prototype is called Bubble Sets and is described in subsubsection 5.5.1 (card diary). It was chosen because aesthetically it integrates well in a playful context due to use of manifold colors and soft shapes that can be often found in video games. It facilitates the comprehension between sets of information and the relations between them in form of subsets. This type of visualization makes sense if sufficient learning content is present. Then, this visualization can be a fast way to access learning content target-oriented and to discover related activities.

The last research question, RQ6, focused on the type and format of the data necessary to be visualized. In the beginning of the design of the TICKLE application, we were certain that time and geolocation data are candidates for meaningful visualization but also learning categories were deemed useful if a certain overlap between categories exist. Therefore, we developed an event framework that tracks every behavior in the platform with the help of a rudimentary grammar consisting of actor, also called subject, action (predicate) and object (see subsection 5.6.4). This basic grammar is an implementation of the xAPI specification which is intended to keep track of learning experiences in e-learning software. It defines the structure of a learning record store that keeps track of all different learning activities and makes them accessible for later usage, which is visualization in our case. Our event system does not only provide a scaffolding for the current visualization used in TICKLE but also for future visualizations because not all types of events have been exploited in the current version of TICKLE. After having discussed the answers to all our research questions, we return to our research objective: to design a conceptual framework for creating digital environments that offer opportunities for lifelong learning and can support informal as well as formal learning activities, and which are suitable for Digital Natives, more in particular

youngsters. To understand the needs and characteristics of digital natives, we studied the literature in this context. The results are reported in section 2.3. Next, we also studied different technology enhanced learning environments (section 2.4) to position our solution, and studied related work (chapter 4). Based on all the findings, we defined the Mobile Playful Learning Environment (MPLE) Model. We motivated the main features of such an environment and its learning pipeline, and indicated how the different components in this pipeline interact with each other to achieve their goal. This model does not only describe the conceptual features to be included in an application that aims to facilitate informal learning, it also propose a set of functional components that log and visualize learning data to playfully persuade the user for self-reflection and continuous use. How we established and justified our model is documented in chapter 3.

As proof of concept for the MPLE model, we developed TICKLE, a mobile playful learning environment for youngsters at risk for school dropout, and evaluated this environment in different settings. In this way, TICKLE shows that a technical implementation of our model is feasible and in addition it provides a way to indirectly evaluate the model.

TICKLE also provides a generic architecture including a plugin system that makes it suitable to adopt the platform for different activities in different domains and for different types of users. In this way, TICKLE can be used as platform to support different situations, such as:

- The reactivation of youngsters in the context of school dropout as shown in this thesis;
- A civic engagement platform for elderly people as shown in (Lindberg et al., 2019);
- Other opportunities, such as adult learning, advertisement of employment opportunities, marketing of physical shops, for takeaway restaurants, in tourism, to inventory particular organizations and institutes, and so on.

In this way, we reached our research objective. As a proof of concept, we developed and evaluated TICKLE, a mobile playful learning environment for youngsters at risk for school dropout. Note that the development of this proof-of-concept provided answers to some of the research questions for the specific case. Those questions seemed to be hard to answer in general, as the context for answering them was important.

6.2 Discussion

In this dissertation, we argued for the need of a learning environment that can support youngsters in informal as well as formal learning, and thus be able to support lifelong learning. Our argumentation was mainly based on the ambivalent relationship of youngster with the overabundance of information and tools available. To provide researchers a conceptual framework for such learning environment and to give designers and developers guidelines to create such an environment, we developed the Mobile Playful Learning Environment (MPLE) model. We recognize that this reference model is only one way to achieve this goal. In our model, the focus is on learning in a *playful way* while being in different environments or on the route (thus while being mobile). To stimulate this way of learning and to try to turn it into a habit, *persuasive techniques* are used. In addition, a special focus is given to *reflection* because reflection is recognized by researchers as a key aspect for learning.

Our model is unique in the sense that it targets the sweet spot between:

- a conceptual framework for informal learning that normally gives only high level account of concepts (e.g. information visualization, persuasion, playfulness) needed to improve informal learning;
- a data pipeline to show the flow of data and dependencies between components;
- and design guidelines to apply playful, visualization and persuasive principles to provide a positive user experience.

Coupled with a user centered design process, such as (Abras et al., 2004), the MPLE model can help to:

- Identify the user's needs for informal learning and suggest ideas for requirements for applications focusing on informal learning.
- Inform the development of conceptual designs including what such an application should do, behave and look like.

To exemplify the usage of this model we created a proof of concept application called TICKLE that does not only target the use-case of school burnout and lack of motivation at school, it also provides a platform to support a wide range of informal and non-formal learning activities as well as formal learning activities. We have shown that it can be used (1) to create city games to explore different aspects of a city including history, civics and architecture (as shown with the VDS street game and the Brussels's city game), (2) for team building activities (like the VDS treasure map environment), (3) to inform youngsters about coming activities and allow them to reflect on them afterwards (the Reboot camp environment), (4) for offering dedicated information (like the environment providing information about youth organizations located in Brussels) and (5) to stimulate the processing of the teaching material in a university course (the TICKLE environment for the course on Object Oriented Modeling).

TICKLE provides a generic architecture including a plugin system that makes it suitable to adopt the platform for different activities in different domains and for different types of users. In this way, TICKLE can be used as platform to support different situations, such as:

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- Other opportunities, such as adult learning, advertisement of employment opportunities, marketing of physical shops, for takeaway restaurants, in tourism, to inventory

particular organizations and institutes, and so on.

TICKLE did not only served as a proof of concept for the MPLE model (showing that a technical implementation of the model was feasible), it also allowed to evaluated, indirectly, the usefulness and contributions of the features of the MPLE model and its pipeline. All features (i.e. mobile user context, data collection and analysis, learner visualization, self-monitoring, persuasion, playfulness, and micro learning) have been implemented in TICKLE, some in a more limited way than others (i.e. for the learner visualization, the data collection and analysis, and the self-monitoring only some of the possible techniques were implemented). Because TICKLE has been evaluated in different contexts, (the implementation of) these features have also been evaluated.

The different evaluations of TICKLE provided us some useful experience that are worthwhile to mention and to take into account in future work. Our evaluations were formative evaluations, meaning that their intent was to improve the artifact being under development. However, we experienced that performing formative evaluations in real life settings is challenging.

- First of all, we found that our target audience, i.e., youngsters, is very demanding, especially concerning look, feel, and usability. Although we always explained very well that the app under evaluation was research work and still required improvements, most of the critique was on the look and feel, and about small usability issues. Also being able to quickly start and resume the app was very important for them.

- Next, there exist a broad range of smartphones with different screen sizes and browser versions. It turned out to be impossible in the context of a research project to ensure that the application was running smoothly and without issues on all possible devices used by youngsters. For that reason, we decided to provide smartphones to perform the evaluations in the third phase. However, for the longitudinal evaluation this may cause some bias. When the youngsters have to use an additional device next to their

own smartphone, they may find this annoying, and it will counteract efforts to make the app *a seamless part of daily life*.

- When performing evaluations in real-life settings, it is not always possible to have full control over the setup. Even after careful preparation, unexpected issues may show up during the evaluation. For instance, this happened during the Reboot Camp evaluation: although we limited the use of the mobile phone to the TICKLE app (so the youngsters could not use it to make phone calls, download or play games, or for other apps), and discussed this with the organizers in advance, it turned out that the strict policy for using mobile devices was also applied to the mobile phones given to the youngsters for the evaluation. Probably, during the camp, it must have been easier to ban the use of any mobile phone during the day, and because we were not allowed to be present during the camp week, we could not intervene.

- Moreover, most available questionnaires on usability and user experience are designed for adults with good literacy. For the evaluations in phase two, we used UEQ in the native language of the participants, but simplified the language somewhat, because a pilot with youngsters of the same age indicated that some terms were still too difficult to understand. When the youngsters were filling out the questionnaire, we also noticed that they had problems in using the Likert scale, especially when the lowest score represented a good result and the highest a bad result. For instance, they had no problem in scoring a statement like "the system was (1) easy to learn...(7) difficult to learn", but a statement like "the system was (1) demotivating...(7) motivating" caused misunderstanding. Apparently, in their education, they were used to associating a high score with a good result. The participants in phase three were even younger, and it was known that their literacy could be an issue, so we simplified the language in the questionnaire even more and used statements that all could be answered with the same scale: "strongly disagree" to "strongly agree". As much

as possible, we tried to avoid negatively formulated statements. In the first evaluation of phase three, the youngsters could ask for an explanation while filling out the questionnaire, but in general they did not use this opportunity. For summative, longitudinal evaluations, even more attention should be paid to the questionnaire, it should be pilot several times, and if possible, an existing validated questionnaire tailored towards children/youngsters and suitable for the purpose should be used.

