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A gamified mobile app for promoting campus-community engagement: The case of Iscte-IUL's 50th anniversary

João Carlos Cambaia Gomes de Almeida

Master in Computer Engineering

Supervisor:
Doctor Fernando Brito e Abreu, Associate Professor, Iscte-IUL

Co-supervisor:
Doctor Jorge Freitas Branco, Full Professor (r), Iscte-IUL

November, 17, 2023

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TECHNOLOGY
AND ARCHITECTURE

Department of Information Science and Technology

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I dedicate this dissertation to my girlfriend and future wife Fernanda, her loving family, my Father and my Mother.

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Acknowledgements

Lisboa, October, 2023

João Carlos Cambaia Gomes de Almeida

First of all, I want to thank my girlfriend Fernanda who kept me motivated and supported me from the beginning until the end of the research and development process, to her I dedicate all my love and focus to always improving myself and reaching for the skies.

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Abstract

Context: The image of a university distinguishes it as an *alma mater* from others. The heritage and history of an institution greatly contribute to its image. However, many of Iscte-IUL's members barely know their university's heritage, partially due to a lack of organized and engaging means to access such information.
Objective: The main goals underlying the research described in this dissertation are to investigate whether a gamified mobile application could bridge the gap between students and the university's past and whether an application can increase public interest in a university event.
Method: We validated the idea of developing a mobile app with gamification strategies to achieve the proposed goal, by conducting a series of interviews, validation from Iscte-IUL's Communications Office, and three separate validation tests where we gathered feedback and suggestions for the improvement of the presented solution. The app was implemented with a cross-platform framework to reduce development time and costs.
Results/Conclusion: The interviews showed the solution's usefulness for the community and offered valuable insight into the possible improvements and the future direction of the application. The answers to the validation feedback forms showed high satisfaction with the application and provided additional feedback to be considered in the final release. Finally, the user's performance during the validation tests was analyzed and it was verified through the quizzes present in the app that the activity helped cement the knowledge regarding the university's history and heritage.

Keywords:
Community engagement;
Gamified app;
University heritage;
Serious game;
Cross platform software development;
Institutional chronology;

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Resumo

Contexto: A imagem de uma universidade distingue-a das outras enquanto *alma matter*. O património e a história de uma instituição contribuem em grande medida para a sua imagem. No entanto, muitos dos membros do Iscte-IUL mal conhecem o património da sua universidade, em parte devido à falta de meios organizados e interessantes para aceder a essa informação.
Objetivo: Os principais objetivos subjacentes à investigação descrita nesta dissertação são investigar se uma aplicação móvel gamificada pode fazer a ponte entre os estudantes e o passado da universidade e se uma aplicação pode aumentar o interesse do público num evento universitário.
Método: Validámos a ideia de desenvolver uma aplicação móvel com estratégias de gamificação para atingir o objetivo proposto, através da realização de uma série de entrevistas, da validação do Gabinete de Comunicação do Iscte-IUL e de três testes de validação distintos, onde recolhemos feedback e sugestões para a melhoria da solução apresentada. A aplicação foi implementada com uma framework multi-plataforma para reduzir o tempo e os custos de desenvolvimento.
Resultados/Conclusão: As entrevistas mostraram a utilidade da solução para a comunidade e forneceram informações valiosas sobre as possíveis melhorias e a futura direção da aplicação. As respostas aos formulários de feedback de validação revelaram uma elevada satisfação com a aplicação e forneceram feedback adicional. Por último, o desempenho dos utilizadores durante os testes de validação foi analisado e verificado através dos quizzes presentes na aplicação que a atividade ajudou a cimentar o conhecimento sobre a história e o património da universidade.

Palavras-chave:
Envolvimento da comunidade;
App gamificada;
Herança universitária;
Jogo sério;
Desenvolvimento de software multiplataforma;
Cronologia institucional

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Acronyms

API Application Programming Interface.

APK Android Package Kit.

BPMN Business Process Model and Notation.

CI/CD Continuous Integration and Continuous Development.

CMS Content Management System.

HTTP HyperText Transfer Protocol.

IDE Integrated Development Environment.

LLM Large language model.

MARS Mobile Application Rating Scale.

NASA-TLX Nasa Task Load Index.

OOP Object Oriented Programming.

ORM Object Relational Mapping.

QR Code Quick response code.

REST Representational State Transfer protocol.

UI User Interface.

YAML Yet Another Markup Language.

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Chapter 1

Introduction

Contents

This chapter presents the background, motivation, and problems this dissertation addresses. In addition, the research question and objectives are also presented.

