Mobile Field Trip

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To my parents, brother and girlfriend, for all the love and support.
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Resumo

A educação tem sentido a necessidade de ferramentas de apoio. Paralelamente, a evolução tecnológica tem causado mudanças nos métodos pedagógicos, atualizando-os, para aproveitar essas novas tecnologias. Na área de Geologia, os recursos educacionais incluem conteúdo geral, porém são direcionados para uma área geográfica específica e ilustram trabalho prático no campo. Atualmente, as avaliações relacionadas com trabalhos de campo, no contexto de uma unidade curricular, ainda dependem de papel e não usam qualquer suporte tecnológico. Os alunos escrevem relatórios acerca do trabalho de campo ou resolvem testes depois da visita de estudo. Devido à natureza prática de alguns exercícios em Geologia e em algumas outras áreas, esta metodologia de trabalho não é eficiente. Por esta razão, há a necessidade de um novo suporte para essas práticas. Este projecto visa desenvolver um sistema integrado que permita a realização de questionários, quando em viagens de estudo ou em sala de aula. O resultado traduziu-se num sistema integrado, chamado Field Trip: este sistema conecta um portal web, onde questionários podem ser criados, a uma aplicação móvel que permite os estudantes resolverem-nos durante as viagens de estudo.

Palavras-Chave

Sistema de Gestão de Aprendizagem (LMS), e-Learning, Geologia, Aplicação Móvel, Questionários, Gamificação.
Abstract

Education, in general, has been feeling the necessity of tools to support it. The evolution of technology has been causing changes in the pedagogical methods, updating them, in order to take advantage of these new technologies. In the area of Geology, educational resources include general content, nonetheless targeted to a specific geographical area and illustrated practical work in the field. Currently, the evaluations related to field works, in the context of a course, still rely on paper and are not using any technological support. The students write reports or have quizzes regarding the field trips. However, due to the practical nature of some exercises in Geology and also in other areas such as History, Geography, or Biology, this work methodology is not very efficient. For this reason, there is the necessity of a new support for these practices. This thesis aims to develop an integrated system that allows Geology teachers, or those of other subjects, to make quizzes, when in field trips or in the classroom. The result was an integrated system, named Field Trip: this system connects a web portal, where quizzes can be created, to a mobile application that allows students to solve them during field trips.

Keywords

Learning Management System (LMS), e-Learning, Geology, Mobile Application, Quizzes, Gamification.
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List of Acronyms

AJAX: Asynchronous Javascript and XML
API: Application Programming Interface
CSS: Cascading Style Sheets
CSS3: Cascading Style Sheets 3
CSV: Comma-separated values
DB: Database
DDL: Data definition language
DBMS: Database Management System
DI: Dependency Injection
DOM: Document Object Model
GIS: Geographic Information System
GPS: Global Positioning System
HTML: HyperText Markup Language
HTML5: HyperText Markup Language 5
HTTP: Hypertext Transfer Protocol
HTTPS: Hyper Text Transfer Protocol Secure
ICT: Information and Communication Technologies
IEEE: Institute of Electrical and Electronics Engineers
JS: JavaScript
JSON: JavaScript Object Notation
KFUPM: King Fahd University of Petroleum and Minerals
KMZ: Keyhole Markup Language
LCMS: Learning Content Management System
LMS: Learning Management System
LOM: Learning Object Metadata
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<td>MVC</td>
<td>Model-View-Controller</td>
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<td>MVVM</td>
<td>Model-View-View-Model</td>
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<tr>
<td>MVW</td>
<td>Model-View-Whatever</td>
</tr>
<tr>
<td>OS</td>
<td>Operating System</td>
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<td>PDF</td>
<td>Portable Document Format</td>
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<td>PHP</td>
<td>PHP: Hypertext Preprocessor</td>
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<td>QR Code</td>
<td>Quick Response Code</td>
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<tr>
<td>QTI</td>
<td>Question and Test Interoperability</td>
</tr>
<tr>
<td>REST</td>
<td>REpresentational State Transfer</td>
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<tr>
<td>SCORM</td>
<td>Shared Content Object Reference Model</td>
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<tr>
<td>SLO</td>
<td>Sharable Learning Object</td>
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<tr>
<td>SOAP</td>
<td>Simple Object Access Protocol</td>
</tr>
<tr>
<td>SRS</td>
<td>Software Requirements Specification</td>
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<td>Secure Sockets Layer</td>
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<tr>
<td>SSO</td>
<td>Single Sign-On</td>
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<tr>
<td>UI</td>
<td>User Interface</td>
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<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
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<tr>
<td>URI</td>
<td>Uniform Resource Identifier</td>
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<tr>
<td>URL</td>
<td>Uniform Resource Locator</td>
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<tr>
<td>XML</td>
<td>eXtensible Markup Language</td>
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Chapter 1

Introduction

This chapter illustrates a background for the context of this thesis and summarizes the motivations subjacent to this project, taking into account the evolution of the technology along with the existing tools for the Education.
1.1 Introduction

In the last decades, the fast evolution of Information and Communication Technologies (ICT) has changed our routine and the paradigm of the lifestyle of our society. Two decades ago this lifestyle arrived into classrooms, opening doors to a new way of providing Education with the introduction of e-learning [1]. E-learning is mentioned as "the use of computer network technology, primarily through the Internet, to deliver information and instruction to individuals" [2]. The use of the ICT revolutionized the distribution of information for students. Likewise, the birth of mobile technologies is enlarging the possibilities of teaching methods.

Mobile learning, also called m-learning, is a subset of e-learning and is the term associated to delivery of teaching and learning [1], through mobile devices: smartphones, laptops, tablets, etc. As mentioned, m-learning is defined as "the process of learning mediated by a mobile device" [3].

This process radically changed the education methodologies, allowing students to participate in field work activities, with all the resources needed available in their mobile devices. This can provide a large number of benefits both for teachers and students, especially if allied with the concept of Gamification [4], [5], which is the transport of 'gaming elements' into an educational context, to capture the students' attention and motivation.

1.2 Motivation

Several courses and subjects, such as Geology, have the necessity of carrying the learning process to the outside of the classroom. The possibility of extending the lessons to practical work on the field, not only increases the student's motivation, but also helps him/her to assimilate the subject topics [6]. Unfortunately, there is a lack of technological platforms that allow student evaluations on the field.

The need to have a tool to help teachers and students to participate on Field Trips and to have technological means to accomplish objective evaluations on a real environment, with the possibility of using a gamification approach is the main motivation for this work.

1.3 Problem Statement

To take the students out of the classroom into a field trip is a big responsibility and requires lots of planning. Furthermore, it is difficult to make organized and objective quizzes on the field that reflect and evaluate the student's understanding of the subject. For this reason, it is really important to have a portable LMS platform, which can be used to visualize quizzes and solve them, during the field work. Furthermore, since this kind of work requires a lot of observation, most of the times it is important to register what is seen and use those observations as an evaluation parameter. Taking into account that there is a big scarcity of these types of platform (which allow answering a question with photos, for example), education is not taking advantage of all the functionalities that mobile technology can bring.
1.4 Objectives

Having stated the problem, the objective of this work is to create a portable LMS to fill the gaps in the existent LMS platforms, when applied to Geology and evaluation on the field. It should give the students the possibility to see and solve structured quizzes and be evaluated outside the classroom.

The main goals of this work are:

- Design the mobile LMS system;
- Develop interfaces to access the LMS: web portal and mobile application;
- Create a database to support this system;
- Establish the communication between the system modules: interfaces and database;
- Define the class of targeted questions at field trips.

With this system, the teacher will be able to create a quiz on the web portal, which should be downloaded by the students. During the field trip, only in the location and/or time of the quiz, the mobile app will allow the students to access and answer the quiz questions, with an offline mode option. After the field trip, the students should upload the quiz answers, using a Wi-Fi connection, enabling the teacher to evaluate them through the web portal.

1.5 Results

After a long process of development and testing, the proposed system, named Field Trip, was implemented accomplishing all the objectives mentioned in 1.4 After some research and analysis of some existing e-learning platforms, the decision was taken to extend the functionalities of the Moodle web portal, since it is an open-source platform with lots of functionalities already implemented: creation of courses, subscription management, realization of quizzes with the classic types of questions, database management, web services, and so on. Furthermore, another recent mobile application created by Moodle was discovered, which is open-source as well. It, too, was used on Field Trip. This application already handled the communication with Moodle using REST services, which was also a great benefit.

Thus, two parts of the system were developed in a parallel way: the Field Trip web portal using Moodle and the Field Trip mobile application with the Moodle Mobile 2. In the web portal, amongst other functionalities provided by Moodle, quizzes can be created and associated to a geolocation. Using the mobile app, when near the correct location, those quizzes can be accessed in a mobile device, which is perfect to evaluations during field trips. This was implemented using the GPS system, incorporated in most smartphones. There is also an offline mode that if activated allows the quizzes to be solved without internet connection, being synchronized with the web portal afterwards, when the application detects an internet signal again. New types of questions have also been developed, with the following answer options:

- Photo;
- Photo with description;
- Geographic Coordinates;
1.6 Structure of the document

The following chapters will explain in a more detailed way the topics summarized in Chapter 1. Specifically, Chapter 2 will present the concepts of e-learning, m-learning and gamification, along with their advantages to Education. The same chapter will detail the Learning Management Systems, which are the technological tools that support this type of learning, the standard specifications for quizzes on these platforms, and some literature about the field trips in the area of Geology, mentioning the obstacles they face. Finally, it will present a review on the existent mobile LMS platforms and some tools directed for the Geology area, showing their gaps and the necessity of a solution to fulfill them.

Chapter 3 will mention the traditional types of questions used in field trips, the innovative and dynamic possibilities that recent technologies can bring and it will specify all the details of Field Trip: its requirements, logical and physical architecture, its data model, the technologies it used and how it was implemented.

Chapter 4 will present a demonstration of the system features and present a discussion of the results. Lastly, Chapter 5 summarizes all the presented chapters in this document and the work that can be done in the future, to continue this project, taking into account the limitations that still can be crossed.
Chapter 2

State of the Art

This chapter will present an analysis of the relevant literature related to this work. In Section 2.1, a brief overview of the e-learning and m-learning processes will be presented. Section 2.2 will present a specific type of technological platforms, called LMS, which allow the e-learning process. On section 2.3 the concept of Gamification and its value for the learning will be addressed, stating that quizzes can be a way to adopt it and at the same time a way to evaluate the students’ knowledge. Section 2.4 presents two standard formats to represent a quiz in a LMS system, named SCORM and QTI, then, in 2.5 the importance of field trips on the subject of Geology will be explained and some helpful tools directed to this area will be presented. In 2.6 some existent mobile LMS platforms, which help on the mentioned field trips, will be analyzed. Finally, in 2.7 the tools presented in 2.5 and 2.6 will be discussed, showing some flaws in their functionalities, and the need to create a solution to overcome these gaps.
2.1 E-learning

Electronic-learning, or simply E-learning [7], is a process of learning that takes advantage of Technology and can be defined as the solution for delivering online, hybrid, and synchronous learning independently of the physical location, time of day, or choice of digital reception/distribution device.

The key for success in e-learning, according to Palloff and Pratt [8] is that the subject of learning is not restricted to the program of the course, being exceeded due to the students’ involvement in the subject. Furthermore, it is easier to distribute information using E-learning platforms [9], providing students with a much larger range of study material as well as with fast and easy access. This is possible due to the huge flexibility and availability [10] of e-learning technologies.

These features also bring the possibility of acquiring knowledge in asynchronous time, meaning that students can access and assimilate information at their own pace. For this reason, they become more independent and able to control their education, developing maturity and responsibility. On the other hand, creativity and a deeper learning is constructed within students [10], as they get more motivated.

