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MLearning-PL: a pedagogical pattern language for mobile learning applications

Maria Lydia Fioravanti

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MLearning-PL: uma linguagem de padrões pedagógicos para aplicativos educacionais móveis

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This work is dedicated to my beloved parents, Antonio and Alvorinda,
for their endless love and support.

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A dream doesn't become reality through magic; it takes sweat, determination and hard work.

(Colin Powell)

Courage, sacrifice, determination, commitment, toughness, heart, talent, guts. That's what little girls are made of.

(Bethany Hamilton)

Abstract

FIORAVANTI, M. L. **MLearning-PL: a pedagogical pattern language for mobile learning applications**. 2018. 190 p. Dissertação (Mestrado em Ciências – Ciências de Computação e Matemática Computacional) – Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo, São Carlos – SP, 2018.

The development and use of computational applications to support teaching and learning, together with the evolution of mobile computing, have contributed significantly to the establishment of a new learning modality known as mobile learning. Despite the benefits and facilities offered by educational applications, some problems and issues they present must be addressed. Challenges associated with mobile learning are not limited to developmental aspects or technologies. We should also consider the pedagogical aspects of this kind of application. When dealing with domain-specific software, we must be concerned about domain requirements. Therefore, it is important to have expert knowledge in the requirements engineering team and, in the case of mobile learning applications projects, such knowledge come from educators, teachers and tutors. However, capturing and transferring tacit knowledge are not trivial tasks and a supporting mechanism that guides the requirements elicitation phase in mobile learning applications projects would be of major importance. Pattern languages as a method to describe tacit knowledge is acknowledged and could be used as a supporting mechanism. Patterns constitute a mechanism for capturing domain experience and knowledge to allow such experience and knowledge to be reapplied when a new problem is encountered. Similarly, pedagogical patterns try to capture expert knowledge of the practice of teaching and learning. Aiming to solve, or at least diminish, the problems associated with mobile learning and due the lack of pedagogical patterns for this purpose, this work aims to create a pedagogical pattern language to assist the requirements elicitation phase of mobile learning applications projects. In this context, a pedagogical pattern language, named `MLearning-PL`, was created. It is composed of 14 patterns and focuses on assisting in the definition of mobile applications in order to keep learners motivated and committed to using such applications, considering their different learning styles and an effective knowledge acquisition. Experimental studies comparing `MLearning-PL` to an ad hoc approach in a pedagogical problem resolution scenario were conducted. The results obtained provided preliminary evidences of the applicability, effectiveness and efficiency of `MLearning-PL`.

Keywords: Mobile Learning, Mobile Learning Applications, Pattern Language, Pedagogical Patterns.

Resumo

FIORAVANTI, M. L. **MLearning-PL: uma linguagem de padrões pedagógicos para aplicativos educacionais móveis**. 2018. 190 p. Dissertação (Mestrado em Ciências – Ciências de Computação e Matemática Computacional) – Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo, São Carlos – SP, 2018.

O desenvolvimento e a utilização de aplicações computacionais como apoio ao ensino e aprendizagem, aliados à evolução da computação móvel, tem contribuído significativamente para o estabelecimento de uma nova modalidade de ensino conhecida como aprendizagem móvel. Neste cenário, as aplicações educacionais existentes, mesmo possuindo diversos benefícios e facilidades, apresentam problemas e desafios. Os desafios associados à aprendizagem móvel não se limitam a aspectos de desenvolvimento ou tecnologias. Deve-se, também, considerar os aspectos pedagógicos deste tipo de aplicação. Ao lidar com software específico de determinado domínio, deve-se considerar os requisitos de tal domínio. Portanto, é importante ter conhecimento especializado na equipe de engenharia de requisitos e, no caso de projetos de aplicativos de aprendizagem móvel, esse conhecimento é proveniente de educadores, professores e tutores. No entanto, capturar e transferir o conhecimento tácito não é uma tarefa trivial e um mecanismo de apoio para orientar a fase de elicitação de requisitos em projetos de aplicativos de aprendizagem móvel seria de suma importância. As linguagens de padrões são reconhecidas como método para descrever o conhecimento tácito e podem ser usadas como mecanismo de apoio. Os padrões são um mecanismo para capturar a experiência e o conhecimento do domínio para permitir que ele seja reaplicado quando um novo problema for encontrado. Da mesma forma, os padrões pedagógicos tentam capturar o conhecimento especializado da prática do ensino e da aprendizagem. Com o objetivo de resolver, ou pelo menos minimizar, os problemas associados à aprendizagem móvel e devido à falta de padrões pedagógicos para este propósito, este trabalho tem como objetivo criar uma linguagem de padrões pedagógicos para auxiliar na fase de elicitação de requisitos dos projetos de aplicações de aprendizagem móvel. Neste contexto, foi criada uma linguagem de padrões pedagógicos, denominada `MLearning-PL`, composta por 14 padrões e cujo foco é auxiliar na definição de aplicativos móveis de maneira a manter os apredizes motivados e comprometidos ao usar tais aplicativos, considerando seus diferentes estilos de aprendizagem e uma aquisição de conhecimento efetiva. Estudos experimentais comparando a `MLearning-PL` a uma abordagem ad hoc em um cenário de resolução de problemas pedagógicos foram realizados. Os resultados obtidos forneceram evidências preliminares a respeito da aplicabilidade, eficácia e eficiência da `MLearning-PL`.

Palavras-chave: Aprendizagem Móvel, Aplicativos Educacionais Móveis, Linguagem de Padrões, Padrões Pedagógicos.

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1

Introduction

Issues related to teaching and learning have been extensively discussed and studied by the scientific community. In particular, learning environments and computational applications have played a key role in teaching and training activities, since they are relevant not only in the academic field, but also in the industrial environment (BARBOSA, 2004; SVETLANA *et al.*, 2009; CRAIG *et al.*, 2012).

In general, such environments, along with the advent and development of ubiquitous computing, have given rise to a learning modality called mobile learning (m-learning) (KINSHUK *et al.*, 2003; O'MALLEY *et al.*, 2005; NAH *et al.*, 2008; WEXLER *et al.*, 2008). Mobile learning is characterized by the ability to provide an effective interaction among users (learners, teachers and tutors), allowing them to contribute, participate and access the educational environment through mobile devices (cell phones, PDAs, smartphones, tablets, laptops, an so forth) anytime, anywhere.

Despite the benefits regarding teaching and learning processes, m-learning also presents some limitations, such as (QUINTA; LUCENA, 2010): variable-size (sometimes monochromatic) screen; variable amount of color supported; reduced processing power; low storage capacity; limited power (battery-dependent on mobile devices); limited interaction mechanisms; low bandwidth and high costs of Internet data plans; lack of standardization in the devices media support; aspects of usability and accessibility; and lack of solutions that promote and stimulate the reuse and interoperability of educational resources for reducing costs and improving the quality of the generated systems.

However, the challenges associated with mobile learning are not limited to development aspects or technologies. We should also consider the pedagogical point of view (BRITO *et al.*, 2014): keeping the learner motivated to avoid high dropout rates, dealing with different learning styles (visual, logical, social, etc.), guiding the learner in self-learning, among other specificities that may be crucial in the design of a mobile learning

application. Brito *et al.* (2014) point out other questions, such as: *Is it possible to integrate the resources obtained from the learner's real life in the pedagogical activities proposed in the classroom with the resources of the mobile and ubiquitous technology, and can this integration help in a more meaningful learning? What is the real impact of the integration of these resources in the planning of the daily activities to be experienced in the classroom?*

In a related perspective, when dealing with domain-specific software, we must be concerned about domain requirements. It is important to have expert knowledge in the requirements engineering team and, in the case of mobile learning applications projects, this knowledge would come from educators, teachers and tutors. However, capturing and transferring tacit knowledge is not a trivial task.

In this scenario, patterns can be important tools to guide the designers and developers of m-learning applications, contributing both to avoid the already known problems without having to rediscover them and to add quality to the software, because they are successful solutions (GAMMA *et al.*, 1995). In addition to providing reuse of the solutions, patterns help to improve communication among developers and the development team can conduct their discussions based on pattern names (GAMMA *et al.*, 1995).

Patterns constitute a mechanism for capturing domain experience and knowledge to allow it to be reapplied when a new problem is encountered (PRESSMAN, 2009; PRESSMAN; MAXIM, 2014), including knowledge in a specific domain, such as programming, architecture, health, and pedagogy. Similarly, pedagogical patterns aim at capturing expert knowledge of the practice of teaching and learning (BERGIN, 2002). However, there is a lack of research initiatives on the use of pedagogical patterns to address the aforementioned problems.

Aiming to solve, or at least diminish, the problems associated with mobile learning and considering the lack of pedagogical patterns for mobile learning applications, this Master's work aims to establish a pedagogical pattern language for this kind of application. The main goals are summarized next.

1.1 Research Objectives

According to the research gap characterized in the previous section, the general research question to be investigated in this work is whether or not the use of a pedagogical pattern language can positively impact on the definition process of mobile learning applications in order to keep learners motivated and committed to using such applications, considering their different learning styles and an effective knowledge acquisition.

Based on this general research question, the main objectives of this Master's research are described as follows:

- **Study on the use of patterns in learning applications:** we aim to provide an overview on the use of patterns in learning applications. The primary idea is to characterize the current scenario of the use of patterns in learning applications. Particularly, we aim to gather evidence for the creation of a pattern language for mobile learning applications. Thus, the goal is to demonstrate if there is a lack of studies in these research areas as well as existing gaps for conducting new research.
- **Study on pedagogical patterns:** we aim to provide an overview on pedagogical patterns found in the literature. The main idea is to identify and catalog pedagogical patterns and pattern languages. Additionally, the goal is to use the results as input for the creation of a pedagogical pattern language for mobile learning applications.
- **Creation of a pedagogical pattern language for mobile learning applications:** we aim to investigate and create a pedagogical pattern language to guide the requirements elicitation phase of mobile learning applications projects.
- **Evaluation of the proposed pedagogical pattern language:** we aim to plan and conduct empirical studies to evaluate the pattern language proposed. Empirical strategies suitable to the research conducted will be used.

1.2 Dissertation Outline

In this chapter we presented the context in which this research is inserted, the motivations related to its achievement and its main objectives. The remainder of this master dissertation is organized as follows.

In Chapter 2, we provide an overview of the background information that supports the topics investigated in this work. Initially, terminology and key concepts related to mobile learning are discussed. Then, theory and concepts associated with patterns are addressed. The chapter also summarizes results of a systematic mapping study that characterizes the state-of-the-art on the use of patterns in the life cycle of learning applications.

In Chapter 3, we present `MLearning-PL`, a pedagogical pattern language for mobile learning applications. In this chapter we also discuss the process used to create it and describe each step.

In Chapter 4, we describe two experimental studies aiming to evaluate `MLearning-PL` in relation to an ad hoc approach.

Finally, in Chapter 5 we conclude this dissertation, revisiting the achieved contributions, summarizing limitations, and presenting perspectives of future research.

CHAPTER

2

Background

In this chapter we provide an overview of the subjects that underlie the research developed in this work. In Section 2.1, we introduce the terminology and main concepts of mobile learning, as well as examples of mobile learning applications. We also discuss the benefits and limitations of this learning modality. In Section 2.2, we present the main concepts on patterns and pattern languages, including a historical perspective, relevant definitions of the area, and a discussion of pedagogical patterns and their examples. Particularly, in Section 2.3, we characterize the state-of-the-art on the use of patterns in the life cycle of learning applications according to the results of a systematic mapping of the literature. Final remarks are given in Section 2.4.

2.1 Mobile Learning

According to Casali *et al.* (1997), learning "is a complex neural process, which leads, when successful, to the construction of memories". Organizations operate in a highly dynamic and competitive environment based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance, which characterizes the "knowledge economy" (POWELL; SNELLMAN, 2004; ZANGISKI *et al.*, 2009; HAZELKORN; GIBSON, 2017). Financial benefits, profitability, skills training and organizational learning are some ways of assessing organizational performance for the maintenance and development of competitiveness (ABUBAKAR *et al.*, 2017).

In addition to companies interested in providing efficient and facilitated training to their employees, educational institutions concerned with ensuring a good quality of teaching to students have invested in Information and Communications Technology (ICT) and new teaching and learning modalities (OLIVEIRA, 2013).

Portable technologies, together with computational networks as well as the dissemination and easy access to the Internet, are becoming more and more present in the daily

life, promoting access to information in an easy and fast way (GROSSI; FERNANDES, 2014).

When such technologies are used for educational purposes, they can promote an improvement in student learning and become pedagogical support for the teacher (MIRANDA *et al.*, 2007). New technologies and teaching techniques, as well as current studies on learning processes, can provide more effective resources to meet and motivate those involved in the teaching and learning processes.

This scenario has favored the emergence of new learning modalities, providing new means to address the deficiencies of traditional teaching, making it more agile, flexible and attractive (BEHRENS, 2005). In this context, distance learning (d-learning) has emerged as the modality that encompasses any kind of non-face-to-face teaching. On the other hand, electronic learning (e-learning) is the learning modality supported by technology (BARBOSA, 2004; KEEGAN, 2005), which offers mechanisms for face-to-face and distance learning based on computers and network technologies. According to Fernandes and Ferreira (2011), e-learning is a learning modality which allows to teach combining appropriately technology and pedagogy.

The miniaturization of electronic components and their cheapening have allowed the development of devices with processing capacity and functionalities equivalent or superior to those of many computers (ZAMFIRACHE *et al.*, 2013). These changes associated with ubiquitous computing have leveraged a new modality of learning called mobile learning (m-learning) (CROMPTON, 2013; WU *et al.*, 2012; TRAXLER; LEACH, 2006; KEEGAN, 2005).

Among the several attempts towards the definition of m-learning, one of the earliest dates from the mid-2000s. According to Quinn (2000) "m-learning is e-learning through mobile computing devices: Palmtops, Windows CE machines, even your digital cell phone".

In 2002, Farooq *et al.* (2002) defined m-learning as an educational and learning process that uses specific devices anywhere and anytime. In another related perspective, Kinshuk *et al.* (2003) defined m-learning as the ability to use portable devices to access learning resources, while O'MALLEY *et al.* (O'MALLEY *et al.*, 2003; O'MALLEY *et al.*, 2005) define m-learning as any type of teaching or learning that occurs when the student is not somewhere predetermined or fixed, or when the individual takes advantage of learning opportunities provided by mobile technologies, thus associating the concepts of technology and mobility.

According to Keegan (2005), in the definition of mobile learning, the focus should remain on mobility and be restricted to devices a lady can carry in her purse or a gentleman can carry in his pocket. The author therefore defines mobile learning as "the provision of education and training on PDAs/palmtops/handhelds, smartphones and mobile phones.".

Wexler *et al.* (2008) approach m-learning as an activity that allows individuals to be more productive when they consume, create or interact with information, mediated by mobile and portable digital devices, that accompany the individual on a regular basis from the beginning to the end of the tasks. In the same line, Nah *et al.* (2008) consider that m-learning refers to the use of mobile phones, handheld computers, such as PDAs, laptops and tablets in teaching and learning.

Nevertheless, mobile learning is more than just using a mobile device to access content and communicate with others – it's about student mobility. Sharples *et al.* (2009) defined mobile learning as "the processes (both personal and public) to come to know through exploration and conversation in several contexts between people and interactive technologies". According to Sharples *et al.* (2009), mobile learning includes the characteristics of mobility in physical, conceptual, and social spaces.

Earlier definitions, which focused primarily on the attributes of mobile technology, were replaced by more sophisticated conceptualizations suggesting that mobility is the central issue. This denotes not only physical mobility, but the opportunity to overcome physical limitations by having access to people and digital learning resources, regardless of place and time (KUKULSKA-HULME, 2010).

In another related perspective, Crompton (2013) defined m-learning as learning in several contexts, with social and content interactions, from the use of personal electronic devices.

Baran (2014) states that the diversity of mobile learning research made it difficult to generate a single definition or determine the generally added benefits. Definitions of mobile learning emphasize mobility, access, immediacy, situativity, ubiquity, convenience, and contextuality. These characteristics are important for teachers and learners because they provide individual, localized, collaborative and informative learning without limitations imposed by physical barriers.

Despite several definitions over the years, there is a convergence in definitions regarding the use of mobile devices to promote learning anytime, anywhere. Based on the aforementioned definitions, we have adopted the following definition for this work:

> "Mobile learning is a learning modality characterized by the ability to provide an effective interaction among users (learner, teachers and tutors), allowing them to contribute, participate and access the educational environment through mobile devices (cell phones, PDAs, smartphones, tablets, laptops, an so forth) anytime, anywhere."

The characteristics of mobile learning can be represented in four dimensions (ECONOMIDES, 2008): pedagogical, technical, socio-cultural and socioeconomic. Technical characteristics are related to hardware and software technologies involved in a mobile learning

application. Pedagogical characteristics are related to educational issues. Sociocultural characteristics refer to the cultural aspects that involve the users of this type of application. Finally, socioeconomic characteristics involve economic and social impacts. In this work we are specifically interested in the pedagogical dimension of mobile learning.

In general, the mastery of mobile educational applications has been increasingly relevant to the current characteristics of society. Aiming to show some of the contributions, next we present some examples of mobile learning applications.

2.1.1 Mobile Learning Applications

According to the Cambridge Dictionary[1], a mobile application is a software program that runs on a mobile phone. Popularly known by its abbreviation *app*, we can say that it is software developed to be installed on a mobile electronic device, such as a PDA, a cell phone, a smartphone or a tablet.

Nowadays, there are several m-learning applications available to be used or under development. Next we present some language teaching applications that were considered in this work.

Duolingo: Duolingo[2] is a freemium language-learning platform that includes a language-learning website and app (Android, iOS and Windows Phone), as well as a digital language proficiency assessment exam. Duolingo already has an application for the new wearable devices that use Android operating system. As of November 2016, the language-learning website and app offer 68 different language courses across 23 languages, with 22 additional courses in development.

One of the pioneers in bringing entertainment to education, Duolingo is one of the most famous and praised language teaching applications on the market, receiving the best app award of the year from the Apple Store and Google Play.

The resources available in this application allow reading, writing and diction related to the language the user wish to learn. This application contemplates the concepts of gamification, encouraging the user to reach daily goals, thus helping in their motivation. Figure 1 shows some screens of the application.

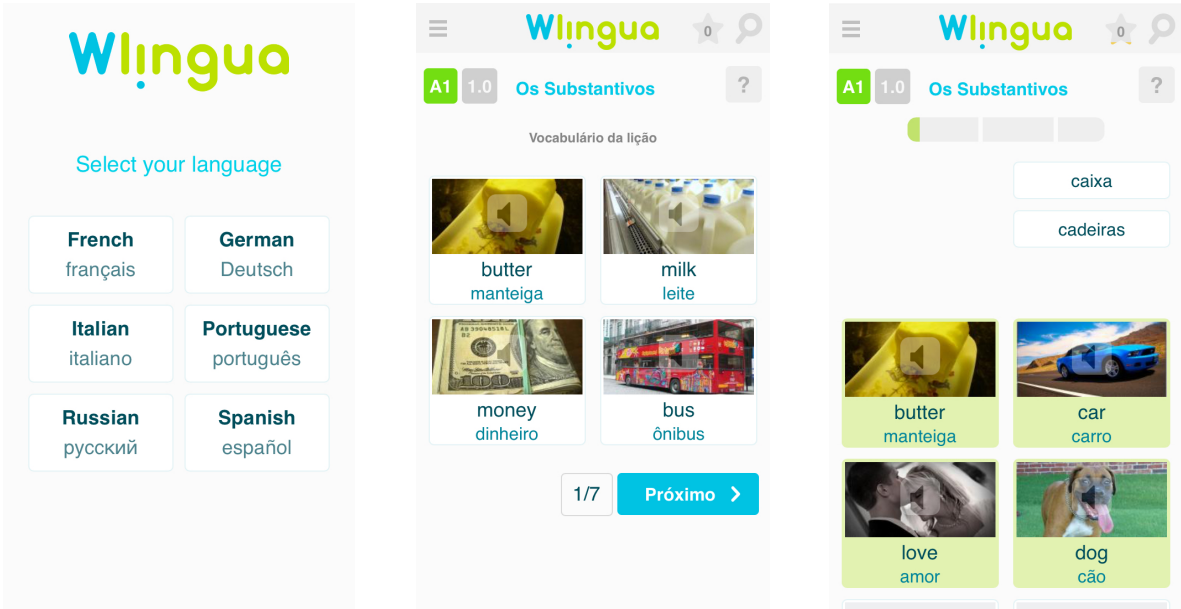
Wlingua: Wlingua[3] is an English and Spanish learning app for web, iOS and Android. Wlingua offers a basic account, which is free but has some limitations, and also a premium account which offers full access to contents and course activities. Figure 2 shows some screens of the application.

[1] <http://dictionary.cambridge.org/>
[2] <https://www.duolingo.com/>
[3] <http://www.wlingua.com/>

Figure 1 – Duolingo

Source: Extracted from Duolingo

Figure 2 – Wlingua



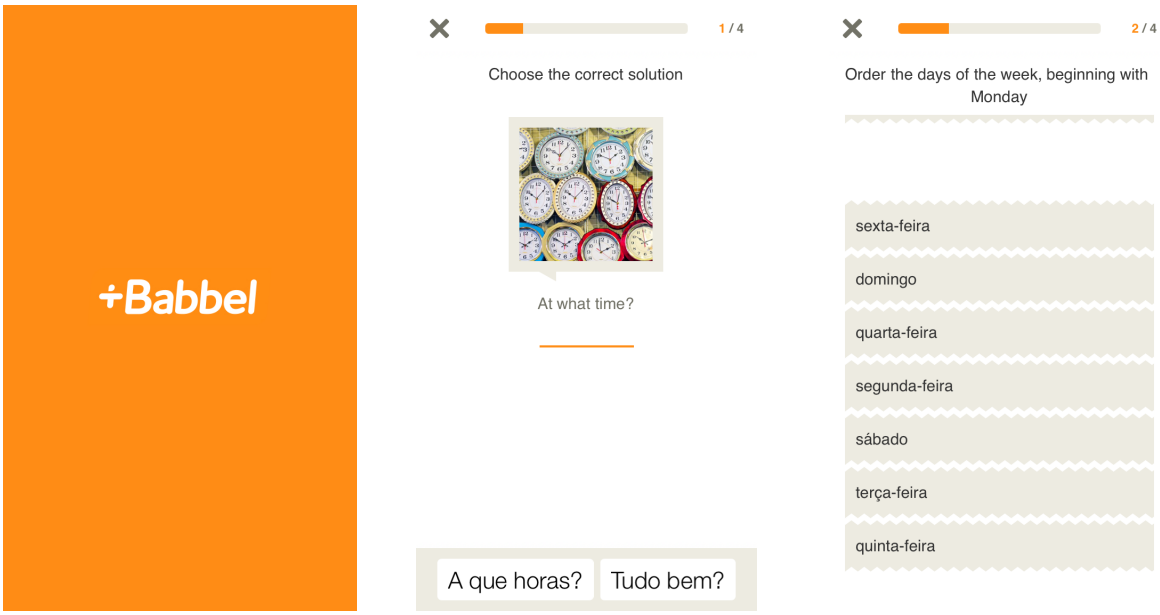
Source: Extracted from Wlingua

Babbel: Babbel[4] is a premium, subscription-based language learning app for web, iOS and Android since January 2008. Babbel currently offers 14 different languages from seven display languages, namely Dutch, Danish, English, French, German, Indonesian, Italian, Norwegian, Polish, Brazilian Portuguese, Russian, Swedish, Spanish and Turkish. The language learning platform was awarded *Comenius EduMedia*

[4] <https://babbel.com>

Seal and *Erasmus EuroMedia Seal of Approval* in 2011. In 2013, Babbel received the *digita 2013* award and the *Innovative 4 Society*. In 2016, Fast Company recognized Babbel as the most innovative company in education. Figure 3 shows some screens of the application.

Figure 3 – Babbel



Source: Extracted from Babbel

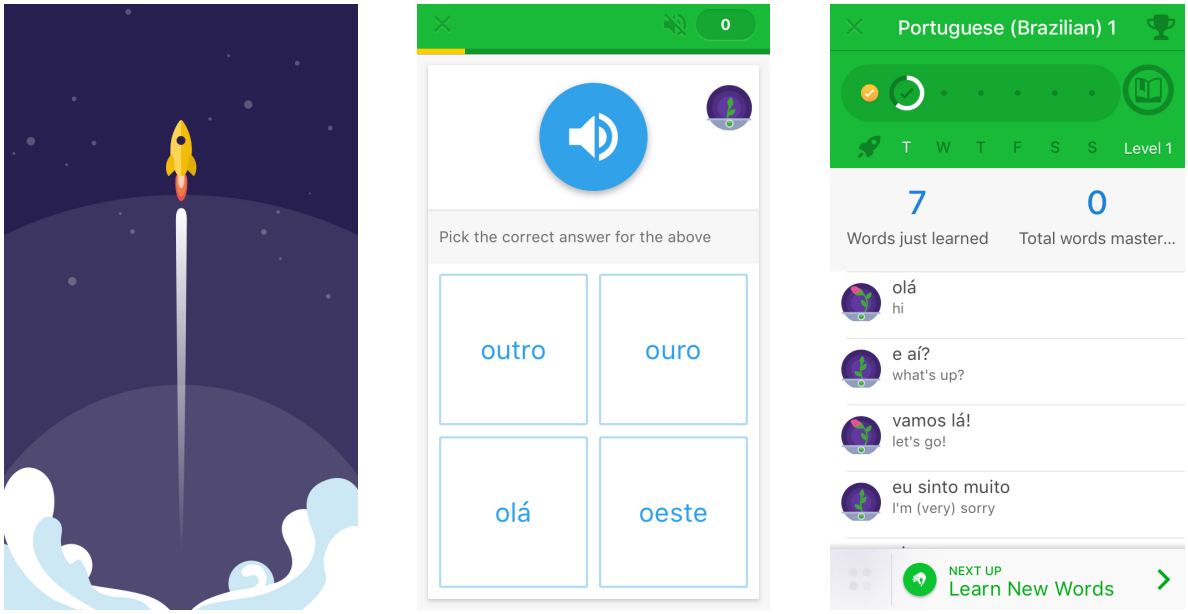
Memrise: Memrise[5] is a user-generated learning platform which uses flashcards as memory aids. It specializes in language learning, but also offers content on a wide range of other subjects. Memrise has more than 150 language courses across 25 languages. Figure 4 shows some screens of the application.

Mondly: Mondly[6] is a website and app designed to help the users learn languages in an interactive way. First of all, the user choose his native language and the language he want to learn. From there he can set the difficulty level and pick topics to perform lessons on vocabulary and conversation. Despite it is a free app, many topics are locked and must be purchased in order to access them. Figure 5 shows some screens of the application.

ABA English: ABA English[7] is an English course that allows the user to learn as if he was living abroad with a programme arranged around 144 didactic units. The user begins to speak and write by actively participating in real-life situations: firstly the user listens and understands and then begins to speak and write. ABA English won

[5] <https://www.memrise.com/>
[6] <https://www.mondlylanguages.com/>
[7] <http://www.abaenglish.com/>

Figure 4 – Memrise



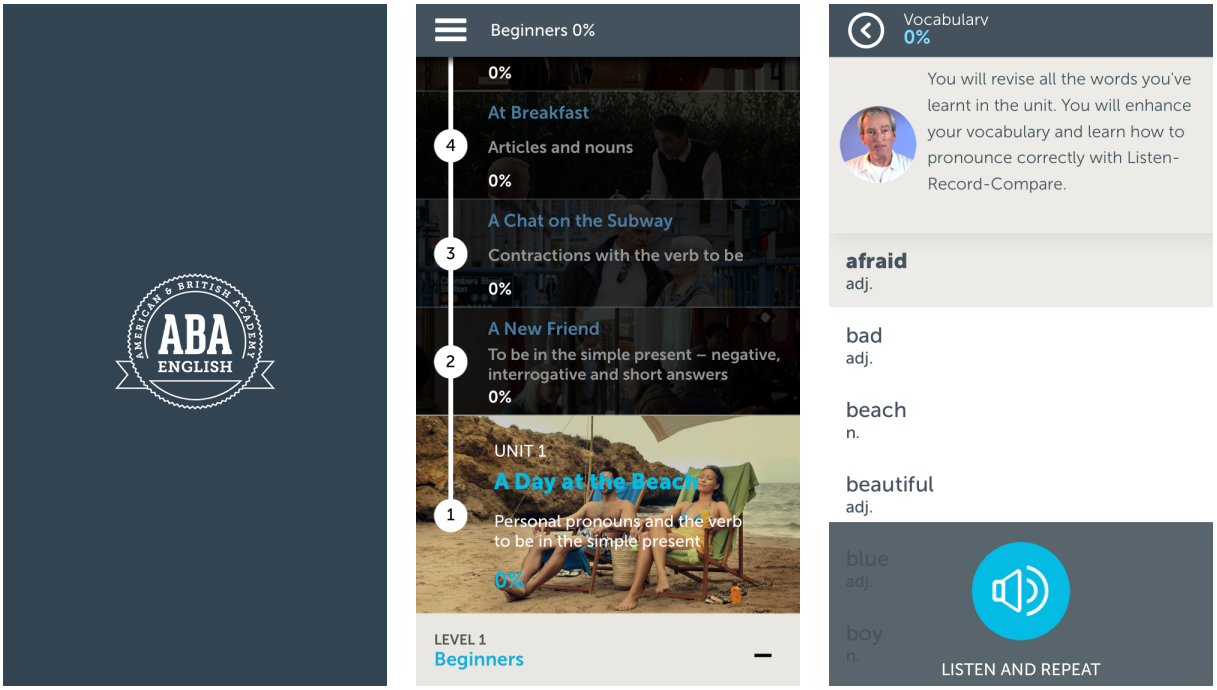
Source: Extracted from Memrise

Figure 5 – Mondly

Source: Extracted from Mondly

the award for the *Best Educational App* of 2015 at the *Reimagine Education Awards*. Figure 6 shows some screens of the application.

Figure 6 – ABA English



Source: Extracted from ABA English

We can also mention other examples in several different domains. Considering math and geometry, we can point out **GeoTouch**[8], which supports the learning of geometry, and **Mathway**[9], which solves basic math, pre-algebra, algebra, trigonometry, pre-calculus, calculus, statistics, finite math, linear algebra, and chemistry.

Some applications also teach programming languages such as **Learn programming**[10], which teaches many languages such as: C, C++, C#, Java, Bash, Javascript, JSP, Perl, Python, R, Ruby, SQL, and so forth.

Several other examples can be found in domains such as Biology, Chemistry, Geography, Music, etc.

2.1.2 Benefits and Limitations

Research into the benefits offered by mobile learning and the limitations for its use has been developed. Studies have suggested the use of mobile learning arouses student interest and stimulates social interaction among the users of the application through communication mechanisms and discussions on the course materials (AL-ANI *et al.*, 2013; FAZLINA *et al.*, 2013; HUANG *et al.*, 2010; MISHRA; CHAVHAN, 2012; PICEK; GRCIC, 2013).

8 <https://play.google.com/store/apps/details?id=com.usp.icmc.geotouch>
9 <https://play.google.com/store/apps/details?id=com.bagatrix.mathway.android>
10 <https://play.google.com/store/apps/details?id=tursky.jan.nauc.sa.html5>

Some of the benefits provided by mobile learning in comparison to conventional learning environments involve the use of cameras, microphones, accelerometers, GPS, gyroscopes, collaboration tools, quizzes, animations, etc. (ZURITA; NUSSBAUM, 2004; SHARPLES *et al.*, 2002). We can observe that the benefits go far beyond accessibility, convenience and communication. In mobile devices learners can use applications, specific learning environments, web access, collaboration tools, social networks, e-books, and so on.

Mobile learning provides users with autonomy to organize their study routine, and repeat classes as many times as necessary, avoiding missing content in case of intercurrences during their execution (AL-ANI *et al.*, 2013; PICEK; GRCIC, 2013).

We can also point out that the use of mobile learning does not mean learning must occur exclusively through a mobile device. It can coexist with other learning methods such as classroom instruction, as a complement. Besides promoting the students' interest in using mobile devices, the collaboration of people who can assist them is also facilitated (ABACHI; MUHAMMAD, 2014; LOOI *et al.*, 2014).

Learning materials, available in a format compatible with mobile devices, facilitate access to course contents, as they are always available, can be updated more easily and allow the use of several media formats in their development (ABACHI; MUHAMMAD, 2014; PICEK; GRCIC, 2013).

In general terms, we can highlight the following benefits offered by mobile learning (ROSCHELLE; PEA, 2002; TOTEJA; KUMAR, 2012; ROSHAN *et al.*, 2013; BHULLAR, 2014; KHADDAGE *et al.*, 2015; SARRAB, 2015):

- student-centered learning (the teacher is only a coadjutor in the construction of knowledge);
- support to student's specific learning needs (learner has control over the activities);
- ease of transportation and access to content anywhere, anytime;
- possibility of taking advantage of idle time (trips, waiting queues, etc);
- collection of results and information through different means, such as audio, writing, video, sensors, etc;
- relatively lower cost in comparison to e-learning devices, face-to-face classes, physical materials, among other artifacts of traditional teaching;
- reuse of content;
- reduction of cultural barriers by the different channels of communication that it has;

- flexibility;
- context sensitivity;
- customization of learning and content, since the learner does it in a device of his own and customize it according to his needs;
- improvement in social learning and eliminating technological barriers;
- independent learning experiences;
- increased collaborative work;
- assistance towards combating resistance to the use of ICTs;
- removal of formal barriers imposed by traditional teaching experiences;
- focus on educational activities for a longer period; and
- immediate feedback.

On the other hand, mobile learning also has some limitations, which may be technical or not. Such limitations vary according to the mobile learning application and the context in which it is embedded. Despite the evolution of mobile devices, there are still limitations related to hardware such as low storage capacity, battery life, which limits the use of the mobile device for a long period of time and the size of the screens and keyboards, which generates limitations on viewing and entering data in the application (AL-ANI *et al.*, 2013; HUANG *et al.*, 2010; PICEK; GRCIC, 2013). In addition, in order to have mobility, the mobile devices must be connected to a network, which can be limited by its coverage area, narrow-band and high access cost (ABACHI; MUHAMMAD, 2014; PICEK; GRCIC, 2013).

Besides the technical limitations previously mentioned, there are still non-technical limitations such as the difficulty of dealing with the technology of mobile devices. Depending on the context in which the mobile learning application is considered, the learner may not have acquired the necessary knowledge to handle this kind of device (SU; CHENG, 2013). In addition, users should also be motivated to study outside the learning environment so that the lack of interest is overcome and does not jeopardize the completion of the proposed activities (MISHRA; CHAVHAN, 2012; PICEK; GRCIC, 2013). Another important point is that the user has in hand a device with many features that can easily distract him (FAZLINA *et al.*, 2013).

The following challenges and limitations can be highlighted (ROSCHELLE; PEA, 2002; EL-HUSSEIN; CRONJE, 2010; LIU *et al.*, 2010; BHULLAR, 2014; SARRAB, 2015):

- restrictions and variations on the size, resolution and color quantity of the screens;

- scarce amount of software and content developed specifically for learning;
- lack of guidelines for content production;
- reduced storage capacity;
- limitations to access speed and traffic limit;
- limited battery life, i.e., battery-dependent;
- fast downtime of devices and technologies;
- different mobile platforms, as iOS, Android, Windows, etc;
- different hardware producers and competitiveness in the market;
- access to content and offensive interactions through mobile devices;
- aspects of usability, accessibility and security;
- prevention of information dissemination of learners in the network;
- feeling of isolation;
- possible greater learning curve for non-technical learners;
- applications not easily integrated with mobile environment technologies;
- lack of incentive for instructors and teachers for the use of digital content and information and communication technologies; and
- lack of patterns in relation to mobile learning (architecture, modeling of learning objects, and so forth).

The evolution of technology and digital inclusion has highlighted the importance of m-learning for today's society, despite the significant challenges that must be overcome. This learning modality is a promising possibility to explore the different aspects that mobile devices offer.

As discussed earlier, from several positive highlight, we can mention reusing content, which reinforces the importance of reuse, in general. However, it has been observed that the lack of patterns in relation to mobile learning is a challenging factor that needs to be further investigated. Thus, the adoption of patterns can add more quality to mobile learning applications, besides the possibility of solving or diminishing the other challenges previously mentioned.

2.1.3 Mobile Learning Requirements

Sommerville (2010) stated that the requirements for a system are the descriptions of what the system should do – the services that it provides and the constraints on its operation. These requirements reflect the needs of customers for a system that serves a certain purpose such as controlling a device, placing an order, or finding information.

Requirements engineering provides appropriate mechanisms for the understanding of customers' demands, analyzing needs, assessing feasibility, negotiating a reasonable solution, specifying the solution unambiguously, validating the specification, and managing the requirements as they are transformed into an operational system (PRESSMAN; MAXIM, 2014).

An important and hard task in this process is requirements elicitation (also called requirements gathering), which combines elements of problem solving, elaboration, negotiation, and specification. At first, the gathering of information on the desired software from customers, user and stakeholders seems a simples task. However, several problems may arise during this process such as: problems of scope, problems of understanding; problems of volatility. As a solution to help overcome these problems, we must approach requirements gathering in an organized manner (PRESSMAN; MAXIM, 2014).

Although the requirements elicitation is performed in an organized manner, analysts are susceptible to errors. Errors in a requirements document may lead to higher rework costs when such problems are discovered during the development or after the system is in service (SOMMERVILLE, 2010). The cost of fixing a requirements problem by making a system change is usually much greater than repairing design or coding errors. The reason for this is that a change to the requirements usually means that the system design and implementation must also be changed.