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Chapter 1
Introduction

1.1 Background and motivation

Background When enrolling in a higher education program, students will consider many aspects, including the quality of its faculty and alumni, the quality and quantity of its research projects, and also its unique identity. This identity distinguishes the organization from others, it is the *Alma Mater* of its current and former students.

A unique identity gives the community involved in the organization something more tangible to hold onto. For example, if an organization proclaims that it is "against deforestation"then its community of customers, supporters, or, in the case of a university, its academic community, will be able to identify with that message, it will be something they can "resonate"with, the community as a whole will feel that it is contributing to a cause and will be able to work together to achieve that cause. When a message is well communicated and the organization's identity is well defined, a social aggregation "force"begins to generate, attracting more and more people with the same principles and identity as the organization.

The Alma Matter of any organization is of great importance, it is an essential strategic management tool because it can be used to attract future students, professors, and partner entities such as research centers and companies to enroll and collaborate with the university.

Universities that have been operating for many years, such as those in Bologna, Salamanca, Paris, or Coimbra, have such a large backlog of stories that their millennial heritage can intrinsically contribute to their *Alma Matter*, which is often associated with great historical campuses, symbols, and traditions. But even for them, managing such a resource is no easy task, as they still need to keep up with recent changes and fields of science that newer universities were born to dominate while maintaining continuity and connection to their vast past.

On the other hand, younger universities struggle with not having a backlog of stories and accomplishments to guide them on the path to a unique identity, but they have the slight positive of not having a historical record, so their reputation can still be carved into any shape they want to achieve. They struggle mainly with asserting themselves positively in an environment where tradition still plays a large role in social reputation.

Motivation Iscte-IUL, one of the three public universities in Lisbon, Portugal, celebrates its fiftieth anniversary. With the spirit of making its history public, a considerable chronological corpus of historical elements is being collected to celebrate the occasion and showcase its best moments. In this sense, a large amount of historical material is being collected, including documents, photographs, and recorded testimonies from former professors and other staff members, as well as from alumni and current members of the campus community.

With the act of interviewing the community that lives their everyday life in our university, it was quickly realized that their knowledge of the campus heritage was little to none, emphasizing the fact that Iscte-IUL's *Alma Matter* has not spread to the current generation that is enrolled in the organization, the aura that surrounds Iscte-IUL is not well defined and therefore

the students don't have knowledge of its history, its ongoing projects and the research that it is conducting. Therefore, the documents and historical markers that are being collected are also, for the most part, unknown to the community and remain, almost, hidden from the public; therefore, the unique identity that categorizes Iscte-IUL remains in the shadows for most of us.

An application that aims to bring all these aspects to light would be very appropriate for the current context in which the university finds itself. The fact that *university students are quick adopters of such new technological changes* [19] makes such a digital approach a natural choice.

With this in mind, the present dissertation details the entire process of developing a cross-platform mobile and web application that, in an attempt to increase public engagement and identification with Iscte-IUL's *Alma Matter*, among other things, provides easy access to the chronological corpus of university identity evidence being collected by a dedicated team on behalf of Iscte-IUL. Using a gamified approach that provides a sense of competition through a virtual championship composed of quizzes on the historical content being collected, combined with geographical elements distributed across the campus, pitting internal affiliations against each other (e.g. students as members of a particular BSc, MSc or PhD program, professors as members of a particular department).

By combining informational questions with the geographical space of the campus, it is hoped that the users participating in the competition will gain knowledge about the physical space to which the content is related, and establish a deeper connection with the content being displayed, ultimately keeping this content in the minds of the participants for a much longer period.

Research relevance The relevance of the current research topics has been recognized by the A-Mobile workshop at the 38th IEEE/ACM International Conference on Automated Software Engineering (ASE 2023) conference, where a paper focused on our development approach, titled Cross-platform mobile app development: the IscteSpots experience, was presented.

1.2 Research questions and objectives

RQ1 Can a gamified mobile application connect students to their university's past?

RQ2 Can a mobile application increase public interest in a university event?

The main objective of this research is to foster the relationship between the student and the university by effectively spreading the heritage and history of our institution to current and future generations of alumni. We aim to accomplish this by developing a mobile application that encourages its users to explore and embrace the University's heritage while exploring its physical campus.

1.3 Contribution goals

This research aims to create a modern, more effective method to achieve a deeper connection between the students and the institution, allowing them to identify themselves with the organization, feeling that they are "part of a bigger whole". In other words, we aim that the current

Iscte-IUL community will generate much more public interest directed at the university than the previous generations so that more candidate students will choose our university over others, while creating more knowledge and innovation within the institution, a major thriving factor. The following contributions of this dissertation are aligned with the former objectives:

Contribution 1 A mobile application for learning about the history of Iscte-IUL, as an institution, providing quizzes, puzzles, and a timeline, all about the history and heritage of the university, published in the Android and IOS application stores;

Contribution 2 A website that serves as a showcase for the history of Iscte-IUL in the form of a timeline, as a means of collecting feedback on said timeline, correcting any errors, and as a means of data collection;

Contribution 3 A literature review on the topic of "mobile applications for learning"and "organizational identification".