E-learning is a solution for some educational models formulated in the last decades, namely Discovery Learning [11], born in the 1970s, and the Socio-constructivist Learning [11], 1990s. The first one says that knowledge is discovered through an active participation in the learning process, while the second claims that it is an interdependently co-construction between the social and the individual involvement. E-learning promotes the active participation of the learner in an individual way but also through a social process, if supported by platforms that feature online or offline discussions. However, it could not be enough to cover other educational models, such as the Constructivist Learning, formulated in the 1980s, or the Problem-based Learning, established in the 1990s [11]. The first states that knowledge is developed through interactions with the environment and the second says that it is expanded through working on tasks and skills comparable to the environment in which they will be handled. Well, in some areas, being behind a desk doesn’t allow the contact with an authentic or simulated environment for which the students are preparing themselves. To support all these models and aided by the appearance of mobile technologies, a new subtype of electronic-learning came up: mobile-learning.

2.1.1 M-learning

Mobile-learning, also known as m-learning, is a specific practice of e-learning: it provides access for learning contents through mobile devices, extending even further the flexibility and availability of the e-learning tools. Easily, with a mobile learning platform, students can improve their knowledge anywhere, anytime.

There are many definitions of m-learning, and some were criticized for taking a technocentric approach [12], but in this thesis the one considered most representative is given by Sharples [13], [4]: mobile learning is the learning process that makes use of mobile devices and for that reason is not restricted
to a fixed place. This pedagogical practice can be used inside or outside the classroom, in a formal lesson. It can be used spontaneously, when the learner develops an interest for a particular subject, and it can be directed by others, or self-directed, when the student defines his strategy of learning [11].

These new learning methodologies are personalized, learner-centered, cooperative [14] and in the case of m-learning, comparing to e-learning, it is even more context-aware, meaning that it is influenced by the historical context and the environment. Moreover, it makes perfect sense to explore it, since mobile devices became ubiquitous [15] and offer a huge diversity of learning options. Figure 1 shows the increase of smartphone users around the world.

![Figure 1 - Number of smartphone users worldwide from 2014 to 2020 (in billions) [16].](image)

### 2.1.2 E-learning Platform Architecture

There are several technologies that implement the e-learning concept. However, regardless of the technology used, even the most simplistic architecture for e-learning platforms requires a Server, responsible for supplying all the contents and resources such, databases for data management and activity registers. There are different types of management modules[17]:

- **LMS** – Learning Management System, manages and tracks the activity and progression of the students;
- **LCMS** – Learning Content Management System, manages the learning resources, according to the characteristics of each student.

Figure 2 presents how a LMS and a LCMS can be integrated to promote e-learning.
However, the focus of this dissertation is only the LMS system, and exploring the advantages that mobile technology can take from it.

### 2.2 Learning Management Systems

Learning Management System [6] (LMS) is one of the effective tools to enable e-learning. According to Lohn and Teasley [18], LMS can be defined as follows: *web-based systems allow instructors and students to share instructional materials, make class announcements, submit and return course assignments, and communicate with each other online*. Its effectiveness is highlighted on the flexibility and availability of the content, as well as in the involvement of the student in the subject. Some platforms also enable m-learning, which further extends those qualities and is the concept that this thesis intends to explore.

One of the functionalities that an LMS should have is the possibility of Online Discussion. Mustafa Hariri [6] indicates that Online Discussion is the main tool of Students’ engagement and interactivity. Brown [19] also stated that asynchronous online discussion allows the students to take the time they need to research about the topic before participating in the discussion and helps them overcome their shyness and express themselves freely and with confidence. This allows for a deeper and more accurate learning. Brown believed this approach provides a rich social learning environment.

Mustafa Hariri [6] also mentioned other tools and features important in a LMS, relevant to establish an effective communication, namely: e-mail, announcement and grade-book.

The first one allows even the shyest of students to state their doubts easily, as is the case of the online discussion. The announcement is useful for delivering important messages such as time and place of an exam, information on new material uploading, new discussion topics or even to clarify specific issues.
Chickering and Gmason [20] provide seven good education practices. One of them is to return fast feedback to the students about their performance, in order to make them aware of it and improve their weaknesses and/or build their strengths. The grade-book tool in the LMS is a means to engage this practice.

In Saudi Arabia, the King Fahd University of Petroleum and Minerals (KFUPM) tested an LMS platform called Blackboard CE8 (formerly WebCT CE8), in the Graduate Geology Course. Although it is not just a Geology Tool, it was notoriously important for the teaching and practice of this subject.

WebCT, or Blackboard Learning System, is an online proprietary virtual environment system, licensed to colleges and other institutions. It allows tools such as discussion boards, mail systems, live chat, and other functionalities depending on the software version [20].

Initially, the objective of using the LMS “Blackboard - CE8" was to increase the students' engagement, participation, communication and contribution to the subject of the course, which are considered essential factors for better learning and understanding [6].

At the end of the platform testing period, evidently, this Learning Management System has shown improvements in the learning of the contents of the Geology subject mentioned. The results were explained by how easy it is to distribute the course material, including several case-studies and real world examples. Moreover, as an LMS, it enabled creative thinking and the development of problem-solving skills [6].

### 2.3 Gamification

Gamification is a strategy that can be used in e-learning to capture the student’s attention and motivation. According to Dixon and Nacke, “Gamification is the use of game design elements in non-game contexts”[21]. Using tests, quizzes, exercises, edu-games, badges, etc., in Education, makes the students’ interest and participation increase [4].

Nevertheless, to ‘gamify’ a learning process, it is important to understand which ‘game elements’ bring in this quality. Reeves and Read [22] identified the “Ten Ingredients of Great Games”: Self-representation with avatars; three-dimensional environments; narrative context; feedback; reputations, ranks, and levels; marketplaces and economies; competition under rules that are explicit and enforced; teams; parallel communication systems that can be easily configured; time pressure. These features only make sense when grouped, for each one isolated wouldn’t be identified as ‘gameful’ [5].

Notwithstanding, the difference between a ‘gamified’ application and a ‘full’ game may sometimes depend on the context and the perception. For example, adding an informal rule or a shared goal can make this conversion. Another way to bring in gaming elements is using augmented reality [23], transporting the students to their past experiences with videogames. A great example of a tool that can fit in all these scenarios is ARIS [24], which is an open-source and user-friendly platform for the creation of games, tours and interactive stories, using mobile technology, such as GPS, QR Codes, etc.
Additionally, solving quizzes [25] is also a great way to bring in gamification. They are great multimedia resources that can be seen as games and mediators of knowledge. Furthermore, quizzes can help teachers to understand the students' strengths and weaknesses, helping students to learn and teachers to know how to teach with a differentiated pedagogy [26]. For instance, in Geology courses, playing didactic games or answering challenging quizzes related to relevant places they can find on the field can bring great value to the learning, as it stimulates the students’ excitement for exploring the area, discovering the materials and the structures with a geological interest.

Well, most of the LMS platforms feature quizzes, and are able to import them or export from or into other LMS systems, but for that they have to use a standard specification for the quiz representation. Section 2.4 will present some of the most common standards.

## 2.4 Quiz Specification

Quizzes can be represented in LMS platforms in many different formats. However, the time and effort needed to create learning or assessment objects is bigger than it was envisioned and for that reason there is still a resistance to the use of e-learning [26]. To fight this resistance, and make a cost reduction, solutions like the reuse of content in different LMS platforms or in different learning contexts were developed. Well, this interoperability between different systems, which allows them to import or export quizzes and maintain the information even if the support technology has changed, is only possible with the use of standard representation formats. The most common specifications are SCORM and QTI.

### 2.4.1 SCORM

The Shared Content Object Reference Model (SCORM) [27] is a set of standards for packaging and sequencing of e-learning content, including assessments, which are compatible with most of the existing Learning Management Systems. It specifies how to organize learning objects with the following goals: portability, reusability, interoperability, durability, accessibility and sequencing [28], [29]. Creating SCORM objects with these qualities is not trivial, due to its complexity, but some tools like the free Reload Project Editor¹ can help creating them.

A Sharable Learning Object (SLO) is an independent unit of learning content with only one specific learning purpose. These objects are constituted by a collection of aggregated and sequencing resources, such as text, sound, images, animations, videos, and web pages, called assets in the SCORM terminology. SLOs can be set in different ways and combined with other objects, being more effective if organized with a metadata classification system, in a repository.

¹ This editor provides support for IMS Metadata, IEEE LOM, IMS Content Packaging 1.1.4, SCORM 1.2, and SCORM 2004 [92].
SCORM, until now, has been the most widely used standard for e-learning content, in many different LMSs, but maybe in the future it can be substituted by a new and more flexible version, called Tin Can API [27], [30], or “the new generation SCORM”, that recently appeared and can be promising.

2.4.2 QTI

The IMS Question and Test Interoperability specification (QTI) [31] defines a basic structure for the representation of question (item) and test (assessment) data.

Independent of the specifications, the design of each LMS using QTI is not limited, like all IMS specifications. Those specifications could be user interfaces, pedagogical paradigms, technology or policies that constrain innovation, interoperability, or reuse.

The QTI specification [30] is a data model, described in Unified Modeling Language (UML) and delivered using the eXtensible Markup Language (XML), to enable interoperability between systems. This document defines the structure of the questions, assessments and their results. Thus, multiple different LMS technologies, can import these questions and answers when implementing this standard.

The construction of the questions can be done using a core set of presentation and response structures [31]. Furthermore, there are diverse methods to collect and score the question results. Examples of Standard Question types can be: multiple choice, fill in the blank, true/false choice, etc.

QTI specifies ‘Item’ as the container of the needed data elements to compose, render and score the questions. An organized group of Items constitutes a ‘Section’ and an ‘Assessment’ (e.g. a ‘test’) is formed by one or more sections. Finally, a ‘Participant’ is the person that interacts with the ‘Assessment’.

Table 1 summarizes all these terms.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>Combination of interrogatory, rendering, and scoring information</td>
</tr>
<tr>
<td>Section</td>
<td>Collection of zero or more items and/or other Sections</td>
</tr>
<tr>
<td>Assessment</td>
<td>Collection of one or more Sections</td>
</tr>
<tr>
<td>Participant</td>
<td>The user interacting with an assessment</td>
</tr>
</tbody>
</table>

2.4.3 Quiz Specification Discussion

Both standards, SCORM and QTI, have great benefits in incorporating quizzes or assessments in the LMS platforms. The scope of QTI is more limited [32], being directed only to assessments, while SCORM ensures interoperability and coherence to all learning content, with a compact collection of specifications for every aspect related to LMSs. Furthermore, SCORM specifies the dynamic interactions between
learning content, such as assessments. The final argument for this comparison is that SCORM is widely spread and used amongst most of the LMS systems, as mentioned before.

Yet, besides the LMS platforms that implement these standards, there are others which are also quite effective, and with the same functionalities, such as Moodle. This platform [33], amongst many other functionalities, allows for the creation of tests, with a big diversity of question types, and also the development of new types of questions. Furthermore, despite it not representing quizzes in a standard format, it allows the upload of SCORM packages to include in the course [34]. The weakness of this tool is that it promotes only a one-way interoperability, since it doesn’t export content to SCORM packages, but merely imports it.

2.5 Geology Field Trips

Field trips are a way to pique the interest of students towards the subject of study, getting them motivated to actively participate. Especially in the area of Geology, it is a good learning strategy because it allows direct observation of the natural environment of materials and its geological processes. According to Rebelo et al. [35], the outdoor activities are perfect complements to the formal classroom learning. However, they must be well planned and exploited [36].

Several authors had been stating the didactic importance of the field work in the Geosciences’ teaching, as a learning tool: Orion N. [37], D. Rebelo & L. Marques [38], A. Monteiro [39], M. L. Ramalho [40], among many others. Woefully, as always happened in History, change is met with some resistance, in this case, by means of teaching methodology, by some teachers, in the area of fieldwork (Rebelo & Marques [38], among others). It may happen due to the recognition of scientific, organizational, and logistical difficulties. Scientific difficulties are due to the lack of supporting documents to prepare and guide the field trips. Additionally, according to E. R. Pedrinaci et al. [41], the organizational nature and logistics are related with the deficit of teachers with interest, or inadequate training in the preparation of practical materials for students.