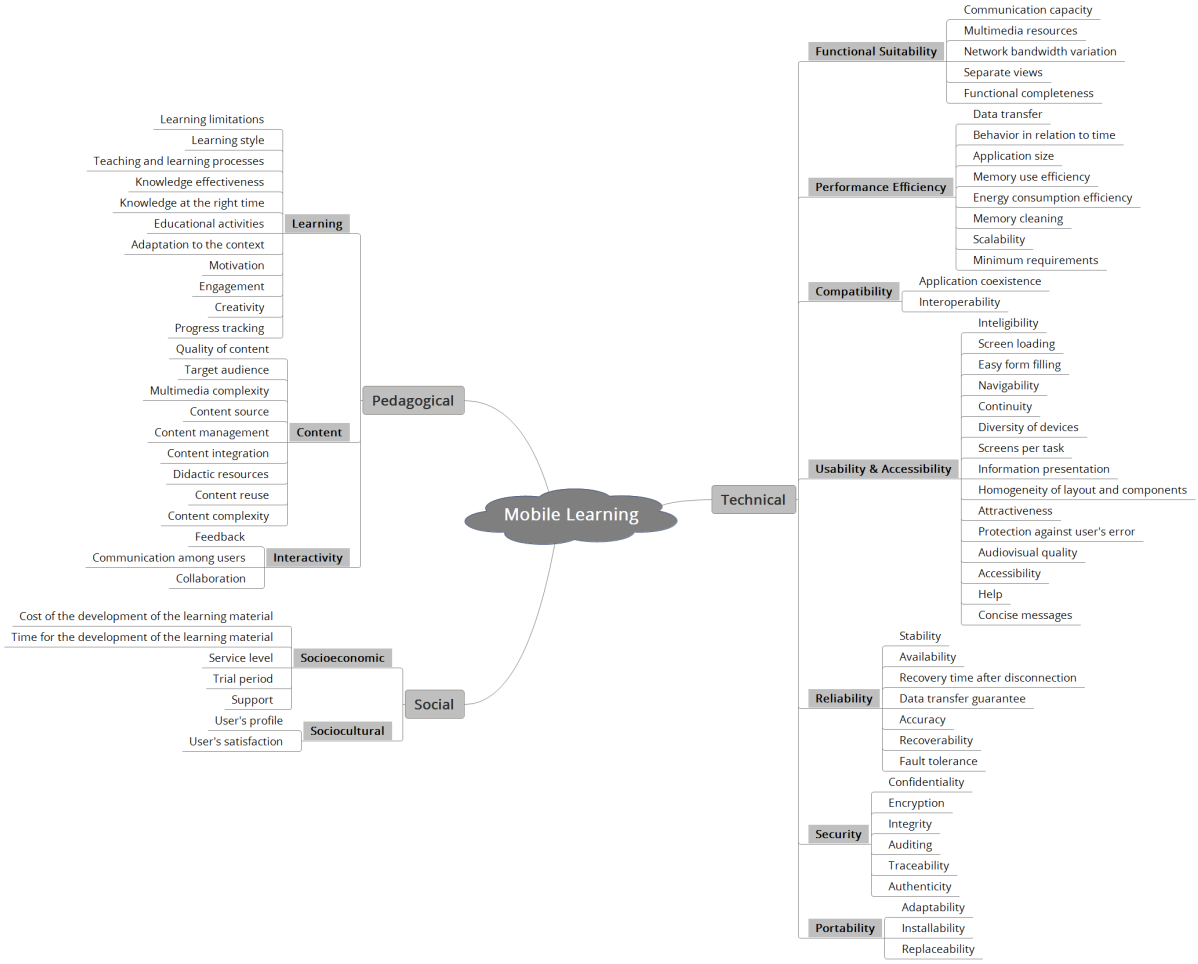
In a related perspective, when dealing with domain-specific software, we must be concerned about domain requirements, which are derived from the application domain of the system rather than from the specific needs of system users (SOMMERVILLE, 2010). The problem with domain requirements is that software engineers may not understand the characteristics of the domain in which the system operates. They often cannot tell whether or not a domain requirement has been missed out or conflicts with other requirements.

Therefore, it is important to consider the expert's knowledge in the requirements engineering team. In the case of mobile learning, this knowledge would come from educators, teachers and tutors. However, capturing and transferring tacit knowledge is not a trivial task and many can benefit from a supporting mechanism to overcome the burdens of this process.

Soad *et al.* (2017) proposed *ReqML-Catalog* (Figure 7), a requirements catalog for mobile learning applications. The proposition of *ReqML-Catalog* was motivated by a

scenario where there was no complete and well defined set of requirements for mobile learning applications. Aiming to bridge this gap, the work of Soad *et al.* (2017) intended to be a step forward in this direction.

Figure 7 – ReqML-Catalog



Source: Soad *et al.* (2017).

The categories defined in the catalog are divided 12 requirements subcategories. Three subcategories are defined for the *Pedagogical* category. The first is *Learning*, which is defined by the application's ability to provide features that contribute to student learning. Additionally, *Content* is defined by the ability to deliver manageable and quality content and *Interactivity* is defined as the ability of the application to provide features that help users interact with each other and with the application.

The *Social* category comprises *Socioeconomic* and *Sociocultural* subcategories. Finally, the *Technical* category is subdivided into *Functional Suitability*, *Performance Efficiency*, *Compatibility*, *Usability*, *Reliability*, *Security* and *Portability*.

The contents of *ReqML-Catalog* were previously presented in the paper entitled

"*ReqML-Catalog: The Road to a Requirements Catalog for Mobile Learning Applications*", published in the Proceedings the 47th Annual Frontiers in Education Conference (FIE 2017) (SOAD *et al.*, 2017).

2.2 Patterns

Although several initiatives have been developed for mobile learning, it still lacks standardization and supporting mechanisms that guide the requirements elicitation phase. In this context, the significance of pattern languages as a method to describe tacit knowledge is acknowledged and a great candidate as a supporting mechanism (PRESSMAN; MAXIM, 2014).

So far, we presented an overview on mobile learning, its definitions and characteristics, some examples and its advantages and limitations. In general, mobile learning aims to provide access to educational content anytime and anywhere, increase access to content, expand the limits out of the classroom in a ubiquitous way, and provide means for the development of innovative of learning methods.

However, in spite of the benefits provided by such learning applications, different factors are involved in their development and should be taken into account. Besides technical aspects, we should consider aspects related to the pedagogical dimension. In this scenario, pedagogical patterns have been investigated and are relevant to the requirements elicitation of mobile applications. Next, we present the concepts about patterns as well as examples that illustrate such concepts.

2.2.1 Foundations and Terminology

According to Pressman and Maxim (2014), patterns constitute a mechanism for capturing domain experience and knowledge to allow it to be reapplied when a new problem is encountered. In some cases, domain knowledge is applied to a new problem in the same application domain. In other cases, domain knowledge captured by a pattern can be applied by analogy to a completely different application domain.

Pressman and Maxim (2014) also stated that a pattern can save from "reinventing the wheel", or worse, inventing a "new wheel" that is slightly out of round, too small for its intended use, and too narrow for the ground it will roll over.

In general terms, a pattern describes a solution to a problem in a recurring manner. However, the early history of software patterns begins not with a computer scientist but a building architect, Christopher Alexander, who recognized that a recurring set of problems were encountered whenever a building was designed in the late 70's. He characterized these recurring problems and their solutions as patterns and wrote two

books (ALEXANDER, 1977; ALEXANDER, 1979) to exemplify and describe his method for documenting patterns.

Alexander (1977) stated that:

> "Each pattern describes a problem that occurs over and over again in our environment and then describes the core of the solution to that problem in such a way that you can use the solution a million times over without ever doing it the same way twice".

Later, Alexander (1979) affirms that a pattern can be characterized as "a three-part rule which expresses a relation between a certain context, a problem, and a solution".

Considering the scenario of software patterns, Beck and Cunningham (1987) used the Alexander's concepts in a pattern language to design windows in Smalltalk. After this pioneering work, other initiatives involving software patterns have emerged. Coad (1992) described seven different analysis patterns. Then, Coplien (1992) published a book defining several "idioms", which are specific programming patterns to the C ++ language. In 1993, Gamma *et al.* (1993) introduced the first of their 23 design patterns, which would be published in 1995 (GAMMA *et al.*, 1995).

The book of Gamma *et al.* (1995), later called "GoF book", began the dissemination of software patterns to the scientific community. The aforementioned works are the pioneers in patterns, followed by many others in the following years.

A software pattern describes a solution to a problem that occurs frequently during software development, and can be considered as a "problem/solution" pair (BUSCHMANN *et al.*, 1996). Patterns, when already known, allow designers and developers to apply them immediately to design problems without having to rediscover them (GAMMA *et al.*, 1995). Appleton (1997) stated that:

> "A pattern is a named nugget of instructive information that captures the essential structure and insight of a successful family of proven solutions to a recurring problem that arises within a certain context and system of forces.".

In a different perspective, Coplien (2005) characterizes an effective design pattern in the following way:

- *It solves a problem:* Patterns capture solutions, not just abstract principles or strategies.
- *It is a proven concept:* Patterns capture solutions with a track record, not theories or speculation.

- *The solution isn't obvious:* Many problem-solving techniques (such as software design paradigms or methods) try to derive solutions from first principles. The best patterns generate a solution to a problem indirectly – a necessary approach for the most difficult problems of design.
- *It describes a relationship:* Patterns don't just describe modules, but describe deeper system structures and mechanisms.
- *The pattern has a significant human component (minimize human intervention):* All software serves human comfort or quality of life; the best patterns explicitly appeal to aesthetics and utility.

The use of patterns provides a common vocabulary for communication among designers, creating abstractions at a higher level than classes, and ensuring uniformity in software structure (GALL *et al.*, 1996). Moreover, they act as building blocks from which more complex projects can be built (GAMMA *et al.*, 1995). We can highlight that they provide the reuse of knowledge obtained by experienced designers, guiding those who have less experience in their decision making (GAMMA *et al.*, 1993).

Software patterns can cover different levels of abstraction and, therefore, can be classified into several categories to facilitate their retrieval and use. So far, we discussed software patterns and a kind of software pattern, namely design pattern. However, there are many other kinds of patterns and even other kinds software patterns; for instance analysis patterns and organizational patterns. Patterns have encompassed all aspects of software engineering including (APPLETON, 1997): development organization, software process, project planning, requirements engineering, software configuration management, and so forth.

Design patterns still seem to be the most popular ones and Pressman and Maxim (2014) discuss the broad spectrum of abstraction and their application:

(i) architectural patterns describe broad-based design problems that are solved using a structural approach;

(ii) data patterns describe recurring data-oriented problems and the data modeling solutions that can be used to solve them;

(iii) component patterns address problems associated with the development of subsystems and components, the manner in which they communicate with one another, and their placement within a larger architecture;

(iv) interface design patterns describe common user interface problems and their solution with a system of forces that includes the specific characteristics of end users; and at a lower level of abstraction; and

(v) idioms describe how to implement all or part of a specific algorithm or data structure for a software component within the context of a specific programming language.

In their work, Gamma *et al.* (1995) proposed the first taxonomy for patterns, classifying them into types, also popularly known as families: creative, structural, and behavioral patterns. Appleton (1997) also says that patterns can be domain-specific, that is, patterns to any other domain you can think of. Other kinds of patterns are discussed in Coplien and Smith (1995), Vlissides *et al.* (1996), Martin *et al.* (1998), Rising (2000), Pressman and Maxim (2014) and Hillside repositories[11].

In a contrary perspective, if a pattern represents a "best practice", then an anti-pattern represents a "lesson learned" (APPLETON, 1997). There are two notions of "anti-patterns": (i) those that describe a bad solution to a problem that resulted in a bad situation; or (ii) those that describe how to get out of a bad situation and how to proceed from there to a good solution. Therefore, anti-patterns can be valuable because it is often just as important to see and understand bad solutions as it is to see and understand good ones.

2.2.2 Pattern Elements

Different pattern formats can be used to describe a pattern. The pattern description format used in Alexander's work (ALEXANDER, 1977) is called the "Alexandrian form" (sometimes "canonical form"). Among the best known, we can mention also the formats of Portland, Coplien, GoF and Appleton (FOWLER, 2006).

According to Vlissides *et al.* (1996), it is necessary to reflect on the pattern being written and not get stuck to the writing format. Regardless of the particular format/headings used (or lack thereof), the following essential elements should be clearly recognizable upon reading a pattern (APPLETON, 1997):

Name: *It must have a meaningful name. This allows us to use a single word or short phrase to refer to the pattern, and the knowledge and structure it describes.*

Problem: *A statement of the problem which describes its intent: the goals and objectives it wants to reach within the given context and forces.*

Context: *The preconditions under which the problem and its solution seem to recur, and for which the solution is desirable.*

Forces: *A description of the relevant forces and constraints and how they interact/conflict with one another and with goals we wish to achieve (perhaps with some indication of their priorities). A concrete scenario which serves as the motivation for the pattern is frequently employed.*

Solution: *Static relationships and dynamic rules describing how to realize the desired outcome. This is often equivalent to giving instructions which describe how to construct*

[11] <http://hillside.net/patterns>

the necessary work products. The description may encompass pictures, diagrams and prose which identify the pattern's structure, its participants, and their collaborations, to show how the problem is solved. The solution should describe not only static structure but also dynamic behavior.

Resulting Context: *The state or configuration of the system after the pattern has been applied, including the consequences (both good and bad) of applying the pattern, and other problems and patterns that may arise from the new context. It describes the post-conditions and side-effects of the pattern. This is sometimes called resolution of forces because it describes which forces have been resolved, which ones remain unresolved, and which patterns may now be applicable.*

Rationale: *A justifying explanation of steps or rules in the pattern, and also of the pattern as a whole in terms of how and why it resolves its forces in a particular way to be in alignment with desired goals, principles, and philosophies. It explains how the forces and constraints are orchestrated in concert to achieve a resonant harmony. This tells us how the pattern actually works, why it works, and why it is "good".*

Examples or Known Uses: *One or more sample applications of the pattern which illustrate: a specific initial context; how the pattern is applied to, and transforms, that context; and the resulting context left in its wake. Describes known occurrences of the pattern and its application within existing systems. This helps validate a pattern by verifying that it is indeed a proven solution to a recurring problem.*

Related Patterns: *The static and dynamic relationships between this pattern and others within the same pattern language or system.*

2.2.3 Pattern Languages

When performing the analysis of many patterns, we notice that a pattern solves a problem, but its application can generate other problems, that can be solved through the use of other patterns. In short, no pattern is an isolated entity. Each pattern can exist in the world, only to the extent that is supported by other patterns (ALEXANDER, 1977): the larger patterns in which it is embedded, the patterns of the same size that surround it, and the smaller patterns which are embedded in it.

In short, a pattern and its variants describe solutions to very similar problems, which vary in some of the influences involved. Therefore, we must think of ways to group existing patterns according to some criterion, in order to facilitate their recovery and reuse. In this context, Buschmann *et al.* (1996) have classified different kinds of pattern collections of varying degrees of structure and interaction into pattern catalogs, systems, and languages.

A *pattern catalog* is a collection of related patterns (perhaps only loosely or informally related). It typically subdivides the patterns into at least a small number of broad categories and may include some amount of cross referencing between patterns. A pattern catalog adds a pinch of structure and organization to a pattern collection, but does not usually go very far beyond showing only the most outwardly visible structure and relationships (APPLETON, 1997).

A *pattern system* is a cohesive set of related patterns that work together to support the construction and evolution of whole architectures. Not only is it organized into related groups and subgroups at multiple levels of granularity, but it also describes the many interrelationships between patterns and their groupings and how they may be combined and composed to solve more complex problems. The patterns in a pattern system should all be described in a consistent and uniform style and need to cover a sufficiently broad base of problems and solutions to enable significant portions of complete architectures to be built. A pattern system adds deep structure, rich pattern interaction, and uniformity to a pattern catalog (APPLETON, 1997).

In a software development perspective, a *pattern language* is a structured collection of patterns that rely on each other to transform requirements and constraints into an architecture (COPLIEN, 1998). A pattern language is a way of subdividing a general problem and its complex solution into a number of related problems and their respective solutions. Each language pattern solves a specific problem in the common context shared by the language. It is important to note that each pattern can be used separately or with a number of patterns of the language. This means that a pattern alone is considered useful even if the language is not being used in its fullness.

Alexander (1977) drew a parallel between natural languages and pattern languages

> "In summary: both ordinary languages and pattern languages are finite combinatory systems which allow us to create an infinite variety of unique combinations, appropriate to different circumstances, at will."

Alexander (1977) also stated:

> A collection of patterns forms a vocabulary for understanding and communicating ideas. Such a collection may be skillfully woven together into a cohesive "whole" that reveals the inherent structures and relationships of its constituent parts toward fulfilling a shared objective."

Lastly, Appleton (1997) stated that both pattern systems and pattern languages form coherent sets of tightly interwoven patterns for describing and solving problems in a particular domain. But a pattern language adds robustness, comprehensiveness, and wholeness to a pattern system. The primary difference is that, ideally, pattern languages are computationally complete, showing all possible combinations of patterns and their variations to produce complete architectures. In practice, however, the difference between pattern systems and pattern languages can be extremely difficult to ascertain. While a pattern system may be a cohesive collection of patterns about a very broad topic, a pattern language has to be about more than just a "broad topic".

2.2.4 Pedagogical Patterns

According to the Oxford English Dictionary[12], pedagogy is the method and practice of teaching, especially as an academic subject or theoretical concept. Libâneo (2001) states pedagogy is the science whose study objective is education. Libâneo (2001) stated that:

> "Pedagogy, through scientific, philosophical and technical-professional knowledge, investigates the educational reality in transformation, to explain objectives and processes of methodological and organizational intervention regarding the transmission/assimilation of knowledge and modes of action. It aims at understanding, overall and intentionally directed, educational problems and, for this, uses the theoretical contributions provided by other educational sciences".

Apart from technical aspects, pedagogical aspects related to mobile learning must be considered. Most educators and trainers are not taught how to teach. Rather, they often find themselves teaching by accident (ECKSTEIN *et al.*, 2002; BERGIN *et al.*, 2012). Typically, an individual with a skill that is in demand, such as a particular programming language, will be asked to teach it, once skillful individuals in a certain subject are assumed to be competent in teaching it. However, knowing a subject is very different from knowing how to teach it (BERGIN *et al.*, 2012).

The effective communication of a knowledge is often a struggle for teachers and instructors. According to Bergin *et al.* (2012), they may try various teaching strategies, but this trial and error process can be time-consuming and fraught with error. Usually, advice is often sought from other expert instructors, but these individuals are not always readily available. This creates the need to find other ways to facilitate the sharing of teaching techniques between expert and novice teachers.

The scenario described was the motivation for the *Pedagogical Patterns Project*[13], which aims at creating a method that documents and shares best practices for teaching and learning. The educators involved in the project introduced the concept of a pedagogical pattern as a means to achieve them.

Patterns provide a method for capturing and communicating knowledge in a specific domain, such as pedagogy. In this sense, Bergin (2002) defined:

> "Pedagogical patterns try to capture expert knowledge of the practice of teaching and learning. The intent is to capture the essence of the practice in a compact form that can be easily communicated to those who need the knowledge. Presenting this information in a coherent and accessible form can mean the difference between every new instructor needing to relearn what is known by senior

[12] <http://www.oed.com/>
[13] <http://www.pedagogicalpatterns.org/>

faculty and easy transference of knowledge of teaching within the community".

A number of educators have been involved in the *Pedagogical Patterns Project* for several years. The project began at OOPSLA'95 and started holding workshops in 1996 at ECOOP, OOPSLA[14] and TOOLS[15] conferences.

Bergin (2007) presented, in one of his works, 14 pedagogical patterns for the development of courses in the area of Computer Science. The patterns have several levels of application, from the overall organization of a course to even classroom practices and are presented in order of scale, i.e., from with those that involve the planning of semester courses to daily activities in classrooms.

After 17 years, Bergin *et al.* (2012), based on their own work, reviewed each of the patterns already proposed, rewrote them in the form of Alexander (1979) and, finally, published a pattern language resulting from all those years of work, but which is always evolving.

In a related perspective, Iba and Miyake (2010a) conducted a project called *Learning Patterns Project*, in which they developed pedagogical patterns (by them called learning patterns) to support the learning of university students. Iba and Miyake (2010a) stated the difficulty of teaching and learning is well known. An option for circumventing it is the use of guidelines to be followed, however, it can limit students regarding the development of their own way of learning. Furthermore, there is another difficulty to provide adequate guidance for learners in different situations. So, is it possible to provide something to help the learners to think of their way of learning? As a solution, Iba *et al.* (2014) proposed a pattern language for learners to share several 'knacks' against the way of creative learning as a good way to help the student design their learning because it focuses on providing a new vision for the reader so that they can think.

Several other initiatives regarding pedagogical patterns, especially related to teaching with Learning Management System (LMS)[16] (AVGERIOU *et al.*, 2003) or to e-learning modality (NETO *et al.*, 2005; ANACLETO *et al.*, 2009a) have been undertaken. Figure 8, for instance, shows a pedagogical pattern that aims to diminish the problem of searching for learning resources in a LMS, since they are numerous in such an environment.

[14] ECOOP (European Conference on Object-Oriented Programming) and OOPSLA (Object-Oriented Programming, Systems, Languages & Applications) are annual conferences covering topics on object-oriented programming systems, languages and applications.

[15] TOOLS (Technology of Object-Oriented Languages and Systems) conference series was a long-running conferences on object technology, component-based development, model-based development and other advanced software technologies.

[16] A Learning Management System is a software application for the administration, documentation, tracking, reporting and delivery of educational courses or training programs. They help the instructor deliver material to the students, administer tests and other assignments, track student progress, and manage record-keeping.

Figure 8 – Searching for learning resources in a LMS

Searching

i. **Problem:** How can the users search through the learning resources and find something, effectively and without wasting too much time in irrelevant pages?
ii. **Motivation:** There are cases where the learning resources are numerous and diverse, resulting in the students spending much time and effort in trying to locate them. Browsing through the resources is therefore not the most effective way to find what one is looking for, in an educational context. Also the learners are often overburdened with information resulting in a cognitive overload in expense of the learning process.
iii. **Solution:** LMS should have the provision of incorporating search engines such as the ones found in generic web sites. These search engines though are differentiated from common web site search engines, in that they are specialized in learning resources and therefore can be smarter than common search engines. That can be achieved by adding contextual semantic information for learning resources in the form of *learning object metadata*, which describe relevant characteristics of learning objects in order to facilitate search, evaluation, acquisition, and use of learning objects, for instance by learners or instructors (IEEE LTSC, 2001b). There are several metadata standards (e.g. IEEE LTSC, IMS, Ariadne) that can be adopted by LMS so that these descriptions of learning resources can be formalized and even exchanged between them.
iv. **User category:** learners and instructors.
v. **Known uses:** Search engines that facilitate searching in the learning content are offered by WebCT, COSE, Intralearn and TopClass. None of them so far has adopted an international standard for learning object metadata, but some LMS have announced that they plan to do so. However COSE, TopClass, LearnLinc, Saba and LearningSpace support proprietary metadata formats to enable searching of learning resources.
vi. **Related Patterns:** Searching can apply to all learning resources, therefore this pattern is related to E-book delivery, Glossary, Course announcements. The patterns 'Selectable Search Space', 'Selectable Keywords', 'Structured Answer', 'Selectable Search Engine' and 'Simple Search Interface' (Lyardet et al., 1999) are relevant for providing guidelines on how to make effective search engines for Web Information Systems.

Source: Avgeriou *et al.* (2003).

In this section, we presented concepts about software patterns and pedagogical patterns, as well as examples. We could observe that the use of patterns adds several benefits related to reuse and patterns have been recognized as an important method to describe tacit knowledge. Therefore, patterns have proven to be effective tools for solving, or diminishing, the problems associated with mobile learning.

Next, we present a systematic mapping, carried out with the purpose of characterizing the current scenario of the use of patterns in learning applications.

2.3 Patterns and Learning Applications: A Systematic Mapping

In this section, we present a Systematic Mapping Study (SMS) of the literature conducted for the characterization of the current scenario of use of patterns in learning applications. The purpose is that the obtained results provide evidence for the creation of a pattern language for new teaching modalities, i.e., the goal is to demonstrate if there is a lack of studies in these research areas as well as existing gaps for conducting new research.

Contents of this section were previously presented in a paper entitled "*Utilização de Padrões no Ciclo de Vida de Aplicações de Aprendizagem: Um Mapeamento Sistemático*",

published in the Proceedings of the XXVI Brazilian Symposium on Computers in Education (SBIE 2015) (FIORAVANTI *et al.*, 2015).

The systematic mapping followed the guidelines proposed by Kitchenham and Charters (2007), who established three main phases for its conduction, namely: (i) Planning the Review; (ii) Conducting the Review; and (iii) Reporting the Review.

2.3.1 Planning

The planning phase of a systematic mapping consists in the definition of the research goals and the research questions to b answered. The search strategy is also defined and includes the definition of search sources, languages, and criteria for selection of studies.

2.3.1.1 Research Goals

The main goals of this study are the identification, classification and analysis of studies that consider the use of patterns throughout the life cycle of electronic learning applications. An analysis of the retrieved studies that have proven evidence for the establishment of a set of patterns for mobile learning is also included in the goals.

2.3.1.2 Research Questions

Aiming to achieve the established goal, we have defined a protocol that guides the mapping and the following research questions have been raised:

RQ1: What patterns are applied throughout the life cycle of e-learning applications?

RQ2: What patterns are applied throughout the life cycle of m-learning applications?

The method proposed by Petticrew and Roberts (2006), entitled PICOC (population, intervention, comparison, outcome, context) was employed for helping the identification of relevant topics for the research.

Population: Research related to the life cycle of e-learning and m-learning applications.

Intervention: Patterns related to software development and life cycle.

Comparison: Not applicable

Outcome: Overview of studies that address the proposition or use of patterns in the life cycle of electronic learning applications.

Context: Industry and Academia

2.3.1.3 Search Strategy

After the definition of the research questions and PICOC criteria items, the next step in the planning of an SMS is the definition of how the searches for primary studies will be conducted.

Data Sources

In this SMS, searches were performed automatically in electronic databases of higher relevance for the area of computing and education (shown in Chart 1), i.e., databases that index a large number of articles related to different conferences and journals of the area of interest of the mapping (BRERETON *et al.*, 2007; ZHANG *et al.*, 2011).

Chart 1 – Electronic Databases

Research database	**URL**	**Rationale for inclusion**
Scopus	http://www.scopus.com	Zhang *et al.* (2011)
Web of Science	http://apps.webofknowledge.com	Zhang *et al.* (2011)
IEEE Xplore	http://ieeexplore.ieee.org	Brereton *et al.* (2007)
ACM Digital Library	http://dl.acm.org	Brereton *et al.* (2007)
Science Direct	http://www.sciencedirect.com	Brereton *et al.* (2007)

Source: Elaborated by the author.

Languages

English, the language mostly used in international publications and Portuguese, the local language of the researchers who conducted the systematic mapping were chosen.

Keywords

An important step in automatic searches is the definition of the search string. In the present mapping, the string was defined also through the attachment of terms of higher relevance to the research, shown in Chart 2. The search terms and their synonyms were defined according to experts' opinions, the literature and the research questions.

2.3.1.4 Study selection criteria

The supporting criteria were also defined for the screening of papers during the mapping execution for the selection, among the works obtained from the automatic search, of those that would potentially answer the research questions and were directly related to the subject studied (PETERSEN *et al.*, 2008). Chart 3 shows the inclusion and exclusion criteria.

Chart 2 – Keywords

Keyword	Synonyms
pattern	patterns
e-learning	elearning, electronic learning, electronic-learning
m-learning	mlearning, mobile learning, mobile-learning

Source: Elaborated by the author.

Chart 3 – Inclusion and Exclusion Criteria

Type	Criterion
Inclusion	**I1.** Primary studies that present the proposition or use of a pattern in the context of e-learning **I2.** Primary studies that present the proposition or use of a pattern in the context of m-learning
Exclusion	**E1.** Primary studies that do not involve the research questions. **E2.** Primary studies that are neither in English, nor in Portuguese. **E3.** Primary studies that are not available for downloading in the databases selected. **E4.** Duplicated studies. **E5.** Primary studies not related to the areas of computing, engineering or education. **E6.** Primary studies published before 1990. **E7.** Studies that are not published in conferences or journals.

Source: Elaborated by the author.

Exclusion criterion E5 was considered because we aimed at including only studies related to computing, software engineering or education and the terms chosen might bring results related to areas that were not of interest. The constraint established in the exclusion criterion E6 was placed considering that 1990 was the time of the emergence of patterns in the context of computing.

2.3.2 Conducting the mapping

This phase provides a set of primary studies that can contribute to the mapping, partially or completely answering the research questions established. It is divided into three main stages, namely: (i) definition and application of the search string; (ii) preliminary selection; and (iii) final selection.

2.3.2.1 Definition and application of the search string

As shown in Chart 2, the main terms used in the mapping are related to patterns and types of electronic learning applications, in particular e-learning and m-learning. After

their identification, the union between them and their synonyms was performed with logical operator *"OR"* and, finally, the parties were joined with logical operator *"AND"*. The generic search string defined is shown in Chart 4.

Chart 4 – Search string

("pattern" OR "patterns")
AND
(("electronic learning" OR "eletronic-learning"
OR "e-learning" OR "elearning")
OR
("mobile learning" OR "mobile-learning"
OR "m-learning" OR "mlearning")

Source: Elaborated by the author.

Terms related to e-learning and m-learning were separated by logical operator *"OR"* because the primary studies needed to address only one of these themes. After the definition of the generic search string, it was adapted to each database selected in accordance with its specificities.

Searches were performed in each database[17] thourgh the application of filters per date and area of interest. The third step consisted in the download, in each database, of the references of the studies resulting from the search. Finally, after gathering the results of all the electronic databases, duplicate studies were excluded. In addition, 10 papers were conference announcements or indexes of proceedings, and were also excluded at this stage.

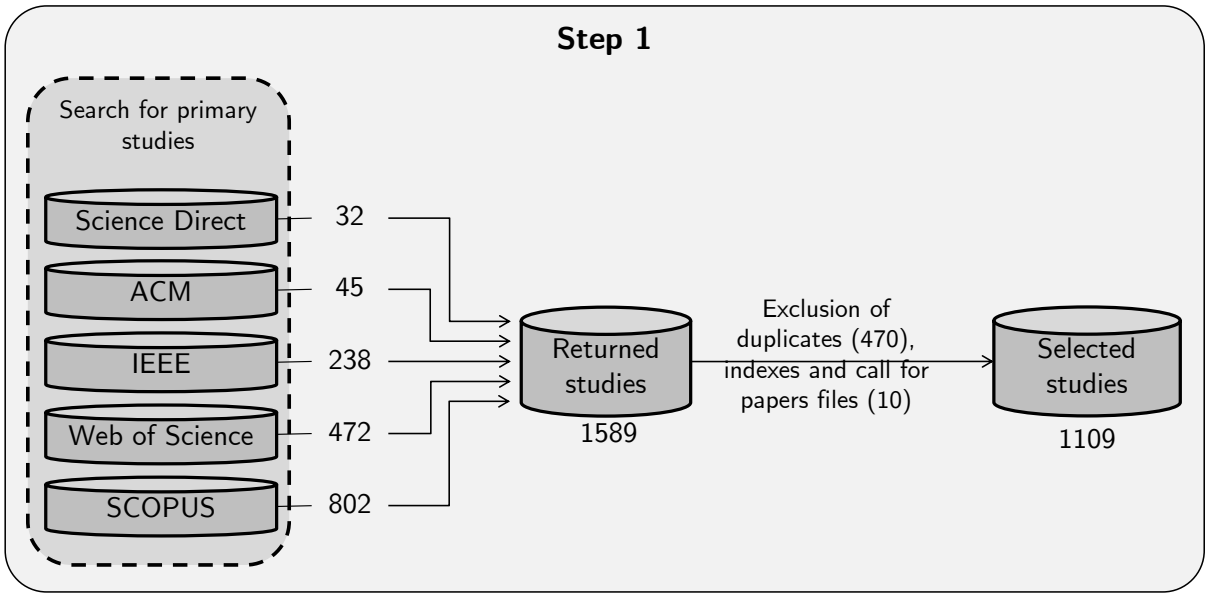
We obtained 1589 studies, from which 480 were eliminated because they were duplicate or indexes, call for papers, etc., resulting in 1109 selected studies, as shown in Figure 9.

Electronic database Scopus showed the largest number of papers returned, which totaled 50% of the results. This database indexes most of the relevant works in the area, besides conferences also addressed by other bases. On the other hand, Web of Science, IEEE, ACM and Science Direct databases provided 30%, 15%, 3% e 2%, respectively, of the results.

Step 1 was carried out collaboratively by two researchers responsible for planning the SMS and retrieving primary studies.

[17] The searches were conducted on October 17th, 2014.

Figure 9 – Search for studies and deleting duplicates or indexes



Source: Elaborated by the author.

2.3.2.2 Preliminary selection

In Step 2, the inclusion and exclusion criteria were applied to the studies selected in the previous step. Based on the reading of the titles and abstracts of all studies, the researchers decided on the studies to be included for the next step. Each researcher analyzed half of the papers and applied the criteria for their selection for the next step. In case of doubt, the other researcher was consulted and if it persisted, the study was included for a more detailed analysis.

An object must be sorted several times, for example, by more than one judge (FLEISS, 1981), for its classification to be considered reliable. In this scenario, *Cohen's Kappa statistic* (COHEN, 1960) can be used to obtain the inter-rater agreement, which is the degree of agreement among raters. The score it provides refers to the homogeneity, or consensus, in the ratings given by judges. Kappa is a measure whose maximum value is 1, which represents total agreement. Interpretations of other Kappa values are shown in Chart 5.

To guarantee a consensus between the researchers and reliability to the selection process, 21 studies were arbitrarily selected to obtain the Kappa measure. Table 1 shows the data analysis of the 21 papers selected by Judges A and B and the decision on their inclusion (I) or exclusion (E).

The overall Kappa value (0.618) calculated with the results shown in Table 1 indicated a substantial agreement among researchers. As the value was very close to

Chart 5 – Interpretation of Kappa Values

Kappa Values	**Interpretation**
< 0	No agreement
0–0.19	Poor agreement
0.20–0.39	Fair agreement
0.40–0.59	Moderate agreement
0.60–0.79	Substantial agreement
0.80–1.00	Almost perfect agreement

Source: Landis and Koch (1977).

Table 1 – Data used in the calculation of Kappa Value (Measurement 1)

		JUDGE B		
		Cat. 1 - I	Cat. 2 - E	Total
JUDGE A	Cat. 1 - I	8	2	10
	Cat. 2 - E	2	9	11
Total		10	11	21

Source: Research data.

the moderate agreement range, the researchers chose to analyze the disagreements on a case-by-case basis and retake the measurement with 21 other papers after discussing the divergent points. Table 2 shows the data analysis of the 21 selected papers.

Table 2 – Data used in the calculation of Kappa value (Measurement 2)

		JUDGE B		
		Cat. 1 - I	Cat. 2 - E	Total
JUDGE A	Cat. 1 - I	2	1	3
	Cat. 2 - E	0	18	18
Total		2	19	21

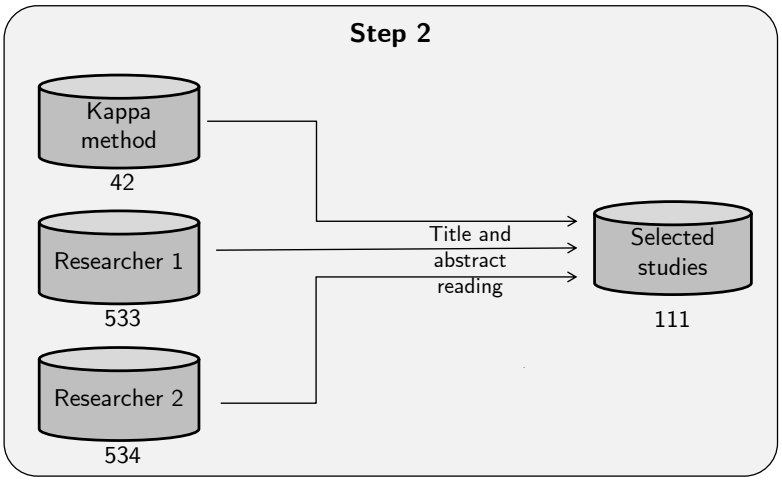
Source: Research data.

The overall Kappa value calculated with the results shown in Table 2 increased to 0.774, which still indicates a substantial agreement, but much closer to the almost perfect agreement. Only one divergent classification was detected. Due to the size of the sample, almost perfect agreement would be achieved only with no disagreement between the judges. Therefore, the researchers considered the result satisfactory for guaranteeing reliability in the studies selection. Another point to be highlighted is the fact that in a dubious scenario, the researchers always chose to include the study for further detailed analysis later.

According to Figure 10, from the 1109 studies selected, 42 were used in the Kappa method for the calculation of concordance, whereas the others were divided between the researchers for selection. Thus, one selected 533 studies and the other selected 534. From

the 1109 primary studies analyzed, 111 were selected for the next step.

Figure 10 – Selection of studies by titles and abstracts

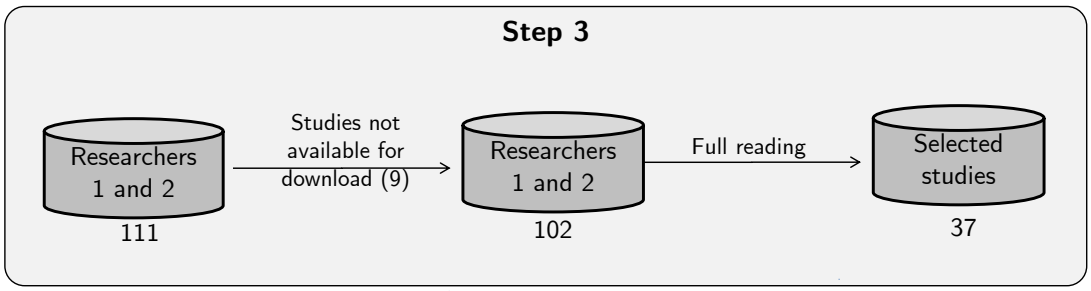


Source: Elaborated by the author.