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Chapter 2

Related Work

Contents

In this chapter, it is presented a comprehensive state of the art of Mobile applications and Organizational Identity

In the introductory section 2.1, we have a brief introduction to the review protocol used in this study and its characteristics. Planning phase Section 2.2 reviews each step in defining the protocol used to select the studies that approach the same themes as the ones being studied. The conducting section 2.4 describes how each of the defined steps in the Planning phase is used to conduct the planning phase. Section 2.5 presents the proposed taxonomy and consequent classification of each primary study. Section 2.6 presents the conclusions taken from the analysis of the related work.

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Chapter 2
Related Work

2.1 Introduction

To understand the scientific work done in the area of "Mobile applications"combined with "Organizational identification", a Rapid Review was executed from January 2023 until February 2023.

A *Rapid Review*, also called a Rapid systematic review, is a fast, smaller in scope version of a *Systematic Literature Review* (SLR), a methodology that establishes multiple criteria and a protocol that the review should follow.

The focus and objectives of the research, which databases will be consulted, which search strings are used, possible time constraints, and other variables are all pre-defined within the protocol, before any research is conducted, making the process reproducible by other researchers who can validate it, possibly improve upon it and even compare it to other reviews.

A systematic protocol is necessary to remove potential bias in analyzing related work, as clearly defining each step removes room for arbitrary choice in deciding which work is relevant and which one is not, giving every article a fair chance of being reviewed.

To describe such a process in detail, the Business Process Model and Notation (BPMN) diagram in figure 2.1 will be used to hold a visual representation of every step and how these interact with each other. In the diagram, it can be seen what artifacts are produced, where they are created, and where they are consumed.

2.1.1 Research environment

The diagram divides its tasks into three different lanes, each representing the software used throughout its included tasks, in our case the software consists solely of different websites that each serve a different purpose.

Of these websites, two of them serve a development environment role, the same way a software development Integrated Development Environment (IDE) is used to support the developer.

The websites Parsif.al and Overleaf support the researcher, by creating a pipeline to support each task of the Systematic literature review process within Parsif.al and a streamlined collaborative online environment for writing this dissertation paper in the LaTeXlanguage.

Finally, Scopus was used for querying its database for primary studies to be used in this systematic review.

2.2 Planning phase

According to *Parsif.al*'s dissection of a systematic review protocol, initially, the researcher must prepare and define any criteria and infrastructure later used to conduct the review. As can be seen in the diagram in figure 2.1 the first task is named the "Planning phase", an expanded task