Hopefully, it is possible to overcome those obstacles, by giving formation to the teachers in this area, disseminate local scientific spots of geological interest and, finally, it would be important to prepare documents to support the field trips [42] along with other supporting technological tools.

2.5.1 Features

Traditionally, the typical tool used in field work was a rudimentary paper notebook. It was used to annotate all the information collected in the trips. Nowadays, due to the evolution of technology, there are much more sophisticated tools to register field data. The possibility to have applications available on mobile devices such as smartphones and tablets allows for the collection of much more precise data, in an easier and faster way. Furthermore, most of mobile devices nowadays have an integrated camera,
being able to take pictures of the materials in an evaluation environment on the field and automatically registering the time and location of the picture. If searching for certain information is required, using these devices, it is also possible to access the Internet and open different types of maps, including relief maps, etc.

In order to understand the land and the context of the sample, it is essential for the geologist to know the sample’s location [43]. In this task, mobile applications are much more efficient than the old-school way. Moreover, having the information of the context of the geological materials, geologists can make a better prediction of what data they should collect next, or where to go next, to complete their investigation [43].

Another great benefit of using mobile devices in the field is the possibility of data manipulation in real time, data insertion in databases, observation of graphical results, or in any format desired, having the right application. The time spent importing data to a GIS program, traditionally a manual work, is saved, because since the data is collected in the app, it is already in a digital form. Additionally, smartphones don’t require any extra hardware [43], due to the fact that this technology already has internal sensors to gather data, whose costs are significantly less than specific instruments, such as GPS systems, compass and clinometers.

Since the focus of this thesis is the development of a mobile LMS platform that could be used in field trips, in diverse areas but with some specific utilities for Geology, 2.5.2 will gather some existent geological tools for field trips and 2.6 will mention some existent LMS platforms that support m-learning.

2.5.2 Geological Mobile Tools

In Geology, there is the necessity to increase the knowledge of Earth structures and to establish the connection with the Geological processes in the origin of their formation. However, it is difficult to accomplish this without having the right tools.

It is possible to find specific tools useful in the area of Geology, not just for students but also for professional geologists. Depending on their functionalities, they can be really useful in some activities, such as accessing needed resources or collecting data on the field.

As mentioned before, mobile applications are the perfect tools to help in the geologist field work. “An Overview of Mobile Applications for Field Science” [43] reveals twelve popular applications for mobile devices: Lambert, FieldMove, Rocklogger, GeoCompass, Geology Sample Collector, Strike and Dip, GeoId, GeoAssist, FieldNotesLT, eGeoCompass, GS and Qgis. All of these apps are available in the Apple App Store or in the Google Play Store and were tested and reviewed, with the main objective of evaluating and comparing their functionalities which could be helpful to geologists in the field, such as the possibility to support certain types of data and save geographic coordinates.

The authors of this report started to establish criteria for the evaluation of these applications, as shown in Table 2.

Table 2 - Criteria for Mobile tools evaluation in Geology Field Work.
<table>
<thead>
<tr>
<th><strong>Criteria</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Platform</strong></td>
<td>Built for Android or iOS, and whether it runs on specific devices.</td>
</tr>
<tr>
<td><strong>Connection Assumptions</strong></td>
<td>Whether data connection is required for the application to work on the field.</td>
</tr>
<tr>
<td><strong>Metadata Collected</strong></td>
<td>Focus on the measurements that the app can collect or hold about a sample or site. Example: geographic coordinates, time of collection, and simple orientation information such as strike and dip.</td>
</tr>
<tr>
<td><strong>Data Export</strong></td>
<td>Concerns about the various formats an app is able to export the held data. Example: CSV.</td>
</tr>
<tr>
<td><strong>Maps</strong></td>
<td>Details the app’s ability to display data in a visual geospatial format, benefiting the ability to work with offline maps.</td>
</tr>
<tr>
<td><strong>User Input</strong></td>
<td>Concerns about the control and possibility to edit the collected data.</td>
</tr>
<tr>
<td><strong>Usability</strong></td>
<td>Whether an application is helpful and easy to use or not.</td>
</tr>
</tbody>
</table>

In the next sections the highest-rated applications evaluated will be described, according to the opinion of the authors in the report “An Overview of Mobile Applications for Field Science” [43].

**Lambert**

Lambert [44] is an app that turns the smartphone into a geological compass, allowing the user to measure the direction of dip and the angle of dip of geological strata. The current device orientation is also shown in a real-time stereographic projection. The data can be previewed in projection diagrams (Wulff and Schmidt Net) and transferred to the computer. It also lets the user add text to the measurements and plot the measurement localities on a map.

In the authors' opinion, this app has a well-organized interface to collect basic metadata (e.g., GPS location, strike and dip), allows the user to override recorded values or add comments, and provides a stereonet display with several different views. The application even allows deletion of data points directly in the stereonet. On the other hand, the application doesn’t support the possibility to export data in CSV format, exporting only in plaintext.
FieldMove

FieldMove [45] is a digital compass-clinometer for data capture on the iPhone, optimized to use the device’s GPS location and orientation sensors. This Geology app allows the user to use their phone as a traditional hand-held bearing compass as well as a digital compass-clinometer for measuring and capturing the orientation of planar and linear features in the field. FieldMove brings the possibility to make large amounts of measurements, making the data more statistically valid. It also allows to capture and store georeferenced digital photographs and text notes.

A great advantage of FieldMove is the support of offline maps, allowing for the importing of georeferenced basemaps and collection of data without internet connection. Another great advantage of this app is the flexibility to export the data in several different digital formats: MOVE, CSV or KMZ files.

However, in order to display geological data on an equal area or equal angle stereonet, it is necessary to upgrade to the paid Pro version.

Rocklogger

Rocklogger [46] is a geological tool for measuring the orientation of rock outcrops. It also allows the use of the phone's compass and orientation sensors to measure dip & dip direction, or dip & strike, in an easy way. Additionally, it brings other functionalities as GPS and magnetic field measurements storage, plot logs on a map, with correct dip/strike symbols or the use of the camera to take photos while logging. One other advantage is the possibility of exporting data into CSV files.

Unfortunately, to plot logs on alternate basemaps from other sources such as MapBox, zip files and the web, or plot poles or planes from logs on a stereonet it is necessary to use the paid version.

Another negative aspect is that the application doesn’t allow the correction of the collected values.

GeoCompass

GeoCompass [43] is an application that supports a very complete set of metadata (Strike, Dip, Dip Direction, Azimuth, Coordinates, Altitude and Location of the site [47]). Furthermore, some positive points are related with its good accuracy of measurements and the possibility of using photos and video, with quality control. As is the case with some of the other apps, it supports CSV export via email. The organization of the user interface is simple, providing an easy navigation throughout. However, the application does not support offline mapping due to the use of Apple MapKit and users can’t edit the measurements’ values.
Analysis

Through the evaluation of the previous applications, it was possible to verify that each has positive and negative aspects. Some have advantages inexistent on other apps, but fail comparing with them in other details. This means that each has its own strengths, however, none is perfect and complete, and covering all the needs a geologist could have. Furthermore, none of the apps is available open source, being impossible to extend them and complete their limitations. Most of the apps can be categorized as Freemium, offering basic functionalities with extra tools in a paid upgraded version. Another thing taken into account was the possibility of accessing offline maps, without the need of connection to the Internet, which is supported by most of the apps. Also an essential detail is the CSV export support, which only four of the twelve apps tested allow. Moreover, the stereographic projection plotting functionality is available for free only in the Lambert application. It was also observed that only three applications enable the user to override recorded values, and the only two applications that could add new fields are the ones created by MajorForms (Geology Sample Collector & Strike and Dip).

Table 3 resumes the evaluation parameters of each of the previous apps.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Lambert</th>
<th>FieldMove</th>
<th>Rocklogger</th>
<th>GeoCompass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform</td>
<td>iOS</td>
<td>iOS</td>
<td>Android</td>
<td>iOS</td>
</tr>
<tr>
<td>Connection Assumptions</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required (only to access maps)</td>
</tr>
<tr>
<td>Metadata Collected</td>
<td>GPS, strike, dip, timestamp, magnetic field</td>
<td>GPS, strike, dip, timestamp, plane type, rock type, comment, locality</td>
<td>GPS, strike, dip, timestamp, plane type, rock type, plane type</td>
<td>GPS, strike, dip, timestamp, plane type, azimuth, altitude, address</td>
</tr>
<tr>
<td>Data Export</td>
<td>Stereonet export in PDF, plaintext</td>
<td>CSV, Move (.mve)</td>
<td>CSV</td>
<td>CSV (via e-mail)</td>
</tr>
<tr>
<td>Maps</td>
<td>Google Maps (offline)</td>
<td>Google Maps (offline), Mapbox</td>
<td>Google Maps (offline)</td>
<td>Apple Mapkit</td>
</tr>
<tr>
<td>User Input</td>
<td>Override values</td>
<td>Override values</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Usability</td>
<td>Allows delete data points in stereonet</td>
<td>Easy navigation, data sorted by location, photos are not matched to data collected</td>
<td>Export easy with sharing menu, easy to calibrate</td>
<td>Easy navigation, photo/video quality options, media deletion after data deletion, color and map type options</td>
</tr>
</tbody>
</table>
From Table 3, it is possible to register some of these features that would be essential on our system and Table 4 summarizes the useful functionalities in each app:

Table 4 - Useful functionalities for this work.

<table>
<thead>
<tr>
<th>Application</th>
<th>Functionalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambert</td>
<td>GPS, strike, dip, timestamp, plane type, Google Maps</td>
</tr>
<tr>
<td>FieldMove</td>
<td>GPS, strike, dip, timestamp, plane type, rock type, comment, Google Maps locality</td>
</tr>
<tr>
<td>Rocklogger</td>
<td>GPS, strike, dip, timestamp, plane type, rock type, plane type, Google Maps, sharing menu</td>
</tr>
<tr>
<td>GeoCompass</td>
<td>GPS, strike, dip, timestamp, plane type, azimuth, altitude, address, photo/video quality options</td>
</tr>
</tbody>
</table>

In conclusion, in the authors’ opinion, and taking into consideration the desired features stated in Table 4, Lambert and FieldMove are the most helpful and effective in the assistance of geologists’ field work but they’re limited to the apps that were already created by developers, without the possibility to extend their limitations. Furthermore, these apps would be difficult to fit in an educational environment and as evaluation elements: don’t allow the visualization and answering of quiz questions, don’t give any guarantee that the collected data is trustworthy, and not falsified, and the teachers would hardly have elements to evaluate the students.

2.6 Mobile LMS platforms

In the Capterra website [48], it is possible to see a list of the most popular LMS systems, and filter them by a set of features. The ‘mobile learning’ and ‘gamification’ options were chosen, the five most rated LMS with these features were picked and compared, as shown in Table 5. This table only presents the relevant features for the proposed objective.
In short, all of these LMS platforms are competitive and share, in most cases, the same functionalities. However, Moodle is the only tool that has all the features in the table and is still open-source.

### 2.7 Tools Discussion

In 2.5.2 we have explored the functionalities of some mobile applications, directed to field trips in the area of Geology. After that, in 2.6 we have seen some useful LMS platforms that can be used for m-learning. Most of them can also fit in an Educational context and allow for the creation and application of quizzes.

However, we haven’t seen any tool that could bring a conjugation of these two approaches in just one platform. It would be really useful for students to have a tool where they could solve quizzes, as well as access course-related information and take advantage of the sensors, GPS receptors and cameras of their mobile devices, to solve the quizzes, with a driving and stimulating gamification approach.

<table>
<thead>
<tr>
<th>Features</th>
<th>Moodle</th>
<th>Canvas</th>
<th>Totara LMS</th>
<th>EduBrite</th>
<th>Schoox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>SCORM Compliant</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Asynchronous Learning</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Classroom Management</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Gamification</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Gradebook</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Mobile Learning</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Social Learning</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Student Portal</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Synchronous Learning</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Quizzes</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Tin Can API</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Open-source</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>
Chapter 3

System *Field Trip*

Chapter 3 will draw a solution to overcome the existent limitations in Field Trips, mentioned in the Chapter 2.