2.3.2.3 Final selection

Step 3 of the systematic mapping consisted in the full reading of the 111 studies for searching elements that might answer the research questions. Nine studies were not found for download, and were excluded due to unavailability. The remaining 102 papers were read entirely by both researchers and, in consensus, were selected as relevant or not. Among the 102 articles read, 37 were selected for extraction and data summarization. Figure 11 shows Step 3.

Figure 11 – Selection of studies by full reading



Source: Elaborated by the author.

During the full reading of the studies, those not excluded were analyzed and some information was extracted. The next phase of the mapping was based on this information.

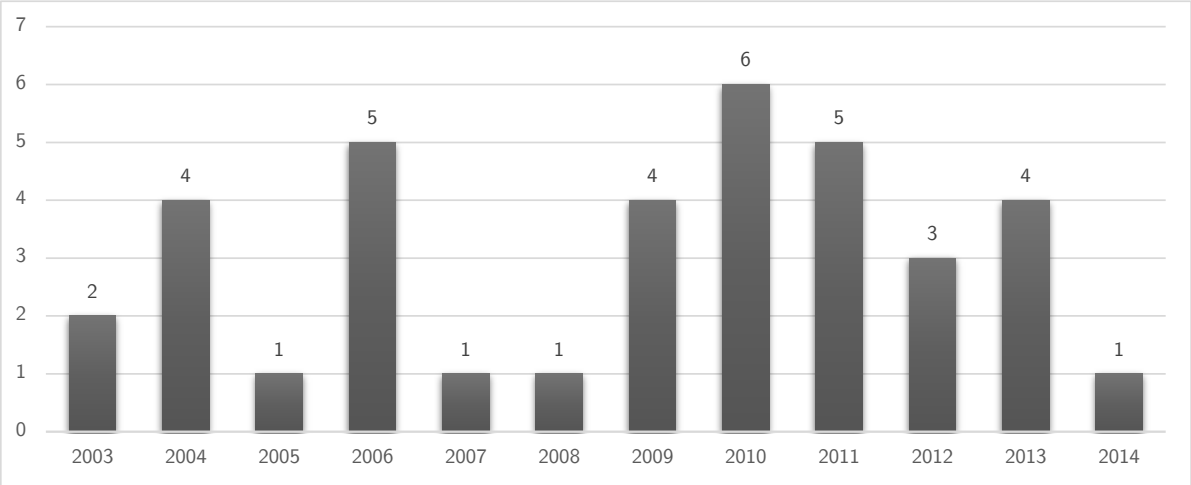
2.3.3 Analysis of Results

In this phase, the data of the primary studies are extracted and summarized towards answering the research questions. The first step of the phase was the extraction of the fol-

lowing data: Title, Author, Source (conference or journal), Learning modality (e-learning or m-learning), Pattern category, and Pattern name. This extraction was carried out through the reading of the 37 final papers selected.

In the second step, the data of the selected studies were gathered towards answering the research questions. Figure 12 shows the number of studies per year of publication. Among the 37 studies retrieved, there was no standard distribution per year. However, we observed a subtle trend towards higher exploratation on the theme between 2009 and 2013.

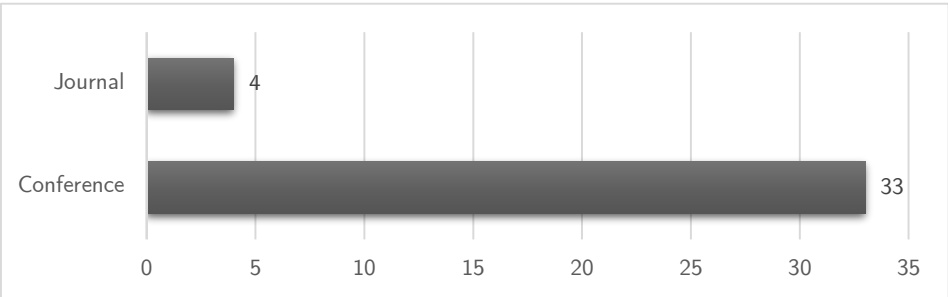
Figure 12 – Number of studies per year of publication



Source: Research data.

Regarding publication venues, Figure 13 shows 33 studies published in conferences and four studies published in journals, which may suggest some immaturity of the research area.

Figure 13 – Number of studies by publication source

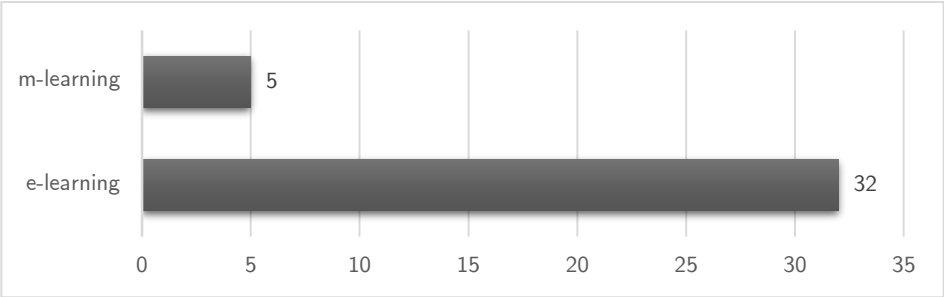


Source: Research data.

The classification of the retrieved studies regarding learning modality (Figure 14) shows the e-learning modality has been extensively explored and 86.49% of the retrieved

studies address the use of patterns in this modality. On the other hand, m-learning still requires more research initiatives.

Figure 14 – Learning Modality



Source: Research data.

The next discussions are based on results from the analysis of the 37 primary studies identified and provide answers to the research questions. Table 3 shows the 37 selected studies and their information.

Table 3 – Selected Studies

Reference	**Title**
González *et al.* (2003)	Adaptable contents visualization (VIC)
El-Bakry and Mastorakis (2009)	Advanced Technology for E-Learning Development
Sierra *et al.* (2008)	A language-driven approach for the design of interactive applications
Liu and Wang (2012)	An online examination system based on UML modeling and MVC design pattern
ZadahmadJafarlou *et al.* (2011)	A pattern-oriented and web-based architecture to support mobile learning software development
Chimalakonda and Nori (2014)	A Patterns-Based Approach for Modeling Instructional Design and TEL Systems
Xu and Yang (2011)	Application of Struts framework based on MVC in Online countryside Teachers' Training System in China
Castillo *et al.* (2013)	A system for mobile learning: a need in a moving world
Fiaidhi and Mohammed (2006)	Collaborative virtual learning model for Web intelligence
Ruddeck and Martens (2010)	Communication Patterns in Component-Based Intelligent Tutoring Systems
Sehring *et al.* (2006)	Conceptual content management for pattern-based software design: An e-learning experience

Continued on next page

Table 3 – *Continued from previous page*

Reference	Title
Hernandez-Leo *et al.* (2006)	CSCL Scripting Patterns: Hierarchical Relationships and Applicability
Gad (2010)	Data Synchronization Architectural Pattern for Ubiquitous Learning Systems
Randriamalaka (2005)	Design patterns approach for usage analysis in re-engineering process of learning systems
Millard *et al.* (2006)	Design Patterns for Wrapping Similar Legacy Systems with Common Service Interfaces
Avgeriou *et al.* (2004)	Design patterns in Adaptive Web-based Educational Systems: An overview
Rajam *et al.* (2010a)	Design Patterns in Enterprise Application Integration for e-Learning Arena
Ji *et al.* (2013)	Development of a Sencha-Touch mTest Mobile App for a mLearning System
Rajam *et al.* (2010b)	E-Learning Computational Cloud (eLC2): Web Services Platform to Enhance Task Collaboration
Rajam *et al.* (2010c)	Enterprise Service Bus dependency injection on MVC design patterns
Diggelen and Overdijk (2009)	Grounded design: Design patterns as the link between theory and practice
Kolås and Staupe (2004)	Implementing delivery methods by using pedagogical design patterns
Zitter *et al.* (2009)	In search of common ground: A task conceptualization to facilitate the design of (e)learning environments with design patterns
Martens *et al.* (2009)	Multi-perspective Cooperation Based on Boundary Objects
Mylonakis *et al.* (2013)	Octopus: A collaborative environment supporting the development of effective instructional design
Steeples and Zenios (2004)	Organisational patterns for E-learning centres
Sehring *et al.* (2007)	Pattern Repositories for Software Engineering Education
Restrepo and Herrera (2011)	Seat & play: A virtual learning environment for harmony
Bauer and Baumgartner (2012)	Showcase of Learning: Towards a Pattern Language for Working with Electronic Portfolios in Higher Education
Derntl (2004)	The Person-Centered e-Learning pattern repository: Design for reuse and extensibility
Avgeriou *et al.* (2003)	Towards a pattern language for learning management systems
Tiron *et al.* (2011a)	Use of Creational Patterns in e-Learning

Continued on next page

Table 3 – *Continued from previous page*

Reference	Title
Tiron *et al.* (2011b)	Use of Structural Patterns in e-Learning
Molina *et al.* (2006)	Using Patterns in Reengineering Processes for Mobile Learning User Interfaces
Hussein *et al.* (2010)	Web 2.0 Based Service-Oriented E-Learning Systems: Recurrent Design and Architectural Patterns
Veiga *et al.* (2012)	Web-based learning of electrical machines simulation tool - IMotor
Rogier *et al.* (2013a)	What Learners Teach Us: E-Learning Patterns for Adult ICT Education

Source: Research data.

The systematic mapping identified several patterns applied throughout the life cycle of e-learning and m-learning applications. However, not all studies showed the essential components of the patterns (APPLETON, 1997) (subsection 2.2.2). Based on what was defined in the data extraction and summarization phase, we would have to extract the name and classification of the presented pattern to answer the research questions, but in most retrieved studies it was not possible to explicitly find it, so the researcher had to figure out the category. Chart 6 shows the number of patterns found for each category.

Chart 6 – Number of Patterns per Learning Modality

Category	e-learning	m-learning
Architectural Patterns	4	2
Design Patterns	21	10
Communication Patterns	2	0
Visualization Patterns	0	1
Conceptual Patterns	1	0
Patterns for the educational domain	69	0

Source: Research data.

Only architectural patterns were identified for both e-learning and m-learning modalities and show ways of organizing the fundamental structure of a system under development. Design patterns were also identified, which facilitates the reuse of solutions in the design phase of a software project. More details on the patterns for e-learning and m-learning modalities are given next.

2.3.3.1 What patterns are applied throughout the life cycle of e-learning applications?

From a total of 32 selected studies of e-learning modality, 12 refer to the use of architectural patterns, e.g. *Model-View-Controller* (MVC)[18]. As shown in Chart 6, another pattern category that frequently appears is design patterns, such as *Composite*, *Abstract Factory*, or even GoF and J2EE patterns, which totaled 21 patterns. In some cases, the term is used interchangeably with software patterns or patterns in general, whereas in others, once the name of the pattern is not shown, the type of pattern addressed is not known. Communication and conceptual patterns were also identified in the e-learning context.

In addition to design patterns, which aim to address the problems of implementation of the application, considering its architecture or object orientation, 69 patterns for educational applications were identified. Pedagogical patterns, collaborative learning patterns, and evaluation patterns are examples of patterns that support the development of educational applications. *Content authoring*, *Video lecture*, *Personalization*, *E-book delivery* and *Glossary* are some examples of the educational patterns found.

Avgeriou *et al.* (2003) proposed a pattern language for LMS that contains patterns with some of the components recommended by Appleton (1997). The pattern called *Personalization*, for instance, aims to address the problem of the visual organization of the various courses a user attends, that must be presented to the user in his customized set of courses. The motivation presented is the fact that a user is involved with several courses each semester, and in each one of them can act differently (tutor, student, etc). A solution is presented and suggests the creation of a personalization service for all users. Such a service customizes their home page according to a unique account that enables access and the courses attended by the user can be identified. The authors also present User Category, Known Uses, and Related Patterns.

As shown in Chart 6, patterns for e-learning applications have been explored in two aspects, namely educational patterns, and patterns that support the e-learning application development. However, only 11 studies address specific patterns for the educational domain, which was evidenced although the subject has been investigated, the literature lacks deeper research on the pedagogical aspects for the creation of applications.

2.3.3.2 What patterns are applied throughout the life cycle of m-learning applications?

Among the five studies retrieved in the context of m-learning, three cited the use of two different architectural patterns. From the three studies, two address the use of MVC pattern. Another type of pattern that is mentioned is design patterns, being mentioned

[18] Model–view–controller (MVC) is a software architectural pattern for implementing user interfaces on computers. It divides a given application into three interconnected parts. This is done to separate internal representations of information from the ways information is presented to, and accepted from, the user.

10 different ones. One of the studies also focused on the use of visualization patterns, i.e., patterns for the selection of the best visualization technique for an interface.

The scenario of the use of patterns in the context of m-learning, unlike e-learning, has not been extensively investigated. The selected studies do not focus on the proposition or use of a set of patterns, but use consolidated patterns for the development of their applications. The patterns listed for mobile learning applications are not domain-specific patterns, but architectural patterns and design patterns, often used in applications built using the object-oriented paradigm.

As shown in Chart 6, patterns for the educational context have not been explored, therefore, some points can be investigated according to the mobile learning domain and the several challenges and limitations associated, such as the need of patterns that guide the solution to the problem of screens of variable size or reduced processing power. Research on pedagogical patterns should also be considered to address common challenges in mobile learning, as distraction from other applications.

The SMS results enabled the characterization of the state-of-the-art of the use of patterns in the life cycle of learning applications. In short, the use of patterns has been investigated in learning applications, however the educational aspects have been investigated only in the e-learning context, which shows a lack of research aiming to address educational aspects in the m-learning context.

2.4 Final Remarks

This chapter has presented the background for the Master's research conducted. Firstly, the terminology and fundamental concepts of mobile learning were discussed. Following, the theory associated with patterns was addressed. The state-of-the-art of the use of patterns in the life cycle of learning applications was also characterized through a systematic mapping study.

Despite the several benefits offered by mobile learning, some challenges and open issues must be addressed. The systematic mapping study showed a lack of research initiatives on the use of patterns to address such problems. Based on the results, we could highlight the need for the adoption of patterns to assist in the requirements elicitation phase of mobile learning applications projects. Particularly, in our research, we aim to address the pedagogical dimension of mobile learning (ECONOMIDES, 2008).

Therefore, in the next chapter, we report on the creation of `MLearning-PL`– a pedagogical pattern language for mobile learning applications.

CHAPTER

3

A Pedagogical Pattern Language for Mobile Learning Applications

Mobile learning has emerged as a new and promising learning modality that provides more interactivity and flexibility for learners, tutors and teachers for their educational activities and practices. Despite their several benefits and facilities, mobile learning applications present problems and challenges that must be better investigated. These problems and challenges are not limited to technical aspects, also including pedagogical issues.

The pedagogical issues related to mobile learning must be considered for the definition of requirements of mobile learning applications. For instance, how can we handle the various distractions offered by mobile devices? In this sense, pedagogical patterns can be an important supporting mechanism to describe best practices, good designs, and capture of expert's knowledge and experience so that other can reuse this experience regarding the practice of teaching and learning. To the best of our knowledge, there is still no pedagogical pattern language focusing on the mobile learning context.

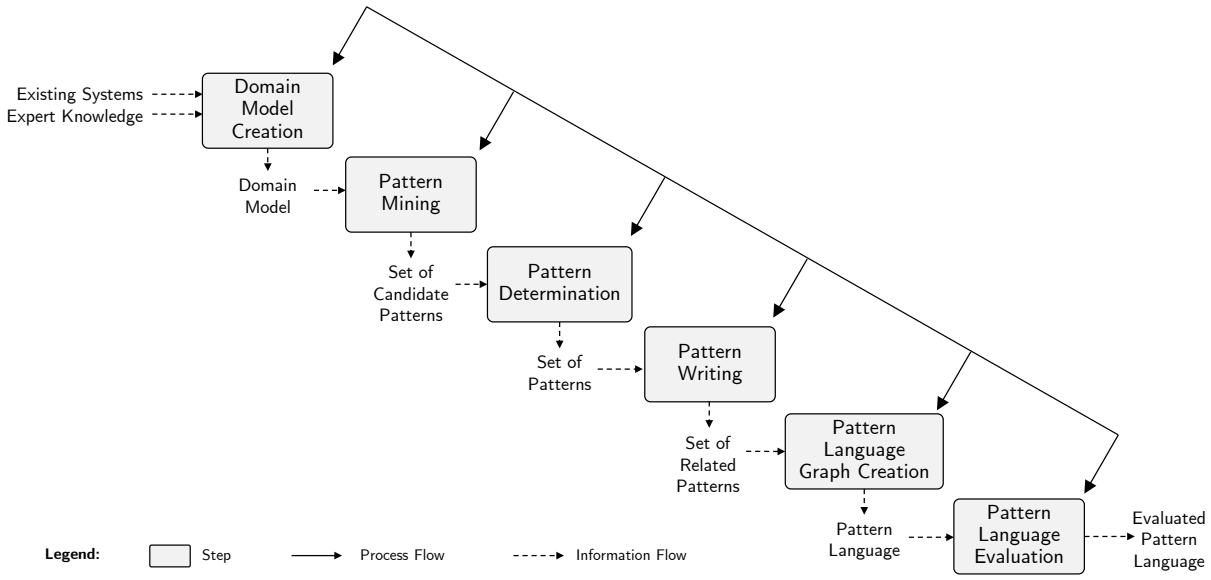
In this chapter we discuss the proposition of a pedagogical pattern language entitled `MLearning-PL`. `MLearning-PL` has been proposed to guide the requirements elicitation phase of mobile learning applications projects. The main idea is to provide support on pedagogical issues for helping analysts to avoid or diminish the already known pedagogical problems, particularly motivation, engagement, learning styles and knowledge effectiveness. The chapter is organized as follows. In Section 3.1, we present the process used to create `MLearning-PL`, detailing each of its steps. In Section 3.2, we present the m-learning domain model used in the process of creating the pattern language. In Section 3.3, we characterize the state-of-the-art on pedagogical patterns by means of a systematic mapping study. Finally, in Section 3.4 we present `MLearning-PL`, providing details of its creation. Final remarks are given in Section 3.5.

3.1 Pattern Language Creation Process

The work of Meszaros and Doble (1997) provides guidelines for pattern writing, but it focuses on the patterns format and disposition of the patterns throughout the pattern language, i.e., nothing is mentioned about how to discover the patterns based on the knowledge about a particular domain, or how to organize them or to delimit their scope.

Aiming to systematize the creation of pattern languages, Braga *et al.* (2007) proposed a process to create analysis pattern languages for specific domains. In a related perspective, Iba *et al.* (2011) proposed a procedure for establishing a pattern language based on their experience in creating a pattern language for creative learning. We have adapted such processes to our work's needs; the resulting process is shown in Figure 15.

Figure 15 – Pattern Language Creation Process



Source: Elaborated by the author.

The process is divided into six steps applied in an iterative and incremental manner.

Step 1 - Domain Model Creation: Patterns are usually documented according to practice and experience. Consequently, the solutions commonly employed to solve recurring problems in a certain domain must be observed in the creation of a pattern language that covers applications. Thus, the starting point for the creation of a pattern language is the obtaining of a model for the target domain, i.e., a model that captures the functionalities present in most applications of that domain.

Step 2 - Pattern Mining: Patterns embodied in minds and activities within the target community must be discovered. Patterns reported in the literature should be

analyzed, as some are likely to be present in the domain analysis model. Firstly, writers should explore their own experience, obtained episodes, and observation of the target community and people concerned for mining patterns. Through exploration, they must identify the acts of experts in the community, which ought to cooperate to form a whole, and then understand the skill of the acts. Pattern repositories should also be searched, specially by automatic tools, for facilitating this task. When a pattern is found, the problem solved by it should be specialized to the specific domain, originating a new pattern to which should be assigned a name reflecting the domain-specific problem.

Step 3 - Pattern Determination: This step regards the partitioning of the domain model into an initial list of candidate patterns. The domain model resulting from the previous step is used as a basis for the identification of the patterns that will compose the pattern language. The resulting artifact is a list of patterns that will indeed compose the pattern language.

Step 4 - Pattern Writing: This step is related to the writing of patterns. After the definition of the patterns that will integrate the pattern language, their format must be established and each pattern us detailed according to this format.

Step 5 - Pattern Language Graph Creation: The way patterns relate to each other within the pattern language must be understood. Therefore, this step regards the definition of a graph that shows the patterns interaction, containing pattern names and IDs.

Step 6 - Pattern Language Evaluation: This is the last step of the pattern language creation process and validates the pattern language through its application to a scenario as close to real world ones as possible.

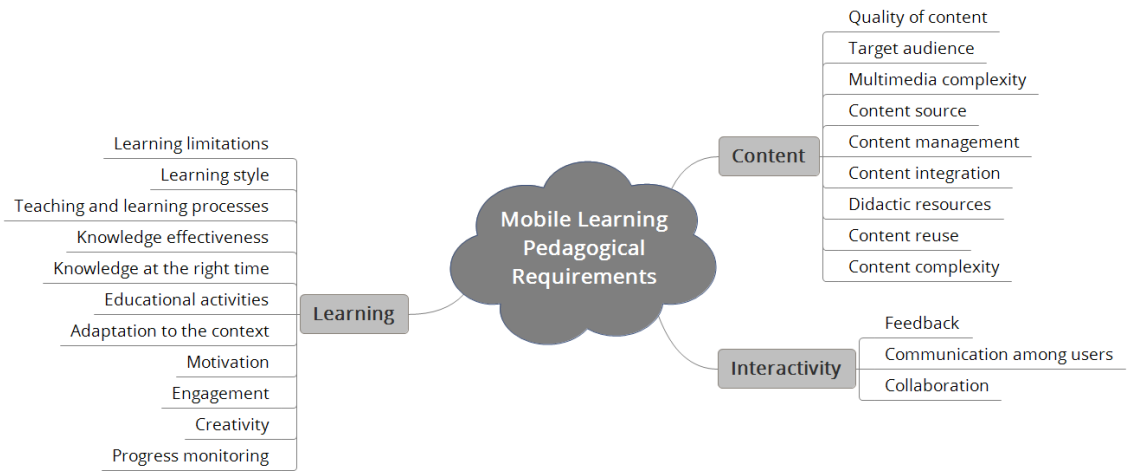
3.2 Mobile Learning Pedagogical Requirements

Step 1 for the creation of a pattern language regards the creation of a domain model, i.e., obtaining the information about the target domain. In order to gather information about the mobile learning domain, we considered ReqML-Catalog, the requirements catalog proposed by Soad *et al.* (2017), once it summarizes important aspects to be contained in a mobile application based on the existing systems and expert's knowledge. In the scope of our work, we considered only the pedagogical subset of requirements shown in Figure 16.

The characteristics related to the pedagogical category address the issues related to teaching and learning, defined as follows (SOAD *et al.*, 2017):

- **Learning:** ability of the application to provide features that contribute to learning.

Figure 16 – Subset of ReqML-Catalog



Source: Adapted from Soad *et al.* (2017).

- Learning limitations: ability to help the identification of knowledge gaps.
- Learning style: identification of different learner's learning profiles (auditory, visual and kinesthetic).
- Teaching and learning processes: well defined teaching and learning processes used.
- Knowledge effectiveness: ability to evaluate the user's effective knowledge acquisition.
- Knowledge at the right time: content offered at the correct stage of learning, for the avoidance of a very advanced content that depends on non-gained knowledge.
- Educational activities: different types of activities related to education, that enable, for instance, knowledge acquisition, guidance from a tutor, instructions that guide the user during learning.
- Adaptation to the context: ability to adapt to the user's context taking into account age, gender, education, physical conditions of the environment, among other context factors.
- Motivation: stimuli through which the user acts in relation to knowledge acquisition.
- Engagement: functional commitment to roles and responsibilities for the achievement of a goal associated with emotional involvement for the development of such activities.
- Creativity: ability to solve tasks and develop ideas differently from the normal pattern for the establishment of a certain purpose.

  - Progress monitoring: use of a set of information on day-to-day teaching and learning and summative assessments for an overview of the learner's progress.

- **Content:** ability of the application to deliver manageable and quality content.
  - Quality of content: quality content related to situations and problems of learner's interest which is free of misspellings and contains no invasive, negative or discriminating messages.
  - Target audience: group of people with some common characteristics (age, gender, profession, interests, etc.) to whom the application is devoted.
  - Multimedia complexity: definition of a limit of multimedia elements that do not distract the user.
  - Content source: all available content must be provided by a reliable source.
  - Content management: control, management and monitoring of the content offered.
  - Content integration: integration of contents for a defined flow among them.
  - Didactic resources: didactic resources that assist the learning process.
  - Content reuse: ability to reuse content.
  - Content complexity: gradual adaptation of the content complexity according to the user's level, so that a complex content does not become an obstacle to users' understanding.

- **Interactivity:** ability of the application to provide features that help users interact with each other and with the application.
  - Feedback: ability to enable reciprocal feedback between students and teachers.
  - Communication among users: communication among users (learners, tutors and/or teachers) through blogs, forums, groups, and other media.
  - Collaboration: collaboration in activities for the interaction among learners, tutors and teachers through wiki, games, microblogs, forums and groups.

3.3 A Systematic Mapping on Pedagogical Patterns

Step 2 of the pattern language creation process regards pattern mining, i. e., discovery of patterns embodied within the target community and also patterns found in the literature.

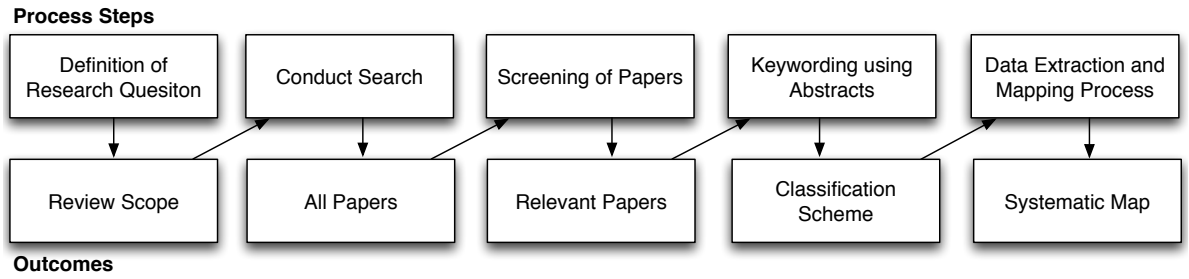
According to the educational setting, patterns have been explored mainly in the context of electronic learning (FIORAVANTI *et al.*, 2015) and used for mobile learning, but not pedagogical patterns. Therefore, the idea was to retrieve the existing pedagogical patterns and analyze those that could be used in the mobile learning context.

A systematic mapping study was conducted for retrieving such pedagogical patterns. In short, systematic mapping is a type of secondary study that provides a process for a broader review of primary studies and aims to obtain a broad overview of the research area from the relevant primary studies discovered. It identifies the evidence available, as well as the gaps in primary studies and the areas where more primary studies must be conducted (KITCHENHAM; CHARTERS, 2007).

The contents of this section were partially presented in the paper entitled "*A Systematic Mapping on Pedagogical Patterns*", published in the Proceedings of the 46th Annual Frontiers in Education Conference (FIE 2016) (FIORAVANTI; BARBOSA, 2016).

Our systematic mapping followed the guidelines proposed by Petersen *et al.* (2008), which establish the steps shown in Figure 17, and was fully performed by one researcher.

Figure 17 – The Systematic Mapping Process



Source: Petersen *et al.* (2008).

3.3.1 Definition of Research Questions

The systematic mapping conducted aimed at the identification and analysis of studies on full pedagogical patterns and pattern languages.

Aiming to achieve the established goals, a protocol was defined to guide the mapping, in which the following research questions were defined:

RQ1: What pedagogical patterns have been used?

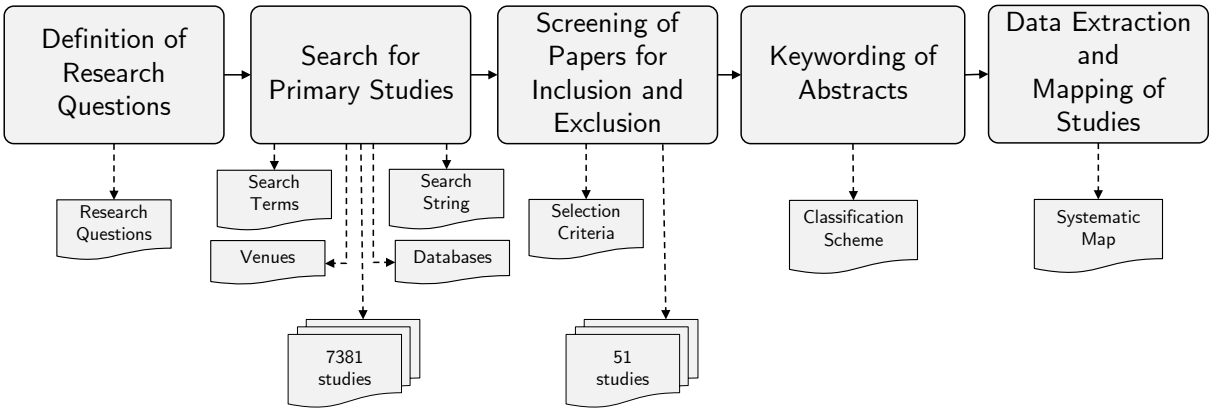
RQ2: What problem or challenge do such pedagogical patterns aim to solve or mitigate?

As shown in Figure 18, the research questions are the outcomes of this step.

3.3.2 Search for Primary Studies

The primary studies were identified by search strings in scientific databases or a manual browse through relevant conference proceedings or journal publications. A good way of

Figure 18 – Systematic Mapping Steps



Source: Elaborated by the author.

creating search strings is to structure them regarding *Population*, *Intervention*, *Comparison*, and *Outcome* (PETERSEN *et al.*, 2008). Therefore, we additionally used the PICOC criteria proposed by Petticrew and Roberts (2006) to frame the research questions.

- **Population:** Research related to pedagogical patterns;
- **Intervention:** Problems and challenges solved or diminished with the use of patterns;
- **Comparison:** Not applicable;
- **Outcome:** Overview of studies that discuss pedagogical patterns or pattern language; and
- **Context:** Industry and Academia.

For our systematic mapping, the string was defined also through the attachment of terms of higher relevance to the research, namely *pedagogical pattern*, *pedagogical patterns*, *educational pattern*, *educational patterns*, *learning pattern*, *learning patterns*, *teaching pattern* and *teaching patterns*. The search terms and their synonyms were defined according to experts' opinions, the literature and the set of research questions. The generic search string defined is shown in Chart 7.

Searches were performed in the following databases[1](BRERETON *et al.*, 2007; ZHANG *et al.*, 2011): ACM Digital Library, EI Compendex, IEEE Xplore Digital Library, ISI Web of Science, Science@Direct, Scopus and Springer Link. The generic search string was adapted to each database selected in accordance with its specificities, which resulted

[1] The searches were conducted on January 26th, 2016 and updated on May 8th, 2017.

Chart 7 – Search string

("pedagogical pattern" OR "pedagogical patterns" OR "learning pattern" OR "learning patterns" OR "teaching pattern" OR "teaching patterns" OR "educational pattern" OR "educational patterns")

Source: Elaborated by the author.

in 6650 studies retrieved. A manual search was also performed in important venues in the context of patterns such as: PLoP, EuroPLoP, online repositories and so forth, and other 731 studies were included. The number of studies found in each database is shown in Table 4.

Table 4 – Studies found per research database

Research database	**URL**	**Rationale for inclusion**	**Total of studies**
ACM Digital Library	http://portal.acm.org	Brereton *et al.* (2007)	145 (1.96%)
EI Compendex	http://www.engineeringvillage.com	Brereton *et al.* (2007)	938 (12.71%)
IEEE Digital Library	http://ieeexplore.ieee.org	Brereton *et al.* (2007)	378 (5.12%)
ISI Web of Science	http://www.isiknowledge.com	Zhang *et al.* (2011)	860 (11.65%)
Science@Direct	http://www.sciencedirect.com	Brereton *et al.* (2007)	164 (2.22%)
Scopus	http://www.scopus.com	Zhang *et al.* (2011)	1373 (18.60%)
Springer Link	http://link.springer.com	Brereton *et al.* (2007)	2792 (37.83%)
Manual Search	-	-	731 (9.90%))
Total			*7381 (100%)*

Source: Research data.

3.3.3 Screening of Papers for Inclusion and Exclusion

In this step, the supporting criteria for the screening of papers during the mapping execution were defined. Such a definition aimed at the selection, among the works obtained from the automatic search, of those that could potentially answer the research questions and were directly related to the subject studied. The results were not filtered by year to assure no important study would be missing. Chart 8 shows the inclusion and exclusion criteria.

After the removal of duplicate studies and application of the inclusion and exclusion criteria, 51 studies were selected for the next step.

3.3.4 Keywording of Abstracts

In this step, we read the abstracts and searched for keywords and concepts that reflected the main contribution of the paper. The context of the research was also identified, which helped the reviewers to define the data to be extracted in the next step.

Chart 8 – Inclusion and Exclusion Criteria

Type	Criterion
Inclusion	**I1.** Primary studies that have at least one full pedagogical pattern.
Exclusion	**E1.** Primary studies that do not involve the issue of research questions. **E2.** Primary studies that are not available for downloading in the databases selected. **E3.** Primary studies written neither in English, nor in Portuguese. **E4.** Duplicated studies. **E5.** Cover files and proceedings index.

Source: Elaborated by the author.

Our classification scheme considered two main facets. The research facet reflects the research approach used in the papers. We chose an existing classification of research approaches by Wieringa *et al.* (2006), which proposes the following types of research: Validation Research, Evaluation Research, Solution Proposal, Philosophical Papers, Opinion Papers, Experience Papers. The category facet structured the patterns according to their specific applications was based on ReqML-Catalog (SOAD *et al.*, 2017), specifically in the pedagogical category (Section 2.1.3).

3.3.5 Data Extraction and Mapping of Studies

To summarize the results, extract data from the primary studies and answer the research questions, we developed the template shown in Chart 9. The main results and the answers to the questions are presented next.

Chart 9 – Data Extraction Form

Data Item	Value	RQ
Study ID	Letter 'S' followed by an integer	
Article Title	Title of the article	
Author(s) Name	Names of the authors	
Year of Publication	Calendar year	
Pattern ID	Letter 'P' followed by an integer	
Pattern	Name of the pattern	RQ1
Problem	Problem solved or diminished by the pattern	RQ2
Research Type	Classification of the research according to Wieringa *et al.* (2006)	
Category	Pedagogical application of the pattern according to Soad *et al.* (2017)	

Source: Elaborated by the author.

3.3.6 Pedagogical Patterns Map

In this section, we present an overview of the primary studies found, the patterns extracted, the problem solved and also the category the pattern belonged to and also a discussion of the main results extracted from the 51 studies, towards answering the research questions.

Firstly, we present the 51 selected studies and their information in Table 5.

Table 5 – Selected Studies

ID	Reference	Title
S01	Angster *et al.* (2003)	Patterns in teaching software development
S02	Bauer and Baumgartner (2010)	The Potential of Christopher Alexander's Theory and Practice of Wholeness: Clues for Developing an Educational Taxonomy
S03	Bennedsen and Eriksen (2003)	Applying and developing patterns in teaching
S04	Berenbach and Konrad (2008)	The Reinforcement Pedagogical Pattern for Industrial Training
S05	Bergin (2006)	Active Learning and Feedback Patterns: Version 4
S06	Bower (2008)	The "Instructed-teacher": A Computer Science Online Learning Pedagogical Pattern
S07	Breuer *et al.* (2007)	Interaction design patterns for classroom environments
S08	Carroll and Farooq (2007)	Patterns as a paradigm for theory in community-based learning
S09	Cobos *et al.* (2013)	A hybrid system of pedagogical pattern recommendations based on singular value decomposition and variable data attributes
S10	Anacleto *et al.* (2009b)	Cog-Learn: An e-Learning Pattern Language for Web-based Learning Design
S11	Erickson and Leidig (1997)	A Pedagogical Pattern for Bringing Service into the Curriculum via the Web
S12	Harashima *et al.* (2014a)	Creative Education Patterns: Designing for Learning by Creating
S13	Iba and Miyake (2010b)	Learning Patterns: A Pattern Language for Creative Learning II
S14	Iba *et al.* (2011)	Pedagogical Patterns for Creative Learning
S15	Iba and Sakamoto (2011)	Learning Patterns III: A Pattern Language for Creative Learning
S16	Jiang *et al.* (2011)	P2N: A Pedagogical Pattern for Teaching Computer Programming to Non-CS Majors
S17	Keenan and Steele (2011)	Developing a Pedagogical Infrastructure for Teaching Globally Distributed Software Development

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Table 5 – *Continued from previous page*

ID	Reference	Title
S18	Köppe (2011a)	Continuous Activity: A Pedagogical Pattern for Active Learning
S19	Köppe (2011b)	A Pattern Language for Teaching Design Patterns (Part 1)
S20	Köppe (2011c)	A Pattern Language for Teaching Design Patterns (Part 2)
S21	Köppe and Nijsten (2012)	A Pattern Language for Teaching in a Foreign Language: Part 1
S22	Köppe (2013)	A Pattern Language for Teaching Design Patterns
S23	Köppe and Pruijt (2014)	Improving Students' Learning in Software Engineering Education Through Multi-level Assignments
S24	Köppe and Portier (2014)	Lecture Design Patterns: Improving the Beginning of a Lecture
S25	Köppe and Schalken-Pinkster (2015)	Lecture Design Patterns: Laying the Foundation
S26	Larson *et al.* (2008)	Continuous Feedback Pedagogical Patterns
S27	Miller *et al.* (2015)	Patterns on Civic Engagement, Service Learning and Campus Community Partnerships from the "Program for the Advancement of Service Learning and Social Responsibility of Universities"
S28	Mor (2010)	Guess my X and other techno-pedagogical patterns: toward a language of patterns for teaching and learning mathematics
S29	Rogier *et al.* (2013b)	What learners teach us: e-learning patterns for adult ICT education
S30	Ruskov *et al.* (2010)	Pattern for Graduate Student Company
S31	Schmolitzky (2007)	Patterns for Teaching Software in Classroom
S32	Seffah and Grogono (2002)	Learner-centered software engineering education: From resources to skills and pedagogical patterns
S33	Sharp *et al.* (1996)	Pedagogical patterns—successes in teaching object technology: a workshop from OOPSLA'96
S34	Smith *et al.* (2010)	Blended learning patterns for course design
S35	Bergin *et al.* (2001)	Patterns for gaining different perspectives
S36	Eckstein *et al.* (2002)	Patterns for active learning
S37	Harashima *et al.* (2014b)	Learning Patterns for Self-directed Learning with Notebooks
S38	Köppe and Schalken-Pinkster (2013)	Lecture Design Patterns: Improving Interactivity
S39	Kohls (2012)	Patterns for Creative Thinking
S40	Köppe *et al.* (2016)	Flipped classroom patterns - Controlling the pace
S41	Cortie *et al.* (2013)	Learning Patterns for Group Assignments: Part 2

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Table 5 – *Continued from previous page*

ID	Reference	Title
S42	Avgeriou *et al.* (2003)	Towards a pattern language for learning management systems
S43	Goodyear (2005)	Educational Design and Networked Learning: Patterns, Pattern Languages and Design Practice
S44	Bergin (2000)	Fourteen Pedagogical Patterns
S45	Shibuya *et al.* (2013)	Educational Patterns for Generative Participants: Designing for Creative Learning
S46	Holden *et al.* (2010)	Patterns for the Creation of Elearning Content and Activities in a University Setting
S47	Köppe (2012)	Learning Patterns for Group Assignments: Part 1
S48	Köppe and Nijsten (2012)	A Pattern Language for Teaching in a Foreign Language: Part 2
S49	Bergin *et al.* (2012)	Pedagogical Patterns: Advice For Educators
S50	Iba *et al.* (2014)	Learning Patterns: A Pattern Language for Creative Learning
S51	E-LEN Project (2004)	E-learning Design Patterns Repository

Source: Research data.