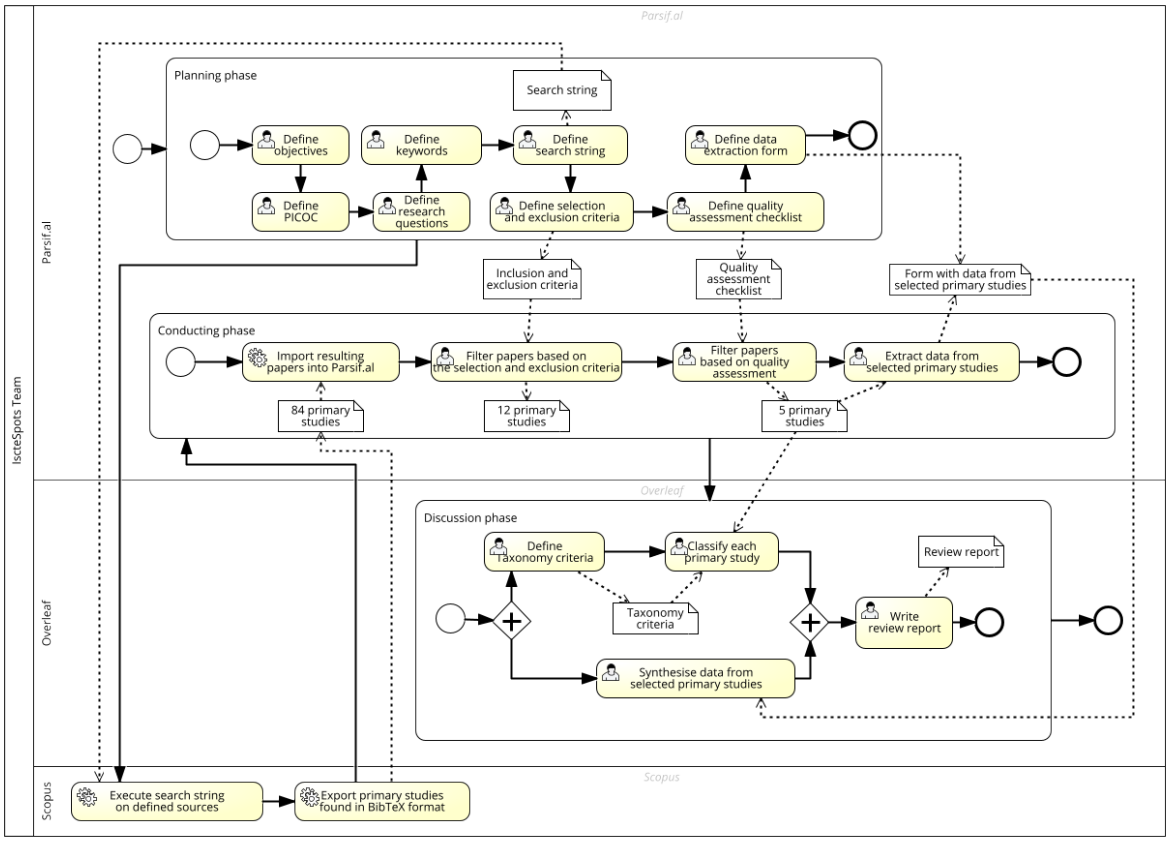

Figure 2.1: Rapid systematic literature review process

to display all the sub-tasks required in this initial phase of the review process, each described in the following sub-sections 2.2.1 to 2.4.3

2.2.1 Research objectives

The first task in the planning phase is the definition of the following research objectives.

To promote and assess the identification of Iscte-IUL's academic community through the knowledge of its 50-year history using a serious gaming app.

2.2.2 PICOC

Secondly, a PICOC, standing for **P**opulation, **I**ntervention, **C**omparison, **O**utcome, and **C**ontext, was defined for later use and creating a better understanding of the research questions at hand and helping in the development of the inclusion, exclusion criteria and quality assessment later described in sections 2.2.6 and 2.4.3.

With all of this in mind, the following *PICOC* was established: The Scientific papers using at least one of the identified interventions in the identified context are defined as belonging in the **Population** of the study. The identified **Intervention** is to assess the adoption of a gamified multi-platform app (Android, iOS, and web) for the promotion of campus community engagement. The study **Compares** other strategies for campus-community engagement or gamified app-based community engagement in other fields and expects an **Outcome** of a Systematic

study of methodologies, practices, techniques, and tools that characterize the current state of the art in the identified context of the 50th anniversary of a university.

2.2.3 Research questions

Two research questions were defined, providing a clear focus and direction for the review and the current research as a whole.

The following two questions were the ones defined in this planning phase: *Can a mobile application increase public interest in a university's event?* and *Can a gamified mobile application connect students with the past of their university?*

2.2.4 Keywords

A set of keywords was then automatically extracted from the PICOC and the research questions by the Parsif.al website and also manually adjusted. The final set of keywords can be found below:

alma mater; *community engagement*; *digital ethnography*; *gamified app* or *gamified application*; *university heritage* and *university identity* or *place identification*;

2.2.5 Search string

Due to the nature of the current study, the search string was engineered in a way that encompassed both studies related to the technical side, with "mobile applications"or "serious games"and the theoretical/ anthropological side with "organizational identification"

A **technical** section aimed at finding research regarding application/software related to "serious gaming", to filter out work aimed at video games, as this project is more mature, closer to a traditional, more serious, questions and answers game.

```
( "mobile application"OR "mobile app"OR "web app"OR "web application") AND ( "serious game"OR "serious gaming")
```

A **theoretical** section that is focused on the connection that people can create with organizations and their history.

```
( "organization identification"OR "organizational identity"OR "organizational orientation"OR "organizational history"OR "organizational chronology")
```

Common sections combine the others with "university"OR "college"to keep the scope close to the current project and also further filter for academic documents about the development of techniques and methods that promote or stimulate;

```
("university"OR "college")
```

```
( "method"OR "technique"OR "tool"OR "promote"OR "raise"OR "develop"OR "stimulate"OR "nurture"OR "assess"OR "encourage"OR "engage")
```

The **full** search string:

TITLE-ABS-KEY ((("mobile application"OR "mobile app"OR "web app"OR "web application") AND ("serious game"OR "serious gaming")) OR ("organization identification"OR "organizational identity"OR "organizational orientation"OR "organizational history"OR "organizational chronology") AND ("university"OR "college") AND ("method"OR "technique"OR "tool"OR "promote"OR "raise"OR "develop"OR "stimulate"OR "nurture"OR "assess"OR "encourage"OR "engage"))

2.2.6 Inclusion and exclusion criteria

A list of criteria was developed to determine what papers to include and what to exclude from the ones found later in the Conducting phase from the defined sources, accordingly, the primary studies written in English that can be scoped in the current PICOC are included while studies with less than 6 pages, without access or where there is a later version of the same paper are excluded.