Section 3.1 will describe the usual options for evaluations in academic field trips. Then, in 3.2 their limitations, mostly due to the scarcity of technological tools, will be underlined.

In 3.3 and 3.4 a solution, named *Field Trip*, will be presented to fulfill the gaps seen in the existing technologies, presenting the requirements, the logical and physical architecture for this solution.

Then, in 3.5 it will be described how this solution was implemented, referring all the technologies used.
Usually, on field trips, a curricular evaluation requires the students to realize a report of what they have seen or learned, or also a quiz about the topics approached.

When the second method is chosen, generally, the questions are printed in paper support and formatted in the standard question types.

### 3.1 Conventional Question Types

In this section, the conventional types of questions used in the quizzes will be mentioned, explaining their function and how to answer them.

#### 3.1.1 Essay/Open answer

Gives the students the scope to interpret and answer with the information they think is appropriated. In this type of question students can write a small text with or without a limited number of characters.

#### 3.1.1 Multiple-choice (select one)

The template of this question type includes the question and a list of answers in which only one is fully correct. The students must choose the answer they consider correct.

#### 3.1.2 Multiple-choice (select many)

As is the case with the previous question type, in this one, the template has a question and a list of answers. However, in this case, one or more answers may be chosen.

#### 3.1.3 True or false

It includes a list of statements. In each statement, the respondent must select from two options: True or False.

#### 3.1.4 Short answer

The response to this closed type of question should be a word or a small phrase. This question type differs from the open-answer in the length of the answer and in the scope of the answer, if defined in the question: “yes” or “no”, for example.
3.1.5 Matching

A group of sub-questions and answers is presented, not sequentially. The student should “match” the questions to the correct answers.

3.1.6 Ordering

It displays a list of statements in a specific context that should be ordered.

3.2 Question types discussion

Besides the presented types of questions also others, less frequent, could be used, or a combinations of them. Any question may also include an image as support for the text in order to help the reader to interpret it.

Even though this group of question types already has some diversity, it could be much more enlarged and promote Gamification if the right technology resources are utilized. Mobile devices such as smartphones or tablets can be used to support and display the quizzes, providing a bigger and more dynamic variety of question types: answering with photos taken in real-time; using the device sensors to measure angles or orientation; the receptors of the phone to communicate with a GPS system and get geographic coordinates, etc. These new functionalities and types of questions would enlarge the number of options to perform didactic games in field trips. Those limitations lead us to the requirements of the proposed system, Field Trip.

3.3 Requirements

This section presents the functionalities and the requirements that the system should fulfil. The following requirements are based on the IEEE SRS specification [49].

3.3.1 Target User

The target users for this application will be the administrators of the platform, the teachers and their students. Only the administrators and the teachers will have access to the web portal. All users will have access to the mobile application.
3.3.2 External Interfaces

Hardware Interfaces

The mobile application will have to access a camera and GPS, inclinometer and compass sensors. However, neither the mobile application nor the web portal have the need for extra hardware, because it is expected that the mobile device already has a camera and the above mentioned sensors. Both the physical GPS and the camera are accessed by the mobile application.

Communication Interfaces

This system requires an Internet connection, in order for the teachers to upload, through the web portal, all the questions and resources needed.

In a similar way, the students will need Wi-Fi connection, to download the questions, on their mobile devices, before the field trip. The students shouldn’t have the need to use paid data plans.

The web portal will exchange information with the server through HTTP and AJAX requests while the mobile application will use REST services, which put another layer of abstraction between the app and the database, protecting it and facilitating their compatibility.

3.3.3 System’s Features

This section presents the features of Field Trip and how to work with them. Some features are generic to LMS platforms, such as the creation of school subjects, user accounts and subscription on the classes. For this reason, an existent LMS web platform can be used, instead of implementing those features. Along with them, the following features will be available in the system:

Download the Mobile app (Students)

Functionality that allows the students to download the Field Trip free mobile application.

The students should download and install the mobile app, which should be available on the Application Stores (as Apple App Store, Google Play, etc.), on their mobile devices. Furthermore, the app should be free, having no costs for download or extra functionalities.

The students must have enough memory on their devices to install the app.

Create quiz (Teacher)

Functionality that allows teachers to create quizzes on the Field Trip web portal. The quiz can be associated to a geolocation and the offline mode can be activated.
Before any field trip, the teacher should access the web portal, login correctly and select a class. Then, activate the edit mode, click on “Add an activity or resource” and select the quiz option. The page is redirected to the quiz configuration page, where the name and the behavior of the quiz can be edited. The most relevant options to this project remain with the possibility of restricting the quiz access to a geolocation, by clicking on a map, and the offline mode, allowing the students to answer the quiz on the mobile application, without an internet connection.

Once the configuration is done, the teacher should click on “Edit quiz”, and then they have the following options to add questions: create a new question, select a question from the question bank or add a random question from the question bank. Choosing the first option will involve also choosing the question type, then filling it and saving it.

**Quiz download (Students)**

Functionality that allows students to download the quizzes, using the *Field Trip* mobile application. The download should be done before the field trip, so that the student doesn’t require an internet connection via data plans.

On this step, the application requires an internet connection. The student must login on the *Field Trip* mobile application, choose a class, the activity section where the quiz is saved (or by clicking “All sections”), choose the quiz and start the attempt. After this, the quiz is downloaded. If the offline mode was chosen, the student can leave the quiz and then access it again without internet connection, because the application holds the quiz in the internal secure storage.

**Solve the quiz (Students)**

Functionality that allows students to solve and submit the quizzes, using the *Field Trip* mobile application. If a geolocation is set on the quiz, a GPS system is required and students only have access to the quiz when in the right location. The application can be in an offline mode, holding the submitted answers till internet connection is found, moment when is able to upload them.

To use this functionality, the student just needs to have had downloaded the quizzes previously and set the location on the device, if the quiz geolocation is activated. In this case, when he is found on the quiz location, he is able to visualize and answer the quiz questions. In any other location, these questions are unavailable.

The student is able to answer each question, selecting, writing or inputting data, according to the question type.

When the quiz is completed the student clicks on the “Submit all and finish” button which uploads the answers directly to the server or, as is the expected behavior in the offline mode, the answers are saved in the secure internal storage waiting for an internet connection to synchronize with the server.
Upload solved quiz (Students)

Functionality that allows students to upload the quizzes, after solving them, using the Field Trip mobile application. This requires internet connection.

The app will allow students to upload the answers after the field trip, when Wi-Fi connection is available. The answers remain in secure storage till the upload is done.

The student should connect the device to a Wi-Fi network, select the answered quiz and the answers are automatically uploaded, leaving all devices synchronized. When the upload is complete, the student can see the time of the last synchronization and the files are deleted from the device’s internal storage. After this step the teacher is able to see, on the web portal, the students’ answers to the quiz.

Get the quiz answers and evaluate them (Teacher)

Functionality that allows teachers to obtain the students’ answers to the quiz and classify them with a mark. This is done in the web portal.

The teachers should login into their web portal account, select the class, the quiz and then “Quiz administration”->”Results”->”Responses” and visualize a list of answers from all the students of the class. Each question can be reviewed and manually graded if needed. Afterwards, the students can see the evaluation results both on the web portal and on the mobile application.

Visualize the quiz review and grades (Students)

Functionality that allows students to obtain their marks and see the correction of each answer in the mobile application. Requires internet connection.

After login, the student should see a list of courses and below each one a button labelled “grades”. By clicking on it, they will see the list of quizzes with the respective marks.

Another way to access the grades is by entering the quiz again and see the review, which is automatically shown after solving the quiz. The questions with the feature that allows automatic grading will automatically show up with a mark in the review, without the teacher needing to correct them.

3.3.4 Evaluation Question types

The Field Trip mobile application brings not only the conventional types of questions, existent in many other platforms, but also innovative types of questions, oriented towards field work.

Those question types arose in a meeting with my co-adviser and Geology teacher, Anabela Cruces, and with the teacher Susana Fernandes. They are the following:
Photo

Question in which the student has to answer with one or more photos, related to the question. Those photos must be captured with the phone’s camera, inside the mobile application context, by clicking the button “Camera”, in the moment of answering. This is a question evaluated and classified manually by the professor.

Photo with description

Similarly to the previous question type, the student has to insert one or multiple photos. The difference is the existence of a mandatory open-answer text field, which can be used to describe the photo(s) or answer with other information, according to the question. Once again, the photos must be taken in the moment of answering, and the given answer is manually classified by the professor.

Geographic Coordinates

Question with two answer fields that should be filled with latitude and longitude values, in degree units, obtained through the GPS system, accessed by the phone. These values can be manually edited by the students, yet the application verifies if they are valid coordinates: must be numerical values, latitudes and longitudes must be bound, respectively, by $\pm 90^\circ$ and $\pm 180^\circ$. In this type of questions it can be asked, for example, to search for a specific place or object in the field and retrieve its geographic coordinates.

Conversely to the previous cases, this is an automatically evaluated and graded question type: along with the question text, also an unlimited set of possible answers, distance tolerance and their classifications is saved and compared to the students’ answers, classifying them instantaneously. In more detail, the student’s response is compared to the previously saved possible answers, one by one, in the same order. Once the program finds one with a lower distance between the both pairs of coordinates, than the associated tolerance, in meters, the corresponding classification is given to that answer. If the response doesn’t fit any of the saved possible answers, the given classification is zero.

Angle

This type of question needs to be answered by indicating an angle in degrees. That angle can be manually inserted or using the application tilt measurer: clicking on the “Measure angle” button, the application retrieves the tilt angle of the phone, which can be used to measure any object’s angle, against the gravitational axis. The answer field is automatically refreshed with the measured angle, which changes with the phone inclination, and at any time the student can block the value, by clicking “Ok”.

As mentioned, the other widely available questions types were also integrated:
3.3.5 Non-Functional Requirements

This section will state the non-functional requirements considered relevant to the proposed solution.

Performance

- Latency or delay less than 100 milliseconds, approximately, which is the minimum latency value perceptible by humans in the system response [50];
- The download and upload must not block the app. It should be done asynchronously, running in the background;
- The app should have an energy consumption that allows for a minimum of 2h of use duration without draining all battery in mobile devices;
- The system must be easily scalable;

Security

- All data must be kept secure and private;
- Each student must not have access to private information of other students, teachers or administrators, as well as that of the other external systems interacting with the app;
- All the communications in the system must be secure, encrypted, protecting all data from interceptions;
- Database must have secure access control mechanisms;
- Students, teachers and administrators must be authenticated on their accounts;
- Students must not have access to quiz questions before the assessment time and location.
- The functionality “Solve quiz” must only be available at the evaluation time, when the user is near the quiz location;
- Students must not be able to edit quiz answers after it is finished;
3.4 Architecture

This section will detail the Physical and Logical architecture of the developed system.

3.4.1 Physical architecture

Figure 3 presents the general structure of the Field Trip system, relating its components.

Web Portal

The web portal interface allows for the subscription of the teachers in classes, the upload of resources, the creation of quizzes in the respective classes, the visualization of the quiz answers and the insertion of evaluation marks. However, it is just a front-end interface, directed to teachers and administrators of the system. For this reason, all the content, data inserted or observed is stored in a database server. The exchange of information between this module and the server is made by HTTP or AJAX requests, which will invoke queries to the database if the data is required.
Mobile Device

The Mobile app, same as the web portal, is a front-end interface that doesn't contain any resources or information. Once again, the information stored in the database is obtained through REST Services that invoke queries in the database.

The app is directed to the students, allowing them to visualize information given by the teacher, and solve the field trip quizzes, using device features such as motion (accelerometer), camera, location services, which use the GPS system, and secure storage.

Global Positioning System [51], or just GPS, is a satellite-based navigation system constituted by a constellation of 24 satellites, placed into orbit by the U.S. Department of Defense. Working 20,200 kilometers above the Earth, these satellites are equally spaced in six orbital planes, communicating via two specially coded carrier signals, one for civilian use, and other for military and government use. The GPS receivers process the satellite signals and compute the location, with a 10 meters accuracy or better, in 3 coordinates: latitude, longitude, and altitude [52].