6.2.1 Limitations & Future Work

First of all, informal learning is a broad topic and discipline including many different activities and mental processes. As already indicated, in this dissertation, we focused on some particular aspects, specifically on reflective practices based on D. A. Kolb (2014) and others described in chapter 2 and the use of micro learning to improve informal learning. But there are many more activities that occur away from a structured, formal classroom environment which can be considered as informal learning. Informal learning comes in many shapes, including viewing videos, self-study, reading articles, participating in forums and chat rooms, playing games and so on. It was impossible to consider all these different activities within one conceptual framework and one proof of concept application. One has to make decisions on which features to include and which not in a research project that is limited in terms of time and money.

Right now, the MPLE model considers the learning activities to be part of the learning environment. In the future, we want to examine how to extend the model to allow to deal with learning activities that are happening outside the environment. To support this, one has to come up with a flexible communication service to other platforms providing such activities. We showcased such a principle with a prototype implementation to communicate with the Canvas LMS to capture results of formal learning units. However, in the future such a mechanism needs to be represented in the reference model itself.

Moreover, the model is very limited in its support for the validation of informal learning

practices, i.e. ways to have achievements performed in informal learning acknowledged by peers, instructors, institutes, and so on. This is especially difficult because, by definition, informal learning does not lead to any certification. However, the European Council's Recommendation of December 2012[1] urged member states to proceed with the validation of non-formal and informal learning, to enhance employability and mobility of the youth on the job market. In lifelong and life-wide learning, "validation" is a crucial element to ensure visibility and to indicate the appropriate value of the learning that took place anywhere and at any time in the life of the individual (Colardyn & Bjornavold, 2004). Furthermore, validation has the potential to bring wide benefits to young people who are in danger of dropout. Finding opportunities in informal learning practices that happen outside of school can lead to a huge confidence-boost, which is the first step towards a return to formal learning or finding a pathway to employment.

Next, the validation of the MPLE model is limited to the development of a proof of concept application, TICKLE, and the evaluation of this application. Some parts of the objectives, such as improved self-reflection capabilities and learning impact could not be fully evaluated because summative and longitudinal evaluations were not possible due to the COVID-19 restriction imposed in 2020 and 2021. To overcome this limitation, we want to evaluate our MPLE model with domain experts in the field of design and development of digitally enhanced learning environments, i.e. an expert-based evaluation. As such we can assess the quality of the model directly without the need to test a resulting application separately.

Next, TICKLE app is only a prototype implementation. It was created as a proof of concept application for the MPLE model. As such, it still can be improved on several aspects. This is also reflected in the evaluations done with TICKLE where participants faced problems in some of the learning activities and visualization tasks. Especially, the navigation was a problem. Some users struggled to exit menus and did not know that they

[1] https://epale.ec.europa.eu/en/resource-centre/content/council-recommendation-validation-non-formal-and-informal-learning-20

could interact with some features of the visualizations. In future evaluations, we want to set up a usability study with a couple of participants to track down all possible usability problems prevalent in the application. Other future work in the context of TICKLE includes the support a broader range of learning activities; allow user to collaborate, and to help and learn from each other; and allow learners to create learning activities for others.

We also identified the need to ease the authoring of learning activities. In the context of the TICKLE app and while creating the different demonstrators, it turned out that the authoring of learning activities was a bottleneck to create fast and effective informal learning experiences. It takes a major effort to create meaningful and appealing learning activities. First of all, the author needs to design the learning activities and next (s)he has to defined them within the TICKLE authoring tool which is very time consuming because a wide range of different learning variables have to be specified, i.e. a title and a description, illustrations, aims, location, time availability, classification tags, points, and of course the content of the activity and how the user's activity should be rated. During the development, we identified a range of web services as possible ways to scaffold the authoring by pre-filling certain variables. For instance, Google Maps offers a service to identify points of interests as possible location for learning activities, or certain artificial intelligence powered web services can auto-classify content.

Another area for future work is the personalization of learning activities and the user experience. Although most ingredients are available in TICKLE, the personalization still needs to be done manually by the supervisor. An automatic process that adapts content and user experience dynamically to the behavior of the user would be a very useful additional feature.

6.3 Conclusion

We aimed to provide the conceptual foundations of digital environments supporting informal learning in our digital age. After studying which learning types and learning strategies

are relevant, how digital natives access and deal with information, and how learning is currently supported, we introduced the Mobile Playful Learning Environment (MPLE) model that aims to provide a reference model for such a type of learning environments. The features of our MPLE model and how they should interact with each other were defined and motivated based on the findings from this extensive literature review.

Based on the defined MPLE model and as a proof of concept of such an environment, we developed TICKLE, a mobile playful learning environment platform for youngsters. Several demonstrators were developed with this platform and a number of these demonstrators were evaluated in real-life situations.

In summary, the contributions of the thesis are:

- A clarification of the conceptual foundations for digital learning environments for informal learning and lifelong learning;
- The identification of fundamental features for such digital learning environment;
- The definition of the Mobile Playful Learning Environment (MPLE) model, being a reference model that can be used as a starting point for developing digital learning environments aiming to support youngsters with informal learning or lifelong learning. This model does not only describe fundamental conceptual features to be included in such an environment, it also presents a set of functional components needed to support the realization of those features;
- TICKLE, a proof of concept application for the MPLE model, developed as a generic mobile playful platform suitable of supporting different activities, for different users, and in different domains.

REFERENCES

Abdessettar, S., Hotte, R., Gardoni, M., & Abdulrazak, B. (2016). Persuasive technologies for efficient adaptable Self-Education, In *The eighth international conference on mobile, hybrid, and on-line learning, c*, researchgate.net.

Abras, C., Maloney-Krichmar, D., Preece, J., Et al. (2004). User-centered design. *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, *37*(4), 445–456.

Adams Becker, S., M., C., Davis, A., Freeman, A., Hall Giesinger, C., & Ananthanarayanan, V. (2017). NMC horizon report: 2017 higher education edition. Retrieved July 11, 2021, from https://www.unmc.edu/elearning/_documents/NMC_HorizonReport_2017.pdf

Alharbi, M. T., Platt, A., & Al-Bayatti, A. H. (2012). Context-aware personal learning environment, In *2012 international conference for internet technology and secured transactions*, De Montfort University.

Asada, M., & Harris, P. (2020). No one-size-fits-all: Participation in the mathematics classroom. Math Values Blog, Mathematical Association of America. Retrieved July 11, 2021, from https://www.mathvalues.org/masterblog/no-one-size-fits-all-participation-in-the-mathematics-classroom

Ash, K. (2013). 'personal learning environments' focus on the individual [Accessed: 2020-4-28]. Retrieved July 11, 2021, from https://www.edweek.org/ew/articles/2013/05/22/32el-personallearning.h32.html?cmp=SOC-SHR-FB

Attwell, G. (2007). Personal learning environments-the future of elearning? *Elearning papers*, *2*(1), 1–8.

Bamidis, P. D., Konstantinidis, S. T., Bratsas, C., & Iyengar, M. S. (2011). Federating learning management systems for medical education: A persuasive technologies perspective, In *2011 24th international symposium on Computer-Based medical systems (CBMS)*, ieeexplore.ieee.org.

Baumer, E., Khovanskaya, V., Matthews, M., Et al. (2014). Reviewing reflection: On the use of reflection in interactive system design. *Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS*.

Baumer, E. (2015). Reflective informatics: Conceptual dimensions for designing technologies of reflection, In *Proceedings of the 33rd annual ACM conference on human factors in computing systems*, Seoul, Republic of Korea, ACM.

Bawden, D., & Robinson, L. (2009). The dark side of information: Overload, anxiety and other paradoxes and pathologies. *J. Inf. Sci. Eng.*, *35*, 180–191.

Behringer, R., Soosay, M., Gram-Hansen, S. B., Øhrstrøm, P., Sørensen, C. G., Smith, C., Mikulecká, J., Winther-Nielsen, N., Winther-Nielsen, M., & Herber, E. (2013). Persuasive technology for learning and teaching–the europlot project, In *Proceedings of the international workshop on EuroPLOT persuasive technology for learning, education and teaching*, eprints.leedsbeckett.ac.uk.

Bekker, T., Sturm, J., & Eggen, B. (2010). Designing playful interactions for social interaction and physical play. *Pers. Ubiquit. Comput.*, *14*(5), 385–396.

Berking, P. (2016). Choosing a learning record store (lrs). Retrieved July 11, 2021, from https://www.adlnet.gov/publications/2016/05/Choosing-a-Learning-Record-Store-LRS/

Berkovsky, S., Freyne, J., & Oinas-Kukkonen, H. (2012). Influencing individually: Fusing personalization and persuasion. *ACM Trans. Interact. Intell. Syst.*, *2*(2), 1–8.

Biel, P., Pérez, E., Rodrigo, C., & Serrano, A. (2016). Use of symbaloo edu for improving information management processes in work by modules. *JCIT*, *18*(4), 22–35.

Blackboard data & analytics. (n.d.). Retrieved December 7, 2020, from https://www.blackboard.com/teaching-learning/data-and-analytics

Blohm, I., & Leimeister, J. M. (2013). Gamification. *Business & Information Systems Engineering*, *5*(4), 275–278.

Boghossian, P. (2006). Behaviorism, constructivism, and socratic pedagogy. *Educational Philosophy and Theory*, *38*(6), 713–722.