Table 6 shows all the 312 patterns found and the problems they solve.

Table 6 – Patterns and Problems extracted from Studies

Pattern ID	Study ID	Pattern Name	Problem
P001	S51	(Learning) Routines	How can the development of Learning Routines be supported?
P002	S50	A Bug's-Eye and Bird's-Eye View	You have trouble improving the quality of an idea or mediocre result.
P003	S49	Abstraction Gravity	Concepts that must be understood at two levels of abstraction require time for a Spiral approach to learning. However this can be time consuming.
P004	S13, S50	Acceleration to Next	It frequently happens that people slack off their efforts subconsciously just before the goal
P005	S49	Acquire Participants' Feedback	You believe you use a teaching style that enables learning. However you have just a one-sided view on your teaching style and you can never be sure how well this style is received by the students and how well this supports their requirements of a good learning environment.
P006	S36, S49	Active Student	The deep consequences of a theory are unlikely to be obvious to one who reads about, or hears about the theory. The unexpected difficulties inherent in using the theory or applying the ideas are not likely to be apparent until you actually do use the theory.

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P007	S40	Additional Resources	Some students do not sufficiently grasp the concepts based on the standard course material. They will likely start to run behind schedule, which makes helping them during the in-class meetings much harder and more time consuming.
P008	S36, S49	Adopt An Artifact	Students typically develop an artifact by themselves. This requires a complete understanding of the artifact's domain. However, because the students are human, they try to solve all problems in a similar way, using their individual thinking or problem solving process. But a lot can be learned by understanding an artifact produced by somebody else.
P009	S49	Anonymous Feedback	Often your students know things about your course that you do not. Sometimes they have definite opinions about the things you do, some positive and some not. If you don't find out about these things you can't respond to them.
P010	S47	Ask When Uncertain	Some — or all — parts of the assignment description are vague and not understandable. Starting the assignment under these circumstances can lead to a wrong start of the work and also lead to time loss if things are done the wrong way.
P011	S42, S51	Asynchronous collaborative learning	How to allow and facilitate learners and instructors to asynchronously collaborate and interact, to engage learners in problem-solving and critical thinking about issues in a domain, to be able both to mentor and to assess these interactions?
P012	S27	Attract Unbiased Teaching Staff	It is always a challenge to encourage teaching staff to use new innovative methods, most of all if they have been in their position for a long period of time.
P013	S50	Attractive Expressions	Your idea/product seems to be unattractive to others.
P014	S02	Ball Bearing (alias: Double Circle, Onion, Zipper)	Presentations in face-to-face training are too exhaustive
P015	S50	Be Extreme!	Despite your best efforts, you and your results hardly see the light of day.
P016	S19	Best Fitting Pattern Choice (alias: Perfect Fit)	Students often choose inappropriate patterns without exploring if the problem they have is the same as the problem addressed by the pattern. And even if this fits, the context or forces may be different or the consequences are worse than the original problem. If pattern names are part of the vocabulary of a domain, choosing an inappropriate pattern also leads to miscommunication
P017	S37	Big Goals	You find self-directed learning boring. The purpose of your work gets "submitting a note". Without planning, your work may become boring.
P018	S13, S50	Brain Switch	Thinking tends to be leaning to only logic or intuition, which each is not enough to achieve a breakthrough
P019	S50	Brave Changes	There seems to be no solution to the current dilemma.
P020	S49	Build and Maintain Confidence	Students expect the one and only right solution to a problem from the instructor. But often there is no single answer, but many equally correct answers.
P021	S49	Built-In Failure	Learning comes from experience, and much useful experience comes from failure. But a learner who lacks confidence will fear failure, and this fear impedes or even prevents learning.
P022	S26	Carefully Crafted Questions	Instructors often ask questions that fail to achieve the desired goals of the lesson.
P023	S12	Celebrate Together	Some learners can't feel the project is as their own

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P024	S50	Chain of Excitement	It is not easy to actively continue exploring and studying.
P025	S40	Challenge Assignments	It is hard to provide valuable in-class meetings for all students if some of them already grasped the concepts of the current level and want to run ahead of the schedule, and to learn the upcoming concepts of the course.
P026	S49	Challenge Understanding	Students may think they understand a topic when in fact they do not. If they think they understand, they will not ask questions and will not know the gaps in their knowledge. In addition it is not possible to cover all nuances of a topic in notes or in verbal instruction such as lecturing.
P027	S14	Challenging Mission	There are many missions that tend to be unsuitable to creative learning because they either make learners too free and unfocused
P028	S07	Change Mode	The more gestures a system supports the more difficult it becomes to differ gestures from drawing within a single interaction mode
P029	S24	Clear Starting Signal	When the lecture begins, many students are still focused on other activities than the lecture at hand. Such a beginning is not of much value for both students and lecturer.
P030	S51	Coherence Principle	Which kind of media should be used in e-lessons? When does additional entertaining material like background music affect the learning process?
P031	S38	Collaborative Summary (variation of Active Student)	It keeps the students passive if you just present the list of content covered to the students and run through all the bullets.
P032	S21, S48	Commented Action (alias: Think Aloud Protocol, Show and Tell)	The vocabulary and expressiveness of the students will not increase if the students only see the activities done by the teacher. They might be able to execute them themselves, but will have difficulties describing in the foreign language what they are doing.
P033	S13, S50	Community of Learning	Individual's capacity is limited
P034	S51	Concept Building	The pattern should be used if the learning goal is to convey a new concept.
P035	S35, S44, S49	Consistent Metaphor (Alias: Analogy)	It is easy to get lost in the details of the current topic, especially when teaching beginning students. Students then may not see how this topic is related to larger goals. It is also difficult for many students to quickly see how things fit together and to make correct predictions about how the technology should behave. We would like to let students draw on what they already know to help them learn new material.
P036	S51	Construction Of A Lived Value System	How it is possible to transform value systems by the means of pedagogy?
P037	S51	Contemplative Learning	How can Contemplative Learning be facilitated?
P038	S21, S48	Content-Compatible Language (alias: Content-Complementary Language)	Only mastering the obligatory language of a course's content limits the students in their expressiveness and does not improve the overall quality of students' language skills, even though it might be sufficient to fulfill the course's requirements.
P039	S21	Content-Obligatory Language	Some lexical items and terminology of the foreign language are so closely related to the content of a course that mastering them is crucial to students in order to achieve the course objectives.

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P040	S19	Context, Problem and Consequences First (alias: First Things First, Focus Beyond The Solution)	Students who start to learn patterns often go straight to the solution and apply it, hastily skipping the problem, context, forces, and consequences parts of the pattern
P041	S51	Contiguity Principle	Which ways of presentations for texts and graphics are possible and effective?
P042	S18	Continuous Activity	If students get an assignment and a deadline, they mostly start too late to work on the assignment and they often are not able to finish the assignment in the best possible quality and on time
P043	S17	Continuous Development	Difficulty to teach students how to supplement their resources with those of the remote team
P044	S50	Copycat Learner	It is difficult to find your own way from the beginning.
P045	S42	Course announcements	Given a sizeable LMS with numerous courses and users, how can the users see the announcements about courses that are of interest to them?
P046	S42, S51	Course Creation and Customization	How can the instructors be assisted in building on-line courses in LMS so that some of the tasks they need to perform can be automated?
P047	S50	Creative Learning	Opportunities for improving your creative skills and knowledge are limited
P048	S15	Creative Project	Maybe you are unwilling to learn just by acquiring knowledge and skills
P049	S49	Critique	You want your students to use and apply principles of modeling to substantial examples, but they are not yet proficient enough to do the modeling for themselves.
P050	S50	Daily Use of Foreing Language	It is difficult to read, write, and speak a foreign language without any practice.
P051	S47	Deliver High Quality Products	If the work product/s delivered on the date of the deadline are incomplete or not of sufficient quality regarding the defined requirements, then the grading of these products will be low.
P052	S51	Demographic Data	What information should be included as demographic data in a user model that is to be used in an Adaptive Web-based Educational System (AWES)?
P053	S40	Descentralized Group Instruction per Level	A general group instruction does not work anymore if there are student groups with different levels of concept acquisition and there is not enough time to help all individual students.
P054	S15	Design Your Learning	It is not easy to learn how to learn
P055	S32	Design-Implement-Redesign-Reimplement (DIRR)	It is hard to explain new concepts and methods based on old concepts and also often hard to get students to make the paradigm shift from functional programming to object oriented programming.
P056	S51	Development As The Aim Of Education (Developmental Transformation)	How could this higher stage of development be reached?
P057	S35, S49	Different Approaches	Communication always takes place between a sender and a receiver, and the effectiveness of communication isn't measured by what the sender says, but by what the receiver understands. Every person obtains information differently, using different sensory modalities. Some people, the visuals, learn most effective by watching; the auditories, by listening; and the kinesthetics, through action. Be aware: Not every student uses the same sensory modality as you!

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P058	S36, S49	Different Exercise Levels	The most important aspect of exercises is to allow the participants to improve their newly acquired skills by working on a topic on their own. If everyone is given the same exercise, then some participants will find it overly simple, and do not learn anything, while others consider the exercise too difficult, are frustrated because they can't do it, and do not learn anything. To improve his skills, the exercise must be located at the upper limit of the participant's current skill level, but this will be different for each participant.
P059	S49	Differentiated Feedback	Your students are individuals and so they learn differently and at different rates. For example they may understand you with differing degrees of precision and they have different backgrounds that make it easier or harder for them to grasp certain topics. Because of this, one piece of feedback will be more or less appropriate for any one student, but you want your feedback to be as effective as possible for all students.
P060	S49	Digestible Packets	People can only concentrate for a limited period of time. This is the primary reason to include regular Breaks. If a topic takes longer than the time people can concentrate, the participants will have difficulties understanding the topic in its entirety. Because comprehension decreases, the motivation will decrease, too, and the seminar will be considered difficult.
P061	S19	Discover Your Own Pattern (alias: Pattern Discovery)	Students see patterns as something that intelligent people have written. They don't understand that these mostly are captured "best known practices" and that experienced people use them without thinking about them
P062	S14	Discovery-Driven Expanding	If you introduce collaborative learning as a way for learner-centered learning suddenly, it is difficult for learners to perform and learn from their experience effectively.
P063	S43	Discussion group	"Discussion groups are the most common way of organising activity in networked learning environments. The degree to which a discussion is structured, and the choice of structure, are key in determining how successfully the discussion will promote learning for the participants."
P064	S46	Diverge-converge cycle	How to create a unit of learning design collaboratively allowing innovative approaches to the design while achieving a consistent style?
P065	S44, S49	Early Bird	How can you get the students working on larger artifacts without overwhelming them?
P066	S49	Early Warning	If your students fall behind or miss early material it will be difficult for them to catch up and difficult to succeed.
P067	S42, S51	E-book delivery	How can the instructors be facilitated with an easy and consistent way of creating and structuring electronic course books using hypermedia content?
P068	S12	Editing Discovery	The meeting often ends without settlement of opinions, just with various opinions
P069	S50	Effective Asking	It is difficult to get the right answers when you ask vague questions.
P070	S15, S50	Embodied Skills, Skill Embodiment	It is not enough to memorize the "how to"

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P071	S49	Embrace Correction	Artifacts produced by students are evaluated and graded as delivered. But this is not true of the real world, and it is almost impossible for students to get it right the first time. Furthermore a lot can be learned by revising artifacts.
P072	S24	Emphasize Relevance First	If students do not have the feeling that they get something of value in your lecture, then they're likely to drop out fast and the lecture becomes a burden—for both teacher and students.
P073	S49	Expand the Known World	Experienced students will relate a new concept to their own real-world experiences, and will form a deep understanding of it, but if their experience does not validate the concept, then its significance may be lost, and if their experience does validate the concept then although understanding may appear deep, it may also be narrow.
P074	S19	Experience of Benefits (alias: Rewarding Sweets)	It is hard for students to see the advantages generated by correctly applied pattern solutions if they are only told to them. This has negative impact on the intrinsic motivation of the students to use patterns outside of the educational setting
P075	S19	Experience of Problems (alias: Feel The Pain)	Students often apply patterns without understanding why the problem really is a problem and they are not aware of the consequences if this problem is not addressed properly
P076	S49	Experiencing in the Tiny, Small, and Large	A complex concept is difficult to understand unless you have experienced it by example. However concepts are often so complex that experiencing the whole in one step doesn't help either.
P077	S35, S49	Explore for Yourself	A person's success is based mainly on her ability to learn new concepts efficiently and to act as a team player by sharing knowledge and insights. You want to give your students the ability to learn in the future and to communicate their wisdom, but students are often afraid of taking responsibility for their own learning.
P078	S33	Explore-Present-Interact-Critique (EPIC)	Two of the most important abilities of software developers are to be able to learn new material efficiently and to be able to share knowledge and insights with the other members of the work group. How to train them? This pattern allows the students to acquire these abilities by forcing them into being the teacher for themselves.
P079	S49	Expose the Process	Examples and exercises form a vital part of any teaching effort. However, often examples and (correct solutions to) exercises only show the final result. The process of getting there, including the necessary decisions, dead-ends and backtrackings, alternatives and principles are not obvious.
P080	S49	Fair Grading	You want to be fair in your grading to each individual student. You also want the students to be satisfied that you are fair and satisfied with their own accomplishments.
P081	S49	Fair Project Grading	If your grading scheme is too monolithic, some student or team may suffer because they missed some technical detail you were looking for in an otherwise fine piece of work.
P082	S49	Fair Team Grading	You need to make the grading fair to the whole team and to each individual.

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P083	S49	Feedback	Giving students exercises to challenge their understanding will help them improve their skill and will help you know what level of understanding they have achieved. Unless the work is assessed and feedback is given, you won't be able to correct any misunderstandings, the students won't know where they are at fault and their learning will be incomplete.
P084	S49	Feedback Sandwich	You need to point out where the students' understanding is faulty and to correct any misunderstanding they have, but you do not want to undermine their confidence.
P085	S15, S50	Field Diving	You cannot touch upon reality only by referring to documents
P086	S03, S44, S49	Fill in the blanks	How to allow students working in larger project without overwhelming them
P087	S47	Fill Knowledge Gaps	One or members of the group do not have sufficient knowledge needed for working on the tasks assigned to the them.
P088	S05	Final Learning Check	Many times an individual class will have many parts, some of which are complex, and students may not have the ideas in mind
P089	S50	Firm Determination	It is too easy to give up on challenging activities.
P090	S44, S49	Fixer Upper	Too often students work on only "toy" problems because they may not have the experience or skill to build large artifacts from scratch and there is only just so much time. But all realistic problems are large and the day in which small problems were interesting is about past.
P091	S37	Focus Style	You can't concentrate on your work. It's hard to concentrate on your work for even an hour. In other hand, if you have a long break, you can't motivate yourself and feel bored.
P092	S51	Forming groups for collaborative learning	How can a well functioning group for collaborative learning in an educational context be formed?
P093	S50	Frontier Finder	You have to know the frontiers of exploration to conduct valuable activities.
P094	S50	Fruit Farming	It is difficult to produce a big result at once
P095	S14	Generative Participant	Communication for the collaboration doesn't always go smoothly, and often stops and sometimes falls into the situation where a very few members control the ow and others follow it
P096	S07	Gesture-Based Interaction	Dealing with small and big screen devices in order to keep user input and system response in the same space
P097	S47	Give a First Warning	Some group members are not fulfilling the expectations and goals agreed on earlier which leads to an unbalanced participation in the group and endangers a good assignment completion.
P098	S42	Glossary	How can the students be provided with definitions or explanations of terms that appear inside the learning material?
P099	S44, S49	Gold Star	Normally the reward structure is private. In grading you give the student praise, but this loses the opportunity to show other students what you value most highly.
P100	S50	Good Rivals	It is difficult to maintain efforts alone.
P101	S44, S49	Grade it Again Sam	An education or training situation should provide a safe environment in which students can make mistakes, and learn from them, but sometimes students fear they will suffer because of the grading structure.

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Pattern ID	Study ID	Pattern name	Problem
P102	S30	Graduate Student Company Pattern	How does one motivate and educate science and technical student to have entrepreneurial competences and attitude.
P103	S31	Group Design Challenge	Learners will not understand abstract design or programming concepts well without applying the imparted knowledge; but if they apply it on their own they do not get immediate and qualified feedback on their work which can manifest wrong understandings.
P104	S36, S49	Groups Work	You are only one resource for the students. Given the number and difficulty of student questions and concerns you are actually a rather small resource. Your students need frequent feedback on what they do and how they do it.
P105	S28	Guess My X	A teacher wants to design a game for learning concepts, methods and meta-cognitive skills in a particular mathematical domain. This game should use a combination of available technologies. Many complex concepts require an understanding of the relationship between the structure of an object and the process which created it. Novices may master one or the other but find it challenging to associate the two.
P106	S26	Hands Free Help	Students experience difficulties solving problems and want the solution given to them instead of drawing on their past experiences and prior knowledge to solve the problem on their own.
P107	S50	Hidden Connections	Unexpected discoveries hardly manifest from conventional classifications.
P108	S19	Holistic Pattern Understanding (alias: Understand Design Patterns)	Patterns are conceptually different from other design techniques or methods, and not taking this into account when teaching them often results in students applying patterns in an inappropriate way
P109	S26	Honest Appraisal	Students don't always make connections between new material and previously learned concepts. They don't take time to think about how this new material might be applicable to their interests and goals.
P110	S36, S49	Honor Questions	Some students are afraid of asking questions in front of the whole group, because the question might make their problem with the topic obvious, which might in turn be interpreted as weakness. However questions show that the participant is interested in a topic or that he needs a different explanation in order to fully understand the topic.
P111	S49	Human Professor	At some point in your teaching, students will make serious transgressions of the code of conduct. If the punishments are overly harsh there will be little learning and much resentment. Students lives can be ruined by actions taken in desperation. But it is seldom true that the student is without merit or the situation has no redeeming factors whatsoever.
P112	S51	Hypertext Learning	How can the process of hypertext learning be supported?
P113	S05	Icebreaker	If the students don't know one another their early interactions will be awkward and they will have little trust in one another's abilities to contribute
P114	S39	Idea Triggers	The more you know about a domain, a solution or a concept, the harder it gets to develop new ways of doing things. Old clichés are taking for granted and finding a new path is biased by your current thought patterns. You need a push into a new direction.

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Pattern ID	Study ID	Pattern name	Problem
P115	S25	Imagination Stimulation	Being presented just pure facts and step-by-step instructions is boring for students. Providing the content in a well structured way does not support student learning by itself.
P116	S05	Immediate Feedback	Need to know if it is time to move to another topic/activity or if students are lost
P117	S27	Improve Students' Cooperation Skills	The problem arises when students work in personal cooperation with a community partner organization, what they usually do in service learning projects.
P118	S10	In Practice	How can teachers exemplify the recently shown concept in the students' environment?
P119	S34	Independent Learning	Students may not be motivated to complete reading assignments that lead to in-class activities.
P120	S40	Individual Support	Addressing the needs of all students with general activities becomes increasingly difficult if the gap between the expected knowledge of some students and their actual knowledge is growing.
P121	S49	Industry Partner	Even the most experienced teacher can't know everything. In addition, teachers that spend most of their time in the classroom aren't well versed on what is happening in industry. Yet, they want their students to have an appreciation for how the topic they are studying is relevant and useful in the work place.
P122	S08	Informal developmental learning	Lack of control over IT
P123	S42	Information distribution	How to allow users to view and share events with other users about education-related events?
P124	S21	Input Selection	Available material often differs in both language levels and comprehensibility, and can be too difficult or too easy for students. Both cases will lead to problems during the course
P125	S06	Instructed-Teacher	How to expose, develop and share student's mental models in virtual classroom environments in a practical and relevant way that allows students to effectively integrate all types of knowledge
P126	S49	Introvert - Extrovert	Many of your students consider themselves shy. You will recognize them in class as they seldom speak up, ask questions, or volunteer for visible tasks. You know, however, that they will need to assume more public personas if they are to be successful in the real world.
P127	S36, S49	Invisible Teacher	Usually, the teacher is the central point of a training environment. Often the students only trust the teacher and (maybe) themselves, therefore, when students struggle, the obvious step is to ask the teacher for help. However, in the work environment the teacher will not be around.
P128	S50	Jump In	You still doubt that the community is suitable for you.
P129	S46	Keep it in the family	How can the team rapidly prototype activities and assignments in learning designs to ensure that they are clear and practicable? How can the team generate examples of the ways in which assignments might be tackled to aid student learning?
P130	S41	Keep Motivated	During the execution of a group assignment, insufficient participation, bad quality deliverables or simply not getting satisfaction from the given tasks can be the result of decreased motivation.

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Pattern ID	Study ID	Pattern name	Problem
P131	S49	Key Ideas Dominate Grading	If your grading scheme weights material according to its difficulty, or gives equal weight to all topics, you may be giving students the wrong impression about which topics are key.
P132	S49	Kinds of Exam	You have to examine the knowledge of your students, but not all topics can be examined equally. You have to examine every student uniformly, however every person benefits differently from the usage of her own sensory modality capability.
P133	S51	Knowledge Building (Learning of word meanings)	How can the process of knowledge buildng be supported?
P134	S10	Knowledge Retention	How to keep newly acquired knowledge continuously working in the student's short term memory, while she prepares to learn more
P135	S10	Knowledge View	How can the teacher introduce new concepts to the students?
P136	S21, S48	Language Monitor (alias: Formative Assessment)	Judging the progress students make with language acquisition is not possible during lecturing, but without judgement you don't know if the students make progress with language acquisition.
P137	S21	Language Role Model	Learning is also imitating, but imitating incorrect language usage of a teacher will affect the students' learning of the language negatively.
P138	S15, S50	Language Shower	To master languages is tough
P139	S21	Language Status Quo	Without knowing the actual level of foreign language competences of the students it is likely that the language parts of the course design are either too difficult for the students which hinders them in grasping the content or are too simple for them which means that their language understanding probably does not improve.
P140	S44, S49	Larger Than Life	When faced with a new concept, students often focus on low level details, ignoring its higherlevel aspects.
P141	S24	Late Attendant Discouragement	Late attendants, especially in small classrooms or lecture halls with doors near the lecturer, can be quite disturbing. Not only do they miss part of the lecture, they can disturb the flow of the lecture and break the concentration of other attending students.
P142	S03, S44, S49	Lay of the Land	Apathy to a topic if its overview is not well presented
P143	S31	Learners Do Challenge	You want to engage the learners as much as possible and use the time of the course as effectively as possible.
P144	S50	Learning by Creating	You are not willing to learn just by acquiring knowledge and skills
P145	S50	Learning by Teaching	You have no idea how to improve your understanding.
P146	S26	Learning Contract	Students do not accept responsibility for their own learning and tend to hold the teacher or other external factors accountable for a low grade.
P147	S13	Learning Design	It is not easy to learn how to learn, while it is na essential ability in a complex changeable society
P148	S51	Learning Strategies	How can the acquisition of independent learning of an acquired strategy be supported?

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Pattern ID	Study ID	Pattern name	Problem
P149	S45	Learning Through Accidents	You take too much work of the project on yourself to resolve the accident. Projects with new challenges will hardly go exactly as planned. However, from the sense of responsibility as a teacher, you tend to think failures aren't allowed when unexpected events occur in the project. So you tend to make a correction to the course of the lesson plan and curriculum. But, many problems can't solve alone, and the situation can become all the more complicated because of your brief solution.
P150	S51	Learning Through Discovery	How can learning through discovery be facilitated?
P151	S51	Learning Through Experience	How can children, students, experts, etc. be enabled to learn through experience?
P152	S51	Learning Through Realistic Discourses	How should discourse situations be designed to make learning possible?
P153	S51	Learning to Negotiate	How can the learning of negotiating skills be facilitated?
P154	S25	Lecture Structuring	Students do not learn much in a lecture if all the content is completely presented, but in isolated and unordered pieces.
P155	S36	Let them Decide	You want to take the participants specific interests into account, but you are not completely sure about how to do this regarding the contents, the schedule, or the methodology. Sometimes it is impossible, to make these decisions in advance, because the exact skills or interests of the participants are not known.
P156	S26	Line of Reasoning	A student catches you off guard by presenting a solution to a problem or answering a question in a way you didn't anticipate.
P157	S10	Linkage	How can the teacher introduce students to a new topic?
P158	S35, S49	Linking Old to New	Learning something new is exciting, but it often involves questioning things that the learner already knows. Learning too many new things often leads to a sense of rejection and then to stress.
P159	S37	List of Likes	The number of your interests varies each day. Even if you find many interesting topics for one day's menu, it's hard to research them completely. In other hand, when you find few things, you have difficulty in writing the contents.
P160	S21	Lucky Language Clover (alias: The Four Skills)	Exposing the students to language comprehension only — reading and listening — is not sufficient for creating a lasting effect in learning the foreign language. They might be able to understand content input, but unable to produce content output in the foreign language.
P161	S51	Making online learners trust each other	How can you bring together learners in groups for collaborative learners or (online) communities) and make them trust each other?
P162	S15	Making Opportunities	There are few good opportunities for learning compared with your expectations
P163	S41	Manage the Project	The project cannot be finished successfully if you are running out of time due to unfinished tasks.
P164	S47	Manage Work Products	If the work products are not available in the current versions to all concerned students, inconsistencies and incompleteness can occur as students might work on different versions which later have to be merged.
P165	S42, S51	Management of on-line questionnaires	How can web-based questionnaires be created, delivered and graded?

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Pattern ID	Study ID	Pattern name	Problem
P166	S28	Mathematical Game Pieces	How do you design (or choose) a game to convey mathematical ideas in an effective and motivating manner? How do you judge if a proposed game is an adequate tool for teaching particular mathematical concepts?
P167	S10	Means the Same	How to make the student see how the topic is connected to the main goal of the lecture and to understand how the concepts are connected.
P168	S41	Mediate the Dispute	There is a dispute between group members, which has a negative impact on the motivation and the participation. There might be negative consequences on the project results.
P169	S21	Metatalk	Students are not aware of their foreign language shortcomings and keep using incorrect language constructs and terms.
P170	S26	Minimum Distance	A traditional classroom or lecture hall provides a built-in spatial separation between most of the students and the lecturing instructor that can be interpreted by the student as disinterest on the part of the instructor.
P171	S45	Mining of Relationship	You cannot force a learner to participate, just by explaining the purpose of the project. Even if learners have high motivation for doing project style learning, they usually won't get interested in the project only by hearing an explanation of the project. However, it is almost impossible to design the project to fit to all of the individual interests. In addition, even if the learners appear to be working happily, it might be just that the learners are enjoying the activities that the teacher has planned. The learners in such posture don't take action like inspecting the necessary knowledge for the project or devising their own way of working.
P172	S49	Mission Impossible	Often new learners arrive at an abstraction not via generalization from a deeper understanding but from a simplification of something they do not yet understand. Such simplistic truths are dangerous, because they lead learners to construct simplistic solutions that do not really solve problems. Worse, the learners' lack of experience prevents them from recognizing the shortcomings in their thinking.
P173	S44, S49	Mistake	Students are knowledgeable and are able to give helpful feedback, but often they are not confident about the relevance of their experience and are unsure about the value of their own knowledge.
P174	S49	Mock Exam	In order to have a meaningful examination you can't tell them the exam in every detail, however you want to help the students to prepare themselves.
P175	S51	Modality Principle	How should explanations to graphics or animations be given, as onscreen text or as spoken text?
P176	S51	Moderation of an asynchronous on-line group	Experience teaches that a moderator can have a positive affect on the activities and learning results of on-line groups. What should a moderator do in order to facilitate effective learning in asynchronous on-line groups.
P177	S49	Multi Pronged Attack	Sometimes eliminating stuff for making room for new topics is the best choice, because some topics are becoming obsolete by the introduction of new ones. But often you will find that there are no topics to leave out and that the new ones are just coming on top of them.

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Pattern ID	Study ID	Pattern name	Problem
P178	S23	Multi-Level Assignment	Student learning is suboptimal when assignments can be completed by merely applying techniques and concepts without requiring a deeper conceptual understanding of them. In that case the students might learn less than they could have.
P179	S51	Multimedia Principle	What combination of media should be taken into consideration if you want to present texts and graphics together on one screen?
P180	S39	Multiple Perspectives	By looking at a thing only from one perspective, you will miss important facts, potential paths and undesired consequences. A single perspective will never reveal everything. You will miss opportunities, alternatives and potential obstacles.
P181	S28	Narrative spaces	How can the epistemic power of narrative be harnessed by educators and learners in the construction of mathematical meaning?
P182	S49	New Pedagogy For New Paradigms	The thing you need to teach has characteristics different from what you are used to, requiring different thinking modes on the part of users.
P183	S49	Nobody Is Perfect	Students expect the one and only right solution to a problem from the instructor. However, on the one hand there is often no single answer, but many equally correct answers. And on the other hand you might not know the best answer.
P184	S11	NPO Website Service Project	How to benefit students from the experience of working on a diverse team, doing a project for a customer with real requirements and interests
P185	S28	Objects to talk with	Most computer-mediated discussion tools are strongly text-oriented, prompting users to express their thoughts lucidly in words or symbols. Yet two important elements of natural conversation are lost: the embodied dimension, i.e. gestures, and the ability to directly reference the objects of discussion.
P186	S49	One Concept – Several Implementations	An abstract concept is hard to understand without a concrete implementation or realization. However, teaching a theory using a concrete implementation might blur the concept itself, because the concrete implementation might not follow exactly the abstract model.
P187	S49	One Grade For All	You want all team members to benefit equally from the teamwork experience, in terms of grading and learning outcomes. But some team members often put in more work than others.
P188	S07	Open (White) Space	Problem-oriented or constructivist learning should emphasize students' self-directed activities and start with students' construction and discussion, but most technologies in the classroom support a teacher centered approach
P189	S26	Open Ended Questions	Students fail to demonstrate higher level thinking skills during class.
P190	S50	Open Learning	Learning tends to be closed and it is difficult to deepen your understanding on your own.
P191	S12	Open the Project	It is difficult to decide assessment for the learners from the objective view
P192	S15	Open-Process Learning	Learning tends to be closed and it is difficult to deepen your understanding only by yourself
P193	S50	Opportunity for Learning	There are few good opportunities for learning compared with your expectations
P194	S50	Output-Driven Learning	It is difficult to keep learning if the necessity is unclear.
P195	S49	Own Words	Students may be able to repeat definitions and other material verbatim but they may not have fully understood them.

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Pattern ID	Study ID	Pattern name	Problem
P196	S16	P2N: Pedagogical Pattern for Teaching Programming to Non-CS Majors	When teaching the entry-level programming course with material more advanced than the standard ones, the time of learning and for practice becomes short and the students may not have enough time
P197	S46	Parallel universe with wormhole	Detailed design decisions made in one element will frequently have implications for the design of other elements. How to organise a concurrent design process so that all team members are aware of the detailed design decisions that are being made by others, to ensure coherence and consistency across the course avoiding unnecessary repetition or inconsistency is avoided?
P198	S17	Partitioning	Difficulty to teach students how to break a large project into discrete components which are each assigned to remote teams who are responsible for their respective design and implementation
P199	S50	Passion for Exploration	It is difficult to choose a subject to explore.
P200	S19	Pattern Implementation Matters (alias: Implementation Matters)	The students have difficulties with implementing the solutions of patterns if they only read or hear about them. It is hard for them to add the information necessary for the pattern implementation, which has been abstracted away during the definition of the pattern
P201	S49	Peer Feedback	Students are knowledgeable and are able to give helpful feedback, but often they are not confident about the relevance of their experience and are unsure about the value of their own knowledge.
P202	S49	Peer Grading	You want to teach your students how to evaluate quality and how to negotiate for it. You want to get them to accept evaluation by peers and to make this comfortable.
P203	S37	Pen and Paper	Even if you have a good idea, you will miss it soon. You go to bed or you are on your way to school. When you start working the self-directed learning, you can't use the idea.
P204	S42	Personalization	How can the different courses that users are involved in, be organized, so that each user is presented with her/his own personalized set of courses?
P205	S51	Personalization Principle	When is the usage of conversational style and pedagogical agents appropriate?
P206	S35, S49	Physical Analogy	You are trying to help learners understand the dynamic qualities in a rather abstract concept. You have provided an overview of the concept, and now would like to help students visualize how it works. While it is rather easy for learners to comprehend concepts that are concrete because they are usually easy to visualize, it is not as easy to do this with abstract concepts.
P207	S26	Piece of Mind	Students don't readily give feedback regarding their perceived progress in class, the concepts they are struggling with, what they might need to be successful, and/or what has helped them succeed so far.
P208	S46	Play, Reflect, Jump	How to kick-start the learning design process, create a shared vision for the aims of the course and ensure the overall vision for the course is reflected in its detailed learning design plan?
P209	S50	Playful Learning	Learning as a duty is ineffective and painful.
P210	S49	Prefer Writing	Students need to practice writing, both because it is a useful skill and because it forces them to be engaged with the ideas.
P211	S26	Pregnant Pause	Teachers and lecturers ask questions of their audience yet do not give them time to formulate a response.

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Pattern ID	Study ID	Pattern name	Problem
P212	S24	Preparation Material Check	Students often do not study the required material or content before class and are therefore not prepared sufficiently for the next lecture. This generally lowers students' learning and also disturbs your lecture planning.
P213	S40	Preparation Status Awareness	Over time, students become less and less motivated to prepare for class. This leads to an increase of differences in knowledge levels at the start of the next class which in consequence makes it harder to offer valuable in-class meetings to all students.
P214	S19	Principle-Supporting Pattern Usage (alias: Principles Are Leading)	While learning design patterns students often focus on the implementation of the patterns in isolation, which regularly results in a bad overall design
P215	S51	Problem Solving	How can students or other people be instructed to gain problem solving competencies?
P216	S15, S50	Prototyping	You cannot clarify an image of what you will create
P217	S51	Provide personal identity information	"People are not or very sporadic collaborating due to a lack of trust and lack of a mental image of other people they ought to be collaborating with. Analysis"
P218	S12	Provoke for High Quality	Learners are not passionate about their creation
P219	S50	Quantity brings Quality	It is difficult to deepen your understanding
P220	S38	Question Boomerang (variation of Active Student)	If all answers are given by you, the students start to rely on you only. They don't recognize that they sometimes already know the answer to the question and stay more passive.
P221	S38	Question Parking Space (variation of Active Student)	Students often have questions that do not directly relate to the content or require a longer or very specific answer. Answering such a question immediately might disturb the flow of the lecture, but not answering them at all might result in an unsatisfied student.
P222	S50	Questioning Mind	You cannot find any obvious reasons for what you are doing.
P223	S39	Random Impulse	You are stuck within your current framework of ideas and methods.
P224	S36, S49	Real World Experience	A lot of concepts are too abstract for students to conceive their value. And even worse students often doubt the viability of these concepts. Assigned problems or lab projects help to make those abstract concepts more concrete. However restricting students to lab environments deprive them of exercising the issues in their rightful habitation – namely the work place.
P225	S49	Rearrangement	You consider teaching these new idea at the end of the course, because in order to understand these new ideas, it is often required to gain some prerequisite knowledge. However, you know that teaching these new ideas early on is essential, because by reflecting the state-of-the-art of the current evolution, they influence the general thinking about the subject matter.
P226	S49	Reduce Risk	You don't want your students to become primarily good exam takers as you have more to give them than that.
P227	S51	Redundancy Principle	Under which conditions is it adequate to present audio and text in a redundant way?