The selection criteria in its entirety are displayed in tables 2.1 and 2.2.

Table 2.1: Inclusion criteria

Criterion	Description
IC1	Paper is written in English
IC2	The paper can be scoped in the described PICOC
IC3	The paper is a primary study

Table 2.2: Exclusion criteria

Criterion	Description
EC1	Papers with less than 6 pages
EC1	Papers without access permission
EC2	There is a later and more complete version of this paper

2.2.7 Quality assessment

Several questions, shown in table 2.3 were defined to rank the remaining papers and select only the ones that met the minimum score.

These questions were answered on a scale of 0 to 4, 0 meaning strongly disagree and 4 meaning strongly agree. The distribution of answers to these questions can be seen in table 2.4, where 100% corresponds to a total of 12 answers.

The questions are represented in the diagram as an artifact produced in the task D̈efine quality assessment checkliständ later consumed in the C̈onducting phase"s task F̈ilter papers based on the selection and exclusion criteria.̈

As there are 11 questions to be answered, each study can have a minimum qualification of 0 and a maximum of 44. All studies with a score lower than 22 were filtered out and only the ones with a score of 22 and above were used for deeper research.

Table 2.3: Quality questions

Question	Quality question
Q1	Was the research focused on the academic community?
Q2	Was the process of appropriation of the gamified instrument described?
Q3	Were the architecture and implementation of the proposed technology described?
Q4	Was Field observation used as data collecting methodology?
Q5	Were the goals and research questions clearly stated?
Q6	Were threats to validity clearly exposed?
Q7	Were negative findings presented?
Q8	Was related work exposed and compared with claimed research results?
Q9	Was the research design clearly specified?
Q10	Were the data used for validation adequately described and available?
Q11	Were the research questions answered?

Table 2.4: Quality answers

Answer	Score
Strongly agree	4
Agree	3
Neither agree nor disagree	2
Disagree	1
Strongly disagree	0

Table 2.5: Results from conducted search

	Scopus
Results from search string	85
After applying inclusion and exclusion criteria	12
After quality assessment selection	5

2.3 Execution of search string

The defined source was the website Scopus, where the earlier defined search string was executed and the resulting studies were extracted in BibTex format to be stored and inserted into the Parsif.al website's workflow.

The 84 resulting primary studies are represented as an artifact resultant of the task "Export primary studies found in BibTeX format", consumed in the first tasks of the "Conducting Phase", "Import resulting papers into Parsif.al".

2.4 Conducting phase

The conducting phase of the research consisted of importing the resulting studies into the Parsif.al platform, filtering said studies utilizing all the filters defined in the previous, Planning phase and finally extracting the required data from each of the final resulting studies.