BookWidgets. (n.d.). Retrieved July 11, 2021, from https://www.bookwidgets.com/

Boud, D., Keogh, R., & Walker, D. (2013). *Reflection: Turning experience into learning*. Routledge.

Boud, D., & Middleton, H. (2003). Learning from others at work: Communities of practice and informal learning. *Journal of Workplace Learning*, *15*(5), 194–202.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative research journal*.

Bowers, D., & Tsai, C. (1990). HyperCard in educational research: An introduction and case study. *Educ. Technol. Res. Dev.*, *30*(2), 19–24.

Bowler, L., Julien, H., & Haddon, L. (2018). Exploring youth information-seeking behaviour and mobile technologies through a secondary analysis of qualitative data. *Journal of Librarianship and Information Science*, *50*(3), 322–331.

Braun, B., Stopfer, J. M., Müller, K. W., Beutel, M. E., & Egloff, B. (2016). Personality and video gaming: Comparing regular gamers, non-gamers, and gaming addicts and differentiating between game genres. *Comput. Human Behav.*, *55*, 406–412.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.*, *3*(2), 77–101.

Bray, B., & McClaskey, K. (2010). Personalization vs differentiation vs individualization. *Ideas Education*. Retrieved July 11, 2021, from http://www.personalizelearning.com/2012/04/explaining-chart.html

Brehmer, M., & Munzner, T. (2013). A Multi-Level typology of abstract visualization tasks. *IEEE Trans. Vis. Comput. Graph.*, *19*(12), 2376–2385.

Bruck, P. A., Motiwalla, L., & Foerster, F. (2012). Mobile learning with micro-content: A framework and evaluation. *Bled eConference*.

Caillois, R. (2001). *Man, play, and games*. University of Illinois Press.

Callanan, M., Cervantes, C., & Loomis, M. (2011). Informal learning. *Wiley Interdiscip. Rev. Cogn. Sci.*, *2*(6), 646–655.

Canvas. (n.d.). Retrieved July 1, 2020, from https://www.instructure.com/canvas/

Card, S. K., Mackinlay, J. D., & Shneiderman, B. (1999). *Readings in information visualization: Using vision to think*. Morgan Kaufmann.

Cárdenas-Robledo, L. A., & Peña-Ayala, A. (2018). Ubiquitous learning: A systematic review. *Telematics and Informatics*, *35*(5), 1097–1132.

Charleer, S., Klerkx, J., Odriozola, S., Luis, J., & Duval, E. (2013). Improving awareness and reflection through collaborative, interactive visualizations of badges, In *ARTEL13: Proceedings of the 3rd workshop on awareness and reflection in Technology-Enhanced learning*, lirias.kuleuven.be.

Chatti, M. A., Jarke, M., Agustiawan, M. R., & Specht, M. (2010). Toward a personal learning environment framework. *Int. J. Virtual Pers. Learn. Environ.*, *1*(4), 66–85.

Chen, M., Ebert, D., Hagen, H., Laramee, R. S., van Liere, R., Ma, K.-L., Ribarsky, W., Scheuermann, G., & Silver, D. (2009). Data, information, and knowledge in visualization. *IEEE Comput. Graph. Appl.*, *29*(1), 12–19.

Churchill, D., Fox, B., & King, M. (2016). Framework for designing mobile learning environments, In *Mobile learning design: Theories and application*. Springer Singapore.

Cialdini, R. (2001). 6 principles of persuasion. *Arizona State University, eBrand Media Publication*.

Cialdini, R. (1993). Influence: The psychology of persuasion.

Clemens, C., Kumar, V., Boulanger, D., Seanosky, J., & Kinshuk. (2018). Learning traces, competence assessment, and causal inference for english composition. *Frontiers of Cyberlearning: Emerging Technologies for Teaching and Learning*, 49–67.

Coates, H., James, R., & Baldwin, G. (2005). A critical examination of the effects of learning management systems on university teaching and learning. *Tertiary education and management*, *11*, 19–36.

Colardyn, D., & Bjornavold, J. (2004). Validation of formal, Non-Formal and informal learning: Policy and practices in EU member states 1. *European journal of education*, *39*(1), 69–89.

Collins, C., Penn, G., & Carpendale, S. (2009). Bubble sets: Revealing set relations with isocontours over existing visualizations. *IEEE Trans. Vis. Comput. Graph.*, *15*(6), 1009–1016.

Conde, M. Á., Garcıa-Peñalvo, F. J., Alier, M., Et al. (2013). The implementation, deployment and evaluation of a mobile personal learning environment. *J. Univers. Comput. Sci.*

Conde, M. Á., Garcıa-Peñalvo, F., Alier, M., Mayol, E., & Fernández-Llamas, C. (2014). Implementation and design of a service-based framework to integrate personal and institutional learning environments. *Science of Computer Programming*, *88*, 41–53.

Conde, M. Á., & Hernández-Garcıa, Á. (2019). Data driven education in personal learning Environments–What about learning beyond the institution? *International Journal of Learning Analytics and Artificial Intelligence for Education (iJAI)*, *1*(1), 43–57.

Dabbagh, N., & Kitsantas, A. (2012). Personal learning environments, social media, and self-regulated learning: A natural formula for connecting formal and informal learning. *Internet and Higher Education*, *15*(1), 3–8.

Devincenzi, S., Kwecko, V., de Toledo, F. P., Mota, F. P., Casarin, J., & da Costa Botelho, S. S. (2017). Persuasive technology: Applications in education. IEEE.

Digman, J. M. (1990). Personality structure: Emergence of the Five-Factor model. *Annual Reviews. Psychology*, *41*(1), 417–440.

Dix, A., Dix, A. J., Finlay, J., Abowd, G. D., & Beale, R. (2003). *Human-computer interaction*. Pearson Education.

Dörk, M. (2012). Visualization for search: Exploring complex and dynamic information spaces. Retrieved July 11, 2021, from https://mariandoerk.de/phd/dissertation.pdf

Dresang, E. T. (2005). Access: The Information-Seeking behavior of youth in the digital environment. *Libr. Trends*, *54*(2), 178–196.

Dur, B. I. U. (2014). Data visualization and infographics in visual communication design education at the age of information. *Journal of Arts and Humanities*, *3*(5), 39.

Durrance, B. (1998). Some explicit thoughts on tacit learning. *Training & Development*, *52*(12), 24–30.

Duval, E. (2011). Attention please!: Learning analytics for visualization and recommendation, In *Proceedings of the 1st international conference on learning analytics and knowledge*, Banff, Alberta, Canada, ACM.

Eberhard, L., & Harribey, L. E. (2002). *The council of europe and youth: Thirty years of experience*. Council of Europe.

Ed Huai-Hsin Chi, & Riedl, J. T. (1998). An operator interaction framework for visualization systems, In *Proceedings IEEE symposium on information visualization (cat. No.98TB100258)*, ieeexplore.ieee.org.

Edge, D., Fitchett, S., Whitney, M., & Landay, J. (2012). MemReflex: Adaptive flashcards for mobile microlearning, In *Proceedings of the 14th international conference on human-computer interaction with mobile devices and services*, San Francisco, California, USA, Association for Computing Machinery.

Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *Br. J. Educ. Psychol.*, *70*(1), 113–136.

Eshach, H. (2007). Bridging in-school and out-of-school learning: Formal, non-formal, and informal education. *J. Sci. Educ. Technol.*, *16*, 171–190.

Eyal, N. (2014). *Hooked: How to build Habit-Forming products*. Penguin.

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, *5*(1), 80–92.

Ferrando, A., De Vries, P., Ruiz, C., & Hennis, T. (2012). Reactivating demotivated Learners–The ReAct approach, In *INTED conference proceedings, sevilla, spain*, researchgate.net.

Figueiras, A. (2014). Narrative visualization: A case study of how to incorporate narrative elements in existing visualizations, In *2014 18th international conference on information visualisation*, ieeexplore.ieee.org.

Filippou, J., Cheong, C., & Cheong, F. (2016). Combining the fogg behavioural model and hook model to design features in a persuasive app to improve study habits, arXiv 1606.03531.

Fischer, G. (2000). Lifelong learning—more than training. *Journal of Interactive Learning Research*, *11*(3), 265–294.

Florian-Gaviria, B., Glahn, C., & Fabregat Gesa, R. (2013). A software suite for efficient use of the european qualifications framework in online and blended courses. *IEEE Trans. Learn. Technol.*, *6*(3), 283–296.

Fogg, B. J. (2009). A behavior model for persuasive design, In *Proceedings of the 4th international conference on persuasive technology*, Claremont, California, USA, ACM.

Fogg, B. J. (1998). Persuasive computers: Perspectives and research directions, In *Proceedings of the SIGCHI conference on human factors in computing systems*, Los Angeles, California, USA, ACM Press/Addison-Wesley Publishing Co.

Fogg, B. J. (2002). *Using computers to change what we think and do*. Morgan Kaufmann Publishers Inc. San Francisco.