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Pattern ID	Study ID	Pattern name	Problem
P228	S35, S49	Reflection	Sometimes, learners believe that the trainer has to deliver all the knowledge, but the students themselves are knowledgeable. Furthermore, students often anticipate that an instructor will solve each and every problem for them, but the knowledge of the instructor is also limited. You want students to trust their own competency rather than just letting them accept what they have learned by listening passively.
P229	S37	Reflection Cycle	Things you have been learning don't connect each other. You are apt to just make the notebook. You see the importance of reflecting, but it's also important to go on the next, so you usually put off reflecting later. You also feel it boring.
P230	S25	Regular Attention Recuperation	Students often find it hard to follow your lecture over a longer period. They fade away in their thoughts or start to do other things. Everything you tell or do at such moments is very likely to be fruitless.
P231	S41	Regularly Check Requirements Fulfillment	If the work products delivered on the date of the deadline are incomplete or not of sufficient quality regarding the defined requirements, then the grading of these products will be insufficient or low.
P232	S04	Reinforcement	Unable to determine comprehension through traditional methods, no immediate feedback available and the material may be difficult to understand
P233	S38	Remote Hand (variation of Active Student)	Presenting the tool all by yourself places the students in a consuming role. Yet it takes too much time and causes disorder to let different students try out the tool in front of the class so that everyone can see or understand what's going on.
P234	S17	Remote Testing	Difficulty to teach students how to delegate the test to a remote team
P235	S49	Repeat Yourself	Things heard only once are more likely to be forgotten.
P236	S01	Restructuration	Teaching concepts and methodologies outdated
P237	S27	Right People for Right Problems	For an ambitious service learning project to be successful, it is essential that the students involved have a motivation to participate.
P238	S35, S49	Role Play	The complexity of some concepts makes them hard to understand with only abstract explanations. Furthermore, difficulties in understanding complex concepts may frustrate the students. You not only would like to provide a positive learning environment, so even learning complex topics might be fun, but you also want to take into account that different people learn things best using different sensory modalities. Most teaching styles respect the auditories, a few the visuals, and even fewer the kinesthetics.
P239	S49	Round and Deep	Experienced students will relate a new concept to their own real-world experiences, and will form a deep understanding of it, but if their experience does not validate the concept, then its significance may be lost, and if their experience does validate the concept then although understanding may appear deep, it may also be narrow.
P240	S49	Round Robin	You want to get everyone's participation and input and you especially want to encourage the quieter members to take a more active role.

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Pattern ID	Study ID	Pattern name	Problem
P241	S49	See Before Hear	Learners often find it difficult to convert what they've heard in the classroom into skills they can use outside the classroom. They will remember less of what they hear than what they see and experience. However, in the typical and quite practical classroom lecture format, instructors are often heard saying such things such a "<this> is what will happen when you do <this>". But, a "hear before see" approach is quite abstract, and can make it difficult for the learner to later make use of the concepts in the lecture.
P242	S46	Seek and Inspire	How to gather and share resources from multiple sources so that everyone in the design team can contribute ideas, review and evaluate ideas of others and be inspired by them without information overload.
P243	S49	Self Test	If your students don't understand what you have presented, they have a poor basis for moving forward. If you don't understand what they really know, you have a poor basis for designing the next part of the course.
P244	S50	Self-Producer	It is difficult to design your career despite your attempts.
P245	S50	Serendipitous Encounters	There are few opportunities to meet people with similar interests as you.
P246	S49	Set The Stage	Topics may run together and students may miss important connections and may get confused by too much detail.
P247	S47	Share Expectations	Students might have different expectations of the results and the way of working on the assignment. This often leads to conflicts or an inefficient way of working.
P248	S49	Shot Gun Seminar	A typical technique to broaden a group of learners' understanding of a field or topic is to have them research the topic and select one learner to report back to the group as a whole via a presentation. Often this results in a good presentation, but poor discussion, as only the presenter is fully motivated to do the research.
P249	S49	Shout It From The Rooftops	Many of your students consider themselves shy. You will recognize them in class as they seldom speak up, ask questions, or volunteer for visible tasks. You know, however, that they will need to assume more public personas if they are to be successful in the real world.
P250	S31	Show It Running	Slides are mainly static, using software is dynamic; thus slides are typically not well suited to capture the characteristics of software.
P251	S31	Show Programming	Programming is a unique interplay of static properties (at writing time) and dynamic properties (at execution time) that is hard to capture with slides; quite often, subtle variations can have major effects.

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Pattern ID	Study ID	Pattern name	Problem
P252	S45	Showing the Art of Creation	You feel the product hasn't reached a quality that is showable to a public audience. To motivate learners to improve the quality of the product and feel the connection with the society through the project style learning, it is very effective to show a public audience the product of the project. However, the learners don't know the quality level to aim for or how to get there since they have little experience in creating something to show to a wide audience. It is difficult for them to notice what points they should polish up more. Nevertheless, you as a teacher are afraid of taking away their chance to learn by themselves, if you tell what to do.
P253	S26	Simple Answer	The instructor is not getting immediate verbal feedback from the students during a lesson.
P254	S19	Simplicity Above Patterns (alias: Keep it Simple)	While learning patterns students want to show that they understand the patterns by implementing as many of them as possible and most often this adds unnecessary complexity without adding value
P255	S51	Social Learning	How can social learning be facilitated?
P256	S28	Soft scaffolding	How do you provide direction and support while maintaining the learners' freedom, autonomy and sense of self, as well as the teachers' flexibility to adapt?
P257	S49	Solution Before Abstraction	An abstract concept can become the basis for a large number of applications. However, it is hardly considered useful unless it is related to concrete experience.
P258	S09, S35, S44, S49	Spiral	Topics in a course are often interrelated and many different topics are required for students to have enough tools with which to solve interesting problems
P259	S41	Spread Tasks Appropriately	If you don't take the limitation of your group members in consideration while assigning the tasks, this could lead to decreased productivity or a missing opportunity to learn new knowledge.
P260	S41	Start Immediately	Procrastinating to work on the project will affect the total amount of work finished at the end, the quality of the project and possibly the grades.
P261	S42, S51	Student Assignments Management	How to create on-line assignments for students?
P262	S44, S49	Student Design Sprint	If we don't teach it then students will develop their own ad-hoc techniques that may reinforce bad habits. If you use a Spiral approach the elements of simple design should come in the first cycle.
P263	S49	Student Driven Lecture	Students will have questions from the previous lecture or their exercise work since the last lecture. If many students have the same questions you may need to spend more time on a given topic, but you need to know this to respond to it. You need a quick way to know all the questions so that you can choose how best to respond.
P264	S05	Student Extends	Students and instructors often find that the provided materials don't meet their needs
P265	S42, S51	Student group management	How should groups of students be created and managed, and how can projects be assigned to these groups?

Continued on next page

Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P266	S38	Student Miners (variation of Active Student)	Just presenting a new concept makes it hard for students to relate this new knowledge to their existing knowledge and keeps them in an undesired passive role.
P267	S49	Student Online Portfolios	Your students need feedback from others as well as yourself. They can get excellent feedback from their peers and others if you can make it easy to obtain. There isn't always an obvious way to make this happen.
P268	S49	Student Selected Activities	Rigid grading schemes increase risk and usually do not increase student creativity.
P269	S42, S51	Student tracking	How can the instructors track the students' progress while they interact with the LMS 's various features? How can the students be informed of what activities they have already performed in a course?
P270	S49	Students Decide	You want to take the participants' specific interests into account, but you are not completely sure about how to do this regarding the contents, the schedule, or the methodology. Sometimes it is impossible, to make decisions concerning course material and approach in advance, because the exact skills or interests of the participants are not known. If the students are more engaged in the process they may be more engaged in the material as well.
P271	S36, S49	Study Groups	Your best students may often be bored while the poorest struggle constantly. You want to foster teamwork and have each member of the team benefit from the experience.
P272	S42, S51	Study toolkit	How can the learners be assisted in studying the learning resources instead of being limited to reading simple HTML pages?
P273	S17	Subordinate Role	Difficulty to teach students how to delegate the implementation to the subordinate remote team
P274	S25	Suitable Content Selection	Lectures often do not fit the capabilities and interests of students, they are either boring or overwhelming. In both cases students won't remember much after the lecture, therefore it was of no value for them.
P275	S25	Suitable Delivery Form Selection	Lectures in which the content is presented in a flow of speech of the lecturer are a challenge for the students' span of attention. It is also of no value if a lot of information is presented in a way that the students find hard to understand or in a way that does not help them grasping the content.
P276	S51	Support choices by providing feedback on collaborative behaviour	Lifelong learners experience problems of information overload, missing information relevant for their choice and increasing "selection time" (time necessary to make a choice) while trying to select effective learning activities out of a large set of possibilities.
P277	S51	Support identifable types of communication	People don't understand eachother, there's a low group cohesion, people have different expectations and people have a feeling of talking along eachother while collaborating mainly text-based online.
P278	S24	Surprise Beginning	Even though all students are aware of the start of the lecture, some are still stuck in their old thoughts and have difficulties focusing their attention on the lecturer and the lecture.
P279	S42, S51	Synchronous collaborative learning	How to allow and facilitate learners and instructors to interact synchronously, collaborate and co-operate with peers?
P280	S49	Take A Risk	Your job is to educate the students. You don't have the option of not doing anything.

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P281	S50	Talking Thinker	Thinking alone often brings you to a dead end.
P282	S15, S50	Tangible Piles / Tangible Growth	It is not easy to keep yourself motivated to learn
P283	S36, S49	Teacher selects Teams	When left to choose teams themselves, students will tend to stick always with the same people. The are people, who are either the ones they like and know, or the ones, who are similar to them, in terms of gender, age, ethnic background, skill level etc. But sticking with the same people slows down the learning ratio, because there is neither a lot of controversy discussion going on, nor does this environment allow new ideas to come up. It is more advantageous and more realistic to have a mixture of people in one team.
P284	S49	Teacher's Language	Your speech should be easily understandable for all participants. If you are hard to follow, your students will close their minds or become distracted.
P285	S49	Team Teaching	Some topics are very broad and complex. These topics provide a real challenge if you want to cover all their aspects. Furthermore time limitation might make it harder for you to get knowledgable in the whole topic. Students, on the other hand sometimes have difficulties to get a holistic understanding of the topic if they are introduced to only one opinion on the subject matter.
P286	S35, S44, S49	Test Tube	When students encounter holes in their knowledge, we would like for them to seek out an answer. Unfortunately, students often resort immediately to the "easy fix" of asking an authority for the answer. We want students to ask questions, but sometimes they have available to them more effective ways to gain knowledge that they never consider.
P287	S45	The Challenging Point	If you repeat the same project conducted before, the reactions of the learners will not be new for you. When the same projects are repeated several times, you would come to be able to roughly predict what kinds of reactions the learners will show, what kinds of things the learners will stumble on, or what kinds of results will be gained. This will bring your facilitation skills of the project, but it will become hard to share the excitement of discovering something new with the learners. In addition, the learners will less feel the challenge for the project if they know that you already know the answer to everything. They feel the activity is not a creative project but only a project of a course of study.
P288	S50	The First-Draft-Halfway-Point	The initial draft is not suitable to be read by others.
P289	S51	The 'Motility' Model	How can motility be supported?
P290	S50	The Right Way	The wrong way will lead you away from your goal.
P291	S26	Think...Pair...Share	Students' focus is not on the lesson.
P292	S15, S50	Thinking in Action	It is difficult to get out of the situation when you are stuck
P293	S49	Three Bears	Finding such a solution requires that the learner have experience with many problems, balancing the demands of each in a particular solution. Until they have sufficient experience, they are likely to be unsuccessful finding the right balance.

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P294	S26	Three Stars and a Wish	You need a way to correct student errors and give feedback without causing your students to become defensive, disheartened, or angry.
P295	S44, S49	Tool Box	The typical intent of a course is that students benefit later from the knowledge the gained earlier in the course. But knowledge is not the only result of the learning effort. Groups Work or Real World Experience may also result in tools. However, these tools are seldom treated as helpers to foster successive learning.
P296	S10	Top-Down	How to introduce a concept that has a large number of subitems?
P297	S50	Tornado of Learning	Effective learning is not brought about by passively receiving information.
P298	S44, S49	Toy Box	Students often have no real concept of the breadth of application of computer science or of its basic theoretical underpinnings such as Turing Machines. Since we have to teach a lot of things, it is often difficult to give this breadth to the students if we want to give them the required depth of understanding.
P299	S50	Triangular Dig	It is difficult to develop your understanding of what you almost know.
P300	S49	Try It Yourself	Engagement/Feedback
P301	S26	Uninterrupted Listening	The teacher assumes what the student is going to say and interrupts, not allowing the student to complete his or her thought.
P302	S51	User Goals	What information should be considered as user goals in a user model that is to be used in an Adaptive Web-based Educational System (AWES)?
P303	S51	User Model Definition	What information should an Adaptive Hypermedia Educational System keep for the user in order to offer him/her the best possible learning experience?
P304	S51	User Model Initialisation	What is the minimum amount of information needed, to kick start the system? What kind of information and what amount is the user capable or willing to provide?
P305	S51	User Model Maintenance	During the course of interaction, many things about the user are changed, e.g. assumed user knowledge, usage data etc. Thus, the user model must be adapted to the new realities. After all, the first letter in AHES stands for Adaptive. How should the system capture those changes so as to maintain a good user model?
P306	S51	User Preferences	What information should be included as user preferences in a user model that is to be used in an Adaptive Web-based Educational System (AWES)?
P307	S29	Video lecture	Students want to follow a lecture with a teacher but have no (more) physical access to the teacher.
P308	S49	War Game	There is no substitute for learning-by-doing. But the traditional classroom or laboratory-based environment is an alien environment for "realistic" problem-solving; especially where issues of scale and/or distribution are involved or when social contexts (such as office politics) are important.
P309	S37	Wide and Deep	When you find just an answer to a question, you can't think about the theme deeply. It's not good to take a note about what you learned only in the class, because your studies don't spread. However, when you search about words concerning the matter, it's hard to stop searching.

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Table 6 – *Continued from previous page*

Pattern ID	Study ID	Pattern name	Problem
P310	S49	Wider Perspective	Even though such realities as economic conditions, human behavior, and organizational politics will affect how students in technical disciplines will be able to do their jobs, they are rarely given an appreciation for these issues. This can give students the impression that expertise in technical topics is all they need to be successful in the workplace. In addition, it will not adequately prepare students to take on a managerial role.
P311	S36	Write Over Read	Reading is more passive than writing. Professionals in computer science create things. They write. They write programs and more than programs. Students, on the other hand, seldom like to write, though they may like to program. Students need to practice writing, both because it is a useful skill and because it forces them to be engaged with the ideas.
P312	S46	Writing on the Wall	How to share ideas and resources and engage with the wider community when materials are in the early stages of design allowing others to contribute to the shaping of the learning?

Source: Research data.

Chart 10 shows the way the selected studies were categorized regarding research type. We can notice that 94.12% of the studies are *Solution Proposal* and the remainder are *Experience Paper* and *Opinion Paper*. No *Validation Research*, *Evaluation Research* or *Philosophical Papers* were found, which means although authors propose several patterns, they lack validation and evaluation.

Chart 10 – Research Type Distribution

Research type	Number	Studies
Experience Papers	1	S33
Opinion Papers	2	S01, S03
Solution Proposal	48	S02, S04, S05, S06, S07, S08, S09, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S28, S29, S30, S31, S32, S34, S35, S36, S37, S38, S39, S40, S41, S42, S43, S44, S45, S46, S47, S48, S49, S50, S51

Source: Research data.

Chart 11 shows the way the 312 patterns extracted from the studies were categorized regarding pedagogical application. Categories, as *Educational activities* (15.71%), *Teaching and learning processes* (13.46%), *Feedback* (10.26%), *Collaboration* (9.94%), *Engagement* (8.01%) and *Motivation* (7.69%) are highlighted, which reflect the reality of the major difficulties in teaching environments relate to both teacher and learner.

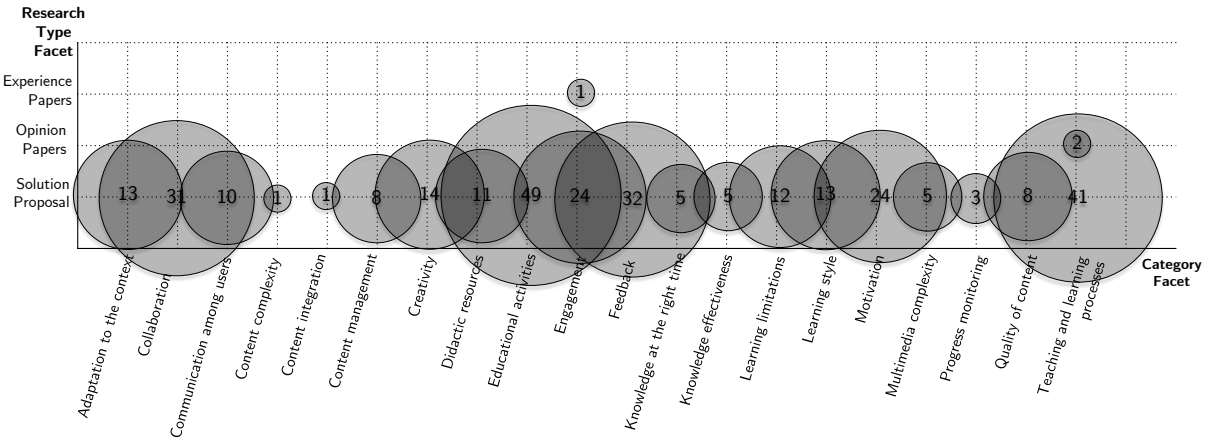
Chart 11 – Distribution of Patterns into Categories

Category	**Number**	**Patterns**
Adaptation to the context	13	P35, P36, P37, P45, P52, P128, P204, P205, P302, P303, P304, P305, P306
Collaboration	31	P10, P11, P33, P51, P62, P63, P64, P73, P87, P92, P95, P97, P104, P117, P126, P141, P145, P161, P164, P190, P192, P217, P239, P240, P242, P245, P247, P271, P279, P285, P312
Communication among users	10	P69, P113, P123, P137, P170, P176, P181, P211, P277, P301
Content complexity	1	P154
Content integration	1	P39
Content management	8	P46, P67, P98, P122, P165, P261, P265, P307
Creativity	14	P13, P15, P19, P27, P47, P48, P114, P149, P171, P180, P193, P223, P252, P287
Didactic resources	11	P07, P25, P30, P103, P105, P143, P175, P196, P250, P256, P272
Educational activities	49	P08, P20, P26, P32, P49, P50, P65, P85, P86, P90, P93, P94, P107, P121, P129, P140, P163, P172, P177, P178, P183, P184, P186, P194, P199, P203, P216, P219, P222, P224, P225, P229, P231, P241, P244, P257, P259, P260, P263, P280, P281, P288, P292, P295, P298, P299, P308, P309, P310
Engagement	25	P06, P24, P29, P31, P60, P78, P89, P100, P110, P127, P146, P210, P230, P233, P248, P249, P266, P268, P270, P278, P284, P286, P291, P300, P311
Feedback	32	P05, P09, P53, P55, P59, P66, P71, P80, P81, P82, P83, P84, P101, P111, P116, P120, P131, P132, P173, P174, P187, P195, P201, P202, P207, P226, P243, P253, P267, P276, P290, P294
Knowledge at the right time	5	P03, P40, P42, P76, P106
Knowledge effectiveness	5	P38, P134, P212, P235, P258
Learning limitations	12	P43, P75, P88, P109, P138, P169, P189, P198, P214, P234, P273, P293
Learning style	13	P18, P57, P58, P77, P91, P139, P155, P158, P182, P206, P228, P238, P283
Motivation	24	P04, P14, P17, P23, P72, P74, P99, P102, P130, P142, P144, P156, P159, P162, P168, P200, P209, P218, P220, P221, P237, P251, P254, P282
Multimedia complexity	5	P41, P112, P166, P179, P227
Progress monitoring	3	P136, P213, P269
Quality of content	8	P16, P61, P124, P274, P28, P96, P188, P264
Teaching and learning processes	42	P01, P02, P12, P21, P22, P34, P44, P54, P56, P68, P70, P79, P108, P115, P118, P119, P125, P133, P135, P147, P148, P150, P151, P152, P153, P157, P160, P167, P185, P191, P197, P208, P215, P232, P236, P246, P255, P262, P275, P289, P296, P297

Source: Research data.

Finally, Figure 19 shows a bubble chart with the distribution of 312 patterns extracted from 51 studies, based on *Research type* (Y axis), related to *Category* (X axis). The size of the bubble represents the number of studies, shown inside the bubble.

Figure 19 – Systematic Map



Source: Research data.

The distribution of studies among research types suggests a gap concerning the use, validation and evaluation of pedagogical patterns. A higher concentration is observed in the solution proposals, as already discussed, which suggests a lack of investigations on the validation of the use of pedagogical patterns. Figure 19 also shows a variation in the distribution of studies among the various categories. For example, *Educational activities*, *Teaching and learning processes*, *Feedback*, *Collaboration*, *Engagement* and *Motivation* show a higher concentration of studies (i.e., approx. 57% of the papers tackle such categories) which may suggest such categories represent the main challenges in the educational setting.

3.3.7 Threats to Validity

Although systematic mappings are more accurate than other approaches, there are some threats to their validity. Regarding *studies identification*, the main threat is the automatic search may not have collected all relevant primary studies, i.e., the search string was not as inclusive as necessary or the digital libraries considered did not include all relevant venues. To mitigate this risk, twofold approach was adopted: (i) a manual search was included in the proceedings of the main publishers in the topic; and (ii) a wide search string was defned, so that the search results were as inclusive as possible, although many papers had been returned.

However, this approach caused a side effect. The *low rate of selected studies*: only 0.69% of the studies extracted from the database had meaningful information, because the terms used to define our search string are also terms used in several other areas.

For instance, *learning patterns* can also refer to an Artificial Intelligence technique, more specifically in the machine learning domain, or to cognitive styles that are "the characteristic behaviours of learners that serve as relatively stable indicators of how they perceive, interact with, and respond to the learning environment" (WANG *et al.*, 2001).

Finally, to mitigate *reproducibility* threats, the steps of our study were clearly stated in our protocol and can be reproduced by other researchers. However, we understand the reproduction of the SMS by other researchers may lead to slightly different sets of primary studies due to biases, e.g., the application of the inclusion and exclusion criteria, or even databases updates may lead to a different set of primary studies to be analyzed. This threat was mitigated to some extent through a comprehensive documentation of challenges faced and decisions made upon them. Despite some potential minor differences, we believe the results and observations would be predominantly similar in replication studies.

3.4 MLearning-PL Creation

Step 3 of the pattern language creation process regards the partitioning of the domain model into an initial list of candidate patterns. After we adapted *ReqML-Catalog* (SOAD *et al.*, 2017) to our needs, in Step 1, three main characteristics and 23 subcharacteristics related to pedagogical requirements for mobile learning applications were obtained. Moreover, in Step 2, 312 different pedagogical patterns were obtained. Given the large number of patterns of the pedagogical dimension that should be considered so that the pattern language covers the whole domain, we chose to focus on a sub-domain.

According to several authors (LONSDALE *et al.*, 2005; COSTABILE *et al.*, 2008; SKIBA, 2011), distraction is one of the most important problems in m-learning. While mobile devices can be considered an important learning tool, they can also be considered a distraction source, due to their several possibilities over the Internet. Therefore, the learners' attention must be captured and they must be motivated and engaged in the learning experience in a didactically correct way.

The analysis of the studies obtained in Step 2 revealed some aspects already extensively investigated in other pattern languages, such as *Collaboration*, *Educational Activities*, *Teaching and learning processes*, and so forth.

Considering this scenario, we started the creation of `MLearning-PL` addressing some strongly interrelated aspects, namely *Engagement*, *Motivation*, *Learning style* and *Knowledge effectiveness* and narrowed our initial list of candidate patterns from 312 to 67 patterns. As shown in Chart 11, 24 patterns regarded *Motivation*, 25 regarded *Engagement*, 13 addressed *Learning Style*, and 5 focused on *Knowledge Effectiveness*.

The idea is to provide support to elicit requirements which address motivation and engagement issues, but also considering that each learner is an individual and has his/her own learning style that must be taken into account to effectively acquire knowledge. The analysis of the 67 patterns revealed if they fitted the mobile learning context.

Then, we proceed to Steps 4 and 5 of the pattern language creation process, which are concerned with patterns writing and graph creation. Regarding the patterns writing, pattern format was established, since our patterns are variants of other already established patterns that were written in different formats.

Appleton (1997) suggests some essential elements that to be used in a pattern language (Section 2.2.2). Based on that, we adopted the format shown in Chart 12 to write the patterns variation of our pattern language. We opted for a more concise format organized in a table format for facilitating the readers' understanding.

Chart 12 – Pattern Template

ID	**Name**
Variant of	Name and Reference of the original pattern
Context	The preconditions under which the problem and its solution seem to recur, and for which the solution is desirable.
Problem	A statement of the problem which describes its intent: the goals and objectives it wants to reach within the given context and forces.
Forces	A description of the relevant forces and constraints and how they interact/conflict with one another and with goals we wish to achieve (perhaps with some indication of their priorities).
Solution	Rules describing how to accomplish the desired outcome. This is often equivalent to giving instructions which describe how to construct the necessary work products.
Known Uses	A description of known occurrences of the pattern and its application within existing systems.
Resulting Context	A description of which forces have been resolved, which ones remain unresolved.
Related Patterns	Relationships between this pattern and others within the same pattern language.

Source: Elaborated by the author.

During the analysis of each pattern chosen for `MLearning-PL`, a variant was written and the relationships among them were captured. After the final choice of the patterns to compose the language, a graph (Figure 20) was created to show the way the patterns relate to each other within the pattern language.

3.4.1 MLearning-PL: Overview

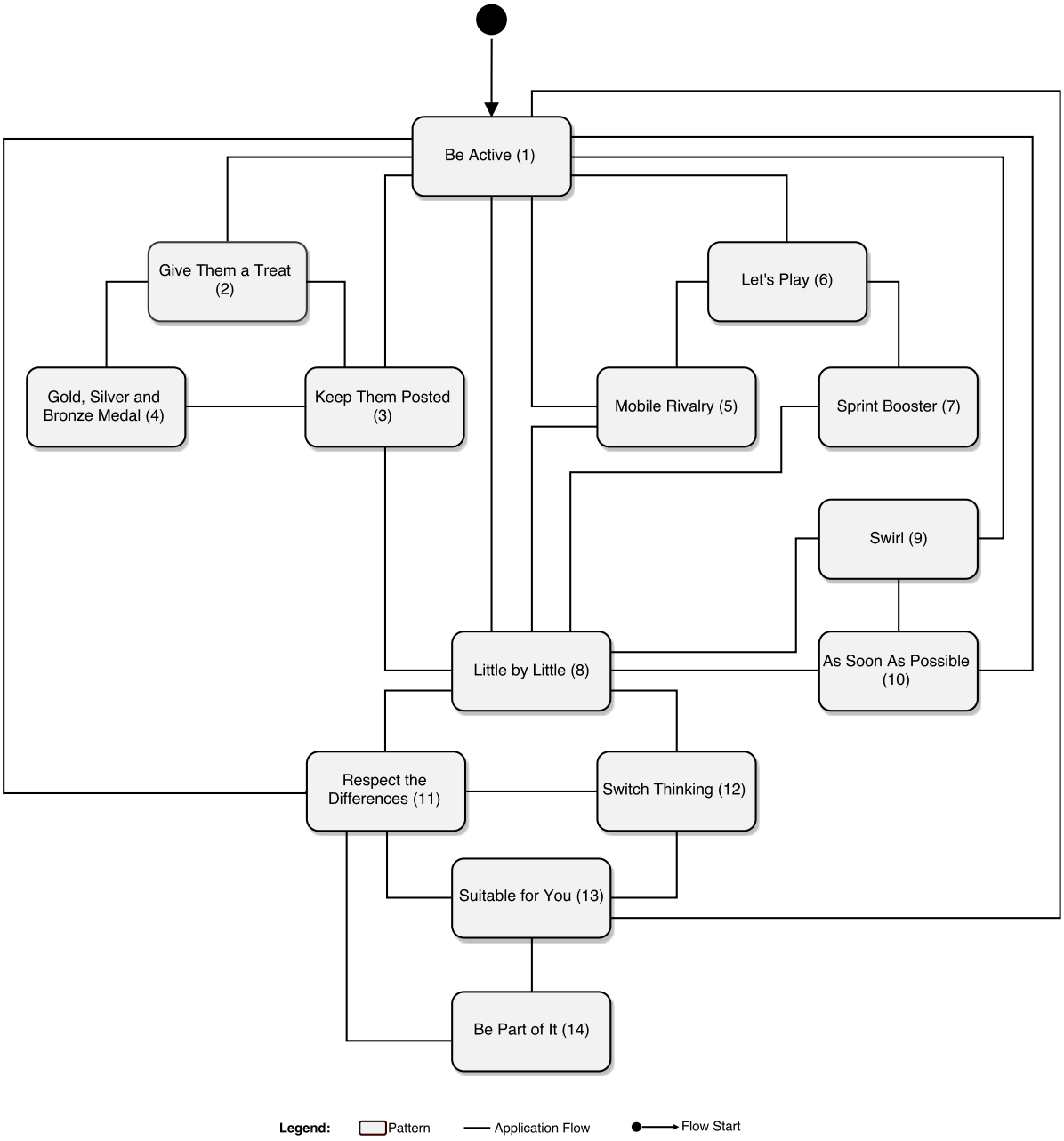
In this section, we present `MLearning-PL`, a pedagogical pattern language for mobile learning applications, to assist in the definition of mobile applications for keeping learners motivated and committed to using such applications, according to their different learning styles and an effective knowledge acquisition. `MLearning-PL` comprises 14 patterns, related as shown in Figure 20.

The main audience of `MLearning-PL` is novice educators who occasionally must play a requirements analyst role in a mobile learning application project. Those educators can be benefited from `MLearning-PL`, once they can reuse pedagogical knowledge from senior educators.

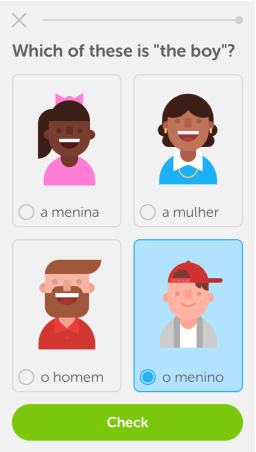
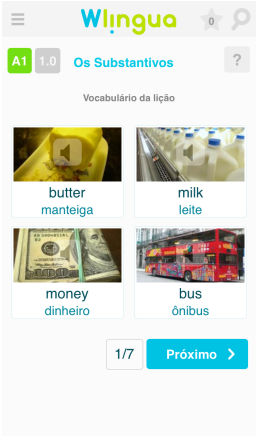
To the best of our knowledge, no initiatives for the use of patterns to address the pedagogical issues in the context of mobile learning applications have been developed (FIORAVANTI *et al.*, 2015). Therefore, `MLearning-PL` is a step forward towards bridging such a gap.

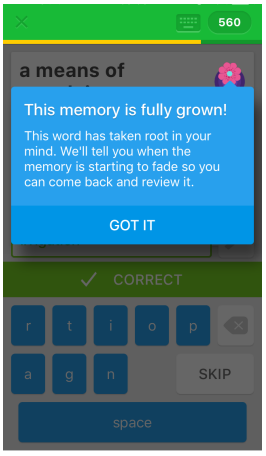
Next, we present `MLearning-PL` graph (Figure 20), which shows the relationship among the patterns, and each one of the patterns that `MLearning-PL` comprises.

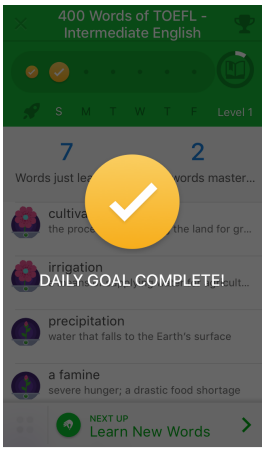
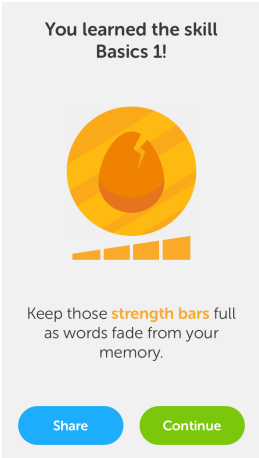
Figure 20 – MLearning-PL Graph

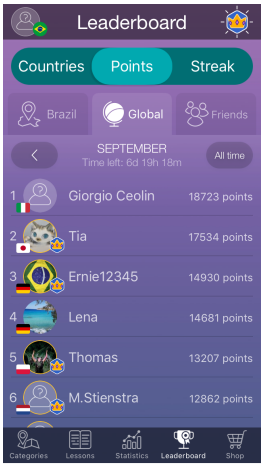
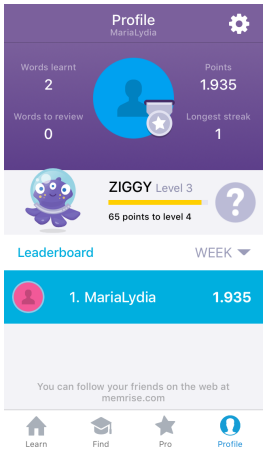


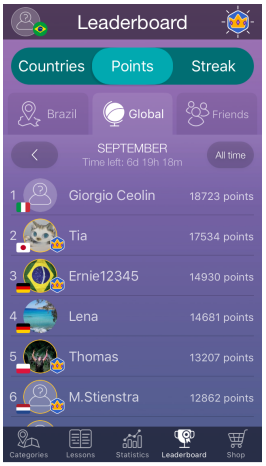
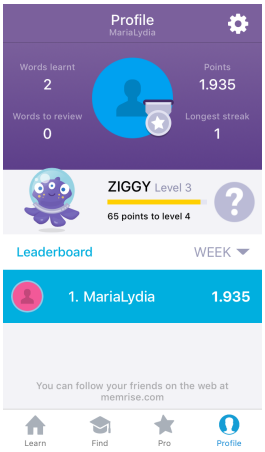
Source: Elaborated by the author.

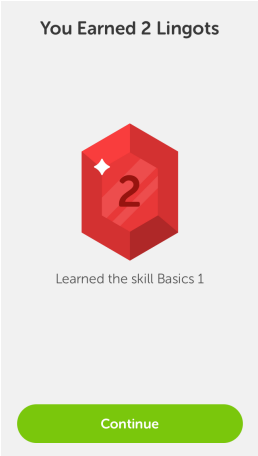
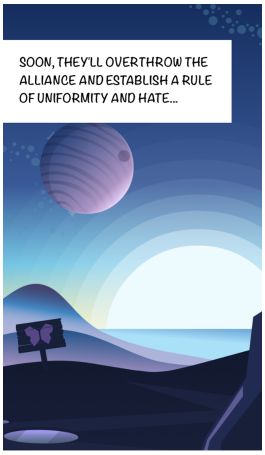
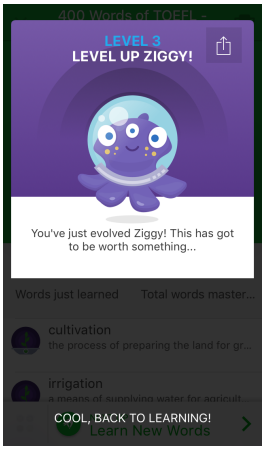
1	**Be Active**
Variant of	Active Student (BERGIN *et al.*, 2012)
Context	You want to maximize student learning.
Problem	The deep consequences of a theory are unlikely to be obvious to one who reads about, or hears about the theory. The unexpected difficulties inherent in using the theory or applying the ideas are not likely to be apparent until the theory is actually used.
Forces	• Passive learners don't learn much. • If learners read to explanations, without themselves becoming engaged, what is learned is unlikely to go into long-term memory. • If the learners don't actively engage the material, they won't retain it. They need to write and they need to do.
Solution	Keep the learners active. They should be active in the app, either with questions or with exercises.
Known Uses	The known uses show questions and exercises provided by *Duolingo* and *Wlingua* to keep the learner active in the app.  Duolingo  Wlingua  Wlingua
Resulting Context	A learner who stays active, performing several activities, retains better the content taught.
Related Patterns	You can use different strategies to keep the learner active: you can *Keep Them Posted* about their accomplishments, *Give Them a Treat* every time they reach a goal or promote collaborative activities (*Let's Play* and *Mobile Rivalry*). You should consider introduce the content *Little by Little* and *Respect the Differences* among the learners, providing exercises of different difficulty levels, different approaches (*Suitable for You*). Also, present the content *As Soon As Possible* and introduce new topics so the learner can solve meaningful problems first (*Swirl*).

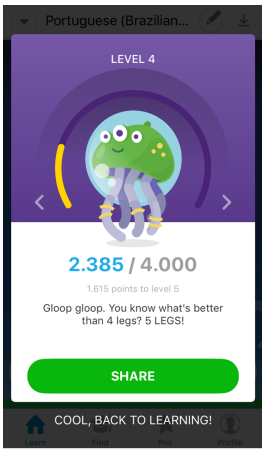
2	**Give Them a Treat**
Variant of	Chain of Excitement (IBA *et al.*, 2014)
Context	The learners have made some learning progress, and perhaps they think they've almost achieved their initial goal.
Problem	It is not easy to actively continue exploring and studying.
Forces	• It is difficult to continue working intensely on tedious tasks. • It is easy to be impressed not only by the beauty of arts and nature but also by intellectual excitement. • Intellectual excitement and academic experiences motivate you to study.
Solution	Make the learners feel the strong emotion of accomplishment by giving them some reward in the app, like a score or a customized message, which will motivate their learning.
Known Uses	In the first known use, *Duolingo* rewards the learner with reinforcement messages. In the second known use, *Duolingo* gives the learner some points as reward. In the third known use, *Memrise* also shows a customized message to motivate the learner.  Duolingo  Duolingo  Memrise
Resulting Context	The learner will feel accomplished by fulfilling the activities and getting rewards.
Related Patterns	You should *Keep Them Posted* about the accomplishments for the learner to *Be Active* in the app. Giving the learners a *Gold, Silver and Bronze Medal* can also engage them in the learning app.