2.4.1 Selection proceedings

1. Apply the inclusion and exclusion criteria based on the title and abstract of the article;

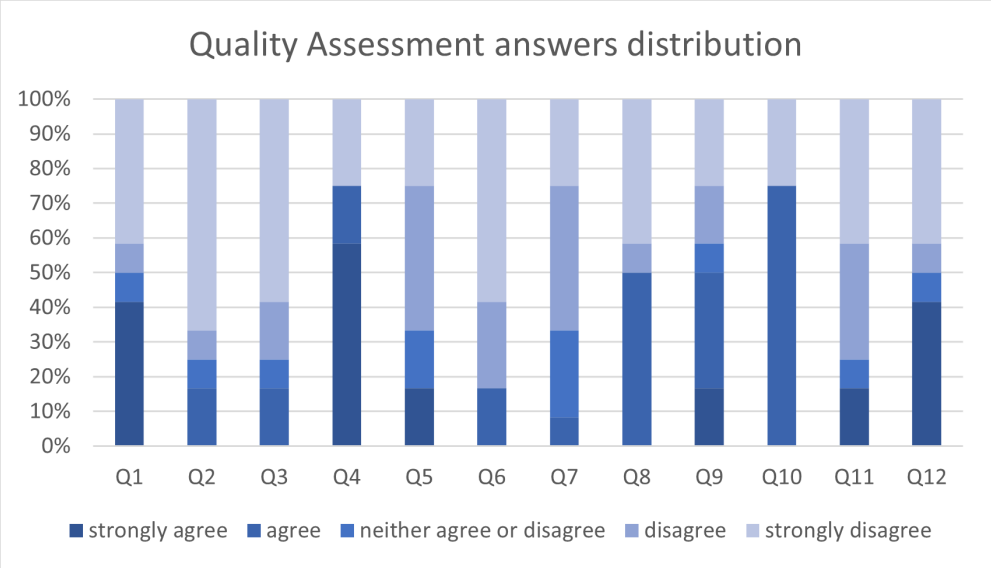

Figure 2.2: Quality assessment answers distribution

2. Filter studies based on the score obtained from answering the quality assessment questions;

3. Use the remaining papers as a basis for forward and backward snowballing;

4. Repeat steps from 1 to 2 on obtained papers from step 3.

The "Mendeley"application was used to store, organize, and read all the papers involved in this research.

2.4.2 Inclusion and exclusion criteria results

After applying the inclusion and exclusion criteria to the title and abstract of each study extracted from the defined source, in our case Scopus, a total of twelve primary studies were left.

2.4.3 Articles extraction analysis

The number of resulting papers following the above steps can be seen in table 2.5.

The distribution of the quality assessment answers for the accepted papers can be seen in figure 2.3.

Assessment question number 4: "Was Field observation used as data collecting methodology?"was the question with the most "strongly agree"answers out of all 11 questions. Question number 2: "Was the process of appropriation of the gamified instrument described?"was the one with the most "strongly disagree"answers.

The distribution of the Scimago Ranking of the journals where the papers were published can be seen in figure 2.4. It can be seen that most of the papers were published in a Journal with a Q1 rank. The N/A entry is a paper [6] that was not published in a journal and was instead published in a conference, with Core Rank Australian B.