Freigang, S., Schlenker, L., & Köhler, T. (2018). A conceptual framework for designing smart learning environments. *Smart Learning Environments*, *5*(1), 27.

Gallardo-Echenique, E. E., Marqués-Molıas, L., Bullen, M., & Strijbos, J.-W. (2015). Let's talk about digital learners in the digital era. *The International Review of Research in Open and Distributed Learning*, *16*(3).

Geocaching. (2020). Retrieved September 30, 2020, from https://www.geocaching.com/

Gilster, P., & Glister, P. (1997). *Digital literacy*. Wiley Computer Pub. New York.

Gonzalez-Perez, C., & Henderson-Sellers, B. (2008). *Metamodelling for software engineering*. Wiley Publishing.

Goodyear, P., & Retalis, S. (2010). Technology-enhanced learning. *Rotterdam: Sense Publishers*.

Govaerts, S., Verbert, K., Duval, E., & Pardo, A. (2012). The student activity meter for awareness and self-reflection. *CHI'12 Extended Abstracts on*.

Govaerts, S., Verbert, K., Klerkx, J., & Duval, E. (2010). Visualizing activities for self-reflection and awareness, In *Advances in Web-Based learning – ICWL 2010*, Springer, Berlin, Heidelberg.

Graham, C. R. (2006). Blended learning systems. *The handbook of blended learning: Global perspectives, local designs*, 3–21.

Grant, A. M., Franklin, J., & Langford, P. (2002). The Self-Reflection and Insight Scale: A new Measure of private Self-Consciousness. *Social Behavior and Personality: an international journal*, *30*(8), 821–835.

Gros, B. (2016). The design of smart educational environments. *Smart Learning Environments*, *3*(1), 15.

Hamari, J., & Koivisto, J. (2014). Measuring flow in gamification: Dispositional flow scale-2. *Comput. Human Behav.*, *40*, 133–143.

Hasanov, A., Laine, T. H., & Chung, T.-S. (2019). A survey of adaptive context-aware learning environments. *Journal of Ambient Intelligence and Smart Environments*, *11*(5), 403–428.

Hassenzahl, M. (2013). User experience and experience design. *The Encyclopedia of Human-Computer*. Retrieved July 22, 2021, from https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/user-experience-and-experience-design

Hassenzahl, M. (2008). User experience (UX): Towards an experiential perspective on product quality, In *Proceedings of the 20th conference on L'Interaction Homme-Machine*, Metz, France, ACM.

Hassenzahl, M., Diefenbach, S., & Göritz, A. (2010). Needs, affect, and interactive products–facets of user experience. *Interact. Comput.*, *22*(5), 353–362.

Hekler, E. B., Klasnja, P., Froehlich, J. E., & Buman, M. P. (2013). Mind the theoretical gap: Interpreting, using, and developing behavioral theory in HCI research, In *Proceedings of the SIGCHI conference on human factors in computing systems*, Paris, France, Association for Computing Machinery.

Helsper, E., & Eynon, R. (2010). Digital natives: Where is the evidence? *Br. Educ. Res. J.*, *36*(3), 503–520.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS quarterly*, 75–105.

Hevner, A., & Chatterjee, S. (2010). Design science research in information systems, In *Design research in information systems*. Springer.

Hoel, T., & Mason, J. (2018). Standards for smart education–towards a development framework. *Smart Learning Environments*, *5*(1), 3.

Horváth, I. Et al. (2007). Comparison of three methodological approaches of design research, In *Ds 42: Proceedings of iced 2007, the 16th international conference on engineering design, paris, france, 28.-31.07. 2007*.

Huang, D., Tory, M., Aseniero, B. A., Bartram, L., Bateman, S., Carpendale, S., Tang, A., & Woodbury, R. (2015). Personal visualization and personal visual analytics. *IEEE Trans. Vis. Comput. Graph.*, *21*(3), 420–433.

Huang, D., Tory, M., & Bartram, L. (2014). Data in everyday life: Visualizing time-varying data on a calendar, IEEE Visualization.

Huang, R., Yang, J., & Zheng, L. (2013). The components and functions of smart learning environments for easy, engaged and effective learning. *International Journal for Educational Media*.

Huffaker, D. A., & Calvert, S. L. (2003). The new science of learning: Active learning, metacognition, and transfer of knowledge in E-Learning applications. *Journal of Educational Computing Research*, *29*(3), 325–334.

Hwang, G.-J. (2014). Definition, framework and research issues of smart learning environments - a context-aware ubiquitous learning perspective. *Smart Learning Environments*, *1*(1), 4.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., Schor, J., Sefton-Green, J., & Craig Watkins, S. (2013). *Connected learning: An agenda for research and design*. BookBaby.

Jia, Y., Xu, B., Karanam, Y., & Voida, S. (2016). Personality-targeted gamification: A survey study on personality traits and motivational affordances, In *Proceedings of the 2016 CHI conference on human factors in computing systems*, San Jose, California, USA, Association for Computing Machinery.

Jonassen, D. H., & Grabowski, B. L. (2012). *Handbook of individual differences, learning, and instruction*. Routledge.

Judd, T. (2018). The rise and fall (?) of the digital natives. *Australasian Journal of Educational Technology*, *34*(5).

Kangas, M., Hyvönen, P., & Latva, S. (2007). Space treasure outdoor game in the playful learning environment: Experiences and assessment. *Proceedings of the 2nd International NBE*.

Kangas, M. (2010). Creative and playful learning: Learning through game co-creation and games in a playful learning environment. *Thinking Skills and Creativity*, *5*(1), 1–15.

Kaplan, B., & Maxwell, J. A. (2005). Qualitative research methods for evaluating computer information systems (J. G. Anderson & C. E. Aydin, Eds.). In J. G. Anderson & C. E. Aydin (Eds.), *Evaluating the organizational impact of healthcare information systems*. New York, NY, Springer New York.

Keim, D., Kohlhammer, J., Ellis, G., & Mansmann, F. (2010). *Mastering the information age: Solving problems with visual analytics*. Goslar: Eurographics Association.

Keim, D., Qu, H., & Ma, K.-L. (2013). Big-data visualization. *IEEE Computer Graphics and Applications*, *33*(4), 20–21.

Kester, L., & Kirschner, P. A. (2012). Cognitive tasks and learning (N. M. Seel, Ed.). In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning*. Boston, MA, Springer US.

Kinshuk, & Graf, S. (2012). Ubiquitous learning (N. M. Seel, Ed.). In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning*. Boston, MA, Springer US.

Knowles, M. S. (1975). *Self-Directed learning: A guide for learners and teachers*. Association Press.

Kolas, L., & Staupe, A. (2007). The PLExus prototype: A PLE realized as topic maps, In *Seventh IEEE international conference on advanced learning technologies (ICALT 2007)*, ieeexplore.ieee.org.

Kolb, A. Y., & Kolb, D. A. (2012). Learning identity (N. M. Seel, Ed.). In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning*. Springer US.

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *AMLE*, *4*(2), 193–212.

Kolb, A. Y., & Kolb, D. A. (2009). The learning way: Meta-cognitive aspects of experiential learning. *Simulation & Gaming*, *40*(3), 297–327.

Kolb, A., & Kolb, D. (2009). On becoming a learner: The concept of learning identity, In *Essays on adult learning inspired by the life and work of david o. justice. learning never ends. CAEL forum and news*, Citeseer.

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2014). Experiential learning theory: Previous research and new directions, In *Perspectives on thinking, learning, and cognitive styles*. Routledge.

Kop, R., & Fournier, H. (2014). Developing a framework for research on personal learning environments. *E-learning in Europe Journal*, *35*, 13–17.

Koper, R. (2014). Conditions for effective smart learning environments. *Smart Learning Environments*, *1*(1), 1–17.

Koutropoulos, A. (2011). Digital natives: Ten years after. *J. Online Learn. Teach.*, *7*(4), 525–538.

Kovachev, D., Cao, Y., Klamma, R., & Jarke, M. (2011). Learn-as-you-go: New ways of Cloud-Based micro-learning for the mobile web, In *Advances in Web-Based learning - ICWL 2011*, Springer Berlin Heidelberg.

Laakkonen, I. (2015). Doing what we teach: Promoting digital literacies for professional development through personal learning environments and participation (J. Jalkanen, E. Jokinen, & P. Taalas, Eds.). In J. Jalkanen, E. Jokinen, & P. Taalas (Eds.), *Voices of pedagogical development – expanding, enhancing and exploring higher education language learning*. Research-publishing.net.

Laal, M., & Salamati, P. (2012). Lifelong learning; why do we need it? *Procedia-Social and Behavioral Sciences*, *31*, 399–403.

Li, I., Dey, A. K., & Forlizzi, J. (2011). Understanding my data, myself: Supporting self-reflection with ubicomp technologies, In *Proceedings of the 13th international conference on ubiquitous computing*, Beijing, China, ACM.

Li, I., Forlizzi, J., & Dey, A. (2010). Know thyself: Monitoring and reflecting on facets of one's life, In *CHI '10 extended abstracts on human factors in computing systems*, Atlanta, Georgia, USA, ACM.