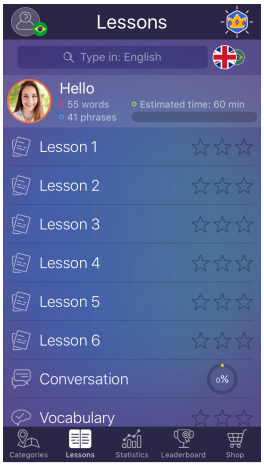
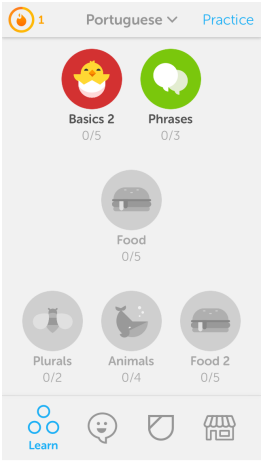
3	**Keep Them Posted**
Variant of	Tangible Growth (IBA *et al.*, 2014)
Context	The learners need to continue practicing the activities to achieve their goal.
Problem	It is not easy to keep the learner motivated to learn.
Forces	• It takes a long time before they realize the effect of learning. • It is difficult to maintain their motivation to work hard.
Solution	Show the evolution of the learners at each advanced stage, so they can realize how their knowledge and skills have grown.
Known Uses	The known uses show different kinds of messages provided by the apps. *Mondly* shows a daily progress and also a weekly one. *Memrise* let the learner know when he/she completed the daily goal. *Duolingo* shows which skills the learner has completely learned.  Mondly  Memrise  Duolingo
Resulting Context	The learner will feel accomplished and motivated to remain in the course
Related Patterns	Giving the learners a *Gold, Silver and Bronze Medal* can engage them in the learning app, but you can also *Give Them a Treat* when they accomplish some goal for the learner to *Be Active* in the app and *Little by Little* learn the whole content.

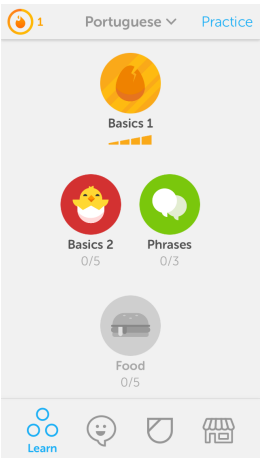
4	**Gold, Silver and Bronze Medal**
Variant of	Gold Star (BERGIN *et al.*, 2012)
Context	You want to encourage excellent work and to praise a learner for work well done.
Problem	Normally the reward structure is private. In grading you give the learner praise, but this loses the opportunity to show other learners what you value most highly.
Forces	• Learners want and need your praise. • Praise can be a prime motivator, and learners work best when they feel good about themselves and feel appreciated. • If other learners see what you value, they may be motivated to focus on these things too.
Solution	When a learner is doing well, or has done something well, praise them publicly for it, by giving them some reward that is shown to all learners.
Known Uses	Both known uses show how the apps *Mondly* and *Memrise* promote an award environment by means of a leaderboard.  Mondly  Memrise
Resulting Context	The learner remains engaged to maintain his good position on the leaderboard or to improve it.
Related Patterns	To keep learners engaged, you should *Keem Them Posted* about the accomplishments and *Give Them a Treat* when they accomplish some goal.

5	**Mobile Rivalry**
Variant of	Good Rivals (IBA *et al.*, 2014)
Context	The learners realized that they need to spend considerable time on achieving their goal.
Problem	It is difficult to maintain efforts alone.
Forces	• Motivation decreases if others don't recognize their effort. • A person who does his/her best touches other's hearts. • It is difficult to keep working on a task when your attempts seem futile.
Solution	Promote some collaborative activities among learners where they compete against each other.
Known Uses	The known uses show leaderboards of *Mondly* and *Memrise* apps as a way to promote the competition among learners.  Mondly  Memrise
Resulting Context	A learner who is immersed in a competitive environment becomes more motivated to achieve the goals to win such competition.
Related Patterns	You want the learner to *Be Active*, so you should consider to promote some fun activities (*Let's Play*) or help him/her to accelerate toward the next goal (*Sprint Booster*).

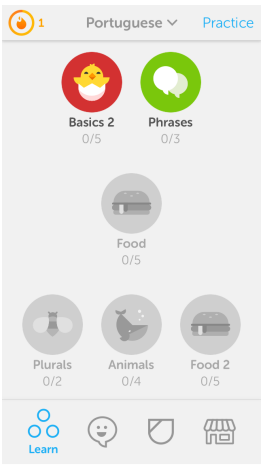
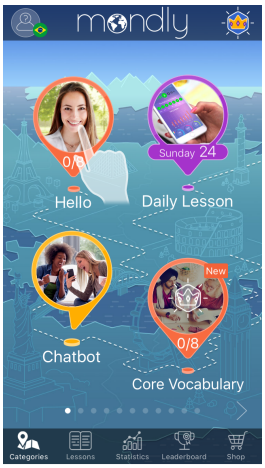
6	**Let's Play**
Variant of	Playful Learning (IBA *et al.*, 2014)
Context	The process of learning bores the learners.
Problem	Learning as a duty is ineffective and painful.
Forces	• It is difficult to continue tedious work. • It is difficult to maintain motivation for ineffective learning. • Necessity is the mother of learning.
Solution	Add games elements to their learning process to make learning fun.
Known Uses	In the first known use, *Duolingo* shows the rewards stimulus. In the second known use, *Memrise* presents some storytelling. In the third known use, *Memrise* levels up the learner.  Duolingo  Memrise  Memrise
Resulting Context	The learner considers the use of the application as a fun and not an duty, which motivates him/her to continue the use.
Related Patterns	You want the learner to *Be Active*, so you should consider to promote some *Mobile Rivalry* or help him/her to accelerate toward the next goal (*Sprint Booster*).

7	**Sprint Booster**
Variant of	Acceleration to Next (IBA *et al.*, 2014)
Context	You have almost achieved your goal.
Problem	Your motivation is faltering even though the goal is within reach.
Forces	• Just before achieving the goal, motivation tends to decrease. • The process of finally finishing your work is always difficult. • Pursuing the goal forces you into more energetic activity.
Solution	Provide small activities that allow the learner to set and accelerate toward the next goal to pass through de current goal without slowing down.
Known Uses	The known uses of *Duolingo* and *Memrise* apps present the strategy to show progress towards the ultimate goal.  Duolingo  Memrise
Resulting Context	The learner who follows his/her progress up and knows that he/she needs little to achieve the goal, becomes more motivated to finish his/her tasks.
Related Patterns	You should also consider to promote some collaborative activities among learners to have fun together (*Let's Play*) or activities where they compete against each other (*Mobile Rivalry*).

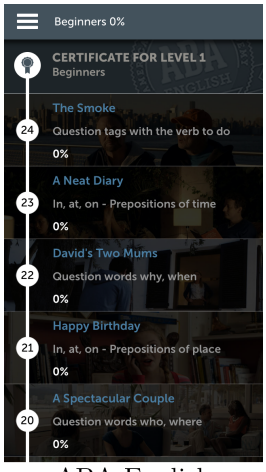
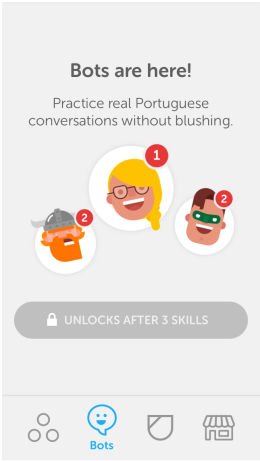
8	**Little by Little**
Variant of	Digestible Packets (BERGIN *et al.*, 2012)
Context	You want to avoid the situation of learners becoming bored and disinterested.
Problem	If a topic takes longer than the time learners can concentrate, the learners will have difficulties understanding the topic in its entirety.
Forces	• Learners can only concentrate for a limited period of time. This is the primary reason to include regular breaks. • Due comprehension decrease, the motivation will decrease, too, and the activity will be considered difficult.
Solution	Organize the app activities in such a way that the topics remain small and understandable.
Known Uses	The known uses extracted from *Mondly* and *Duolingo* show that the course is organized in small topics.  Mondly  Duolingo
Resulting Context	If the topic is small, the learner finishes it more quickly and is not discouraged to proceed to the next.
Related Patterns	You want the learners to *Be Active* in the learning app. To achieve this goal, you can use different strategies: you can *Keep Them Posted* about their accomplishments or promote collaborative activities (*Mobile Rivalry*). If you *Respect the Differences* of the learners and promote *Switch Thinking*, they will become more motivated to use the app. Present the content *As Soon As Possible* and introduce new topics so the learner can solve meaningful problems first *Swirl*. If the learner is still not motivated, help him/her to accelerate toward the next goal (*Sprint Booster*).

9	**Swirl**
Variant of	Spiral (BERGIN *et al.*, 2012)
Context	You want to enable students to solve meaningful problems as early in the course as possible.
Problem	Topics in a course are often interrelated. Too often, many different topics are required for learners to have enough tools with which to solve interesting problems. If we try to do the topics in any logical order we tend to get bogged down in details and leave the learners bored. Learners learn best when they are doing things, and meaningful problems motivate them to work harder.
Forces	• If we try to do the topics in any logical order we tend to get bogged down in details and leave the learners bored. • Learners learn best when they are doing things, and meaningful problems motivate them to work harder.
Solution	Organize the app activities to introduce topics to learners without covering them completely at first viewing so that a number of topics can be introduced early and then used. In the first cycle make each topic introduction as simple as possible without leaving out essential details. Cover several topics quickly. This can get learners working on interesting problems earlier as they have more tools to use, though they have not, perhaps, mastered any of the tools. The instructor can then return to each topic in turn, perhaps repeatedly, giving more of the information needed to master them.
Known Uses	The known uses show how the apps *Duolingo* and *Mondly* organize their activities about a topic in stages.  Duolingo  Mondly  Mondly
Resulting Context	If you do not present the whole topic at once, the learner will be engaged in the course to finish learning about this topic.

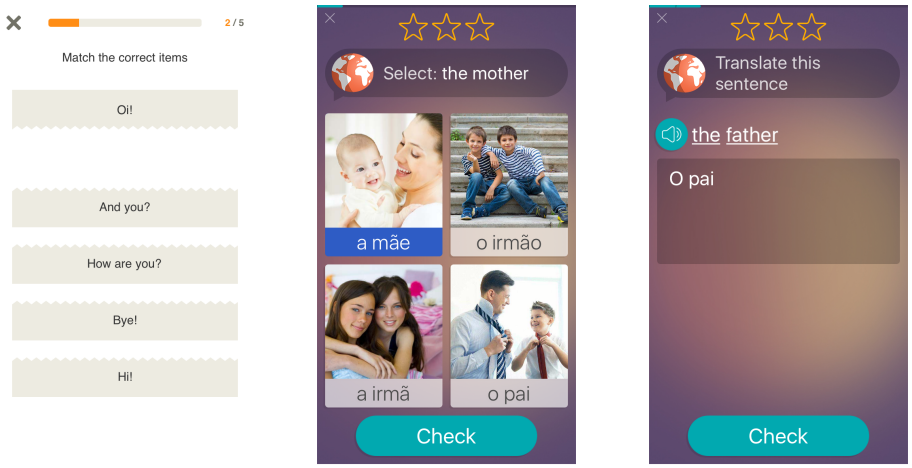
Related Patterns	*Little by Little* you should introduce new topics so the learner can solve more important problems *As Soon As Possible* and *Be Active* in the app.

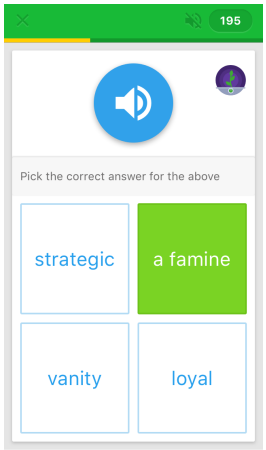
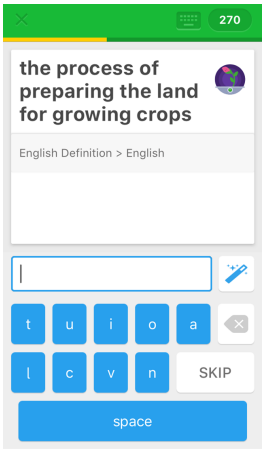
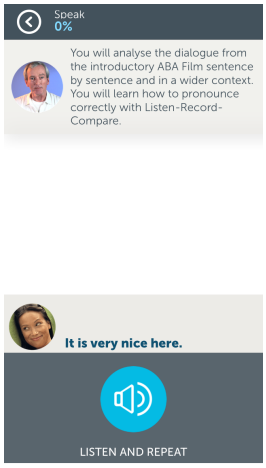
10	**As Soon As Possible**
Variant of	Early Bird (BERGIN *et al.*, 2012)
Context	You want to ensure that your learners remember (at least) the most important ideas.
Problem	Learners have difficulties sometimes distinguishing between the important and the unimportant ideas. However, learners often remember best what they learn first.
Forces	• You have to mine the course for its most important ideas. • These ideas become the fundamental organizational principle of the course. • Learners can be made more aware of what is paramount. • If important topics are left to the end, there may not be enough time to relate them to the content already seen. Still, there may not be enough time to focus on the most important content.
Solution	The ideas, and especially their relationships should be introduced at the beginning of the course and are returned to repeatedly throughout the course. This way the most important things in the course receive more focus from the instructor and the learners. Organize the activities in the app so that the most important topics are taught first. Teach the most important material, the "big ideas", first. When this seems impossible, teach the most important material as early as possible.
Known Uses	The known uses show that *Duolingo* and *Mondly* apps put the most important topics at the beginning of the course.  Duolingo  Mondly

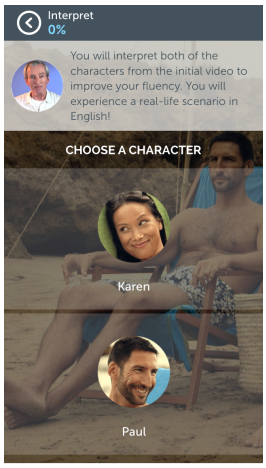
Resulting Context	If the most important content is taught to the learner soon, he will probably understand that content more easily.
Related Patterns	*Little by Little* you should introduce new topics so the learner can solve meaningful problems first *Swirl* and *Be Active* in the app.

11	**Respect the Differences**
Variant of	Different Exercise Levels (BERGIN *et al.*, 2012)
Context	You want learners to practice a newly acquired skill through some exercises, but learners have different levels of ability and you want to challenge each of them.
Problem	To improve learners' skills, the exercise must be located at the upper limit of the participant's current skill level, but this will be different for each participant.
Forces	• The most important aspect of exercises is to allow the learners to improve their newly acquired skills by working on a topic on their own. • If everyone is given the same exercise, then some learners will find it overly simple, and do not learn anything, while others consider the exercise too difficult, are frustrated because they can't do it, and do not learn anything.
Solution	Provide exercises of different difficulty levels, different approaches and different topics to each learner, according to his/her learning style and limitations.
Known Uses	In the first known use, *ABA English* shows how the lessons are divided by levels. In the second known use, *Mondly* uses different real-world situations to get the learner's attentions. In the third known use, *Duolingo* provides bots to support students ashamed of practicing their speaking skills.  ABA English  Mondly  Duolingo
Resulting Context	By considering different levels and interests, the learners tend to be more interested in the application.

Related Patterns	In order for the learner to go through the levels more easily, you can present the content *Little by Little*. You could acknowledge the needs of the kinesthetics by using *Be Part of It*, simulations, or games as possible actions. You can also provide exercises of different difficulty levels, different approaches (*Suitable for You*), different topics to *Switch Thinking*.

12	**Switch Thinking**
Variant of	Brain Switch (IBA *et al.*, 2014)
Context	You are creating an output, and you've made some progress.
Problem	Logical thinking is not sufficient to achieve a breakthrough without intuitive thinking and vice-versa.
Forces	• Logical thinking promotes acute analysis, inference, and persuasion. • Intuitive thinking inspires good ideas, expressions, and impression. • It is difficult to be logical and intuitive simultaneously.
Solution	Provide activities in the app that switch learners' thinking between two modes of logical and intuitive thinking.
Known Uses	In the first known use, *Babbel* introduces an intuitive exercise. In the second known use, *Mondly* presents an exercise of logical thinking. In the third known use, *Mondly* shows an intuitive exercise.  Babbel Mondly Mondly
Resulting Context	Alternating the types of exercises, the learner will not feel tired.
Related Patterns	*Little by Little*, you should provide exercises of different difficulty levels, different approaches (*Suitable for You*) to *Respect the Differences*.

13	**Suitable for You**
Variant of	Different Approaches (BERGIN *et al.*, 2012)
Context	You are teaching students with different backgrounds and characteristics.
Problem	Every person obtains information differently, using different sensory modalities. Some people, the visuals, learn most effectively by watching; the auditories, by listening; and the kinesthetics, through action.
Forces	• Communication always takes place between a sender and a receiver, and the effectiveness of communication isn't measured by what the sender says, but by what the receiver understands. • Some people, the visuals, learn most effectively by watching; the auditories, by listening; and the kinesthetics, through action.
Solution	Provide different approaches and types of medias to the same topic, for instance, texts, videos, infographics, and so on. Accept different learning styles by addressing various sensory modalities. It might be difficult to provide different approaches for every single topic, but make sure to at least change the approach when you change the topic.
Known Uses	In the first known use, *Memrise* provides an activity that exercises the hearing. In the second known use, *Memrise* provides an activity that exercise the writing. In the third known use, *ABA English* provides a listening and speaking exercise.  Memrise  Memrise  ABA English
Resulting Context	By mixing several different approaches, it is more likely to keep most learners engaged.
Related Patterns	You could acknowledge the needs of the kinesthetics by using *Be Part of It*, simulations, or games as possible actions. You should also consider to apply different exercises to *Respect the Differences* and promote a *Switch Thinking*.

14	**Be Part of It**
Variant of	Role Play (BERGIN *et al.*, 2012)
Context	The app must consider the kinesthetic learners and provide kinesthetic learning and a bit of fun for everyone.
Problem	Most teaching styles respect the auditories, a few the visuals, and even fewer the kinesthetics.
Forces	• The complexity of some concepts makes them hard to understand with only abstract explanations. • Difficulties in understanding complex concepts may frustrate the learners. • You not only would like to provide a positive learning environment, so even learning complex topics might be fun, but you also want to take into account that different people learn things best using different sensory modalities.
Solution	Invite the learners to behave as a part of the concept involved in a collaborative role play. Every learner plays one part of the concept to get a deeper knowledge of its underlying structure. Learners see how the different parts of the concepts are all working together to solve a bigger problem.
Known Uses	In the first known use, *Mondly* presents an activity in which the learner has to play a role in a conversation in a given context, for instance, at the restaurant. In the second known use, *ABA English* suggests you to interpret both characters of a conversation in order to improve the fluency.  Mondly  ABA English
Resulting Context	After getting engaged in role playing, kinesthetic learners should be more motivated to learn.
Related Patterns	If you want to take the different sensory modalities of your students more into account, you should also consider *Suitable for you*.

Contents of this section were presented in the paper entitled "*A Pedagogical Pattern Language for Mobile Learning Applications*", published in the Proceedings of 24th Conference on Pattern Languages of Programs (PLoP 2017) (FIORAVANTI; BARBOSA, 2017).

The current version of `MLearning-PL` was obtained after the executions of two experimental studies and the process of *shepherding* of PLoP conference (Chapter 4). Such feedbacks helped to improve and refine the pattern language. Previous versions can be found in Appendix A and Appendix B.

3.5 Final Remarks

This chapter presented `MLearning-PL`, a pedagogical pattern language for mobile learning applications. We discussed its use as a supporting mechanism to assist the requirements elicitation phase of mobile learning applications projects. The main idea is to provide support on pedagogical issues to help requirements analysts to elicit requirements aiming to avoid or diminish already known pedagogical problems, particularly regarding motivation, engagement, learning styles and knowledge effectiveness.

`MLearning-PL` differs from other pattern languages, particularly, because it was created and evaluated by means of a systematic process (Section 3.1). As discussed, `MLearning-PL` is comprised of 14 patterns, which were mined through a systematic mapping and rewritten as variants, considering the mobile learning scenario.

Due the large number of pedagogical patterns available in the literature, we opted out to focus on a sub-domain and, then, we narrowed down the list of candidate patterns from 312 to 67. To cover mobile learning aspects, we analyzed each of the 67 pedagogical patterns to decide whether they should be part of `MLearning-PL` or not. We also investigated the known uses in real mobile learning applications and included them in our pattern language.

The main contribution of this work is `MLearning-PL`.To the best of our knowledge, there was no pedagogical pattern language which addresses pedagogical issues in the context of mobile learning, so `MLearning-PL` is a step forward in this direction aiming to bridge this gap.

In the next chapter, we present two preliminary experimental studies conducted for the evaluation of `MLearning-PL`.

CHAPTER

4

MLearning-PL Evaluation

An experimental study investigates causal relations and processes (YIN, 2013). The identification of causal relations provides an explanation of *why* a phenomenon occurrs, while the identification of casual processes yields an account of *how* it occurrs (YIN, 2013). According to Easterbrook *et al.* (2008), an experimental study is an investigation of a testable hypothesis in which one or more independent variables are manipulated to measure their effect on one or more dependent variables. Experimental studies precisely determines the way variables are related and checks the existence of a cause-effect relationship between them. In other words, an experimental study represents an action towards discovering something unknown or testing a hypothesis involving the collection and analysis of data for providing meaning to the data obtained (BASILI *et al.*, 1999).

An experimental study can be whether an experiment or a quasi-experiment. Wohlin *et al.* (2012) defined experiment (or controlled experiment) in software engineering as an empirical enquiry that manipulates a factor or variable of the studied setting. Different treatments based on randomization are applied to or by different subjects, while other variables are kept constant, and the effects on outcome variables are measured. During an experimental study, subjects are assigned to different treatments randomly. The objective is the manipulation of one or more variables and control of all other variables at fixed levels. The effect of the manipulation is measured and then a statistical analysis can be performed. Quasi-experiments can be used when it is impossible to randomly assign treatments to subjects. According to Wohlin *et al.* (2012), a quasi-experiment is an empirical enquiry similar to an experiment, where the assignment of treatments to subjects cannot be based on randomization, but emerges from the characteristics of the subjects or the objects themselves.

A research method based on experimentation was chosen to evaluate `MLearning-PL` pattern language, particularly for the collection, manipulation and analysis of

the empirical data. A quasi-experiment was adopted for a more rigid control of the environment and a more rigorous manipulation of the phenomenon in study. Conducting an experimental study corresponds to Step 6 of the pattern language creation process, which is concerned with the evaluation of the pattern language.

This chapter describes two experimental studies involving the application of `MLearning-PL`. Both studies were conducted in an academic environment and followed the guidelines of Wohlin *et al.* (2012). The main idea was to evaluate the effectiveness and efficiency of `MLearning-PL`, in the context of mobile learning applications requirements elicitation, in comparison to an ad hoc approach. In Section 4.1, we summarize the planning phase of both experimental studies. In Section 4.2, we describe the first experimental study conducted. In Section 4.3, we describe the second experimental study conducted later on a refined version of `MLearning-PL`. We discuss threats to validity from both experimental and replication study in Section 4.4. In Section 4.5, we describe the validation performed by patterns experts. Final remarks are provided in Section 4.6.

4.1 Planning

In this section, we report the planning of the experimental studies regarding goals, hypotheses, variables and analysis procedure.

4.1.1 Goals

The global objective of both experimental studies was to evaluate `MLearning-PL` in relation to an ad hoc approach, i.e., no specific approach is used, but previous background. Thus, the object of study is `MLearning-PL`, our pedagogical pattern language.

The Goal/Question/Metric (GQM) method has been proposed to support the definition of quantifiable goals and interpretation of collected measurement data (BASILI, 1993). It is a goal-oriented approach to derive metrics from measurement goals to ensure the collected data are usable and serve a purpose. The scope of the experimental studies can be summarized by the GQM template, as follows:

Analyze `MLearning-PL`
For the purpose of Evaluation
With respect to its Effectiveness and Efficiency
From the point of view of the Requirements Analysts
In the context of Teachers and/or Tutors solving pedagogical problems

Effectiveness is defined as the degree to which something is successful in producing a desired result. In our experimental studies, it is related to whether `MLearning-PL` can successfully help the identification of solutions to pedagogical problems.

Efficiency concerns the quality or property of being efficient, i. e., producing at minimum waste and expense, or unnecessary effort. In our experimental studies, it is related to use of only the time necessary for solving the problems.

4.1.2 Hypotheses Formulation

Once the aim was the comparison of two different approaches for pedagogical problems solving, the research questions were formalized into the following hypotheses, so that statistical tests could be conducted:

RQ1. Does the use of `MLearning-PL` help analysts to provide better pedagogical solutions to m-learning problems?

- Null hypothesis: The effectiveness of `MLearning-PL` is lower than or equal to that of an ad hoc approach.
  $H1_0$: Effectiveness(`MLearning-PL`) $\leq$ Effectiveness (ad hoc)
- Alternative hypothesis: The effectiveness of `MLearning-PL` is higher than that of an ad hoc approach.
  $H1_a$: Effectiveness (`MLearning-PL`) $>$ Effectiveness (ad hoc)

RQ2. Does the use of `MLearning-PL` lead analysts to solve pedagogical problems faster?

- Null hypothesis: The efficiency of `MLearning-PL` is lower than or equal to that of an ad hoc approach.
  $H2_0$: Efficiency (`MLearning-PL`) $\leq$ Efficiency (ad hoc)
- Alternative hypothesis: The efficiency of `MLearning-PL` is higher than that of an ad hoc approach.
  $H2_a$: Efficiency (`MLearning-PL`) $>$ Efficiency (ad hoc)

4.1.3 Variables

Some aspects of the experimental studies were kept constant for both approaches used; the approach itself was the aspect that varied. Considering the constant aspects, i.e., the parameters of the experiment (JURISTO; MORENO, 2013), both groups had a minimum background in educational activities, they received a training about mobile learning and also solved the same activities.

An experimental study must be carefully designed or the drawing of meaningful conclusions. In our case, the design that best suited the experimental study was *one factor with two treatments*. The independent variable was the *problem resolution approach* and the two treatments applied were:

- *MLearning-PL*, when the subject had the pattern language to support the problem solving process; and
- *ad hoc*, when the subject had no further artifact to support the process, but only previous background.

The subjects' performance was evaluated according to two different aspects, which were the dependent variables, namely *effectiveness* and *efficiency*. Effectiveness was measured with three different metrics:

(i) *correctness* – average percentage of problems solved correctly, calculated as

$$\frac{\sum_{i=1}^{n} \frac{s_i}{m} 100}{n}$$

where

s_i is the number of problems solved by subject i;
m is the total number of problems to be solved; and
n is the number of subjects in the group.

(ii) *completeness* – average score of solutions' completeness, calculated as

$$\frac{\sum_{i=1}^{n} \frac{\sum_{p=1}^{m} x_i}{m}}{n}$$

where

x_i is the score of completeness;
p is the number of the problem;
m is the total number of problems to be solved; and
n is the number of subjects in the group.

The score of completeness for each solution is measured according to an adaptation of Degree of Closeness (DoC) Evaluation Criteria (MCCRACKEN *et al.*, 2001) shown in Chart 13:

(iii) *complexity* – average score of solutions' complexity, calculated as

$$\frac{\sum_{i=1}^{n} \frac{\sum_{p=1}^{m} x_i}{m}}{n}$$

where

x_i is the score of complexity;

Chart 13 – Degree of Completeness

Score	Interpretation
5	Touchdown. The solution is complete.
4	Close but something missing. The solution is satisfactory, but some details are missing.
3	Close but far away. The solution can be applied, but it is far from being complete.
2	Close but even farther away. The solution is not complete enough.
1	Not even close. The solution shows that the subject had no idea about how to solve the problem.

Source: Adapted from McCracken *et al.* (2001).

p is the number of the problem;
m is the total number of problems to be solved; and
n is the number of subjects in the group.

The score of complexity for each solution also follows an adaptation of Degree of Closeness (DoC) Evaluation Criteria (MCCRACKEN *et al.*, 2001) shown in Chart 14:

Chart 14 – Degree of Complexity

Score	Interpretation
5	Touchdown. The solution has a high degree of complexity.
4	Close but something missing. The solution has a medium degree of complexity.
3	Close but far away. The solution has a low degree of complexity.
2	Close but even farther away. The solution is simple.
1	Not even close. The solution shows that the subject had no idea about how to solve the problem.

Source: Adapted from McCracken *et al.* (2001).

Metric *efficiency* was then defined to be measured as the average time spent on the solving of all problems, calculated as

$$\frac{\sum_{i=1}^{n} x_i}{n}$$

where
x_i is the time spent on the solving of the problems by subject i and
n is the number of subjects in the group.

4.1.4 Analysis Procedure

The analysis procedure included both quantitative and qualitative components. Quantitative data were the first source for the testing of the hypotheses, whereas the qualitative

data were analyzed in order to complement the quantitative analysis, since a small sample of subjects was available.

Considering the quantitative analysis, univariate analyses of the dependent variables *Effectiveness* and *Efficiency* were performed to test the hypotheses. Mann-Whitney tests were performed for all dependent variables , with a level of significance set to $\alpha = 0.05$. In short, the Mann-Whitney test is a non-parametric test that compares two independent samples of the same size or unequal, whose scores are measured by, at least, an ordinal level (SIEGEL; CASTELLAN, 1988).

A qualitative analysis was also conducted, once it could potentially offer additional complementary evidences, and the *feedback form* was further analyzed for a better understanding of the subjects' experience.

4.1.5 Pilot Study and Training

Before conducting the final experimental studies, a pilot test was conducted with four subjects to validate the instruments (forms, activities, artifacts) and also to train the instructors.

At the beginning of each experimental study, a training was given to the subjects. The training to the subjects of the group assigned to use `MLearning-PL` consisted of 15 minutes of theoretical presentation on patterns, pedagogical patterns, pattern languages and a brief overview of `MLearning-PL`; and 5 minutes of theoretical presentation on mobile learning. The training to the subjects of group using an ad hoc approach consisted only of 5 minutes of theoretical presentation on mobile learning. At the end of the training, the subjects performed the experimental study tasks.

4.2 Experimental Study 1

In this section, we report how the first experimental study was designed and conducted. A lab package[1] containing more information and details on the experimental study was created and is available. A lab package describes an experiment providing materials for its replication, highlights opportunities for variation, and builds a context for combining results of different types of experimental treatments (GARCIA *et al.*, 2008).

This experimental study was conducted using the first version of `MLearning-PL` (Appendix A).

[1] <https://sites.google.com/usp.br/mlearning-pl/experimental-studies/experimental-study-1>

4.2.1 Experimental Subjects

As the experimental study aims to analyze the results from the point of view of requirements analysts for mobile learning applications, individuals previously or currently involved in educational activities were recruited, no matter if such activities involved face-to-face, blended or distance learning. Eight Computer Science graduate students from the Institute of Mathematics and Computer Science at University of São Paulo (ICMC-USP), who fullfilled those requirements performed a set of tasks. From the eight participants, four conducted the activities using `MLearning-PL` pattern language, while the other participants did not use any further artifact.

A *subject characterization form* (Section C.1) was applied prior to the experimental study and Chart 15 shows the information gathered from the participants. The sampling of the population is a *stratified random sampling*, whose population is divided into a number of groups or strata with a known distribution between the groups and random sampling is then applied within the strata. We considered the subjects' experience as a teacher to divide them into two groups. In order to balance both groups, we allocated the subject more experienced in teaching (3 and 4) one in each group; those average experienced ones (6 and 7) also in each group; and those with no experience (1, 2, 5 and 8) half in each group. The same idea was applied to the subjects' experience as a tutor and experience with mobile learning applications.

Chart 15 – Experimental Study 1: Subjects' Background

Subject	**What is your experience as a teacher?**	**What is your experience as a tutor or teaching assistant?**	**What is your experience with mobile learning applications?**	**Approach used**
1	None	Between 1 and 3 years	None	`MLearning-PL`
2	None	Between 1 and 3 years	Between 3 and 5 years	Ad hoc
3	Between 3 and 5 years	Between 1 and 3 years	None	Ad hoc
4	Between 3 and 5 years	Between 6 months and 1 year	None	`MLearning-PL`
5	None	Between 1 and 3 years	None	Ad hoc
6	Between 1 and 3 years	More than 3 years	None	Ad hoc
7	Up to 1 year	Between 1 and 3 years	Between 1 and 3 years	`MLearning-PL`
8	None	Between 6 months and 1 year	None	`MLearning-PL`

Source: Research data.

The presence of subjects with no experience in both groups is important, once the results show whether experience is a determining factor in the use of `MLearning-PL`.

4.2.2 Experimental Objects

The subjects performed five activities in a fixed order, which were our experimental objects. The activities consisted of situations involving pedagogical problems to be solved. Firstly, a general context was given to allow a better understanding of a real situation.

The initial text was: *"Suppose you are a specialist consultant of your research topic and have been hired to assist in the implementation of a mobile educational application to teach concepts related to your area. Developer analysts have already listed the technical requirements of the application, however they rely on your advice and pedagogical experience to clearly specify what pedagogical requirements the mobile application must meet. It is known that motivation and engagement in activities are major issues for learners when using distance education tools, thus you should assist them in their doubts using your experience in tutoring and/or teaching in your area of expertise. In this scenario, how would you help them solve the following problems?"*.

After that, the participant was asked solve each one of the following activities.

Activity 1: The initial motivation on using the application is temporary and learners may feel bored, resulting on dropouts. How can you mitigate this problem in the mobile app?

Activity 2: When a topic takes longer to be presented than the learner's concentration time, this may bore him/her and lead to difficulties in the learner's understanding. How can this problem be avoided in the mobile app?

Activity 3: When learning a new subject, the learner must exercise the new knowledge and skills acquired. However, if the learner considers the proposed activity too difficult, he/she may feel frustrated and discouraged. On the other hand, if the activity is considered too simple by some learners, they may have the impression that they are not learning any new content. How to deal with this situation so that all learners carry out the activities and remain engaged?

Activity 4: Keeping learners engaged in the learning process when there is no on-site periodic engagement can be difficult. Therefore, it is necessary that they continue to exercise the knowledge acquired to achieve the established goal, besides knowing what stage they are at before reaching that goal. How can this be handled in the mobile app?

Activity 5: You want to ensure the effectiveness of the knowledge acquired by the learners, but the theory may not be as simple as it seems due to the difficulties that arise during this process. How to deal with this situation without overloading learners?

4.2.3 Experimental Results

4.2.3.1 Quantitative Analysis

The two hypotheses were tested regarding the effectiveness and efficiency of `MLearning-PL` in comparison to an ad hoc approach, and the following measures were obtained for each metric established, presented in Table 21.

Table 21 – Experimental Study 1: Measures

Approach	**Subject**	**Effectiveness**			**Efficiency**
		correctness	*completeness*	*complexity*	*efficiency*
Ad hoc	2	80%	2.30	3.00	48.86
	3	100%	3.00	2.90	28.01
	5	80%	3.20	3.10	41.76
	6	100%	3.80	3.70	10.77
	Median	90%	3.10	3.05	34.89
`MLearning-PL`	1	100%	3.50	3.40	36.04
	4	100%	3.40	3.30	24.96
	7	80%	3.20	3.20	18.86
	8	100%	4.20	4.10	15.49
	Median	100%	3.45	3.35	21.91

Source: Research data.

Two options are available for rejecting the null hypotheses in the Mann-Whitney test:

(i) Compare the U-value obtained to the critical U-value (DIMITROV, 2008), which is 1, in our case; and

- if the U-value obtained is higher than the critical U-value, do not reject H_0; or
- if the U-value obtained is lower than the critical U-value, reject H_0.

(ii) Compare the p-value obtained to the adopted level of significance α, i. e., $\alpha = 5\%$ in our case; and

- if the p-value is higher than α, do not reject H_0; or
- if the p-value is is lower than (or equal to) α, reject H_0.

The Mann-Whitney test provided the U-values and p-values shown in Chart 16.

Since U is not lower than 1 in any of the cases, the null hypotheses cannot be rejected. Similarly, analyzing the p-value, which is higher than α, we can also confirm that the U-test is not statistically significant in this case, thus not able to reject neither of the null hypotheses, which we believe to have occurred due to the small sample size.

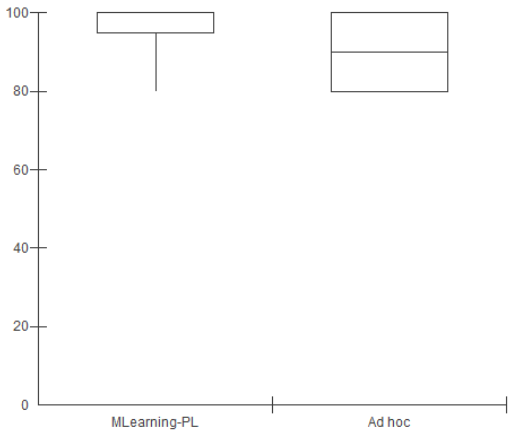
Chart 16 – Experimental Study 1: Values for Mann-Whitney test

Metric	***U*-value**	***p*-value**
correctness	6	0.2819
completeness	3.5	0.0970
complexity	3	0.0745
efficiency	5	0.1932

Source: Research data.