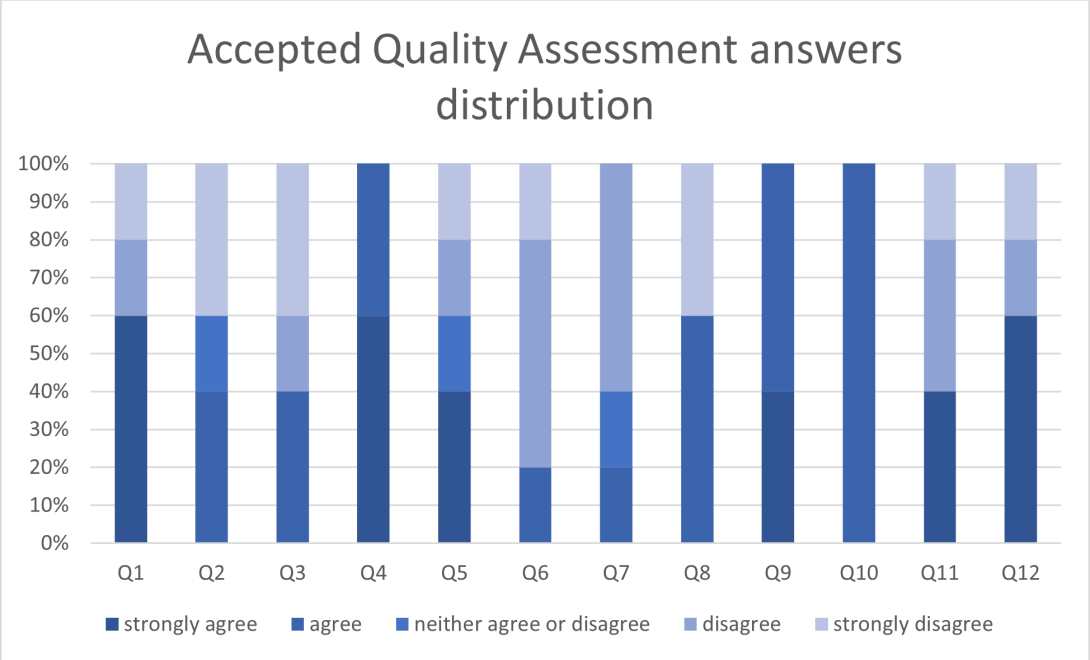

Figure 2.3: Quality assessment answers distribution for accepted papers

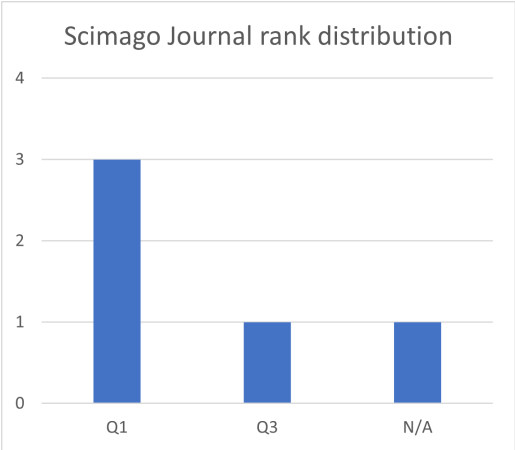

Figure 2.4: Papers Scimago rank distribution

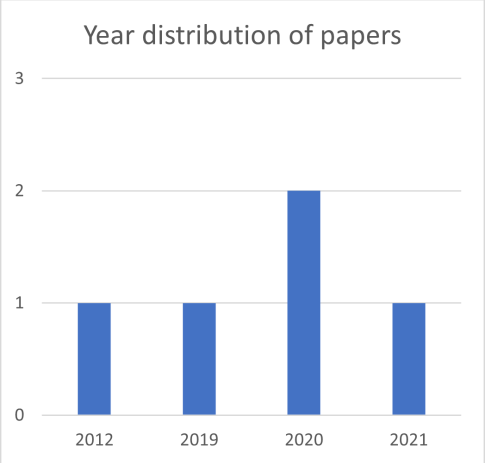

Figure 2.5: Papers yearly distribution

The distribution of the resulting papers by year of publication can be seen in figure 2.5. Where it can be verified that all the articles were published within the last decade.

2.4.4 Validity threats

The review conducted in this research can have its validity threatened due to the small number of resulting papers from the review.

2.5 Discussion phase

In the discussion phase of the research, the studies are simultaneously classified according to defined taxonomy criteria and have their extracted data synthesized, represented through the parallel gateways that split the flow of the diagram in figure 2.1

Table 2.6: Studies grouped for specific taxonomy

Paper	Group
[12] Perspectives of organizational identity in a health higher education institution: a mixed-method analysis [8] Investigating the relationship between transformational leadership style and organizational identity of faculty members in the State Universities of West Azerbaijan Province, Iran	Organizational identification
[13] MANTRA: development and localization of a mobile educational health game targeting low literacy players in low and middle-income countries [16] A mobile serious game about the pandemic (COVID-19 - did you know?): Design and evaluation study [6] A gamified mobile application for engaging new students at university orientation	Mobile Applications for Teaching

2.5.1 Taxonomy definition

In the following section, the taxonomy to be used while classifying each resulting study will be defined and described, analogous to task D̈efine Taxonomy criteriaïn the D̈iscussion Phaseëxpanded task.

Due to the nature of the current review, the studies will be placed into two separate groups, the first one containing studies regarding the creation or use of applications with teaching objectives and the second holding studies aimed at understanding the connection between the individual and the organization, also known as "organizational identification".

2.5.1.1 Organisational Identity studies

The proposed taxonomy criterion can be seen in table 2.7.

Table 2.7: Taxonomy criteria for Organisational identification studies

Criterion	Acronym
Data Analysis	DA

Data Analysis (DA) The analysis performed on the gathered data can be used to categorize the related work

- **Qualitative and Quantitative**(QQ): The study conducted both a Qualitative and Quantitative analysis of its data;
- **Qualitative**(QUAL): The study performed a Qualitative analysis on its data;
- **Quantitative**(QUAN): The study performed a Quantitative analysis on its data;
- **Not applicable**(NA): The study either did not analyze its data or it did not have data to analyze;

2.5.1.2 Mobile Application related studies

The proposed taxonomy criterion can be seen in table 2.8.

Table 2.8: Taxonomy criteria for mobile app studies

Criterion	Acronym
Connectivity	C
Beginner Friendly	BF
Game progression	GP
Game Feedback	GF
Localisation	L

Connectivity (C) Studies can be categorized by the kind of connectivity required to run the developed solution.

- **Offline**(OF): The app can be used offline without ever needing an outside connection after its installation;
- **Partial Online**(PO): The app can be used offline but may need to occasionally connect to the network to save progress or for other purposes;
- **Online**(ON): The app needs to always be connected to the network to properly function;

Beginner Friendly (BF) Studies can be categorized by their level of care towards new users.

- **Friendly (F)**: The app provides a tutorial or an onboarding to explain the app to newcomers.
- **Not Friendly (NF)**: The app does not provide any support for newcomers and expects them to know how to interact with the app.

Game progression (GP) The progression and how it is implemented in a game can categorize the found studies.

- **Visual Progression**(VP): The user's progression is visualized in the user interface of the application in a meaningful way;
- **Normal Progression**(P): The user's progression is stored but not visualized in the user interface of the application in a meaningful way;
- **No progression**(NP): The user's progress is not stored and stars from zero each time the application is loaded

Game Feedback (GF) Feedback can be of great use in a serious game, as it keeps users motivated to use the application and helps them move forward in the desired direction.