Li, Y., & Ranieri, M. (2010). Are 'digital natives' really digitally competent?—a study on chinese teenagers. *Br. J. Educ. Technol.*, *41*, 1029–1042.

Lin, X., Hmelo, C., Kinzer, C. K., & Secules, T. J. (1999). Designing technology to support reflection. *Educ. Technol. Res. Dev.*, *47*(3), 43–62.

Lindberg, R. S. N., Maushagen, J., & De Troyer, O. (2019). Combining a gamified civic engagement platform with a digital game in a loosely way to increase retention, In *Proceedings of the 21st international conference on information integration and web-based applications & services*, Munich, Germany, Association for Computing Machinery.

Liu, S., Cui, W., Wu, Y., & Liu, M. (2014). A survey on information visualization: Recent advances and challenges. *Vis. Comput.*, *30*(12), 1373–1393.

Lo, J.-L., Lin, T.-Y., Chu, H.-H., Chou, H.-C., Chen, J.-H., Hsu, J. Y.-J., & Huang, P. (2007). Playful tray: Adopting ubicomp and persuasive techniques into Play-Based occupational therapy for reducing poor eating behavior in young children, In *UbiComp 2007: Ubiquitous computing*, Springer Berlin Heidelberg.

Maarschalk, J. (1988a). Scientific literacy and informal science teaching. *Journal of Research in Science Teaching*, *25*(2), 135–146.

Maarschalk, J. (1988b). Scientific literacy and informal science teaching. *J. Res. Sci. Teach.*, *25*(2), 135–146.

Malcolm, J., Hodkinson, P., & Colley, H. (2003). The interrelationships between informal and formal learning. *Journal of Workplace Learning*, *15*(7/8), 313–318.

Marsick, V. J., & Watkins, K. E. (2001). Informal and incidental learning. *directions for adult and continuing education*, *2001*.

Medler, B., & Magerko, B. (2011). Analytics of play: Using information visualization and gameplay practices for visualizing video game data. *Parsons Journal for Information Mapping*, *3*(1), 1–12.

Mesquita, A., Moreira, F., & Peres, P. (2017). The customized xlearning environment model: Meeting the needs and expectations of students. *IJOPCD*, *7*(4), 39–52.

Meyers, E. M., Erickson, I., & Small, R. V. (2013). Digital literacy and informal learning environments: An introduction. *Learn. Media Technol.*, *38*(4), 355–367.

Mikulecký, P. (2012). Smart environments for smart learning, researchgate.net.

Milligan, C. D., Beauvoir, P., Johnson, M. W., Sharples, P., Wilson, S., & Liber, O. (2006). Developing a reference model to describe the personal learning environment, In *Innovative approaches for learning and knowledge sharing*, Springer Berlin Heidelberg.

Moon, J. A. (2013). *Reflection in learning and professional development : Theory and practice*. Routledge.

Motiwalla, L. F. (2007). Mobile learning: A framework and evaluation. *Comput. Educ.*, *49*(3), 581–596.

Mott, J., & Wiley, D. (2009). Open for learning: The CMS and the open learning network. *in education*, *15*(2).

Müller, L., Rivera-Pelayo, V., & Heuer, S. (2012). Persuasion and reflective learning: Closing the feedback loop, In *Persuasive technology. design for health and safety*, Springer Berlin Heidelberg.

Muntean, C. I. (2011). Raising engagement in e-learning through gamification, In *Proc. 6th international conference on virtual learning ICVL*, Cluj-Napoca, Romania, Europe.

Nagowah, L., & Nagowah, S. (2009). A reflection on the dominant learning theories: Behaviourism, cognitivism and constructivism. *International Journal of Learning*, *16*(2).

Ng, W. (2012). Can we teach digital natives digital literacy? *Comput. Educ.*, *59*(3), 1065–1078.

Ngan, H. Y., Lifanova, A., Jarke, J., & Broer, J. (2016). Refugees welcome: Supporting informal language learning and integration with a gamified mobile application, In *Adaptive and adaptable learning*, Springer International Publishing.

Nicholson, S. (2018). Creating engaging escape rooms for the classroom. *Childhood Education*, *94*(1), 44–49.

Nicholson, S. (2015). A RECIPE for meaningful gamification (T. Reiners & L. C. Wood, Eds.). In T. Reiners & L. C. Wood (Eds.), *Gamification in education and business*. Cham, Springer International Publishing.

Nordin, N., Embi, M. A., & Yunus, M. (2010). Mobile learning framework for lifelong learning. *Procedia - Social and Behavioral Sciences*, *7*, 130–138.

Offermann, P., Levina, O., Schönherr, M., & Bub, U. (2009). Outline of a design science research process, In *Proceedings of the 4th international conference on design sci-*

ence research in information systems and technology, Philadelphia, Pennsylvania, ACM.

Oinas-Kukkonen, H. (2013). A foundation for the study of behavior change support systems. *Pers. Ubiquit. Comput.*, *17*(6), 1223–1235.

Oinas-kukkonen, H. (2010). Behavior change support systems: The next frontier for web science, In *Proceedings of the web science conf*, Citeseer.

Oinas-Kukkonen, H., & Harjumaa, M. (2009). Persuasive systems design: Key issues, process model, and system features. *Communications of the Association for Information Systems*, *24*(1), 28.

Oreg, S., & Sverdlik, N. (2014). Source personality and persuasiveness: Big five predispositions to being persuasive and the role of message involvement. *J. Pers.*, *82*(3), 250–264.

Ozdamli, F., & Cavus, N. (2011). Basic elements and characteristics of mobile learning. *Procedia - Social and Behavioral Sciences*, *28*, 937–942.

Perkins, D. N. (1991). What constructivism demands of the learner. *Educational technology*, *31*(9), 19–21.

Pettenati, M. C., Cigognini, M. E., M.C. Guerin, E., & Mangione, G. R. (2009). Personal knowledge management skills for Lifelong-Learners 2.0, In *Handbook of research on social software and developing community ontologies*. IGI Global.

Pham, X. L., & Chen, G. D. (2019). PACARD: A new interface to increase mobile learning app engagement, distributed through app stores. *Journal of Educational Computing Research*, *57*(3), 618–645.

Pintrich, P. R. (1995). Understanding self-regulated learning. *New directions for teaching and learning*, *1995*(63), 3–12.

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of Game-Based learning. *Educ. Psychol.*, *50*(4), 258–283.

Pousman, Z., Stasko, J., & Mateas, M. (2007). Casual information visualization: Depictions of data in everyday life. *IEEE Trans. Vis. Comput. Graph.*, *13*(6), 1145–1152.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the Horizon*, *9*(5), 1–6.

Progressive web apps. (n.d.). Retrieved January 10, 2021, from https://developers.google.com/web/ilt/pwa/

Radford, M. L., Connaway, L. S., Agosto, D. E., Cooper, L. Z., Reuter, K., & Zhou, N. (2007). Behaviors and preferences of digital natives: Informing a research agenda. *Proc. Am. Soc. Info. Sci. Tech.*, *44*(1), 1–15.

Räisänen, T., Lehto, T., & Oinas-Kukkonen, H. (2010). Practical findings from applying the psd model for evaluating software design specifications, In *International conference on persuasive technology*. Springer.

Rapp, A., & Cena, F. (2014). Self-monitoring and technology: Challenges and open issues in personal informatics, In *Universal access in Human-Computer interaction. design for all and accessibility practice*, Springer International Publishing.

Rauschenberger, M., Schrepp, M., Pérez Cota, M., Olschner, S., & Thomaschewski, J. (2013). Efficient measurement of the user experience of interactive products. how to use the user experience questionnaire (UEQ). example: Spanish language version, *2*, 39–45.

Reboot kamp. (n.d.). Retrieved July 11, 2021, from https://www.rebootkamp.be/

Redux - a predictable state container for JS apps. (n.d.). Retrieved July 10, 2021, from https://redux.js.org/

Rice, L. (2009). Playful learning. *Journal for Education in the Built Environment*, *4*(2), 94–108.

Rivera-Pelayo, V., Zacharias, V., Müller, L., & Braun, S. (2012). Applying quantified self approaches to support reflective learning, In *Proceedings of the 2nd international conference on learning analytics and knowledge*, Vancouver, British Columbia, Canada, ACM.

Rodriguez Triana, M. J., Prieto Santos, L. P. Et al. (2017). Monitoring, awareness and reflection in blended technology enhanced learning: A systematic review. *Enhanced Learning*, *9*, 126–150.

Rowanne Fleck, G. F. (2010). Reflecting on reflection: Framing a design landscape, In *OZCHI '10 proceedings of the 22nd conference of the Computer-Human interaction special interest group of australia on Computer-Human interaction*.

Rowlands, I., Nicholas, D., Williams, P., Huntington, P., Fieldhouse, M., Gunter, B., Withey, R., Jamali, H. R., Dobrowolski, T., & Tenopir, C. (2008). The google generation: The information behaviour of the researcher of the future. *Aslib Proc.*, *60*(4), 290–310.

Sailor, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological needs satisfaction. *Comput. Human Behav.*, *69*, 371–380.