In this system, the mobile devices will receive GPS signals in order to detect the user’s location and local time, and compare it to the location and time of the quiz. When the student is near this location the app provides him/her access.

Server

The server is the central module in the system and receives requests both from the web portal and from the mobile app. In a succinct way, it can be divided into the following modules: the Authentication Management System, mandatory for all users, the App Server, which is the core of this module and is responsible for accessing the Database Management System (DBMS) through secure queries, retrieving the requested data to the users. It also has the REST API module responsible for processing the REST services received from the Mobile Application, invoking functions in the App Server.
3.4.2 Logical architecture

![Logical Architecture of Field Trip](image)

**Figure 4 - Logical Architecture of Field Trip.**

Mobile *Field Trip* can also be classified as being built in the classical 3-tier architecture (Figure 4), applicable to the Web Portal and the Mobile Application, since they were developed in an analogous and parallel way: most of the functionalities of the first were similarly developed in the latter. In this architecture it is possible to identify the following layers:

**Presentation tier**

This layer represents the user interface and is the highest layer in the system, where the renderers and the html code are generated, displaying the quizzes, configurations, etc.

**Application tier**

This layer is where all the logic libraries are placed to process all the data required.

**Data tier**

This represents the data persistence mechanisms, database servers and the data and file access/storage layer. It is responsible for storing and retrieving all the data required by the application.

The main advantage of this architecture relies on the fact that the user interface, process logic, and data access/storage are independent and isolated modules, which could be easily replaced or upgraded.
3.5 Implementation

In this subsection the technologies, programming languages, communication protocols, representational data formats, storage mechanisms and external libraries adopted by Field Trip will be covered. Notwithstanding the importance of the others already implemented in Moodle, only the technologies used directly in this project will be highlighted.

3.5.1 Supporting system

Field Trip requires some features that already exist in many others LMS platforms, such as students account registration, and in subjects, general configurations, participation in quizzes, and some other new innovative features, with the possibility of mobility. In order to save time and unnecessary repetitive tasks, instead of starting a system from the scratch, the choice was made to use Moodle as the supporting platform for the web portal, which is the open-source LMS with better features and already has a great set of implemented services, validated in 2.6 Furthermore, the project may be granted more visibility by using a world-wide known web portal such as Moodle, which already has a great set of implemented services.

For the mobile application, it was chosen the Moodle Mobile 2 application as the base system due to the innumerable functionalities it already had, such as the REST module for communicating with Moodle (web portal), and the basic functionalities of downloading and answering quizzes, with some of the Moodle question types implemented. Moreover, this is a hybrid application, which will be explained soon, and for that reason is supported both in Android and iOS, that being one of its best advantages.

For all these reasons, Moodle was adopted as the starting point for the Field Trip web portal, and Moodle Mobile 2 for the Field Trip mobile application.

Moodle

Moodle is a platform that can be functional for this work, allowing the creation of quizzes, with a big diversity of question types, and also the possibility to create new types of custom questions. Using an existent LMS platform like this can save a lot of time, instead of developing a new one from the root, and since it is an extendable platform it can cover all the necessities in this work. Another great advantage of this tool is that it allows for the import SCORM learning content, including quizzes.

This platform [53] is a free, online and open-source software Learning Management System (LMS). As an e-learning platform, its goals intend to fulfill all the needs in learning/teaching, allowing distance education, flipped classrooms and e-learning quizzes and projects in schools, universities, workplaces and so on. It is directed to the teachers, students and administrators, taking care of all their needs.

A great advantage of Moodle [33], and the reason it is one of the best options for this work is related to its flexibility and extensibility, allowing educators to create their own private website filled with dynamic
courses. Another reason is the possibility to extend the type of questions possible in the quizzes’ creation, by implementing or accessing a diversified community of public plugins, written in the PHP computer language. Some of the functionalities required for this work are already implemented.

Moodle Mobile

Since the first Moodle release [54], in August 2002, it has been spread and has undergone a huge evolution, being used all over the world. During this period of time, technology has also changed so much and innovating tools such as smart mobile devices have appeared. Obviously, it was time for Moodle to give the next step and escalate to a mobile app. On April 2013 the first Android and iOS versions [55] were released.

The app [56] is a Web Services client that uses REST as the protocol to exchange information with Moodle, the web portal. Initially it used Backbone and jQuery [57] as the JavaScript framework for calling the Web Services, manipulating the DOM and interacting with Phonegap.

On the current version, Moodle Mobile 2 (MM2), a hybrid and the official mobile app for Moodle, is used the Ionic framework, along with AngularJS, a structural framework for dynamic web apps [56]. Hybrid means that it is developed with web languages and it runs in all the mobile OS (such as Android and iOS), but it can behave as a native application as well, since it is also able to interact with the mobile device: camera, accelerometer, location services, etc.

Although the app is developed with web languages it can still access the phone functionalities and behave as a native application, using the Cordova framework, also known as Phonegap [56], [58].

3.5.2 Programming Languages

In this point, the programming languages used in Field Trip will be mentioned. There will also be an explanation on which parts of the system they were used, along with some details of each language.

PHP

PHP [59], the acronym for “PHP: Hypertext Preprocessor”, initially “Personal Home Page”, is an Open Source scripting language, especially directed to web development, which can also be used as a general-purpose programming language. PHP can be embedded into HTML and its syntax is reminiscent of C, Java, and Perl. Its main goal is to let web developers write dynamically generated web pages quickly, allowing form data collection, dynamic page content generation, send and receive cookies, and so on.

In the Field Trip system, the version 5.x of PHP was used to create plugins for Moodle, the first version that introduced the Object-Oriented Programming concept. The plugins followed this approach, where classes were created, extending existent classes in Moodle and overriding some methods.
JavaScript

Released in 1995 [60], JavaScript programming language initially had the main purpose of realizing some input validation, previously left to server-side languages such as Perl.

During all these years, JavaScript has grown so much, becoming an important feature of every major Web browser on the market and known as the language of the Web. JavaScript [61] is a high-level, dynamic, untyped and object-oriented programming language and is part of the triad of technologies that all Web developers must learn: HTML, CSS, and JavaScript: the first, to specify the content of web pages, the second to customize their style and the last to manipulate their behavior.

*Field Trip*, uses JavaScript in the two front-end interfaces of the system: the web portal (extended Moodle) and the mobile application (extended Moodle Mobile). The first element already had a variety of JavaScript modules to create dynamism in its web pages. However, in this project a module was added in a quiz access rule, named “GPS”, using the Google Maps JavaScript API to insert a map on the quiz configuration, which will be explained at a later point. In the Mobile application, JavaScript is the core programming language, responsible for all of its functionalities, including the mobile database access/storage, using the *ydn-db* JavaScript library.

AngularJS

AngularJS is a structural client-side MVC framework for JavaScript, used to develop dynamic single-page, AJAX-style web applications [56]. In a more wide definition [62], AngularJS can be seen as based on the MVW (model-view-whatever) pattern, because programmers can use it to develop MVC (model-view-controller) and MVVM (model-view-view-model) architectures.

This framework brings several advantages: it uses HTML as the templating language, doesn't require an explicit DOM refresh, being capable of tracking user actions, browser events, and model changes to refresh the correct templates. It also provides a way to create new custom HTML tags or attributes and teach a browser how to interpret them, by creating directives (in the version 1.x of AngularJS) [62].

AngularJS also provides dependency injection (DI) and a strong focus on testability, making easy any small application to scale, and has many other hidden treasures.

*Field Trip* mobile application took advantage of these properties and used this framework to create new HTML tags and attributes, by creating directives, and injecting the *Cordova* and *ngCordova* modules, to interact with the mobile device.

The mobile app architecture [56] is the classical for an AngularJS app, englobing controllers, factories, directives, providers, and so on. Furthermore, it is designed in a modular way, implementing plugins in a similar way to the Moodle plugins, in the web portal. This app contains a set of core services for tasks such as authentication handling, configuration, plugin management and download, cache, and specific modules called *add-ons* for tasks like internationalization, quizzes behavior and question types, etc. The app also uses AngularJS logging responsible for the printing of logs, in the developer mode, really useful for debugging.
CSS

Cascading Style Sheets [63], also known as CSS, is a style sheet language for describing the presentation of Web pages. With this language, several properties at once can be assigned to the elements in a page marked with a particular tag, defined in the HTML code. This language provides options to customize those HTML elements, with selectors and properties, including layout, and fonts. It also allows each element to be adapted to different types of devices, such as large screens, small screens, or printers [64] [65]. CSS is independent of HTML, making it easier to maintain sites or share style sheets across pages.

Field Trip makes use of this language both on the web portal and the mobile application, to customize most of the elements contained in the pages or views. Most of these elements were already styled by Moodle and Moodle Mobile, and kept as the original; however some buttons, text areas, and the map shown in the web portal quiz configuration page were personally customized.

XMLDB

Oracle XML DB [66] is a high-performance, native XML storage and retrieval technology. It supports native XML application development and the SQL/XML standard, allowing the use of XML-centric techniques to store, manage, organize, and manipulate XML content stored in the database, and SQL-centric development techniques to publish XML directly from relational data stored.

XMLDB is the Moodle's database abstraction layer that lets Moodle interact with and access the database [67], maintaining everything working properly with both MySQL and PostgreSQL. Moodle contains XMLDB neutral description files [68] to create, modify and delete database objects (DDL: create/alter/drop tables, fields, indexes, constraints).

Some extra tables in the Moodle's database had been created with this language, for each developed plugin.

3.5.3 External Libraries

This section will present the external libraries, which are not the core of the system, but are used as a complement for some of its features. Again, each of the used libraries will be detailed.

Ionic

Ionic is a free and open source library of mobile-optimized HTML, CSS and JS components and tools [69], designed for hybrid mobile app development. It takes three main steps to develop hybrid apps with this technology. In the first one, the apps are built with these Web languages. In the second, they are wrapped into native apps, using Cordova, which goes even further, extending the functionalities of those web apps, allowing them to interact with the mobile hardware. Finally they can be distributed throughout native app stores to be installed on the devices.
Ionic has a good performance on mobile devices, designed with web best practices like efficient virtual DOM rendering, hardware accelerated transitions, and touch-optimized gestures [69].

The main reason for this technology to have been chosen to develop the mobile app was due to its flexibility to have the same web app running natively in any mobile device, without having to develop it from the root in different programming languages. Also the look and feel of this technology is very attractive.

**Google Maps API**

Google Maps [70] is a Web-based mapping service, developed by Google, that provides detailed information about geographical regions and sites around the world. Along with the maps it also provides options such as satellite view, street maps, Street View with panoramic views of streets, Google Traffic which shows the traffic conditions in real-time, and route planning for traveling with different types of transports. This amazing tool also provides a collection of services that allow third-party applications to include maps [71], geocoding, places, and other content provided by Google.

The JavaScript Google Maps API was used in the *Field Trip* web portal, specifically in the quiz configuration page, providing a way to store geographic coordinates in the Moodle's database and associate the quiz to a geolocation.

**Math JS**

Math.js [72] is a math library for JavaScript and Node.js with support for symbolic computation. The Math object allows you to perform mathematical tasks on numbers, including a large set of built-in mathematical methods and constants. This powerful tool is compatible with different data types such as numbers, big numbers, complex numbers, fractions, units, and matrices.

In the developed system, this library is often used in different modules of the web portal and the mobile application, already implemented, and in some of the new modules of the application, such as the *mm.core.tiltmeasurer*, in the calculations to obtain the correct angle.