According to Table 21, considering correctness, the median of `MLearning-PL` (100%) is higher than the that of the ad hoc approach (90%) (Figure 21), which indicates subjects that used `MLearning-PL` can solve more problems correctly than subjects that used the ad hoc approach.

Figure 21 – Percentage of problems solved correctly



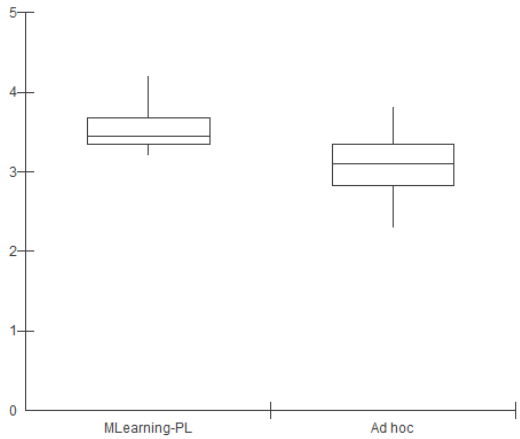
Source: Research data.

The results are analogous for completeness and complexity. When `MLearning-PL` was used, the medians were 3.45 and 3.35 (Figure 22 and Figure 23) for completeness and complexity, respectively, whereas with the use of the ad hoc approach they were 3.1 and 3.05, respectively. The results for `MLearning-PL` are better than those for the ad hoc approach, which suggests `MLearning-PL` assists in the obtaining of more complete and complex solutions.

Finally, concerning efficiency, Figure 24 shows the median of the time spent on the activities. The median for `MLearning-PL` is 21.91 minutes against 34.89 for the ad hoc approach. The difference is even bigger and indicates those who used `MLearning-PL` are faster than those who used the ad hoc approach.

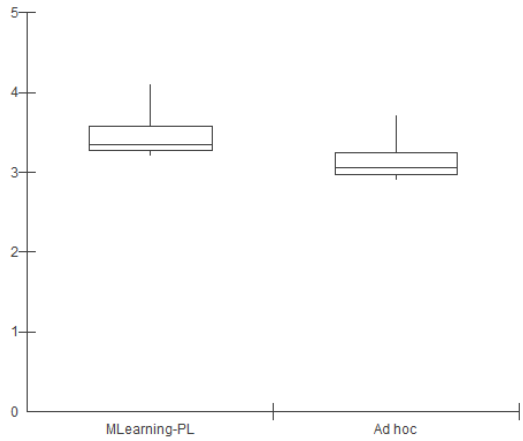
According to the results of the hypothesis test, `MLearning-PL` provided better results than the ad hoc approach, maybe due the systematization introduced in the process by means of using patterns, since systematic approaches are usually better than ad hoc

Figure 22 – Solutions' completeness



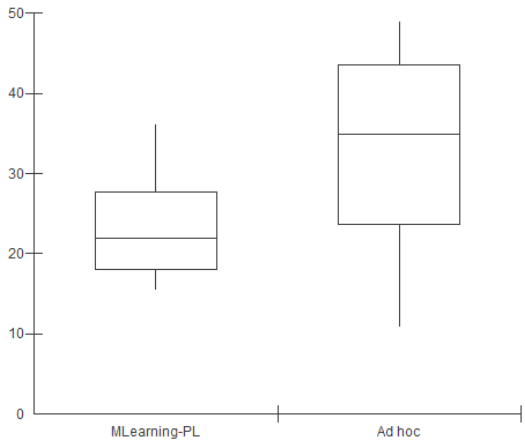
Source: Research data.

Figure 23 – Solutions' complexity



Source: Research data.

Figure 24 – Time to solve all the problems (in minutes)



Source: Research data.

approaches and, particularly, patterns can be used to solve common problems. However, such results are preliminary and other experimental studies should be planned and conducted and involve a larger number of participants and a refined version of the pattern language.

4.2.3.2 Qualitative Analysis

In order to analyze the results qualitatively, besides analyzing the answers provided by the participants, we also analyzed their perceptions regarding the proposed activities.

According to the subjects' answers, those who used `MLearning-PL` were more inclined to reach a solution closer to that expected from the *Activities proof template* (Section C.2). However, a subject (subject 6) excelled in the group using the ad hoc approach, since even without using the pattern language, he obtained much better results than the

other group, in general. Analyzing the background of this subject, we believe that he has obtained such results because of his experience in teaching and tutoring activities.

Concerning the *feedback questionnaires* (Section C.3 and Section C.4), the subjects' answers on the difficulty in performing each activity is summarized in Figure 25. Overall, we could not infer that the use or not of a given approach facilitated the resolution of each one of the problems. Figure 25a shows the opinions are balanced between the treatments (`MLearning-PL` and ad hoc). A different scenario is shown in Figure 25b, where most of the subjects that used `MLearning-PL` considered the activity easy (only one considered it hard). On the other hand, the answers of the subjects that used the ad hoc approach were divided into very easy, easy and moderate. Figure 25c shows two outliers subjects: one using that used ad hoc approach considered the activity very easy, whereas another, who used `MLearning-PL`, considered it hard. The scenario is similar regarding the fourth activity (Figure 25d). Finally, Figure 25e shows all subjects that used `MLearning-PL` considered the activity moderately difficult, whereas the answers of those who used the ad hoc approach were divided into easy, moderate and hard.

It is worth mentioning that those are only subjects' perceptions on the difficulty level of the activities, which may vary due several reasons that are also not related to the experimental study. In general, more experienced subjects were prone to consider the activities easier than those with less or no experience, regardless of the approach used, which suggests the difficulty is more related to each subject's background.

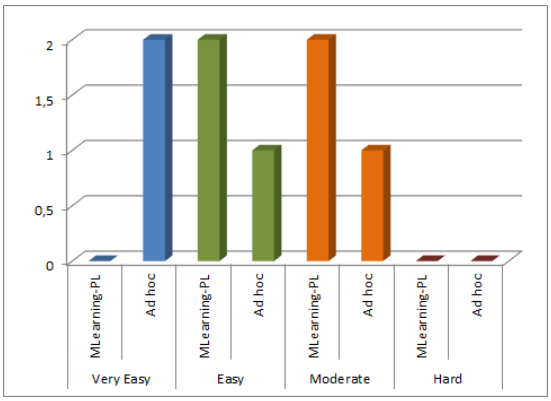
Those who performed the activities with the ad hoc approach were asked if any further artifacts would be useful in the problem-solving process. Figure 26a shows two subjects agreed and two strongly agreed that an artifact could be useful, which suggests the problem-solving activity is not trivial and may be benefited by the use of additional artifacts.

We asked those who used the `MLearning-PL` approach about the pattern language used. Firstly, we asked how helpful it was to support the performed activities and most of them agreed or strongly agreed that `MLearning-PL` helped in the problem-solving process (Figure 26b). We also asker their opinions on the completeness (Figure 26c) and clearness (Figure 26d) of `MLearning-PL`. Regarding completeness, one subject neither agreed, nor disagreed and all the others agreed or strongly agreed that `MLearning-PL` is complete. Considering its clearness, all subjects stated `MLearning-PL` is clear and easy to understand.

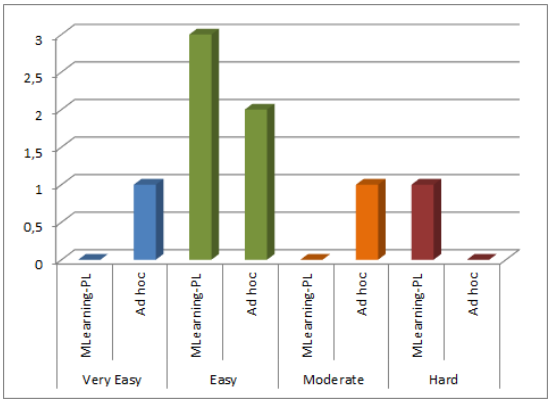
According to the obtained, subjects were enthusiastic and positive about `MLearning-PL` and its importance, which indicates positive evidence on its use over an ad hoc approach for supporting the pedagogical problem-solving process. Such results associated with experts' opinion[2] helped to improve and refine the pattern language.

[2] `MLearning-PL` was under *shepherding* at the 24th Conference on Pattern Languages of Programs (PLoP 2017)

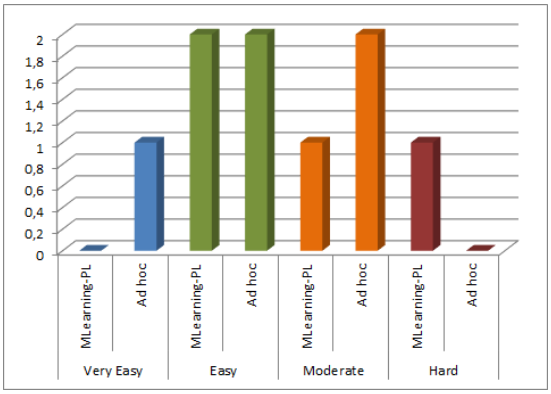
Figure 25 – How difficult was it for you to carry out the activities?



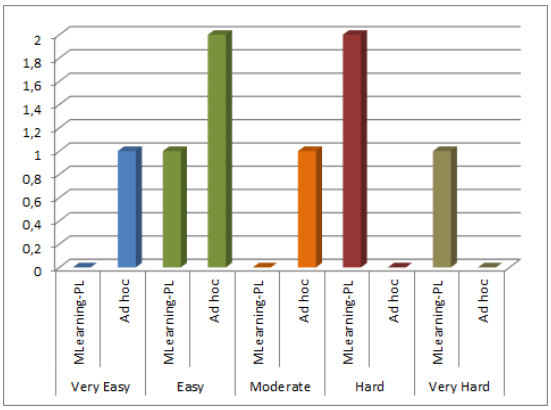
(a) Activity 1



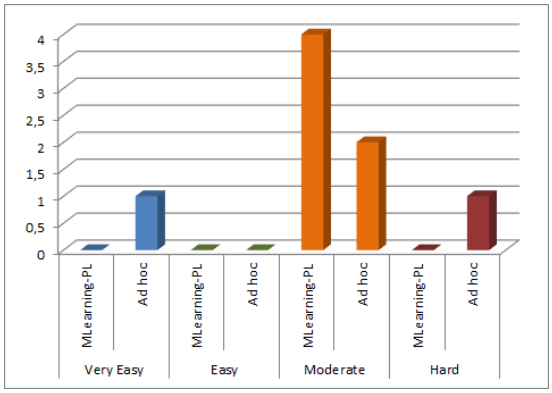
(b) Activity 2



(c) Activity 3



(d) Activity 4



(e) Activity 5

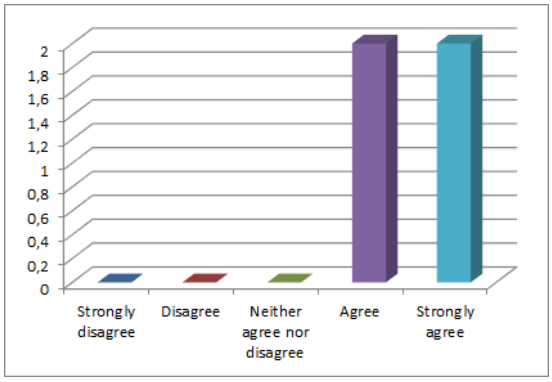
Source: Research data.

4.3 Experimental Study 2

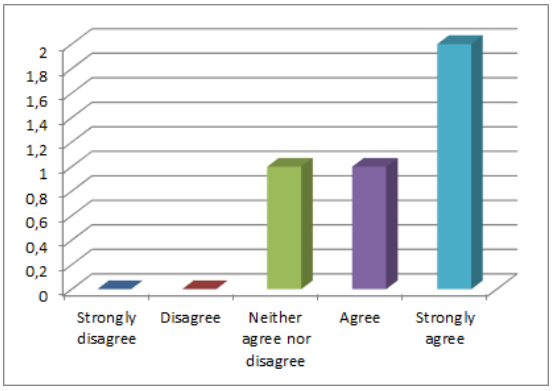
As discussed in Section 4.2, Experimental Study 1 provided inputs for the improvement of `MLearning-PL`. The pattern language was substantially changed and the version used in this experimental study comprised 14 patterns, i. e., additional seven new patterns (Appendix B). In this scenario, the experimental study was conducted again.

when the experimental study was conducted.

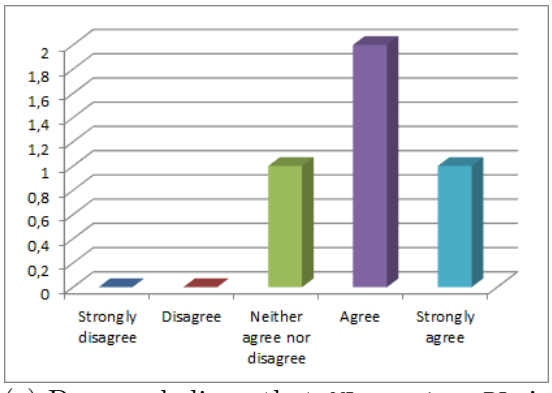
Figure 26 – Answers to the feedback questionnaire



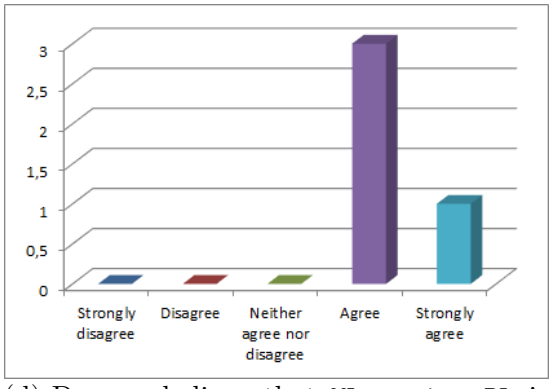
(a) Do you believe that the use of further artifacts would help in the problem-solving process?



(b) Do you believe that `MLearning-PL` helped in the process of solving pedagogical problems?



(c) Do you believe that `MLearning-PL` is complete?



(d) Do you believe that `MLearning-PL` is clear and easy to understand?

Source: Research data.

In this section, we describe how the second experimental study was designed and conducted. A lab package[3] containing more information and details on the experimental study was created and is available.

4.3.1 Experimental Subjects

Similarly to the first experimental study, individuals previously or currently involved in educational activities were recruited, no matter if such activities involved face-to-face, blended or distance learning. 15 Computer Science students from the Institute of Mathematics and Computer Science at University of São Paulo (ICMC-USP), who fullfilled these requirements, performed the tasks in an afternoon. From the 15 participants, eight carried out the activities using `MLearning-PL` pattern language, while the other participants did not use any further artifact.

A *subject characterization form* (Section D.1) was applied prior to the experimental

[3] <https://sites.google.com/usp.br/mlearning-pl/experimental-studies/experimental-study-2>

study and Chart 17 shows the information gathered from the participants. The sampling of the population is a *stratified random sampling*, whose population is divided into a number of groups or strata with a known distribution between the groups and random sampling was then applied within the strata. The subjects' experience was considered for their division into two groups.

Chart 17 – Experimental Study 2: Subjects' Background

Subject	**What is your experience as a teacher?**	**What is your experience as a tutor or teaching assistant?**	**What is your experience with mobile learning applications?**	**Approach used**
1	None	Between 1 and 6 months	None	Ad hoc
2	More than 5 years	More than 3 years	Up to 1 year	Ad hoc
3	Up to 1 year	Between 1 and 6 months	Up to 1 year	Ad hoc
4	Between 3 and 5 years	Between 1 and 6 months	None	Ad hoc
5	None	Between 6 months and 1 year	None	Ad hoc
6	Up to 1 year	Between 1 and 3 years	None	Ad hoc
7	None	Between 1 and 3 years	None	Ad hoc
8	None	Between 1 and 6 months	Up to 1 year	`MLearning-PL`
9	None	None	None	`MLearning-PL`
10	None	Between 1 and 3 years	None	`MLearning-PL`
11	Up to 1 year	Between 1 and 3 years	None	`MLearning-PL`
12	Up to 1 year	Between 1 and 6 months	None	`MLearning-PL`
13	None	Between 1 and 6 months	Up to 1 year	`MLearning-PL`
14	None	Between 1 and 6 months	None	`MLearning-PL`
15	More than 5 years	Between 1 and 6 months	None	`MLearning-PL`

Source: Research data.

4.3.2 Experimental Objects

Similarly to experimental study 1, the subjects performed six activities in a fixed order, which were our experimental objects. The activities consisted of situations involving pedagogical problems to be solved. Firstly, a general context was given for a better understanding of a real situation.

The initial text was: *"Suppose you are a specialist consultant of your research topic and have been hired to assist in the implementation of a mobile educational application to teach concepts related to your area. Developer analysts have already listed the technical requirements of the application, however they rely on your advice and pedagogical experience to clearly specify what pedagogical requirements the mobile application must meet.*

It is known that motivation and engagement in activities is a major issue for learners when using distance education tools, thus you should assist them in their doubts using your experience in tutoring and/or teaching in your area of expertise. In this scenario, how would you help them solve the following problems?".

After that, the participant was asked solve each one of the following activities.

Activity 1: The initial motivation on using the application is temporary and learners may feel bored, resulting on dropouts. How can you mitigate this problem in the mobile app?

Activity 2: Keeping learners engaged in the learning process when there is no on-site periodic engagement can be difficult. Therefore, it is necessary that they continue to exercise the knowledge acquired to achieve the established goal, besides knowing what stage they are at before reaching that goal. How can this be handled in the mobile app?

Activity 3: When a topic takes longer to be presented than the learner's concentration time, this may bore him/her and lead to difficulties in the learner's understanding, especially when the learner has almost achieved his/her goal. How can this problem be avoided in the mobile app?

Activity 4: When learning a new subject, the learner must exercise the new knowledge and skills acquired. However, if the learner considers the proposed activity too difficult, he/she may feel frustrated and discouraged. On the other hand, if the activity is considered too simple by some learners, they may have the impression that they are not learning any new content. How to deal with this situation so that all learners carry out the activities and remain engaged?

Activity 5: You want to ensure the effectiveness of the knowledge acquired by the learners, but the theory may not be as simple as it seems due to the difficulties that arise during this process. Even though you want to enable students to solve meaningful problems as early in the course as possible, you cannot overload them because they must remember the most important ideas and concepts. How to deal with this situation without overloading learners?

Activity 6: You are teaching learners with different backgrounds and characteristics, which means they have different learning styles. How to deal with this situation in the mobile app to provide content that is suitable for several kinds of learners?

4.3.3 Experimental Results

4.3.3.1 Quantitative Analysis

The two hypotheses were tested regarding the effectiveness and efficiency of `MLearning-PL` in comparison to the ad hoc approach. The calculations performed provided the following

measures for each established metric, shown in Table 22.

Table 22 – Experimental Study 2: Measures

Approach	**Subject**	**Effectiveness**			**Efficiency**
		correctness	*completeness*	*complexity*	*efficiency*
Ad hoc	1	100	3.33	2.83	47.43
	2	33.33	1.75	1.67	20.35
	3	50	2.08	2.08	11.61
	4	83.33	2.50	2.50	39.37
	5	100	3.00	2.75	38.81
	6	100	2.92	2.83	34.36
	7	50	2.33	2.08	26.38
	Median	83.33%	2.50	2.50	34.36
`MLearning-PL`	8	100	4.17	3.75	35.03
	9	83.33	3.58	3.25	44.53
	10	100	3.92	3.42	32.77
	11	100	3.33	2.83	34.04
	12	83.33	3.75	3.33	23.73
	13	100	3.58	3.25	42.59
	14	100	4.08	3.75	28.50
	15	66.67	2.58	2.83	23.57
	Median	100%	3.67	3.29	33.41

Source: Research data.

Similarly to the first experimental study (Section 4.2.3.1), the Mann-Whitney test was applied and the U-values and p-values obtained are shown in Chart 18.

Chart 18 – Experimental Study 2: Values for Mann-Whitney test

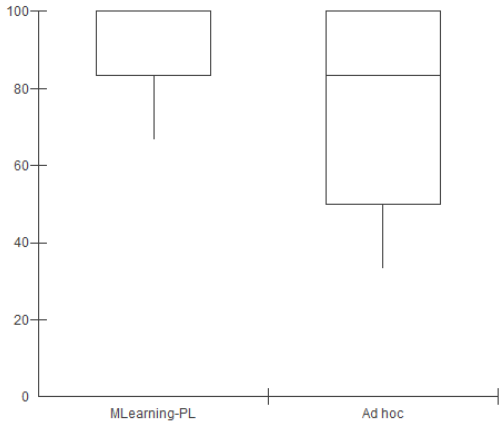
Metric	U**-value**	p**-value**
correctness	18.5	0.1358
completeness	3.5	0.0023
complexity	2	0.0013
efficiency	27	0.4539

Source: Research data.

Since U is not smaller than 1 in any of the cases, the null hypotheses cannot be rejected. The U-test is not statistically significant in this case, because the p-value is higher than α for the two metrics, therefore, neither of the null hypotheses could be rejected.

According to Table 22, considering correctness, the median of `MLearning-PL` (100%) is higher than that of the ad hoc approach (83.33%) (Figure 27), which indicates subjects that used `MLearning-PL` could solve more problems correctly than those who used the ad hoc approach.

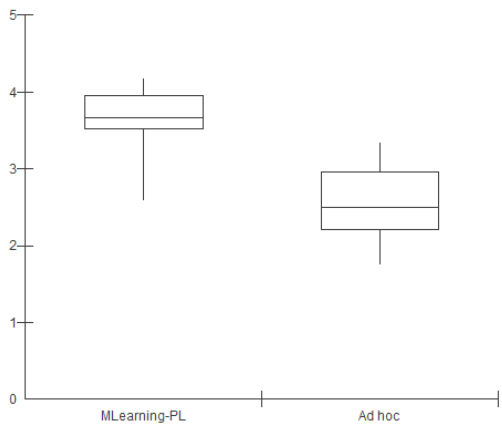
Figure 27 – Percentage of problems solved correctly



Source: Research data.

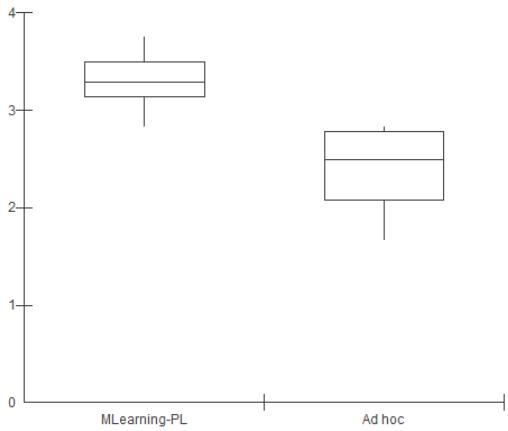
The results are analogous for completeness and complexity. When `MLearning-PL` was used, the medians were 3.67 and 3.29 (Figure 28 and Figure 29) for completeness and complexity of the solutions, respectively, whereas the use of the ad hoc approach obtained 2.5. The first experimental study showed differences of 0.35 and 0.3, respectively, for the completeness and complexity of the solutions obtained with the use of `MLearning-PL` in comparison to the ad hoc approach. The differences are, respectively, 1.17 and 0.79, which are higher than those previously obtained, and reinforce `MLearning-PL` assists in the obtaining of more complete and complex solutions.

Figure 28 – Solutions' completeness



Source: Research data.

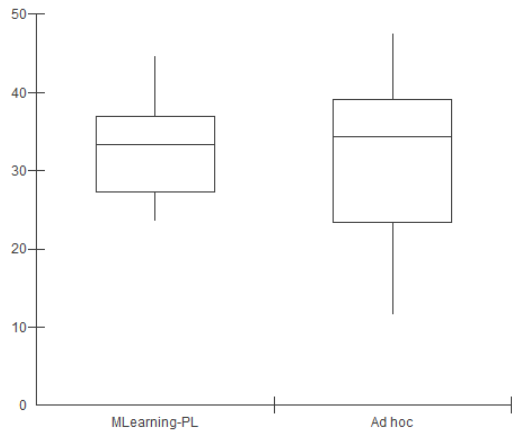
Figure 29 – Solutions' complexity



Source: Research data.

Finally, concerning the time spent on the tasks, Figure 30 shows the median for `MLearning-PL` is 33.41 minutes against 34.36 for the ad hoc approach. The difference is much smaller than that previously obtained, probably due to the larger number patterns available, since the pattern language was substantially changed.

Figure 30 – Time to solve all the problems (in minutes)



Source: Research data.

Again, we could not confirm `MLearning-PL` provided better results than the ad hoc approach by the hypotheses testing. As discussed in the first experimental study, it may have been occurred due the use of patterns, since they introduce systematization in the process of problems' solving.

4.3.3.2 Qualitative Analysis

The answers provided by the participants and their perceptions regarding the proposed activities were considered for the qualitative analysis of the results.

The subjects that used `MLearning-PL` were more inclined to reach a solution closer to that expected from the *Activities proof template* (Section D.2). The time spent on the solving of the problems was similar in both groups, probably because: (i) the subjects that used the ad hoc approach did not know how to answer the questions in detail and did not take longer time detailing the answer; (ii) the subjects that used `MLearning-PL` were more careful and analytical to answer the questions; or (iii) the use or not of an extra artifact does not influence the execution time of the task.

Concerning the *feedback questionnaires* (Section D.3 and Section D.4), the subjects' opinion about the difficulty in performing each activity is summarized in Figure 31. In general, we could not infer the use or not of a given approach facilitated the resolution of each problem. The opinions are balanced (with slight differences) between both treatments for most activities. In the first activity (Figure 31a), for instance, two subjects considered it hard, even with the use of `MLearning-PL` as a supporting artifact. Similarly, in the second and third activities (Figure 31b and Figure 31c), a subject that used `MLearning-PL` considered the activity very hard. Figure 31d shows balanced opinions between both treatments concerning the fourth activity. On the other hand, the scenario is different for the fifth and sixth activities, shown in Figure 31e and Figure 31f, respectively. The

large majority of subjects that used `MLearning-PL` as a supporting mechanism considered the activities easy, whereas those who used an ad hoc approach were divided.

The subjects' perceptions on the level of difficulty of the activities may vary due several reasons that are also not related to the experimental study. In general, more experienced subjects considered the activities easier than the subjects with less or no experience, regardless of the approach used, which reinforces the difficulty is more related to each subject's background.

Those who performed the activities with the ad hoc approach were asked if any further artifacts would be useful in the problem-solving process. Figure 32a shows five subjects agreed and two neither agreed, nor disagreed on the usefulness of an artifact, which indicates the problem-solving activity is not trivial and may benefit from the use of additional artifacts.

Those who used the `MLearning-PL` approach were asked about the pattern language used. Firstly, we asked how helpful it was to support the performed activities and most of them agreed or strongly agreed that `MLearning-PL` helped in the the problem-solving process (Figure 32b). We also asked their opinions on the completeness and clearness of the pattern language. Regarding completeness, the results were not unanimous (Figure 32c), i. e., only 50% (four subjects) agreed it was complete, 25% neither agreed, nor disagreed and the other 25% disagreed. Although the subjects considered `MLearning-PL` not complete enough, they did suggest improvement points to the pattern language, such as new patterns or even modifications of the existing ones. Finally, regarding clearness (Figure 32d), `MLearning-PL` is clear and easy to understand, since 87,5% of the subjects answered "Agree".

The subjects were enthusiastic and positive about `MLearning-PL` and its importance, which indicates positive evidences on its use to support the pedagogical problem-solving process. The experimental results were used as input to improve and refine the pattern language.

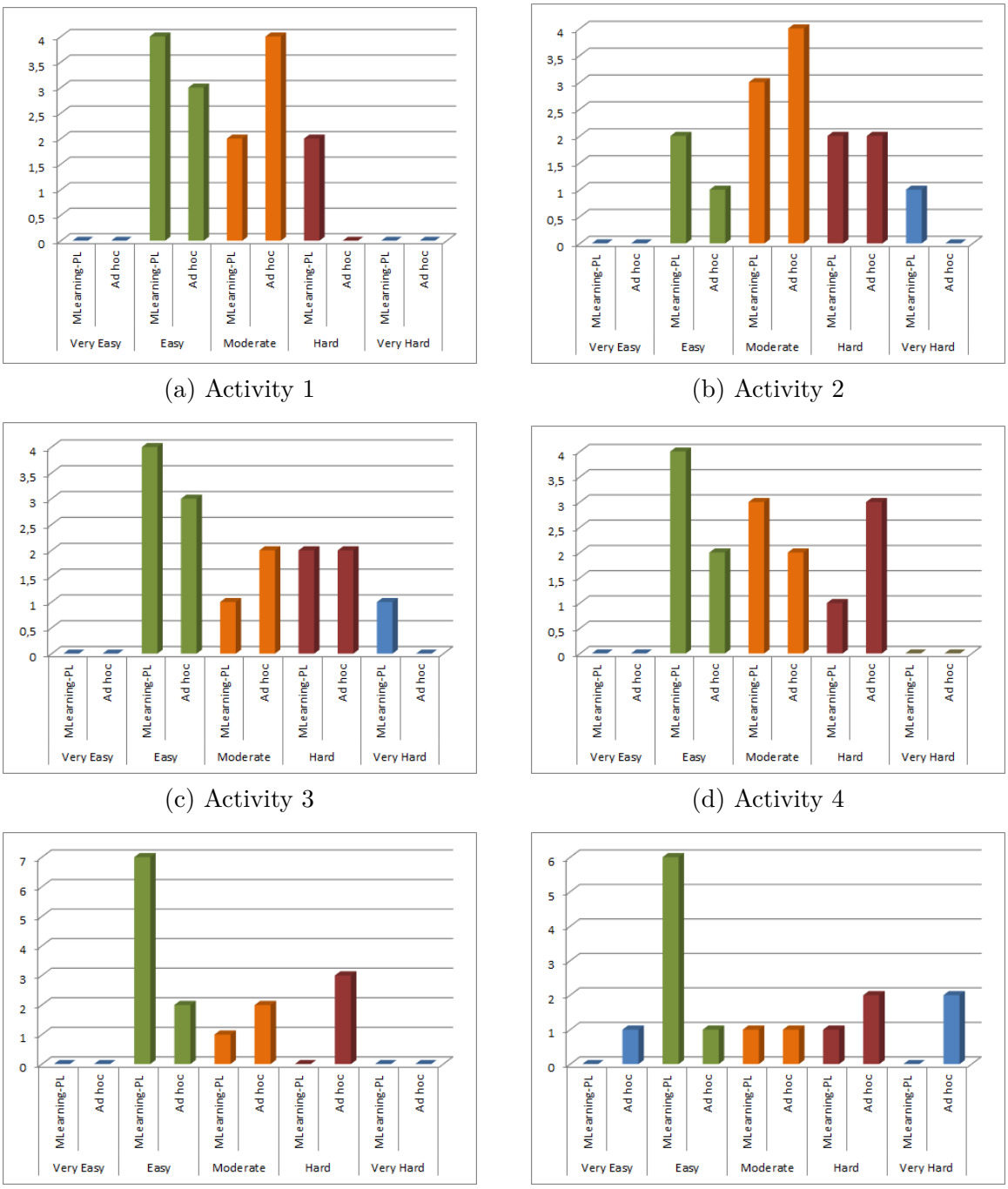
4.4 Threats to Validity

In this section, we discuss the threats to validity of both experimental studies based on the guidelines proposed by Wohlin *et al.* (2012).

Conclusion validity is concerned with the relationship between the treatment and the outcome. A potential threat is the size of the available sample may not be sufficient to provide significant results, therefore, we included descriptive statistics and qualitative analysis towards mitigating this threat.

The subject's involvement in educational activities as a teacher or tutor might be

Figure 31 – How difficult was it for you to carry out the activities?



(a) Activity 1

(b) Activity 2

(c) Activity 3

(d) Activity 4

(e) Activity 5

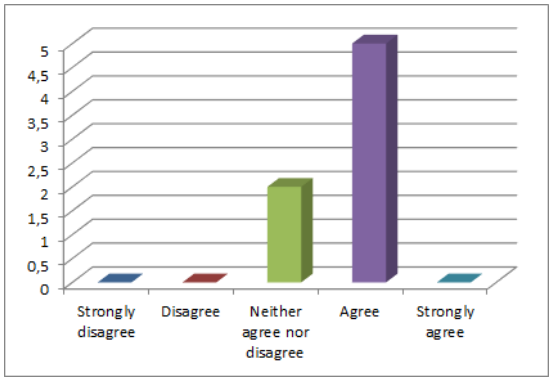
(f) Activity 6

Source: Research data.

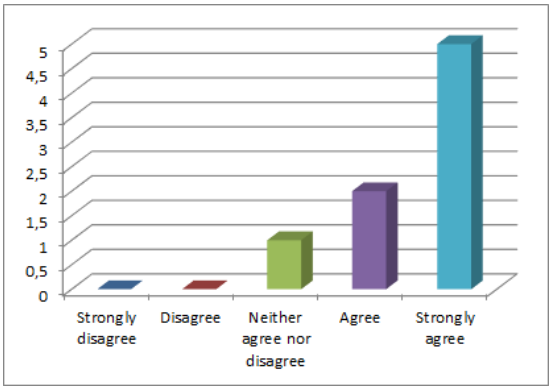
another threat, therefore, we used the characterization form to gather information on the subjects' background and offered a tutorial on mobile learning.

Internal validity is concerned to whether the treatment causes the outcome. The following four potential threats were identified:

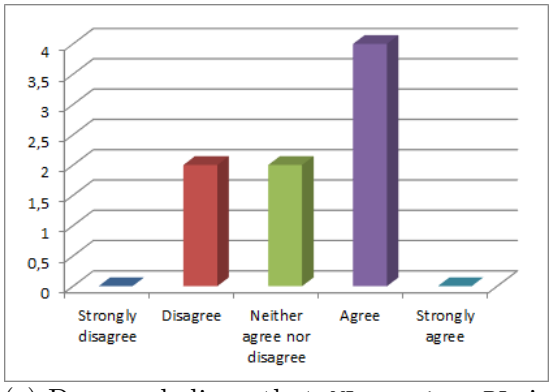
Figure 32 – Answers to the feedback questionnaire



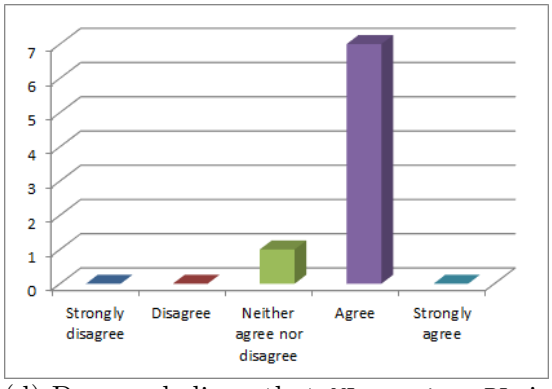
(a) Do you believe that the use of further artifacts would help in the problem-solving process?



(b) Do you believe that `MLearning-PL` helped in the process of solving pedagogical problems?



(c) Do you believe that `MLearning-PL` is complete?



(d) Do you believe that `MLearning-PL` is clear and easy to understand?

Source: Research data.

(i) Each participant's time of experience in education may be a systematic variation in the experimental study. To reduce it, we adopted stratified random sampling to balance the groups.

(ii) The selection of problems to be solved by the subjects may not represent the problems faced in educators' daily basis. To mitigate it, the problems were validated by a specialist.

(iii) The supporting tool used during the experimental study to answer the questionnaires and activities, which was reduced by explaining all the necessary steps to the subjects.

(iv) Dropout subjects is a potential threat that was mitigated consulting the recruited participants to find a day and time suitable for everyone to perform the experimental study.

Construct validity is concerned with the relation between theory and observation. A potential threat is the activities of both groups should have the same level of difficulty, which was mitigated by the running of a pilot for refining the experimental study.

External validity is concerned with generalization. The sample may not be representative of the population, which was mitigated by the application of the *characterization form*.

Such experimental studies show preliminary empirical evidence of the applicability, effectiveness and efficiency of `MLearning-PL`. However, we recognized the threats and limitations of the two studies and general conclusions cannot be drawn from the results discussed in this chapter.

4.5 Validation of Patterns Experts

The software patterns community recommends that all pattern languages be submitted to a writers' workshop in Pattern Languages of Programs (PLoP) conferences (BRAGA, 2003) to improve the patterns.

First, the pattern language is submitted and reviewed in a special reviewing process called *shepherding*. According to The Hillside Group[4], the shepherding process is essentially a reviewing process involving shepherds and sheeps. Shepherds are individuals, with experience in pattern writing, assigned to an author's (sheep's) paper with the expressed interest in helping the author improve the pattern. Most shepherds also have experience with the shepherding procedure, either having been a shepherd before or a sheep. Shepherding is about improving a pattern or pattern language, while the Shepherd maintains that the author is the one doing the pattern writing. The shepherding process is done before the paper is to be presented at the conference and the shepherd guides the sheep into a more mature understanding of his or her pattern or pattern language.

During PLoP conferences, the authors attend the writers' workshop. In each session, the authors of the paper under discussion remain silent while the others discuss it and explain additional insights and views they have about it. From these sessions, authors get a lot of feedback and suggestions from fellow authors and others about how they can improve their work.

Considering this scenario, we submitted `MLearning-PL` to the 24th International Conference on Pattern Language of Programs. During our writers' workshop session, experienced pattern writers suggested some improvement points: (i) PL graph should have a legend; (ii) patterns should have a "Resulting Context" section; (iii) "Related Patterns" section should be written differently; and (iv) some patterns should be refined.

[4] http://hillside.net/conferences/shepherding

The feedback obtained during the writers' workshop served as input to refine `MLearning-PL` to its current version.

4.6 Final Remarks

In this chapter, we discussed two experimental studies conducted for the evaluation of the pedagogical pattern language for mobile learning applications, entitled `MLearning-PL`. The approaches used and the main results were gathered and summarized.