Salmela-Aro, K., & Tynkkynen, L. (2012). Gendered pathways in school burnout among adolescents. *J. Adolesc.*, *35*(4), 929–939.

Savolainen, R. (1995). Everyday life information seeking: Approaching information seeking in the context of "way of life". *Libr. Inf. Sci. Res.*, *17*(3), 259–294.

Schmitt, J. B., Debbelt, C. A., & Schneider, F. M. (2018). Too much information? predictors of information overload in the context of online news exposure. *Information, Communication & Society*, *21*(8), 1151–1167.

Schoen, D. A. (1992). Educating for reflection-in-action. *Planning for Human Systems: Essays in Honor of Russell L. Ackoff, University of Pennsylvania Press, Philadelphia*, 142–161.

Selwyn, N. (2009). The digital native–myth and reality, In *Aslib proceedings*, emeraldinsight.com.

Sharples, M. (2000). The design of personal mobile technologies for lifelong learning. *Comput. Educ.*, *34*, 177–193.

Sharples, M., Arnedillo-Sánchez, I., Milrad, M., & Vavoula, G. (2009). Mobile learning (N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes, Eds.). In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes (Eds.), *Technology-Enhanced learning: Principles and products*. Dordrecht, Springer Netherlands.

Sharples, M., Taylor, J., & Vavoula, G. (2010). A theory of learning for the mobile age (B. Bachmair, Ed.). In B. Bachmair (Ed.), *Medienbildung in neuen kulturräumen*. VS Verlag für Sozialwissenschaften.

Shenton, A., & Dixon, P. (2004). The development of young people's information needs. *Libr. Inf. Sci. Res.*, *28*(89), 25–34.

Shields, P. M., & Rangarajan, N. (2013). *A playbook for research methods: Integrating conceptual frameworks and project management*. New Forums Press.

Smiderle, R., Rigo, S. J., Marques, L. B., Peçanha de Miranda Coelho, J. A., & Jaques, P. A. (2020). The impact of gamification on students' learning, engagement and behavior based on their personality traits. *Smart Learning Environments*, *7*(1), 3.

Smids, J. (2012). The voluntariness of persuasive technology, In *Persuasive technology. design for health and safety*, Springer Berlin Heidelberg.

Soller, A., Martınez, A., Jermann, P., & Muehlenbrock, M. (2005). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *International Journal of Artificial Intelligence in Education*, *15*(4), 261–290.

Spector, J. M. (2014). Conceptualizing the emerging field of smart learning environments. Springer Open.

Steffens, K. (2006). Self-regulated learning in technology-enhanced learning environments: Lessons of a european peer review. *European journal of education*, *41*(3-4), 353–379.

Su, C.-H., & Cheng, C.-H. (2015). A mobile gamification learning system for improving the learning motivation and achievements. *Journal of Computer Assisted Learning*, *31*(3), 268–286.

Sumadyo, M., Santoso, H. B., & Sensuse, D. I. (2018). Metacognitive components in smart learning environment. *J. Phys. Conf. Ser.*, *978*(1), 012025.

TalentCards. (2020). Retrieved July 11, 2021, from https://www.talentcards.com/

Tamir, P. (1991). Factors associated with the relationship between formal, informal, and nonformal science learning. *The Journal of Environmental Education*, *22*(2), 34–42.

Tapscott, D. (2008). *Grown up digital: How the net generation is changing your world HC* (1st ed.). Mcgraw-Hill.

Temdee, P. (2020). Smart learning environment: Paradigm shift for online learning, In *Multi agent systems - strategies and applications*. IntechOpen.

Thieme, A., Comber, R., Miebach, J., Weeden, J., Kraemer, N., Lawson, S., & Olivier, P. (2012). ‘‘ we’ve bin watching you” designing for reflection and social persuasion to promote sustainable lifestyles, In *Proceedings of the SIGCHI conference on human factors in computing systems*, dl.acm.org.

Thompson, P. (2015a). How digital native learners describe themselves. *Education and Information Technologies*, *20*(3), 467–484.

Thompson, P. (2015b). How digital native learners describe themselves. *Educ Inf Technol*, *20*(3), 467–484.

Throuvala, M. A., Griffiths, M. D., Rennoldson, M., & Kuss, D. J. (2020). Mind over matter: Testing the efficacy of an online randomized controlled trial to reduce distraction from smartphone use. *Int. J. Environ. Res. Public Health*, *17*(13).

Thudt, A., Baur, D., Huron, S., & Carpendale, S. (2016). Visual mementos: Reflecting memories with personal data. *IEEE Trans. Vis. Comput. Graph.*, *22*(1), 369–378.

Tikka, P., & Oinas-Kukkonen, H. (2016). Rightontime: The role of timing and unobtrusiveness in behavior change support systems, In *International conference on persuasive technology*. Springer.

Tondello, G. F., Orji, R., & Nacke, L. E. (2017). Recommender systems for personalized gamification. *UMAP '17: Adjunct Publication of the 25th Conference on User Modeling, Adaptation and Personalization*, 425–430.

Tondello, G. F., Wehbe, R. R., Diamond, L., Busch, M., Marczewski, A., & Nacke, L. E. (2016). The gamification user types hexad scale, In *Proceedings of the 2016 annual symposium on Computer-Human interaction in play*, Austin, Texas, USA, Association for Computing Machinery.

Toscos, T., Faber, A., An, S., & Gandhi, M. P. (2006). Chick clique: Persuasive technology to motivate teenage girls to exercise, In *CHI '06 extended abstracts on human factors in computing systems*, Montréal, Québec, Canada, Association for Computing Machinery.

Vainio, J., Kaipainen, K., & Korhonen, I. (2014). Habit change as a learning process: Design framework for mobile interventions, In *IEEE-EMBS international conference on biomedical and health informatics (BHI)*, ieeexplore.ieee.org.

The value of play i: The definition of play gives insights. (2008). Sussex Publishers. https://www.psychologytoday.com/intl/blog/freedom-learn/200811/the-value-play-i-the-definition-play-gives-insights

Vassileva, J., & Sun, L. (2008). Evolving a social Visualization Design aimed at increasing participation in a class-based online community. *Int. J. Coop. Inf. Syst.*, *17*(04), 443–466.

Verbert, K., Manouselis, N., Ochoa, X., Wolpers, M., Drachsler, H., Bosnic, I., & Duval, E. (2012). Context-Aware recommender systems for learning: A survey and future challenges. *IEEE Trans. Learn. Technol.*, *5*(4), 318–335.

Verbert, K., Parra, D., Brusilovsky, P., & Duval, E. (2013). Visualizing recommendations to support exploration, transparency and controllability, In *Proceedings of the 2013 international conference on intelligent user interfaces*, Santa Monica, California, USA, ACM.

Vlieghe, J., & De Troyer, O. (2016a). *Rapport d1: State-of-the-art betreffende mediagebruik bij jongeren enjongvolwassenen in belgië, vlaanderen en brussel* (tech. rep.

No. 1). Vrije Universiteit Brussel. Retrieved July 11, 2021, from https://wise.vub.ac.be/tickle/index.php/reformation/sota-mediause/

Vlieghe, J., & De Troyer, O. (2016b). *Report d2: State-of-the-art on early school leaving and dropouts* (tech. rep.). Retrieved July 11, 2021, from https://wise.vub.ac.be/tickle/index.php/reformation/report-d2-state-of-the-art-on-early-school-leaving-and-dropouts/

Wakefield, J., & Frawley, J. K. (2020). How does students' general academic achievement moderate the implications of social networking on specific levels of learning performance? *Comput. Educ.*, *144*, 103694.

Wang, Q., Woo, H. L., Quek, C. L., Yang, Y., & Liu, M. (2012). Using the facebook group as a learning management system: An exploratory study. *Br. J. Educ. Technol.*, *43*(3), 428–438.

Watson, J. (2008). Blended learning: The convergence of online and Face-to-Face education. promising practices in online learning. *North American Council for Online Learning*.

West, R. (2017). Foundations of learning and instructional design technology (1st ed.). Retrieved July 11, 2021, from https://edtechbooks.org/lidtfoundations

Whitton, N. (2018). Playful learning: Tools, techniques, and tactics. *Research in Learning Technology*, *26*.

Wilson, S., Sharples, P., Griffiths, D., & Popat, K. (2009). Moodle wave: Reinventing the VLE using widget technologies, In *In proc. Mash-Up personal learning environments*, 2nd Workshop MUPPLE'09, CEUR Proceedings, Conference, Nice France.

Wu, J.-Y., & Cheng, T. (2019). Who is better adapted in learning online within the personal learning environment? relating gender differences in cognitive attention networks to digital distraction. *Comput. Educ.*, *128*, 312–329.

xAPI statements. (2021). Retrieved July 11, 2021, from https://xapi.com/statements-101/

Yahya, S., Ahmad, E., & Jalil, K. A. (2010). The definition and characteristics of ubiquitous learning: A discussion. *International Journal of Education and Development using ICT*, *6*(1).