**Cordova**

Apache Cordova [58] is an open-source mobile development framework, used to establish a bridge between the web programming languages and the devices properties and functionalities. With this tool, a developer can use standard web technologies [73], like HTML5, CSS3, and JavaScript for cross-platform development and still interact with the phone or tablet, behaving as native apps, because the applications are executed within wrappers targeted to each platform. Cordova does the translations to the native operating systems’ functions with API bindings, accessing the devices’ sensors, data, network status, etc.
Above Cordova, a higher layer of abstraction was used, ngCordova: a list of AngularJS wrappers for the most popular Cordova plugins, built to help the apps’ developments to be easier and faster [74].

i. Camera

The cordova-plugin-camera API [75] contains methods to access the phone’s camera. This library allows, in the mobile application context, to access the camera and capture a photo. After capturing the photo, those methods can return either a String with the image file location on local storage, or a String with the Base64-encoded photo image.

ii. Device Motion

The cordova-plugin-device-motion API [76] contains functions to interact with the device's accelerometer sensors, detecting the movement changes of the current device inclination.

iii. Geolocation

In order to use the required functionalities of GPS location and GPS time, Cordova provides an API for accessing the GPS system. This library has a plugin, called cordova-plugin-geolocation [77].

3.5.4 Communication

Since Field Trip has different components that communicate with each other, the protocol and the data format for the exchange of information also needed to be defined. The HTTP and AJAX requests between the web portal and the app server are a direct and easy way of communication in the internet, but for the mobile application, being a third party application, a more robust way of communication was required: REST services represented in the JSON format. Those technologies will be explained in this section.

REST

Nowadays, and since the internet got popular and widespread, one of the most used forms to deliver and manipulate content in the enterprise management context is the use Web Services. The World Wide Web is being used more and more as a means of communication between humans and machines [78].

In the world of web services it is possible to distinguish two main topologies: Simple Object Access Protocol (SOAP) and Representational State Transfer (REST).

Each topology has its own advantages and disadvantages. SOAP is for sure the heavyweight option for Web service access. On the other hand, REST is much easier to use, is more flexible and can be seen as the “antidote to the creeping complexity of SOAP-based web services” [79].

REST is an acronym for REpresentational State Transfer, published for the first time by Fielding (2000) [80], and it is a very constrained approach for Web Services, in which clients use URLs and the HTTP operations GET, PUT, DELETE and POST to manipulate resources described in XML or JSON. The
REST architecture intends to induce Performance, Scalability, Simplicity, Modifiability, Visibility, Portability, and Reliability [80]. In RESTful applications, each resource can be called by its URI (Uniform Resource Identifier). Every new resource created has a new URL by which it can be accessed or updated by the client, which is furnished with the entire state of the resource, instead of getting just part of it [81]. This means that the communication between a client and a server is Stateless: servers don’t store any client context during the requests.

The REST services could also allow the Field Trip system to provide services, in a more mature state of the work, helpful for the development of external apps

For this reasons, and taking into consideration the architecture and requirements of the system, REST services were used for the communication between the mobile application and the server.

**JSON**

*JavaScript Object Notation* [82], or simply JSON, is a lightweight data format, which can be used to represent and exchange information. It uses human-readable text to transmit data objects and is easily interpreted by machines. Although it is an independent language, it uses conventions similar to languages like JavaScript, Java, Perl, Python, C, C++, C#, among others.

JSON representation consists in attribute–value pairs, and has some benefits over other formats, such as XML: it is more compact, with a smaller message size, it is easier to parse and consume with JavaScript and promotes a faster exchange of data, with a smaller quantity of traffic.

For these reasons, it is the most utilized data format. It is used for asynchronous communications, by AJAX, and also in the Field Trip REST services for the exchange of information between the mobile application and the Server. Luckily, Moodle Mobile already implemented REST services in a module using this data format.

### 3.5.5 Secure Storage

The Field Trip mobile application needs to store data on the phone: information about the sites, the list of saved sites and also a cache of the REST calls [56].

Every Android and iOS device allows for secure data storage when the app is built with Cordova [83], making this scenario possible not just in native applications but also in hybrid applications. Both cases provide several options for storage: internal key/value storage, structured data storage, etc. However, the most reasonable type of storage may be associated to structured data, because it provides a more efficient way to search for specific values, by making queries with some criteria.

Some other libraries, as the YDN-DB JavaScript [84], also provide different mechanisms for the data storage, such as IndexedDB, WebSQL and localStorage. They also implement polyfills, automatic storage system detection, promises, and so on. IndexedDB combines the internal key/value storage with the structured data storage. As mentioned in Cordova website [83], “the goal of the IndexedDB API
is to combine the strengths of the LocalStorage and WebSQL APIs, while avoiding their weaknesses”. IndexedDB stores arbitrary JavaScript objects, indexed with a key, allowing for the creation of multiple databases, with multiple stores per database. Furthermore, its asynchronous API and search indexes provide performance benefits. For these reasons, along with a cache of the REST calls [56], YDN-DB IndexedDB was the storage option chosen in the mobile application, with the autoSchema option [84], which allows to change the database schema, i.e. the structure of the database, during the life time of the application.

3.5.6 Moodle Extensions

To explain in a precise and clear way how the above mentioned question types and the other plugins were implemented in the Moodle web portal and the Moodle Mobile 2 application, some specifications of each plugin will be presented.

Implemented Question Types

All the question types projected in 3.3.4 were developed, and their implementation will be specified in the next topic. Once again, they are the following:

- Photo;
- Photo with description;
- Geographic Coordinates;
- Angle.

Moodle Question Type Plugin Architecture

The folder organization of each question type plugin in Moodle is presented in Figure 5.

![Figure 5 - Structure of a Moodle Question type plugin.](image-url)
Now that we have an idea of the structure of this plugin, we will explain how each file was adapted for each question type. Notice that ‘NAME’ should represent the name of a general question type.

i. **install.xml**

Inside the install.xml file, auxiliary database tables are defined, in XML DB language, in a structured way. For all the question types was created one table in the database to support it.

ii. **lang folder**

This folder should contain subfolders, named with the locale code of each country for the languages we want the strings to be translated. Each subfolder must contain the ‘qtype_name.php’ file with the text for each used string in the plugin, translated to the respective language. In each question type it was inserted only the locale ‘en’, consequently, *Field Trip* still only has English as the available language.

iii. **icon.gif**

This is an image file, in the gif extension format, with the symbol of the question type, which will be shown in the list of available types, when creating a new question.

iv. **edit_NAME_form.php**

This file contains the *moodle_form* shown in the page where a question of this type is being created. In this file, all the question types extend an existent class named *question_edit_form* and override some of its methods.

In the ‘Photo’ and ‘Photo with description’ question types, only methods to insert some options in the form were used, to select if the attachments are required and the limit of attachments, and some preprocessing to prepare the attachments’ area. In the ‘Geographic Coordinates’ and ‘Angle’ question types, besides adding options to the form, and the fields to save the possible answers, methods to validate those possible answers, which are saved in the database, were also overridden.

v. **lib.php**

This file can be used to insert library code, and has a callback to allow access to files used by questions. However, in *Field Trip* only the name of the question types was changed and no extra code added.

vi. **question.php**

This class, when instantiated, represents the object of a particular question of this type [85], having attributes and methods to shape its behavior.

The *Photo* and *Photo with description* question types, since they’re manually graded types, extend the class so the only methods used are *question_with_responses*, while the *Geographic Coordinates* and the *Angle* question types extend the class *question_graded_automatically*. In the first group, methods to get the data, check if the response is complete or changed, etc. were overridden. In the other question
types, along with these methods, others were used to validate the answers and automatically grade them.

vii. questiontype.php

This class represents not a particular question, but the type of question and its behavior. All of the question types extend the class question_type, using methods to store and access the database, namely the created table for the respective plugin or to use the file storage, for example to save the images in the ‘Photo’ question type. SQL code was not used directly, but the database library in other layer of Moodle was used instead.

viii. renderer.php

This class extends the qtype_renderer class, and is responsible for outputting all the HTML code needed to show the question and the answer fields. Once again, HTML code was not used, but instead we used the Moodle form library.

ix. styles.css

This file is used to customize the presentation styles of each question type, but it has never been used.

x. version.php

This file only indicates some information about the version of the plugin.

Other Implemented Plugins

Besides the question types, a plugin for creating a location based access rule to the quiz was also implemented and the Moodle Mobile additional features plugin was installed, which allows for the offline mode in the quizzes. The access rule consists in setting a geolocation for the quizzes that restricts the access to them if the application doesn’t detect the correct location. As mentioned before, these plugins are built in a parallel way in the web portal and in the mobile application, but in the latter some auxiliary modules also needed to be developed: the Photo uploader, the Tilt measurer and the Geolocation. They will be explained later on, in this chapter.

Location Based Quiz Access

This is the access rule for the quizzes mentioned previously and it is called GPS. On the web portal, this plugin uses the Google Maps JavaScript API and its effects can be seen in the quiz configuration page, which now has an embedded map. A user can now search for a place, click on a spot and get the coordinates, latitude and longitude, of that place, automatically inserted in Moodle textareas. The goal is to store those coordinates in the Moodle’s database and associate the quiz to a certain geolocation.

This plugin has only two relevant files: the install.xml, with the structure of a new table to install in the Moodle database, and the rule.php, where the restricting options are added to the form in the quiz
configuration page and the validation of the coordinates sent by the mobile application is done. Additionally, a JavaScript file was also created, map.js, which uses the Google Maps API to generate the map and give it some interactivity: search for a place, add a mark, get the geographic coordinates of that mark and refresh the textareas with those values.

Changes to the Moodle Mobile app

The structure of the question type plugin in the mobile app is divided into one HTML file and three JavaScript files: template.html, directive.js, handlers.js and main.js.

The template.html represents the view of the question. Not only does it generate code for the question presentation in the mobile app, but it also associates variables to a scope and calls controllers that manipulate data from that scope.

A directive [86], in the AngularJS framework is a marker on a DOM element that tells the compiler to attach a template (HTML code) or a described behavior to that element, with the possibility of also transforming that element and its children.

The handler.js is equivalent to the question.php file in the web portal and has auxiliary functions to get data, check if the response is complete or changed, etc. It also realizes some validation of the answers.

The main.js file is responsible for registering the respective plugin in the $mmQuestionDelegateProvider, which belongs to the module responsible for the questions. It is a way to inject this question type module into the application, and letting it be recognized.

Moreover, it is important to mention the controllers invoked by each of the question views, in the respective template.html file, because those controllers are responsible for accessing the phone hardware (camera, sensors, etc.) and making the features of each question type work.

The Photo and Photo with description question types invoke the controller inside the Photo Uploader component. The Geographic Coordinates type calls the controller of the Geolocation component and the Angle question type invokes the Tilt Measurer component’s controller. These components will be more detailed in the next sections.

i. GPS Access Rule

This plugin is the complement to the GPS access rule in the web portal, but slightly different. If the geolocation option is activated, the student should only be allowed to download and access the quiz if after sending the coordinates obtained by the location services to the server, which validates them, obtains a positive answer authorizing the quiz access. The coordinates are valid within a pre-established radius from the stored coordinates. However, this plugin is limited on the offline mode in the application, since it doesn’t work in this case. For security reasons, the validation of the student’s location is done in the server and not in the mobile application. For this reason, when a quiz is set with a geolocation the student needs to be in the correct location and connected to the internet to be able to download the quiz.
To implement this plugin, Field Trip used the Moodle Mobile web services to send the geographic coordinates obtained by the mobile application to the server, on a REST service. Those coordinates are obtained using the developed Geolocation module. After receiving the student's coordinates, the server compares them to the coordinates stored in the database (i.e. the quiz location) and if the student is near the correct place, within a certain tolerance, the server gives the REST service answer with the authorization for downloading the quiz.

### ii. Photo uploader

Photo uploader is the module developed to support the camera functionality on the question types that need to capture a photo. By injecting this module into those question types’ modules, they can employ this service. As mentioned before, this module is implemented with the Camera Cordova plugin.

Field Trip used the method `camera.getPicture` of the abovementioned `cordova-plugin-camera` API, passing as an argument the option of retrieving the image file location on local storage, which is the default. This method is responsible for launching the phone’s camera in the mobile application context, and capturing a photo, retrieving its path, inside the local storage.