The percentage of problems correctly solved by the subjects, the completeness and complexity of each solution, and the time spent to solve all the problems were taken into account. The data collected were analyzed through a comparison of the results of `MLearning-PL` and an ad hoc approaches. Although the results were not statistically significant, they were complemented by a qualitative analysis, which revealed `MLearning-PL` provides better results than the ad hoc approach. In general, users were enthusiastic and positive about `MLearning-PL` and its importance, which evidences its use over an ad hoc approach to support the pedagogical problem-solving process.

The next chapter concludes this dissertation, summarizing the main contributions of the research conducted, discussing general limitations, and providing an overview on the perspectives for future work.

CHAPTER

5

Conclusions

As discussed throughout this text, topics related to teaching and learning have become an increasing focus of research by the scientific community. Computational learning applications play a key role in educational activities, in both academia and industry (SVETLANA *et al.*, 2009; CRAIG *et al.*, 2012). Due to the decrease in size and the cheapness of electronic components, mobile devices whose processing power is many times higher than that of many computers have been developed (ZAMFIRACHE *et al.*, 2013). Such changes, associated with the emergence of ubiquitous computing, have lead to the establishment of a new learning modality, called mobile learning (CROMPTON, 2013; WU *et al.*, 2012; TRAXLER; LEACH, 2006; KEEGAN, 2005).

In short, mobile learning is a learning modality characterized by the ability to provide an effective interaction among users (learners, teachers and tutors), so that they can contribute, participate and access the educational environment through mobile devices (cell phones, PDAs, smartphones, tablets, laptops, an so on) anytime, anywhere.

Due to the growing popularity of mobile applications in several sectors of society, concern over their design and development have emerged significantly. In this context, technological, pedagogical and social aspects must be considered throughout the project design and development process of such applications. However, despite its several benefits and facilities, mobile learning still presents problems and challenges that must be better investigated.

On the other hand, the software reuse area proposes a systematic set of processes, techniques and tools for the obtaining of high-quality and economically viable products, based on the use of concepts, products or solutions previously developed or acquired for the creation of new software. In short, reuse reduces efforts and saves costs (KESWANI *et al.*, 2014).

In a reuse-related perspective, our research group has investigated the establish-

ment of reference architectures for mobile learning. Particularly, a reference architecture entitled *Ref-mLearning* (Duarte Filho, 2016; FIORAVANTI *et al.*, 2017) was proposed aiming to ensure guidelines for reuse and interoperability of mobile educational environments. In this context, a mobile learning environment, called *ICMC MLE* was developed, based on *Ref-mLearning* (FIORAVANTI *et al.*, 2017).

Another research initiative conducted by our research group is concerned with Software Product Line (SPL). SPL concerns the sharing features within a family of products, addressing business, architecture, processes and organizational aspects and also provides mechanisms for the evolution of products, once new features may arise from stakeholders' needs (CAPILLA *et al.*, 2013). In this context, the creation of new products requires technical support, which hinders and constrains the SPL adoption for development of m-learning applications. In our research group, there are two initiatives using SPL: SPL for m-learning applications under the Android platform (Falvo Júnior, 2015; Falvo Júnior *et al.*, 2014); Falvo Júnior *et al.*, 2014) and SPL for m-learning applications for the teaching of programming (MARCOLINO; BARBOSA, 2017).

In this scenario, other reuse techniques and tools can be used to complement the aforementioned ones and support mobile learning applications projects. For instance, it is important to assure m-learning applications' quality. In this context a quality evaluation method for mobile learning applications, namely *MoLEva*, was proposed (SOAD, 2017; SOAD; BARBOSA, 2017).

This Master's research was conducted within a broader research project of our research group aiming at contribute to facilitate and systematize the building of mobile learning applications.

When dealing with domain-specific software, we must be concerned about domain requirements. In the case of mobile learning, this knowledge would come from educators, teachers and tutors. However, capturing and transferring tacit knowledge is not a trivial task. In this scenario, requirements analysts in mobile learning projects could benefit from a supporting mechanism to guide the requirements elicitation phase in mobile learning applications projects. The significance of pattern languages as a method to describe tacit knowledge is acknowledged and a good candidate as a supporting mechanism (IBA *et al.*, 2011).

To the best of our knowledge, no initiatives using patterns to address the pedagogical issues have been developed (FIORAVANTI *et al.*, 2015). Based on this scenario, this work aimed to create a pedagogical pattern language to assist the requirements elicitation phase of mobile learning applications projects, namely `MLearning-PL`. The main idea is to provide support on pedagogical issues to help analysts to avoid or diminish already known pedagogical problems. In this context, we described and discussed a set of studies to investigate and answer a set of exploration questions, providing the subsidies for the

understanding and development of the Master's research. Firstly, we conducted a systematic mapping study aiming to characterize the current scenario of the use of patterns in learning applications. We identified a lack of studies concerning the use of pedagogical patterns in mobile learning applications. Aiming to bridge this gap, we conducted another systematic mapping study to identify and catalog pedagogical patterns and pattern languages. The results of this SMS provided input for our pedagogical pattern language creation.

Distraction is one of the most important problems in m-learning (LONSDALE *et al.*, 2005; COSTABILE *et al.*, 2008; SKIBA, 2011). While mobile devices can be considered an important learning tool, they can also be considered a distraction source, due their several possibilities over the Internet. In this sense, it is important to capture learners' attention, motivate and engage them in the learning experience in a didactically correct way. Considering this scenario, we chose to start the creation of `MLearning-PL` addressing some strongly interrelated aspects: Engagement, Motivation, Learning style and Knowledge effectiveness.

In order to evaluate the proposed pattern language, we conducted two experimental studies. The goal was to evaluate `MLearning-PL` in the context of mobile learning applications requirements elicitation in comparison to an ad hoc approach. The preliminary results obtained have provided good evidences on the use of `MLearning-PL` over an ad hoc approach to support the pedagogical problem solving process.

5.1 Research Contributions

The main contributions of this Master's research are the following:

- **Characterization of the state-of-the-art on the use of patterns in learning applications:** we conducted a systematic mapping study to characterize the current scenario of the use of patterns in learning applications. This SMS provided an overview (a map) of the patterns that have been used in this context. Particularly, the results showed a lack of research initiatives on the use of patterns to address mobile learning limitations. Our work was a step forward in this direction aiming to bridge this gap.

- **Characterization of the state-of-the-art of the pedagogical patterns reported in the literature:** we conducted a systematic mapping study to identify and catalog pedagogical patterns and pattern languages. It provided an overview (a map) of the existing pedagogical patterns and the problems they aim to solve or diminish. The results were input for the creation of our pedagogical pattern language, `MLearning-PL`.

- **Characterization of pedagogical requirements:** we proposed a requirements catalog, namely *ReqML-Catalog*, in the context of our research group. *ReqML-Catalog* comprises the four dimensions of mobile learning with their characteristics and subcharacteristics. To fit our work's need, we used only the pedagogical subset of characteristics.

- **Creation of a pedagogical pattern language for mobile learning applications:** we created a pedagogical pattern language for mobile learning applications composed of 14 patterns, named `MLearning-PL`. `MLearning-PL` considers aspects such as engagement, motivation, learning style and knowledge effectiveness to help in keeping learners motivated and engaged while using mobile learning applications.

- **Experimental evaluation of the proposed pattern language:** we evaluated `MLearning-PL` by means of two experimental studies. The experimental studies compared `MLearning-PL` and an ad hoc approach in a pedagogical problem resolution scenario. The preliminary results provided good evidences on the applicability, effectiveness and efficiency of `MLearning-PL`.

5.2 Research Limitations

The main limitations related to the work undertaken in this Master's research are summarized as follows:

- **Number of pedagogical subcharacteristics:** In Step 3 of the Pattern Language Creation Process, we had to choose some candidate patterns and noticed that many characteristics and subcharacteristics of the pedagogical dimension should be considered so that the pattern language covers the whole domain. Given this scenario, we chose to start the pattern language addressing characteristics still little explored, but relevant in the context of mobile learning. As previously discussed, we considered aspects such as engagement, motivation, learning style and knowledge effectiveness to help in keeping learners motivated and engaged while using mobile learning applications.

- **Experimental Studies:** A pattern is already an artifact validated by its known uses. However, the relationship among the patterns, their ease of use, clearness, and retrieval of knowledge needed to be evaluated. We chose to conduct experimental studies based on Software Engineering guidelines to evaluate such aspects. A limitation of the conducted experimental studies refers to the experimental subjects. Since we were not able to recruit many subjects for the studies, they were exclusively from the Computing area. In addition, `MLearning-PL` was evaluated by the scientific community of patterns.

- **Pattern Language Application:** Although we conducted experimental studies, `MLearning-PL` was not applied in a real-world context. There is a need to use `MLearning-PL` to elicit requirements in mobile learning applications projects.

5.3 Future Work

Based on the limitations previously discussed, we can identify several possibilities of continuity of the work undertaken in this Master's research and future directions for research. Following we briefly summarize some of them:

- **Evolution of `MLearning-PL`:** Considering that knowledge about any domain emerges, evolves and consolidates over time, there is a need to evolve `MLearning-PL`. The evolution is twofold:

  (i) The pattern language could be evolved by adding more existing pedagogical patterns in the literature to `MLearning-PL`, comprising the other characteristics of the pedagogical dimension. In future versions, more pedagogical patterns can be ethnographically mined and added to `MLearning-PL`, considering mobile learning expertise of educators. In addition, `MLearning-PL` could evolve into a broader context by adding patterns which address the other aspects of mobile learning: technical and social.

  (ii) There are several formats in which a pattern can be written. We adopted a concise format, with elements suggested by Appleton (1997) and arranged in a table. However, some readers may prefer a more verbose format with much more details of each of the patterns. To suit those readers' preferences, each pattern can be written in more detail and accompanied by a *pattlet*[1].

- **Development of mobile learning applications:** In order to assess the applicability of `MLearning-PL` in a real context, mobile learning applications could be developed, using `MLearning-PL` as a supporting mechanism in the phase of requirements elicitation.

- **Conduction of more evaluations:** In addition to validation with experts from the patterns community, it is important to understand the impact of `MLearning-PL` on several others communities. To bridge this gap, case studies or surveys could be conducted for a qualitative analysis. Furthermore, after the evolution of `MLearning-PL`, it is necessary to conduct more experimental studies considering a greater diversity of experimental subjects in relation to the area of expertise and experience in teaching.

[1] A *pattlet* is a short summary of the problem and solution for a pattern. *Pattlets* are often used as an aid to discovering patterns to solve a particular problem at hand.

- **Development of a pedagogical pattern repository:** After the creation of the pattern language, there was a need to make it available so that it could be easily used by interested parties. However, we did not find a repository or tool that stored pattern languages. To bridge this gap, a work is already being developed with the aim of creating such a repository. In the future, `MLearning-PL` will also be available through this tool.

5.4 Resulting Publications

The main publications resulting from the activities conducted during this Master's research are summarized as follows:

- FIORAVANTI, M. L.; BARBOSA, E. F. A Pedagogical Pattern Language for Mobile Learning Applications. In: **Proceedings of 24th Conference on Pattern Languages of Programs (PLoP 2017)**. Vancouver, BC, Canada: , 2017.

- SOAD, G. W.; FIORAVANTI, M. L.; Falvo Júnior, V.; MARCOLINO, A. S.; Duarte Filho, N. F.; BARBOSA, E. F. ReqML-Catalog: The Road to a Requirements Catalog for Mobile Learning Applications. In: **Proceedings of the Proceedings of the 47th Annual Frontiers in Education Conference (FIE 2017)**. Indianapolis, Indiana, USA: , 2017.

- SILVA, J. M.; BARBOSA, E. F.; FIORAVANTI, M. L.; FASSBINDER, A. G. O. Uma Ferramenta de Apoio ao Gerenciamento de Padrões para Propósitos Pedagógicos. In: **Anais dos Workshops do VI Congresso Brasileiro de Informática na Educação (WCBIE 2017)**. Recife, Pernambuco, Brasil: , 2017.

- FIORAVANTI, M. L.; BARBOSA, E. F. A Systematic Mapping on Pedagogical Patterns. In: **Proceedings of the 46th Annual Frontiers in Education Conference (FIE 2016)**. Erie, Pennsylvania, USA: , 2016.

- FIORAVANTI, M. L.; MOREIRA, R. B.; BARBOSA, E. F. Utilização de Padrões no Ciclo de Vida de Aplicações de Aprendizagem: Um Mapeamento Sistemático. In: **Proceedings of the XXVI Brazilian Symposium on Computers in Education (SBIE 2015)**. Maceió, Alagoas, Brasil: , 2015.

Furthermore, other works indirectly related to this Master's work have been published:

- FIORAVANTI, M. L.; SENA, B.; PASCHOAL, L. N.; SILVA, L. R.; ALLIAN, A. P.; NAKAGAWA, E. Y.; SOUZA, S. R. S.; ISOTANI, S.; BARBOSA, E. F. Integrating

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- FIORAVANTI, M. L.; Duarte Filho, N. F.; FRONZA, L. B.; BARBOSA, E. F. Towards a Mobile Learning Environment using Reference Architectures. In: **Proceedings of the 50th Hawaii International Conference on System Sciences (HICSS 2017)**. Waikoloa, HI, USA: , 2017.

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- FIORAVANTI, M. L.; KAMADA, M. K.; SOUZA, P. S. L.; BARBOSA, E. F. I3S Simulator: An Open Educational Resource for Teaching Scheduling in Interactive Systems. In: **XXI Congreso Internacional de Informática Educativa (TISE 2016)**. Santiago, Chile: , 2016. p. 704–709.

- SOAD, G. W.; ESTECA, A. M. N.; FIORAVANTI, M. L.; BARBOSA, E. F. Towards a CSCL Systems Evaluation Catalog. In: **Proceedings of the 31st International Conference on Computers and Their Applications (CATA 2016)**. Las Vegas, NV, USA: , 2016. p. 195–200.

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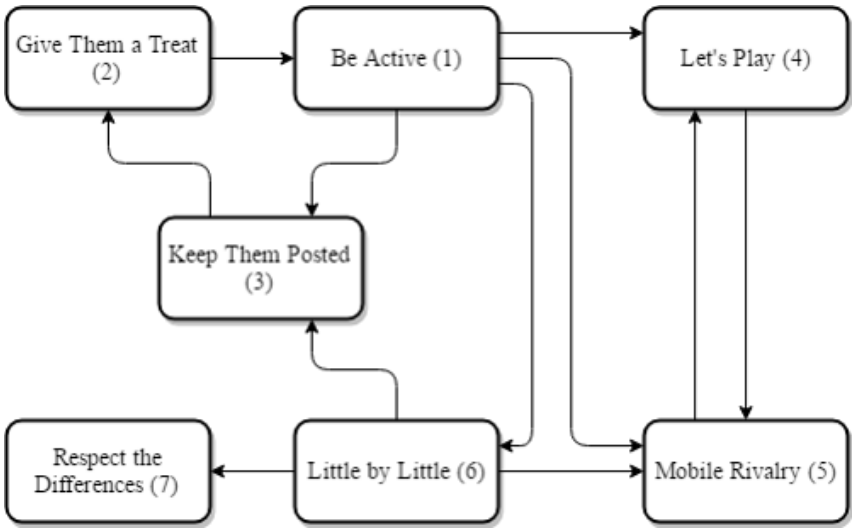
APPENDIX

A

MLearning-PL - Version 1

Figure 33 – `MLearning-PL` Graph - Version 1



Source: Elaborated by the author.

1	**Be Active**
Variant of	Active Student (BERGIN *et al.*, 2012)
Context	You want to maximize student learning.
Problem	The deep consequences of a theory are unlikely to be obvious to one who reads about, or hears about the theory. The unexpected difficulties inherent in using the theory or applying the ideas are not likely to be apparent until the theory is actually used.

Forces	• Passive learners don't learn much. • If learners read to explanations, without themselves becoming engaged, what is learned is unlikely to go into long-term memory. • If the learners don't actively engage the material, they won't retain it. They need to write and they need to do.
Solution	Keep the learners active. They should be active in the app, either with questions or with exercises.

2	**Give Them a Treat**
Variant of	Chain of Excitement (IBA *et al.*, 2014)
Context	The learners have made some learning progress, and perhaps they think they've almost achieved their initial goal.
Problem	It is not easy to actively continue exploring and studying.
Forces	• It is difficult to continue working intensely on tedious tasks. • It is easy to be impressed not only by the beauty of arts and nature but also by intellectual excitement. • Intellectual excitement and academic experiences motivate you to study.
Solution	Make the learners feel the strong emotion of accomplishment by giving them some reward in the app, like a score or a customized message, which will motivate their learning.

3	**Keep Them Posted**
Variant of	Tangible Growth (IBA *et al.*, 2014)
Context	The learners need to continue practicing the activities to achieve their goal.
Problem	It is not easy to keep the learner motivated to learn.
Forces	• It takes a long time before they realize the effect of learning. • It is difficult to maintain their motivation to work hard.
Solution	Show the evolution of the learners at each advanced stage, so they can realize how their knowledge and skills have grown.

4	**Let's Play**
Variant of	Playful Learning (IBA *et al.*, 2014)
Context	The process of learning bores the learners.
Problem	Learning as a duty is ineffective and painful.

Forces	• It is difficult to continue tedious work. • It is difficult to maintain motivation for ineffective learning. • Necessity if the mother of learning.
Solution	Add games elements to their learning process to make learning fun.

5	**Mobile Rivalry**
Variant of	Good Rivals (IBA *et al.*, 2014)
Context	The learners realized that they need to spend considerable time on achieving their goal.
Problem	It is difficult to maintain efforts alone.
Forces	• Motivation decreases if others don't recognize their effort. • A person who does his best touches other's hearts. • It is difficult to keep working on a task when your attempts seem futile.
Solution	Promote some collaborative activities among learners where they compete against each other.

6	**Little by Little**
Variant of	Digestible Packets (BERGIN *et al.*, 2012)
Context	You want to avoid the situation of students becoming bored and disinterested.
Problem	If a topic takes longer than the time learners can concentrate, the learners will have difficulties understanding the topic in its entirety.
Forces	• Learners can only concentrate for a limited period of time. This is the primary reason to include regular breaks. • Due comprehension decrease, the motivation will decrease, too, and the activity will be considered difficult.
Solution	Organize the app activities in such a way that the topics remain small and understandable.

7	**Respect the Differences**
Variant of	Different Exercise Levels (BERGIN *et al.*, 2012)
Context	You want learners to practice a newly acquired skill through some exercises, but learners have different levels of ability and you want to challenge each of them.

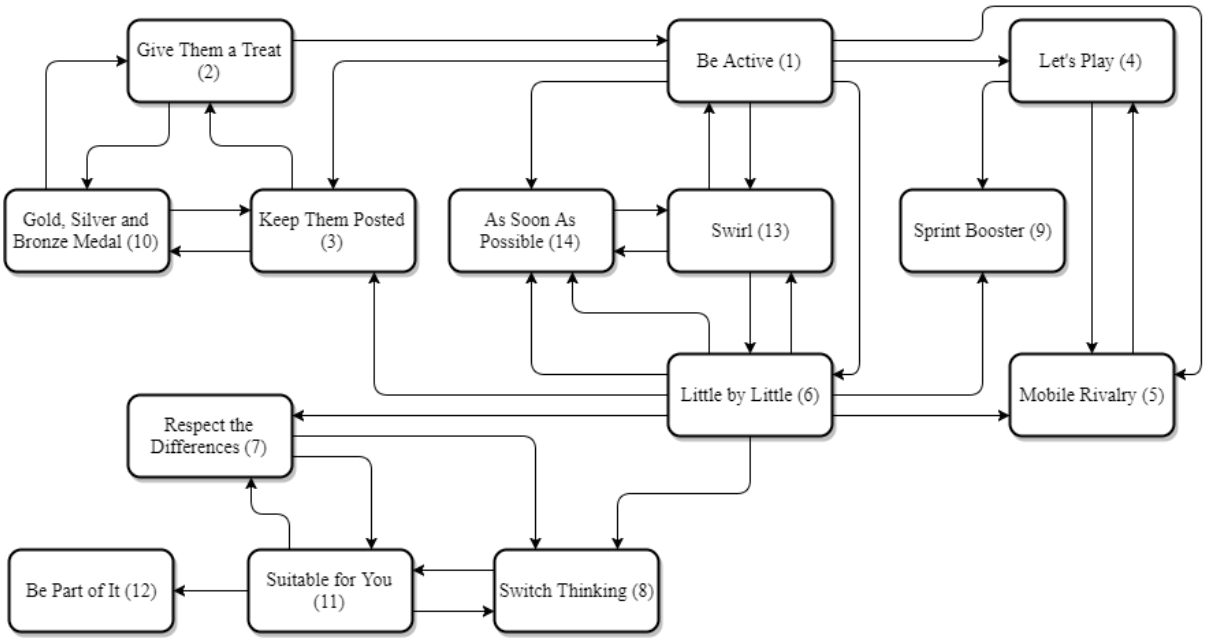
Problem	To improve learners' skills, the exercise must be located at the upper limit of the participant's current skill level, but this will be different for each participant.
Forces	• The most important aspect of exercises is to allow the learners to improve their newly acquired skills by working on a topic on their own. • If everyone is given the same exercise, then some learners will find it overly simple, and do not learn anything, while others consider the exercise too difficult, are frustrated because they can't do it, and do not learn anything.
Solution	Provide exercises of different difficulty levels, different Approaches and different topics to each learner, according to its learning style and limitations.

APPENDIX

B

MLearning-PL - Version 2

Figure 34 – `MLearning-PL` Graph - Version 2



Source: Elaborated by the author.

1	Be Active
Variant of	Active Student (BERGIN *et al.*, 2012)
Context	You want to maximize student learning.
Problem	The deep consequences of a theory are unlikely to be obvious to one who reads about, or hears about the theory. The unexpected difficulties inherent in using the theory or applying the ideas are not likely to be apparent until the theory is actually used.

Forces	• Passive learners don't learn much. • If learners read to explanations, without themselves becoming engaged, what is learned is unlikely to go into long-term memory. • If the learners don't actively engage the material, they won't retain it. They need to write and they need to do.
Solution	Keep the learners active. They should be active in the app, either with questions or with exercises.
Related Patterns	2, 3, 4, 5, 6, 13, 14

2	**Give Them a Treat**
Variant of	Chain of Excitement (IBA *et al.*, 2014)
Context	The learners have made some learning progress, and perhaps they think they've almost achieved their initial goal.
Problem	It is not easy to actively continue exploring and studying.
Forces	• It is difficult to continue working intensely on tedious tasks. • It is easy to be impressed not only by the beauty of arts and nature but also by intellectual excitement. • Intellectual excitement and academic experiences motivate you to study.
Solution	Make the learners feel the strong emotion of accomplishment by giving them some reward in the app, like a score or a customized message, which will motivate their learning.
Related Patterns	1, 3, 10

3	**Keep Them Posted**
Variant of	Tangible Growth (IBA *et al.*, 2014)
Context	The learners need to continue practicing the activities to achieve their goal.
Problem	It is not easy to keep the learner motivated to learn.
Forces	• It takes a long time before they realize the effect of learning. • It is difficult to maintain their motivation to work hard.
Solution	Show the evolution of the learners at each advanced stage, so they can realize how their knowledge and skills have grown.
Related Patterns	1, 2, 6, 10

4	**Let's Play**
Variant of	Playful Learning (IBA *et al.*, 2014)
Context	The process of learning bores the learners.
Problem	Learning as a duty is ineffective and painful.
Forces	• It is difficult to continue tedious work. • It is difficult to maintain motivation for ineffective learning. • Necessity if the mother of learning.
Solution	Add games elements to their learning process to make learning fun.
Related Patterns	1, 5, 9

5	**Mobile Rivalry**
Variant of	Good Rivals (IBA *et al.*, 2014)
Context	The learners realized that they need to spend considerable time on achieving their goal.
Problem	It is difficult to maintain efforts alone.
Forces	• Motivation decreases if others don't recognize their effort. • A person who does his best touches other's hearts. • It is difficult to keep working on a task when your attempts seem futile.
Solution	Promote some collaborative activities among learners where they compete against each other.
Related Patterns	1, 4, 6

6	**Little by Little**
Variant of	Digestible Packets (BERGIN *et al.*, 2012)
Context	You want to avoid the situation of students becoming bored and disinterested.
Problem	If a topic takes longer than the time learners can concentrate, the learners will have difficulties understanding the topic in its entirety.
Forces	• Learners can only concentrate for a limited period of time. This is the primary reason to include regular breaks. • Due comprehension decrease, the motivation will decrease, too, and the activity will be considered difficult.

Solution	Organize the app activities in such a way that the topics remain small and understandable.
Related Patterns	1, 3, 5, 7, 8, 9, 13, 14

7	**Respect the Differences**
Variant of	Different Exercise Levels (BERGIN *et al.*, 2012)
Context	You want learners to practice a newly acquired skill through some exercises, but learners have different levels of ability and you want to challenge each of them.
Problem	To improve learners' skills, the exercise must be located at the upper limit of the participant's current skill level, but this will be different for each participant.
Forces	• The most important aspect of exercises is to allow the learners to improve their newly acquired skills by working on a topic on their own. • If everyone is given the same exercise, then some learners will find it overly simple, and do not learn anything, while others consider the exercise too difficult, are frustrated because they can't do it, and do not learn anything.
Solution	Provide exercises of different difficulty levels, different Approaches and different topics to each learner, according to its learning style and limitations.
Related Patterns	6, 8, 11

8	**Switch Thinking**
Variant of	Brain Switch (IBA *et al.*, 2014)
Context	You are creating an output, and you've made some progress.
Problem	Logical thinking is not sufficient to achieve a breakthrough without intuitive thinking and vice-versa.
Forces	• Logical thinking promotes acute analysis, inference, and persuasion. • Intuitive thinking inspires good ideas, expressions, and impression. • It is difficult to be logical and intuitive simultaneously.
Solution	Provide activities in the app that switch learners' thinking between two modes of logical and intuitive thinking.
Related Patterns	6, 7, 11

9	**Sprint Booster**
Variant of	Acceleration to the Next (IBA *et al.*, 2014)
Context	You have almost achieved your goal.
Problem	Your motivation is faltering even though the goal is within reach.
Forces	• Just before achieving the goal, motivation tends to decrease. • The process of finally finishing your work is always difficult. • Pursuing the goal forces you into more energetic activity.
Solution	Provide small activities that allow the learner to set and accelerate toward the next goal to pass through the current goal without slowing down.
Related Patterns	4, 6

10	**Gold, Silver and Bronze Medal**
Variant of	Gold Star (BERGIN *et al.*, 2012)
Context	You want to encourage excellent work and to praise a learner for work well done.
Problem	Normally the reward structure is private. In grading you give the learner praise, but this loses the opportunity to show other learners what you value most highly.
Forces	• Learners want and need your praise. • Praise can be a prime motivator, and learners work best when they feel good about themselves and feel appreciated. • If other learners see what you value, they may be motivated to focus on these things too.
Solution	When a learner is doing well, or has done something well, praise them publicly for it, by giving them some reward that is shown to all learners.
Related Patterns	2, 3

11	**Suitable for You**
Variant of	Different Approaches (BERGIN *et al.*, 2012)
Context	You are teaching learners with different backgrounds and characteristics.
Problem	Logical thinking is not sufficient to achieve a breakthrough without intuitive thinking and vice-versa.

Forces	• Communication always takes place between a sender and a receiver, and the effectiveness of communication isn't measured by what the sender says, but by what the receiver understands. • Some people, the visuals, learn most effectively by watching; the auditories, by listening; and the kinesthetics, through action.
Solution	Provide different approaches and types of medias to the same topic, for instance, texts, videos, infographics, and so on. Accept different learning styles by addressing various sensory modalities. It might be difficult to provide different approaches for every single topic, but make sure to at least change the approach when you change the topic.
Related Patterns	7, 8, 12

12	**Be Part of It**
Variant of	Role Play (BERGIN *et al.*, 2012)
Context	You want to pay attention to the kinesthetic learners and provide kinesthetic learning and a bit of fun for everyone.
Problem	Most teaching styles respect the auditories, a few the visuals, and even fewer the kinesthetics.
Forces	• The complexity of some concepts makes them hard to understand with only abstract explanations. • Difficulties in understanding complex concepts may frustrate the students. • You not only would like to provide a positive learning environment, so even learning complex topics might be fun, but you also want to take into account that different people learn things best using different sensory modalities.
Solution	Invite the learners to behave as a part of the concept involved in a collaborative role play. Every learner plays one part of the concept to get a deeper knowledge for its underlying structure. Learners see how the different parts of the concepts are all working together to solve a bigger problem.
Related Patterns	11

13	**Swirl**
Variant of	Spiral (BERGIN *et al.*, 2012)
Context	You want to enable students to solve meaningful problems as early in the course as possible.

Problem	Topics in a course are often interrelated. Too often, many different topics are required for students to have enough tools with which to solve interesting problems.
Forces	• If we try to do the topics in any logical order we tend to get bogged down in details and leave the learners bored. • Learners learn best when they are doing things, and meaningful problems motivate them to work harder.
Solution	Organize the app activities to introduce topics to learners without covering them completely at first viewing so that a number of topics can be introduced early and then used. In the first cycle make each topic introduction as simple as possible without leaving out essential details. Cover several topics quickly. This can get learners working on interesting problems earlier as they have more tools to use, though they have not, perhaps, mastered any of the tools. The instructor can then return to each topic in turn, perhaps repeatedly, giving more of the information needed to master them.
Related Patterns	1, 6, 14

14	**As Soon As Possible**
Variant of	Early Bird (BERGIN *et al.*, 2012)
Context	You want to ensure that your students remember (at least) the most important ideas.
Problem	Students have difficulties sometimes distinguishing between the important and the unimportant ideas. However, students often remember best what they learn first.
Forces	• You have to mine the course for its most important ideas. • These ideas become the fundamental organizational principle of the course. • The ideas, and especially their relationships are introduced at the beginning of the course and are returned to repeatedly throughout the course. This way the most important things in the course receive more focus from the instructor and the students. • Students can be made more aware of what is paramount.
Solution	Organize the activities in the app so that the most important topics are taught first. Teach the most important material, the "big ideas", first. When this seems impossible, teach the most important material as early as possible.
Related Patterns	1, 6, 13

APPENDIX

C

Experimental Study 1 - Instrumentation

Some instruments were defined and created to support the conduction of the Experimental Study 1. These instruments are presented next and are also available at <https://goo.gl/XzKYSh>

C.1 Characterization Form

What is your academic background? Fill in the blanks, if applicable, and indicate if any of the degrees are in progress:

Undergraduation: _____

Specialization: _____

Master: _____

PhD: _____

Example:

Undergraduation: Computer Engineering

Specialization: -

Master: Computer Science

PhD: Computer Science (in progress)

What is your experience as a tutor, monitor or teaching assistant?

◯ None

◯ Between 1 and 6 months

◯ Between 6 months and 1 year

◯ Between 1 and 3 years

◯ More than 3 years

What is your experience as a teacher?

◯ None
◯ Up to 1 year
◯ Between 1 and 3 years
◯ Between 3 and 5 years
◯ More than 5 years

What is your experience as a teacher?
◯ None
◯ Up to 1 year
◯ Between 1 and 3 years
◯ Between 3 and 5 years
◯ More than 5 years

C.2 Activities Proof Template

Activity 1
Pattern: *Let's Play* and *Mobile Rivalry*
Solution: Adding game elements to make the learning process more fun and promoting collaborative activities among learners in which they compete for the same goal.

Activity 2
Pattern: *Little by Little*
Solution: The proposed activities in the application should be presented in small and understandable topics.

Activity 3
Pattern: *Respect the differences*
Solution: The proposed activities should be customized for the learners according to their limitations and learning style, so that each student will receive different activities and at different stages of the learning process.

Activity 4
Pattern: *Give Them a Treat* and *Keep Them Posted*
Solution: Learners must have the sense of accomplishment, which can be achieved through motivational messages or in-app rewards. In addition, it is important that learners are always informed of their evolution throughout the stages, so that they are aware of what knowledge and skills have already been acquired.

Activity 5
Pattern: *Be Active*
Solution: The learner must stay active in the application, so keep the learner engaged in activities such as theoretical questions or practical exercises.

C.3 Feedback Questionnaire - Ad hoc

Have you ever solved pedagogical problems?
◯ Yes ◯ No

If "yes", What kind of problems?

How difficult was it for you to carry out the activities? Check the option that best represents your choice.

Activity 1:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 2:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 3:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 4:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 5:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard

In case of difficulties, describe what difficulties you have faced:

Do you believe that the use of further artifacts would help in the problem-solving process?
◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree

Do you know any artifacts that would help in this scenario?
◯ Yes ◯ No

If "yes", which one(s)?

What kind of artifacts do you believe would help to solve these problems?

If you wish, comment on your experience.

C.4 Feedback Questionnaire - MLearning-PL

Have you ever solved pedagogical problems?

◯ Yes ◯ No

If "yes", what kind of problems?

How difficult was it for you to carry out the activities? Check the option that best represents your choice.

Activity 1:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 2:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 3:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 4:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 5:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard

In case of difficulties, describe what difficulties you have faced:

Have you ever used patterns and/or pattern languages?

◯ Yes ◯ No

Do you believe that MLearning-PL helped in the process of solving pedagogical problems?

◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree

◯ Strongly agree

Do you believe that MLearning-PL is complete?

◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree

Do you believe that MLearning-PL is clear and easy to understand?

◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree

If you could change the pattern language presented, what kind of changes would you make?

If you wish, comment on your experience.

APPENDIX

D

Experimental Study 2 - Instrumentation

Some instruments were defined and created to support the conduction of the Experimental Study 2. These instruments are presented next and are also available at <https://goo.gl/HeSpgm>

D.1 Characterization Form

What is your academic background? Fill in the blanks, if applicable, and indicate if any of the degrees are in progress:

Undergraduation: _____

Specialization: _____

Master: _____

PhD: _____

Example:

Undergraduation: Computer Engineering

Specialization: -

Master: Computer Science

PhD: Computer Science (in progress)

What is your experience as a tutor, monitor or teaching assistant?

◯ None

◯ Between 1 and 6 months

◯ Between 6 months and 1 year

◯ Between 1 and 3 years

◯ More than 3 years

What is your experience as a teacher?

◯ None
◯ Up to 1 year
◯ Between 1 and 3 years
◯ Between 3 and 5 years
◯ More than 5 years

What is your experience as a teacher?
◯ None
◯ Up to 1 year
◯ Between 1 and 3 years
◯ Between 3 and 5 years
◯ More than 5 years

D.2 Activities Proof Template

Activity 1
Pattern: *Let's Play* and *Mobile Rivalry*
Solution: Adding game elements to make the learning process more fun and promoting collaborative activities among learners in which they compete for the same goal.

Activity 2
Pattern: *Give Them a Treat*, *Keep Them Posted*, and *Gold, Silver and Bronze Medal*
Solution: Learners must have the sense of accomplishment, which can be achieved through motivational messages or in-app rewards. Besides that, when a learner is doing well, or has done something well, praise them publicly for it, by giving them some reward that is shown to all learners. In addition, it is important that learners are always informed of their evolution throughout the stages, so that they are aware of what knowledge and skills have already been acquired.

Activity 3
Pattern: *Little by Little* and *Sprint Booster*
Solution: The proposed activities in the application should be presented in small and understandable topics and that allow the learner to set and accelerate toward the next goal to pass through the current goal without slowing down.

Activity 4
Pattern: *Respect the differences*

Solution: The proposed activities should be customized for the learners according to their limitations and learning style, so that each student will receive different activities and at different stages of the learning process.

Activity 5
Pattern: *Be Active*, *Swirl* and *As soon as possible*
Solution: The learner must stay active in the application, so keep the learner engaged in activities such as theoretical questions or practical exercises. Also organize the app activities to introduce topics to learners without covering them completely at first viewing so that a number of topics can be introduced early and then used, but the most important topics are taught first.

Activity 6
Pattern: *Suitable for You* and *Be Part of it*
Solution: Provide different approaches and types of medias to the same topic, for instance, texts, videos, infographics, and so on. Accept different learning styles by addressing various sensory modalities. Also invite the learners to behave as a part of the concept involved in a collaborative role play.

D.3 Feedback Questionnaire - Ad hoc

Have you ever solved pedagogical problems?
◯ Yes ◯ No

If "yes", what kind of problems?

_____

How difficult was it for you to carry out the activities? Check the option that best represents your choice.

Activity 1:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 2:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 3:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 4:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 5:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 6:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard

In case of difficulties, describe what difficulties you have faced:

Do you believe that the use of further artifacts would help in the problem-solving process?

◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree

Do you know any artifacts that would help in this scenario?

◯ Yes ◯ No

If "yes", Which one(s)?

What kind of artifacts do you believe would help to solve these problems?

If you wish, comment on your experience.

D.4 Feedback Questionnaire - MLearning-PL

Have you ever solved pedagogical problems?

◯ Yes ◯ No

If "yes", what kind of problems?

How difficult was it for you to carry out the activities? Check the option that best represents your choice.

Activity 1:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 2:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 3:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard
Activity 4:	◯ Very Easy	◯ Easy	◯ Moderate	◯ Hard	◯ Very Hard

Activity 5: ◯ Very Easy ◯ Easy ◯ Moderate ◯ Hard ◯ Very Hard
Activity 6: ◯ Very Easy ◯ Easy ◯ Moderate ◯ Hard ◯ Very Hard

In case of difficulties, describe what difficulties you have faced:

Have you ever used patterns and/or pattern languages?
◯ Yes ◯ No

Do you believe that MLearning-PL helped in the process of solving pedagogical problems?
◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree

Do you believe that MLearning-PL is complete?
◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree

Do you believe that MLearning-PL is clear and easy to understand?
◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree

If you could change the pattern language presented, what kind of changes would you make?

If you wish, comment on your experience.

ICMC USP
SÃO CARLOS