Yang, S. J. H., Okamoto, T., & Tseng, S.-S. (2008). Context-aware and ubiquitous learning (guest editorial). *Journal of Educational Technology & Society*, *11*(2), 1.

Yoshii, A., Funabashi, Y., Kimura, H., & Nakajima, T. (2011). Idetective: A location based game to persuade users unconsciously, In *2011 IEEE 17th international conference on embedded and Real-Time computing systems and applications*, ieeexplore.ieee.org.

Zhou, R., & Rechert, K. (2008). Personalization for Location-Based E-Learning, In *2008 the second international conference on next generation mobile applications, services, and technologies*, ieeexplore.ieee.org.

Appendices

APPENDIX A

ORGANIZATIONS INVOLVED IN EVALUATIONS

- Groep intro - Charles Parentéstraat 6 1070 Brussel,
  https://www.groepintro.be/
- Jeugdienst, Emile Jacqmainlaan 135 1000 Brussel,
  https://www.vgc.be/contact/jeugd
- Abrusco - Ambitieuze Brusselse coach voor jongeren in Brussel, Leopold II Laan 178 1080 Brussel,
  https://www.abrusco.be/
- Steunpunt Vrijwilligerswerk Brussel, Lakensestraat 76 bus 2 1000 Brussel,
  https://www.kenniscentrumwwz.be/
- Don Bosco - Jeugdhulp, François Gaystraat 129, 1150 Sint-Pieters-Woluwe,
  https://www.donbosco.be/
- Kans - Centraal Meldpunt Brussel, Leopold II-laan 178 1080 Sint-Jans-Molenbeek,
  http://www.kans.brussels/
- Tracé Brussel - schakels naar werk, Antwerpselaan 26 1000 Brussel,
  https://tracebrussel.be/
- VDS - Vlaamse dienst speelpleinwerk, Lange Ridderstraat 22 2800 Mechelen,
  https://www.speelplein.net/,
- RiseSmart - Randstad, Mechelsesteenweg 455/6, 1950 Kraainem.
  https://www.randstadrisesmart.be/en-be/

APPENDIX B

ADDITIONAL DATA FROM THE TICKLE EVALUATION

Below you find a selection of comments made by the organizations involved in the evaluations of TICKLE

B.0.1 Protential value of the environment for exploring Brussels

The organizations we consulted pointed out that a lot of youngsters in Brussels, among which those that (eventually may) drop out, hold on strongly to the boundaries of their own quarters. It is thus considered important to break through these boundaries and encourage the youngsters to explore more within their city. Therefore, the organizations indicated the importance of being on the move with the youngsters.

- "Ik denk dat het ook daar een beetje afhankelijk is van jongere tot jongere. Ik herinner mij een onderzoek, van een paar jaar terug dat vanaf dat een jongere in Sint-Pieters-Woluwe, dat die veel verder of groter stuk van de stad zich eigen maakt. Terwijl een jongere die bijvoorbeeld in Molenbeek woont, dat die maar maximum twee metro-stations bewegen. Het was zoiets dat afhankelijk waar je woonde, was je gebruik van de metro of je beweegruimte kleiner of groter. Dus ik denk dat dat ook sowieso wel een drempel is, een stuk voor jongeren."(Jeugddienst)

- "What is funny for instance the youth we are working with they have never left the square kilometer where they live. When you bring them once to the palace of Justice which is basically available for everyone. Do you motivate them to go to a green zone, then they are like 'wow Brussels is actually quite cool'. So I think showing them where cool stuff is happening in Brussels and bringing them there could be attractive and then you can add some 'trivia' about all these areas."(TADA)

Because of its location-based service and on-the-go approach, the organizations do see merit in TICKLE in allowing young people to go out and step outside their own neighborhoods, enabling them to explore new parts of their neighborhood and the city in general. By offering the youngsters different challenges and activities we are able to guide them around and bring them to locations and places they haven't been before.

- "Interviewee I: Ik vind het ook wel goed want de meeste zitten wel in hun quartier en omdat dan wat te verbreden. (...) Interviewee II: Er zijn er bij ons bij in Molenbeek dat de Nieuwstraat nog nooit hebben gezien. Dat is tien minuten eh, maar die... Interviewee I: Ja, dat zijn zo die grenzen dat in dat stadsweefsel zitten, van ja je steekt die straat niet over bewijzen van spreken." (Abrusco)

- "Quartiers doorbreken, goed om hierop in te zetten." (RiseSmart)

- "Dat is een goede. Ik denk dat dat ook een hele mooie linkje is naar het feit dat het location-based is en dat je mensen letterlijk dwingt om hun buurt uit te gaan. Met de jongeren die we dan nu zien van het Molenbeek, zij gaan nooit het kanaal over en zij blijven altijd in hun buurt waar heel veel sociale controle is. Daar wordt heel veel voor hun beslist. En daar komen inderdaad nooit hun buurt uit, waardoor als zij een afspraak krijgen in Sint-Gillis of ergens anders dan komen ze niet. Ze willen wel, maar voor hun is dat iets heel engs, dat doen ze liever niet." (RiseSmart)

- "En inderdaad ook wel zoiets van het idee hebben, enerzijds wel die wensen en die dromen hebben, maar ja misschien in de eerste plaats de praktische belemmeringen zullen zien of dat die er in de realiteit ook wel zijn ja dan nee, maar gewoon dat idee hebben. Dus ik denk dat dat inderdaad de sterkte kan zijn van die, hoe zal ik het zeggen, die obstakels die zij denken die er zijn om die inderdaad weg te halen en hun ergens de weg te wijzen. Of in de eerste plaats misschien sterker begeleid op weg te zetten, om hem te laten zien dat het inderdaad niet zo moeilijk hoeft te zijn. Waarmee niet gezegd is dat dat per definitie altijd gemakkelijk zal zijn. Dat is inderdaad een

volledig ander iets, maar ja dat is wel zo die, hoe zal ik het zeggen, het aanvoelen van die mentale grenzen binnen die stad en het niet verder gaan, die kunnen inderdaad vrij sterk zijn." (Abrusco)

- "Ja, dat gaat echt over het openbreken van die leefwerelden en dat ze zien van er zijn andere zaken waar dat je... Die flexibiliteit om tussen verschillende registers te gaan, tussen verschillende werelden te gaan en u daar ook oké in te voelen en een soort van zelfvertrouwen te hebben in de zin van dit hoeft voor mij geen verboden terrein te zijn of dit hoeft niet per se iets te zijn waar ik mijn ver van moet afhouden. En dat kan er inderdaad over gaan om een museum binnen te stappen. Als je dat nog nooit gedaan hebt en je associeert dat met een bepaald iets of wat je wel of niet doet en niemand van je vrienden heeft dat al ooit gedaan." (Abrusco)

B.0.2 Potential value of the environment for exploring interest areas

In order for the youngsters to be motivated to use the environment and, by doing so, start exploring their city, it was discussed that the TICKLE environment should be made stimulating, challenging and interesting.

- "Stimuleren, het echt interessant en uitdagend genoeg maken, maar ik weet niet of dat al voldoende is want als ik denk aan die jongen die verslaafd is aan gamen, je moet al heel veel in de tegenbalans zetten om zijn aandacht naar school te brengen, dus ik denk echt aan niets anders behalve het stimuleren, uitdagend genoeg werken met hem omdat hij ook verstandig genoeg is." (Don Bosco)

- "als ze graag bijvoorbeeld gaan eten of gewoon voetballen, dan iets doen daarmee. Maar rekening houden met hun hobby's en cultuur. Dat zou al heel goed zijn. Ja, vooral focussen op wat ze graag doen en dat het geen last is om bijvoorbeeld zich te ver te moeten gaan verplaatsen, naar een plaats gaan waar niet echt iets te doen is." (Don Bosco)

The coaches and supervisors indicated that the offer within the environment when it comes to cards, activities and challenges should be very diverse for all youngsters to find something of their interest. Themes within the leisure time, such as sports (e.g., dance and boxing) and music, but also new media and multimedia, were mentioned.

- "Maar ik zou er ook nog zowat vrije tijd insteken, sportieve activiteiten of bijvoorbeeld zoals dat street art, want ik ben aan de groep nu aan het denken en die zitten vooral met sporten in hun hoofd. (...) "Met muziekbeleving zijn ze ook veel bezig zoals achter dj-set vragen ze veel, of workshops." (Try-out)

- "Dus dat is mijn eerste ding. Ik denk sowieso (...) zoals ik zei daarnet dat multimedia en nieuwe media wel zeker aanslaat en ik denk dat het daar ook volledig op zit. Ik denk dat de combinatie met een aantal Pokémon go en geocachen dat dat wel dingen zijn die in mijn ogen wel potentieel hebben. Ik denk inderdaad dat het vooral of waar ik de moeilijkheid in zie is dat de Brusselse jongeren niet bestaat, dat er voldoende diverse kaarten in zitten. Rond sport of video, er zijn zoveel topics. Ik denk dat dat wel de uitdaging wordt om op die manier inderdaad op maat te werken, want dat hoor ik toch wel heel erg in jullie verhaal." (Jeugddienst)

- ""Ik denk dat alles wat met multimedia, dat zien we wel dat dat in het algemeen wel werkt. Daar gebeurt ook wel wat rond. Alles wat rond sport is, maar wat niet wegneemt dat er ook, allee dat zijn de twee spontane antwoorden dat ik geef. Maar wat niet wegneemt dat er soms ook, als we naar de projecten van Afonds kijken dat daar ook heel veel kunstzinnige dingen in zitten, fotografie, film, tentoonstellingen, dat is dan vaak in combinatie met film of met fotografie. Mode ook wel, dans..." " (Jeugddienst)

- "(...) als de jongere niet sportief is aangelegd, wie zijn wij dan om te zeggen dat zij sport moeten gaan doen. Het kan even verrijkend zijn om te gaan schilderen bijvoorbeeld. Ik denk dat dat wel interessant is." (Jeugddienst)

Next to starting from their own interest, the game element within TICKLE was considered a positive and appealing way to motivate youngsters to explore more.