### iii. Tilt measurer

This module was created to ensure the functionalities of the question types that require a way to obtain the mobile tilt angle. Thus, this was developed with the Cordova library, specifically the Device Motion plugin. To use it, those modules need to inject this component.

The controller of this component uses the `watchAcceleration` method [76], from the `cordova-plugin-device-motion` API. This method provides a way to obtain the device's current acceleration at a consistent frequency, in milliseconds, specified in the `accelerometerOptions`, one of the function arguments. Each retrieved acceleration object contains the acceleration readings of the phone in the three axes: x, y, and z. If those readings are collected without errors, the `accelerometerSuccess` callback function is triggered.

This plugin was used in the context of the Angle question type. One of its goals is to obtain the tilt angle of the device, against the gravitational axis (opposite direction of the z-axis), as seen in Figure 6.
According to an NXP application note [87], given the smartphone accelerometer readings in a vector $G_p$,

$$G_p = \begin{pmatrix} G_{px} \\ G_{py} \\ G_{pz} \end{pmatrix} \quad (1)$$

in which $G_{px}$, $G_{py}$ and $G_{pz}$ represent, respectively, the instantaneous acceleration of the device in the $x$, $y$ and $z$-axis, in the native accelerometer units. The tilt angle, $\rho$, in radian units, is given by the following expression:

$$\rho_{rad} = \cos^{-1} \left( \frac{G_{pz}}{\sqrt{G_{px}^2 + G_{py}^2 + G_{pz}^2}} \right) \quad (2)$$

Consequently, the expression, used by Field Trip mobile application in the accelerometerSuccess callback function, to get the tilt angle of the phone, in degrees, is given by

$$\rho_{deg} = \cos^{-1} \left( \frac{G_{pz}}{\sqrt{G_{px}^2 + G_{py}^2 + G_{pz}^2}} \right) \cdot \frac{180}{\pi} \quad (3)$$

iv. Geolocation

For the same reasons, this module was created and injected into the Coordinates question type module, allowing it to obtain the device’s geolocation, latitude and longitude in degrees. It used the Cordova Geolocation plugin, already discussed.

The cordova-plugin-geolocation API contains a function called watchPosition, which returns the device’s current position every time a change in position is detected [77]. When this occurs, the
The `geolocationSuccess` callback is executed with the last position retrieved as an argument. The `Position` object contains, along with other parameters, the geolocation coordinates, latitude and longitude, in decimal degrees and a timestamp, which can be used to get the GPS system time.

The `watchPosition` function also receives as an argument an optional parameter to specify the geolocation options:

- `enableHighAccuracy`: when set to true, allows not only network-based methods to obtain the location, but also more accurate methods, such as satellite positioning;
- `timeout`: The maximum length of time (milliseconds) allowed to pass until the `geolocationSuccess` callback is executed;
- `maximumAge`: age, in milliseconds, until the cached positions are valid.

Data Model

*Field trip* has a complex and vast data model that supports the big variety of functionalities it has, in the web portal and the mobile application. Most of these came with Moodle and Moodle Mobile.

The Moodle database [88] has about two hundred tables, in which around 50 are core tables. Nonetheless, they are well organized with suggestive names, making it easier to understand which tables to look for.

On the other hand, Moodle Mobile [56] has two levels of databases: one level for the app general data, which has only one database, and another level for the Moodle sites’ databases, which has one database for the data of each saved Moodle site.

The great advantage this division brings focuses on the facility to retrieve and delete the site data, once one of the sites is deleted.

In the Moodle Mobile app it wasn’t necessary to extend the database, however, Figure 7 shows the database tables that were inserted into the Moodle’s web portal database.

![Figure 7 - Data Model of Field Trip web portal Database](image)

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3.5.7 Offline mode

As mentioned before, it is not expected that the students should need to pay for an internet connection during the field trips. For this reason, the offline mode was created. This allows the students to solve and submit the previously downloaded quizzes without using any internet connection. If this happens, the app holds the answers, until an internet connection is found, and, at that moment, the system uploads the answers to the server, synchronizing all data.

To allow the access to a quiz in the offline mode, the Field Trip system had to install the Moodle Mobile additional features plugin, which was implemented by Moodle: some of the files are directed to the web portal and others to the mobile application. This plugin inserts a new option in the quiz configuration page, in the web portal, to activate the offline mode. To use it, the user needs to download the quiz, by starting an attempt, which requires an internet connection, but then the connection can be turned off, leaving the application and returning to access the quiz. What happens in the background is that the quiz is securely stored in the phone, after solving it and submitting it the answers are also stored. At that moment, a message is attached to the quiz review notifying that the quiz is not synchronized. When the application detects an internet connection again, it automatically synchronizes the quiz, uploading the answers to the server. The notification message is changed, now showing the time of the last synchronization. If neither the offline mode was activated nor the plugin installed, the application would try to once again download the quiz, returning an error message due to having no connection.

However, this plugin doesn’t cover everything needed by Field Trip to ensure all its functionalities offline. In the case of the Photo question type, after capturing a photo, it is automatically uploaded to the server, before submitting the quiz. This isn’t possible without an internet connection. To solve this, some conditions had to be changed in the Photo Uploader component, and instead of uploading instantaneously the photos after being captured, if the offline mode was activated and no connection detected, the photos would be saved in the phone’s internal storage, and then, in a similar way, synchronized when the connection is detected again. The difficulty here was to maintain the quiz and the photo associated to each other, since the file path of the photo after the upload is hashed.

Moreover, if a geolocation is set in a quiz, it must be downloaded on the field, so internet will be required, but there is not much data spent on the quizzes’ download, since the app uses REST services with JSON, which is a light service for communication. Furthermore, the exchange of images is not needed in the field, only text. Although the download of the quizzes, in this case, needs internet connection on the field, the quiz can be solved offline and the upload of the answers is done afterwards.
Chapter 4

Evaluation and discussion

This chapter presents a discussion of the results of this project, along with a demonstration of its features, underlining the difficulties overcome by this development.
4.1 Main Features

*Field Trip* supports now most of the features envisaged in the requirements and it is easy and intuitive to use. The only feature that was not fully accomplished was the offline mode: it works in quizzes without access rules, but when the GPS access rule is used or the time restriction, internet connection is required. Making the offline mode work in that contexts would imply a big effort on changing the core architecture of Moodle, create new end-points for plugins and develop new web services. The reason is that the Moodle architecture lets us override methods for the quiz access rules, receiving in the arguments pre-flight data, sent through the existent web services. However, it doesn't have a way to send to a third-party application, the coordinates or the time of a quiz, stored in the Moodle’s database. Consequently, the validation of the coordinates and time must be done in the server, and that requires internet connection in the mobile application to send that data to the server. Luckily, sending to the server the coordinates or the current time doesn’t evolve a big amount of data and keeping the validation in the server represents a bigger security safety.

In the user point of view, the applications seem attractive and responsive, while executing all the rest of the features. In this section, a demonstration of the *Field Trip* features will be shown.

4.1.1 Download app (Students)

According to the OS of the student’s mobile device he or she should download the mobile app in the Google Play Store, in the case of Android or in the Apple Store, in the case of iOS.

4.1.2 Create quiz (Teacher)

The first steps of the creation of the quiz are the same as in Moodle. However, in the quiz configuration page a tab named Geolocation was added. Inside this tab, there is a map, shown in Figure 8, where the teacher can search for a place, and click on it to obtain its coordinates.

After clicking on a point, its coordinates are automatically inserted in the Latitude and Longitude *textboxes* and a marker is added to the map, as we can see in Figure 9. It allows to click in other point to change the coordinates and the marker and also to delete them, by clicking in “Delete Markers”.
Figure 8 - Search for a location and click on it to save the coordinates for the quiz location.

Figure 9 - Quiz location added.
In the same page it’s possible to see now an option to allow the offline mode in the mobile app, as we can see in Figure 10.

![Allow quiz to be attempted offline using the mobile app](image)

*Figure 10 – Offline mode option.*

To save the quiz options, we should click in one of the Save options, shown in Figure 11.

![Save and return to course, Save and display, Cancel buttons](image)

*Figure 11 – Save quiz options.*

The following steps are the same as in Moodle, allowing to insert questions in the quiz. Figure 12 shows 3 questions inserted in the quiz.

![Editing quiz: Quiz 3](image)

*Figure 12 - Questions inserted in the quiz: Photo, Angle and Coordinates questions.*
4.1.3 Quiz download (Students)

To download a quiz, first the students must login, open the navigation menu and click on ‘My courses’.

Figure 13 – Download quiz – step 1.

Figure 14 – Download quiz – step 2.

Figure 15 – Download quiz – step 3.

Figure 16 – Download quiz – step 4.

Then, they should click in the course and open the respective quiz from the list, associated to a location.
4.1.4 Solve the quiz (Students)

To solve the quiz, the students should open it, click on ‘Start attempt’ and answer it. To finish the quiz, they should click in the arrow button and then on the ‘Ok’ button in the pop-up window.

Figure 21 - Solve the quiz – step 1.

Figure 22 - Solve the quiz – step 2.

Figure 23 - Solve the quiz – step 3.

Figure 24 - Solve the quiz – step 4.
4.1.5 Upload solved quiz (Students)

To upload the quiz, the student must click on ‘Submit all and finish’ and confirm it.

Figure 25 – Upload solved quiz – step 1.

Figure 26 – Upload solved quiz – step 2.

4.1.6 Get the quiz answers and evaluate them (Teacher)

To grade a quiz in the web portal, the process is the same as in Moodle, as figures 27-33 show.

Figure 27 - Get the quiz answers – step 1.
After selecting the quiz, the questions of the type “automatically corrected” are seen, along with the feedback, as shown in the next figures.

As we can see, the previous question was automatically graded correct and given the complete mark. The following image shows the opposite case, when the answer was wrong.
However, to classify manual graded questions, the teacher has to click on the ‘Manual Grading’ option.

In this case, selecting the question we want to grade will give us the opportunity to see the answer and insert a comment and the mark.
Figure 33 – Classify a manual graded question – step 4.

Question
Take a photo of the rock with a biggest dip. For it, if needed, solve the next Angle Question to measure the rocks' angles.

Insert photo
4.1.7 Visualize the quiz review and mark (Students)

The students can open the quiz again at any time, by clicking on review to check their correct or wrong answers and get their grades, as we can see in figures 34-37.

Figure 34 – See the quiz review – step 1.

Figure 35 – See the quiz review – step 2.

Figure 36 – See the quiz review – step 3.

Figure 37 – See the quiz review – step 4.
4.2 Question types demonstration

In the web portal, after the quiz configuration page, the teacher can insert new questions, selecting the question type, as we can see in figures 38-40.

![Choose a question type to add](image)  
*Figure 38 – Geographic Coordinates question type description.*

By choosing the previous type of question, presented in Figure 38, the teacher is able to edit a *Coordinates* question.
By choosing the previous type of question, presented in Figure 39, the teacher is able to edit an Angle question.

Figure 39 – Angle question type description.

Figure 40 – Photo question type description.
By choosing the previous type of question, presented in Figure 40, the teacher is able to edit a *Photo* question.

Figure 41 shows the quiz edit page after inserting these example questions.

![Editing quiz: Quiz 3](image)

*Figure 41 – Edit quiz page now with some questions.*

On this page, it is possible to save the questions in the quiz, change the maximum grade of the quiz and of each question, and also to return to the course page.
4.2.1 Photo with Description

In figures 42-44 we can see the example of a *Photo with description* question type. The *Photo* type is not worth to be shown because in a practical view it can be considered a fragment of this type.

*Figure 42 – Photo with Description (1).*

*Figure 43 – Photo with Description (2).*

*Figure 44 – Photo with Description (3).*
4.2.2 Geographic Coordinates

In figures 45-50 we can see the example of a *Geographic Coordinates* question type and the answers’ validation.