- "Ik denk dat als je jongeren wilt bereiken en een impact wil hebben op die jongeren, dan ga je moeten werken op die dingen dat die jongeren interesseert. Als je via jullie project jongeren wilt begeleiden, informeren, warm wil maken om toch maar op school te blijven, om die schoolcarrière af te maken, dat dat belangrijk is via een bepaalde methodiek, via die spelformule, dan denk ik dat je dat aan de jongeren moet laten zien. Ik denk niet dat je tegen de jongeren moet gaan zeggen, ik trek het nu effetjes zwart/wit, we moeten niet gaan zeggen van 'ja, jij gaat uitvallen met school, je gaat geen diploma hebben, dààrom doe met ons mee en dan ga je op school blijven zitten'. Dan weten ze ook dat gaat niet werken. Ik denk dat je het net moet proberen te verkopen, in de zin van, oke wij hebben iets ontwikkeld, iets met technologie, iets via ICT, waar dat je sterker van wordt, waar dat je uw skills, enfin ja, uw kwaliteiten mee opbouwt. Ik denk dat je dat in de picture moet zetten, dat je daarrond werkt, dat je rond persoonlijkheid werkt. En dat het resultaat dat je wilt bereiken ervoor zorgt dat ze op school blijven, dat ze hun studies afmaken, dat dat eigenlijk voor de jongeren van geen belang mag zijn. De jongeren moeten zich aangetrokken voelen tot iets wat hen... wat ik al dikwijls straathoekwerkers heb horen zeggen, is right here, right now, er moet nu iets voor mij inzitten, ik moet hier nu iets aan hebben, want als dat iets is binnen vier weken of binnen twee maanden interesseert het hun niet." (Tracé)

- "Hoe dat ik dit zie, in spelvorm, als ze iets willen zoeken, iets willen te weten komen van hun buurt of van Brussel dat dat niet gewoon op Google is en daar beginnen zoeken, maar eigenlijk dat de app mee aangeeft van wat er is in het spelvorm met dan…" (…) "Ik denk dat dat er velen gewoon niet weten wat er allemaal is en daarachter komen en dat dat bij wijze van spreken twee straten verder zou kunnen zijn" (Abrusco)

Within the environment, we responded to the suggestion to start from youngsters' interest areas and living environment by making it possible for the youngsters to indicate a number of areas of interest prior to playing the game. By accepting challenges within these interest areas, the youngster can delve further into the specific topic, build more knowledge about it and grow. By working with the different interests, cards can also be related to one or more of the interest areas. Additionally, youngsters are able to explore other interests areas that were related to the challenge; e.g., when a youngster is interested in movies, and it is a movie about history, the card has the tags 'movie' and 'history'. That way the youngster can start exploring other interest areas.

B.0.3 Potential value of the environment for informal learning

The educational possibilities the TICKLE environment has to or can offer were also further explored with the coaches and supervisors from the organizations. Within the environment the youngster is able to track the cards already played and solved, the themes discovered and his/her own grown. It was indicated that this can offer a moment of reflection and insight in the youngsters own actions and evolution. Furthermore, it also provides ownership over one's own learning process.

- "Persoonlijk vind ik dat één van de meest belangrijke dingen. Of je nu de intentie had om te spelen of effecten van te leren, dat je dan eens terug kan kijken van oké heb ik er een beetje mijn voeten aan geveegd of heb ik het wel goed gedaan. En dan ook dingen ontdekt die ik zelf nog niet eens kan verwoorden of waar dat de begeleiding nu de vinger op ligt. Zodanig dat je dat nog eens kan vastnemen en denkt van 'amai, daar zat meer achter dan ik besefte' en ik kan het nog eens rustig bekijken en verder over nadenken. Dan krijg je een vorm van eigenaarschap over het leerproces ook.(GO!)"

Another idea that was dropped was to include soft skills in the youngster's profile within the environment.

- “Maybe it’s an idea to work with soft skills. Things like don’t give up, entrepreneurship. Because I think youngsters who are at risk of falling out they think they can’t do anything good. They fail at school, they won’t reach a diploma, but they only see at the skills that they earn at school: a diploma for example and they don39;t see that there are skills that they at the moment have or can reach. So I think if you can trigger them with if you go five questions in the quiz and you have them all wrong, but you still want to do another quiz with other questions then you give an idea of you don39;t give up I want to know it, I keep going and that’s also important and so if you can trigger them with. You see that39;s also a positive thing and that’s also something that you need to have if you go looking for a job or... So working on soft skills is maybe a thing that can show them maybe you have other skills that you don’t know for the moment but those skills are also will have and important.” (Tracé) ext, possibilities were seen in orientating youngsters towards potential future studies and jobs.

    - “Ik denk, voor een tienergroep, dat die vaak niet zo weten waar ze naartoe willen, wat ze later willen doen en als ze via zo een systeem ergens kunnen meerdere interesses ontwikkelen of wat ze later willen doen richting beroep en school dat zij dat op die manier zo wat kunnen, dat ze dat zo wat kunnen testen. Ze zeggen vaak ‘kijk maar op de onderwijskiezer’ daar heb je al de richtingen en daar heb je dan een massa richingen die niets betekenen, maar als je dat op die manier... het is misschien voor hen dan makkelijker om een beeld te vormen van wat ze later willen doen of welke richting dat ze willen uitgaan. Ik denk dat ze daar wel onbewust nood aan hebben en dat het gesprek met een CLB dat dat het er niet altijd kan uithalen omdat dat ook niet altijd het doel is.” (KANS)
    - “Ja, want bij die schooluitvallers van 18+, bijna 18+, de meesten weten ook niet dat je nog volwassenenonderwijs kunt gaan doen, dat je je examencommissie nog kunt hebben, die weten dat allemaal niet. Bij mij was gewoon dat dan op computer opzoeken opendeurdag en daar naar toe gaan, dan kun je daar eventueel ook insteken

'ha! 39;t is opendeurdag' schrijf je hier in, dan moet je niet meer naar die site gaan of een link met, dan gaat die drempel veel..." (Abrusco)

- "dat zorgt ervoor, wat jongere interesseert, waar ze ook ergens kunnen buiten komen, dat ze dingen bijleren, dat ze een beter beeld kunnen vormen van wat ze naar de toekomst willen doen, dat niemand daar eigenlijk eerder opgekomen is..." (KANS)
- "want bijvoorbeeld op vlak van oriëntatie, welke richting ze willen doen." "dat je zo de leerwinkel en de werkwinkel er ook in kan zetten." "Ja, maar ook vooral naar scholen toe. Bijvoorbeeld als je gaat verder studeren of je wilt een in die richting, maar..." "bijvoorbeeld ik wil later iets in die richting doen, waar kan ik dan naartoe gaan, welke school bij wijze van spreken, niet de onderwijskiezer, maar qua oriëntatie..." (Kans)

Furthermore, it was indicated that it would be valuable to guide youngsters around within the educational, social(-cultural) and support and service landscape.

- "Want ze hebben heel veel vragen rond hulp en ze vinden niet gemakkelijk de weg naar ... om dat in kaart te brengen. (...) voor ons is dat belangrijk, want als zij daar in een spel al eens mee in contact komen zoals een JAC, dat ze dan weten bijvooorbeeld als je elke dag rookt.. dat ze dan weten waar ze terecht kunnen. Want dat is voor velen taboe. Ze gaan dat nooit op een onderwijsproject te weten komen. Zij zijn heel slim in het verbergen van alles, ook in seksualiteit zijn er heel veel problemen rond alles en nog wat." (Try-out)
- "That is a problem in Brussels. There is no mapping of everything in Brussels and that is sad. But it can go far. Like child abuse at home, you can only get to know it if you know the child. We have a case like this, they don't have anyone to trust and social services... which one and where do you knock on the door. So until where do you go you know. That is the difficulty. Children who don39;t get to learn or go to school is because they have few people who believe in them and so they don't believe

in themselves and what they learn at school is not fun and the effect of ‘blijven zitten’ is only reinforcing this feeling, because they only end up with students who are two years younger than themselves and they feel stupid and they keep seeing the same at school.” (TADA)