![Figure 45 – Geographic Coordinates (1).](image1)

![Figure 46 – Geographic Coordinates (2).](image2)

![Figure 47 – Geographic Coordinates (3).](image3)

![Figure 48 – Geographic Coordinates (4).](image4)
4.2.3 Angle

Figure 51 represents an example of an Angle question type. In a similar way to the Coordinates type, it also has input validation.
4.2.4 Quiz in paper vs quiz in mobile app

After testing the application, and as it is possible to see in the previous demonstration, the development of a tool of this nature brought boundless advantages: It allows not only a new set of question types, unachievable in the conventional quizzes in paper, but also more interactivity and dynamism.

4.2.5 GPS Access Rule

Figure 52 shows the screen in which the student must insert his/her location. To do it, he must click on ‘Obtain location’ and ‘Ok’ buttons. The location services retrieve the phone coordinates, which are automatically inserted in the correct fields and then the student can send them for validation. If a positive answer is received, the student is able to access the quiz.

![GPS Access Rule screen](image)

*Figure 52 – GPS Access Rule screen.*
4.2.6 Offline Mode

In Figure 53 it’s possible to see a ‘cloud’ icon. That symbol indicates that the quiz has the offline mode activated.

![Figure 53 – Offline mode icon.](image)

After solving and submitting the quiz, in the offline mode, a message warns that the quiz needs to be synchronized (Figure 54). After connecting to the internet, the quiz’ answers are automatically uploaded and now the app shows a message with information about the last synchronization (Figure 55).

![Figure 54 – Offline mode: before synchronization.](image)

![Figure 55 – Offline mode: after synchronization.](image)

4.3 Communication

*Field Trip* fulfilled the expected communication requirements. The login, download and upload of the quizzes require an internet connection, but once the first two steps are done, the mobile application can hold the data in the offline mode, allowing the students to answer and finish the quizzes without any internet connection.

Moreover, the exchange of information between the mobile application and the database server is implemented with REST services, and the data is represented in the modern and lightweight JSON format. On the web portal, HTTP requests and AJAX services are used.
4.4 Non Functional Requirements

This section will evaluate the proposed non-functional requirements and state which were accomplished and which were not.

4.4.1 Performance

Field Trip includes caching mechanisms. This allows for a growing performance during the use. The first time a user accesses a page and some data needs to be downloaded, the response time is a little longer, but on the following access times the system is responsive. The fact that the communications use REST with JSON may also be responsible for a faster exchange of data.

In a general perspective, Field Trip can be considered to have a reasonable performance. The following list gives more details about the proposed performance goals.

Latency or delay less than 100 milliseconds

Even though it was not timed with a chronometer, Field Trip only takes more time when needs to download a considerable amount of data, otherwise is fast, depending on the internet conditions. We can say that on average this requirement is accomplished.

Asynchronous download and upload

This requirement is partially done. The upload is asynchronous if the offline mode is used: when internet connection is found again the mobile application uploads the answered quiz in the background. However, in other conditions it is synchronous and the download is always synchronous, which blocks the app during that period. These happens because the Moodle Mobile 2 application already implemented those features in this way. Those features were not changed due to the insignificance of this limitation compared to the effort and time it would need, which were saved for the development of more important features.

2h of energy consumption

This requirement is accomplished. What could consume more battery in the phone is in the first place the location services and then the use of internet data plans. Well, the internet is just used some seconds to download the quiz. On the other hand, the location required by the GPS access rule is only needed in the first the quiz is accessed, since then it is stored on the phone database. Moreover, the use of location services to answer the Coordinates questions just take a few seconds. For these reasons, the Field Trip mobile application doesn't have a high energy consume, so it’s expected to sustain the phones' battery at least 2h.
Scalable system

Field Trip is organized in a modular form, with the 3-tier architecture and end-points for plugins’ development. For this reason, the system can freely scale and if it implies the change of one of the modules, it can be done without compromising the rest of the system.

4.4.2 Security

Field Trip has some security mechanisms. The web portal, if using a Moodle version superior than 2.3 can be configured to work over HTTPS connections, when logging, or over the whole site [89]. This is an encrypted connection, preventing the data to be read by hackers. In this case, the server would have to work with an SSL connection.

On the other hand, the mobile application with the Moodle Mobile additional features [90] installed supports sites using SSO authentication methods (Shibboleth, CAS and Google OAuth 2) and sites using MNet authentication (Moodle Network authentication).

Moreover, the data is kept secure. The information stored in the device’s databases is only accessible by the Field Trip application and the correct authentication is necessary to get this data. Besides that, each user cannot see information about other users.

Moodle also generates, automatically, from the 2.5 version, a random string called salt for each individual user that is added to his/her password before realizing the cryptographic hash function to the password, which increases the security [91]. The algorithm used for the hash function is the MD5. Also the files’ paths are hashed.

Another security mechanism relies on the fact that the students can’t insert images stored in the phone, while answering a Photo question type; they are obligated to capture the photos in real time.

Furthermore, the application doesn’t allow the students to access a quiz associated to a geolocation if they are not in the correct location, using the GPS signal, within a fixed distance tolerance. The following list will detail which were the accomplished security measures.

Secure and private data

This requirement is accomplished. All data is securely stored in the system databases.

Secure and encrypted communications

This requirement is partially completed. The communications are only encrypted in the logging.

Database secure access control mechanisms

This requirement is accomplished. The access to the database is only done by the data tier of Field Trip.
Authentication

This requirement is accomplished. All users need to be correctly authenticated in *Field Trip*, with the mentioned mechanisms.

Quiz location and time access restrictions

This requirement is also done. A geolocation and time can be set to any quiz to restrict their access.

Answers cannot be edited after finishing quiz

This requirement is accomplished. When the quiz is finished, the answers are submitted. Once they are submitted no longer can be edited.

4.5 Development Discussion

During the realization of this project, and the reason why it took a reasonable time to complete it, endless problems and obstacles were coming up.

It started with the Moodle installation, along with all the software needed to make it work. There were some software compatibility problems, and also their configuration. For example, to use the latest functionalities of the Moodle Mobile, Moodle 3.2 was required and, consequently, it required PHP versions higher than 5.6, but the versions 7.x were also not working. An Apache XAMPP server was used for personal quizzes, along with MySQL. Also, the *php.ini* file inside the xampp folder, which would make Moodle work, was complicated to configure. Some other mishaps occurred with the version of MySQL. The Moodle Mobile application brought installation problems as well, whether with the software versions, or with the process of compilation and running of the application. In this case, another obstacle was to find the correct commands that would solve this situation and some properties that had to be changed in some files.

After solving all these difficulties, understanding the structure of Moodle and Moodle Mobile, with more than 16.000 files and 5.000 files, respectively, of real and not generated code, was also a big challenge, specially taking into account the poor documentation they had. Although it brings lots of advantages extending a project, instead of starting it from the root, it could be even more complicated studying what has already been done, and building above that, without the possibility of changing the original architecture. Another obstruction, along with the scarcity of the API documentation, relies on the fact that many functions had the same name in different classes, many classes had similar names, making it difficult to understand which ones were being extended or overridden. Additionally, some functions belonged to an endless chain of functions, often in different classes and files, to perform a certain task.
Some tools that were a great help to this project also took some time to be found, such as xdebug, to debug the PHP code and to generate stack trace files with the profiler option enabled, cachegrind, to create a tree visualization of the functions in the stack trace, the ionic live reload, to retrieve, in real time, the logs of the app into the computer, and Fiddler to intercept the communication packets between the application and the server, which allowed the author to see the JSONs exchanged. Besides that, to quiz the modules which used the Cordova library, since its goal was to access the phone’s hardware was not possible on a computer simulator, for example with the ionic serve tool. To make things worse, each time the application code was changed and needed to be tested in a real device, the compilation and installation took a long time, and the ionic live reload option was just working with the ionic@1.2.1-beta1 version. On some other tries, when there was no needed to test a Cordova feature, since it was much faster running with ionic serve, another version of ionic needed to be installed. All these technical issues resulted in a big time loss.

Likewise, some bugs of Moodle and Moodle Mobile needed to be solved, and to find the errors in such a complex project was an arduous task. One of these bugs took almost two months to be fixed, and was not directly in the scope of this project. For example, to get the upload of photos to work with the application, with the already existing implementation of the web services module in the app, some changes had to be made in the server, to get it to accept and save the files.

Finally, the last challenge was to deal with dependency injection in the app, whose architecture induced sometimes in circular dependency, throwing errors. In these cases, some functions had to be changed to other modules to make it work.
Chapter 5

Conclusions

This chapter closes this work, mentioning the conclusions related with each step of the thesis, and presents its expectations, along with the future work that can be continued.
The main goal of this thesis was to develop, or extend a system, taking advantage of the recent technologies to allow for evaluations in field trips, in an academic environment.

The first chapter introduced the technological advances and the possibility of taking advantage thereof as well as to improve the quality of Education, by using LMS platforms as m/e-learning interfaces. The importance of field trips for some practical courses was highlighted, emphasizing the area of Geology, and how the evaluations outside the classroom contribute to a deeper understanding of the subject. The main motivation for this thesis was to realize the necessity of innovative tools that would fill the existing gaps in these areas.

In Chapter 2, the concept of e-learning and m-learning was explored, along with the advantages these methodologies can bring to Education, such as the motivation, independency and maturity stimulated in the students, along with the possibility of learning at a distance, at the student’s pace. Then, the Learning Management Systems (LMS) were introduced as the supporting platforms for e-learning and how they can be used to provide interactive evaluations that students can interpret as games. This topic makes the bridge to the concept of Gamification, which has a great value for Education. One standard structure was also referenced for the representation of questions and quizzes, promoting interoperability and shareability between different LMS platforms. After that, there came the analysis of some literature about the field trips in the area of Geology and the ongoing obstacles related to them. Finally, a review of the existent mobile LMS platforms and tools was brought up, directed to the Geology area, showing their inadequacy and insufficiency to realize evaluations in the field and the inexistence of a system to bring all those features together.

Chapter 3 briefly describes the traditional types of questions used in field trips and how technology could create innovation and dynamism in these quizzes, dragging them into the area of gamification and illustrates Field Trip, a solution capable of fulfilling the scarcity of tools for dynamic evaluations in field trips. This chapter also specified all the requirements, physical and logical architecture of the system, along with the technologies adopted and how they were used to implement Field Trip.

In Chapter 4, an evaluation and demonstration of the system was made and the results were discussed, comparing the conventional types of evaluations, on paper, with the supported of Field Trip and showing the advantages this project brought.

Field Trip is an innovative tool that allows quizzes to be created in a web portal, resolved on the mobile application during field trips, using location services to access them or to answer a question, the phone’s camera to answer with photos and its accelerometer to measure tilt angles. It has a great variety of question types, including the conventional questions as well. Moreover, it can work on an offline mode, except during the download of the quizzes, when the geolocation mode is activated, which also concerns some security measures. This tool can be really useful for evaluations in Geology field trips, with a gamification approach.

In the future, more question types could be implemented, or combinations of them, for example, Photo with multiple choice answer, Video or Audio answers, Topographic Profile that automatically generates a graphic with the altitude along with the walked distance, instead of just sending the array of coordinates
and altitude, *Fill in the gaps* with photos captured in the field trip or with geographic coordinates, the *Angle* question could evolve into an *Attitude* question type and instead of measuring the tilt of a plane, measuring the Strike and Dip with the correspondent directions (example: N90°W, 33N) etc. The last type, would involve a combined use of the phone accelerometer, to measure inclination angles, with the compass, to obtain the phone orientation.

Likewise, the restrictions in the access to the quizzes can be extended to restrict the quizzes not only to a geolocation, but also to a starting and ending time, both in the offline mode. Those functionalities already exist in the online mode, but do not work when offline. Moreover, the timestamp obtained in the *Cordova Geolocation plugin* could be utilized to use the time of the GPS system instead of the phone time, granting more security measures.

Finally, both the mobile application and the web portal styles could be customized with a more attractive look and feel, especially the web portal, which is older.

To conclude, it is expected that this solution motivates students, bringing them a practical and interactive way of learning, in a real environment, while providing teachers with a way to evaluate them on the field.
References