- **Feedback**(F): The application provides meaningful feedback to the user while he is interacting with it.
- **No Feedback**(NF): The application does not provide any visual or physical feedback of any meaningful means to the end user.

Localisation (L) The applications resulting from the studies can be categorized by their efforts to localize their content to specific target audiences.

- **Design Localisation**(DL): The application's design and/or assets can change to accommodate different end users.
- **Localisation**(L): The application's language can be changed;
- **No Localisation**(NL): The application is static to country changes and can only be used in the original language it was developed for;

2.5.2 Review report

Once the taxonomy is established, the obtained studies need to be classified according to the different criteria, followed by compiling a detailed report. This report will analyze each resulting paper within the taxonomy categories, providing in-depth descriptions for each.

2.5.2.1 Organizational Identity studies

Junior et al., "Perspectives of organizational identity in a health higher education institution: a mixed-method analysis", 2021 [12] *Objective* The study aims to explore how a newly established organization defines itself among its members and how they identify themselves with the organization as a whole.

Technical Summary The study gathered people to answer questionnaires, the volunteers were grouped according to their administrative positions (mainly the students group and the professors/staff group).

A questionnaire was composed of 12 statements, each with answers from one to five, representing the different levels of agreement.

Qualitative and quantitative analyses were performed on the responses from the questionnaires.

Table 2.9: Classification of "Perspectives of organizational identity in a health higher education institution: a mixed-method analysis"

Source	DA
[12]	QQ

Hesar et al., "Investigating the relationship between transformational leadership style and organizational identity of faculty members in the State Universities of West Azerbaijan Province, Iran", 2019 [8] *Objective* The objective of the study is to research the relationship between transformational leadership and the organizational identity of university members in West Azerbaijan Province, Iran.

Technical Summary The study used already established questionnaires in both areas in question, the "Multifactor Leadership Questionnaire (MLQ)"and the "Organizational Identity Questionnaire (OIQ)"

The only change done to these questionnaires is the reduction in the number of questions in the second questionnaire, OIQ, originally it had 25 questions that were reduced to 12.

Table 2.10: Classification of "Perspectives of organizational identity in a health higher education institution: a mixed-method analysis"

Source	DA
[8]	QQ

2.5.2.2 Mobile Application related studies

Mueller et al., "MANTRA: development and localization of a mobile educational health game targeting low literacy players in low and middle-income countries", 2020 [13] *Objective*

The main goal of this study is to teach geohazard, maternal, and neonatal health to remote, low-literacy populations. In specific, Nepal.

This is achieved through the development of a serious game in the form of a mobile application that

Technical Summary

Due to the characteristics of the potential users of the application, the serious game needed to have a simple and intuitive structure which led to a "drag and drop multiple-choice format"

The game was developed in the Unity game Engine and installed on six smartphones. Internet connection is not required, as many people in these communities do not have access to mobile data networks.

It features a touchscreen tutorial and a training level to ease the less familiarised users into the game. The game has three levels of increasing difficulty and each level can be summarised into the player correctly pairing (using drag and drop motions) "learning objectives"to their corresponding pictogram. When the correct answer is selected, a green check mark and fireworks are used as positive feedback, while if the incorrect answer is selected, a black "X"and an audio clip of thunder are used as negative feedback. Furthermore, flowers and leaves are used to visually represent the progress of the user in the current session, giving them a visual incentive to keep playing.

A focused form of Localisation was implemented into the app, the majority of the visual assets used are always contextualized in a way that the target audience can create a deeper connection with them, for example, the thunder audio clip and progress flowers and leaves are common in the natural and rural areas of Nepal, where this study is focused.

Classification Although the app's language or design cannot change to accommodate different idioms or cultures, its original design was already created with its target group in mind, explaining the Design Localisation classification received.

Table 2.11: Classification of "MANTRA: development and localization of a mobile educational health game targeting low literacy players in low and middle-income countries"

Source	C	BF	GP	GF	L
[13]	OF	F	VP	F	DL

Souza et al., "A mobile serious game about the pandemic (COVID-19 - did you know?): Design and evaluation study", 2020 [16] *Objective* Providing access to accurate information

in times of calamity and globally impacting events is very important, this study developed a gamified mobile application that assesses the player's knowledge about COVID-19-related topics.

Technical Summary The developed application is available on different platforms, such as mobile and web, does not require registration, requires an internet connection, and does not use much mobile data.

The Ionic framework was used together with JavaScript, Typescript, HTML5, CSS, and Angular to develop the application. The Google Analytics Application Programming Interface (API) was used as a data gatherer on the app. Obtaining information about how the users interact with the game.

The information in the game was grouped into topics, each having its specific questions that the users would answer and then get feedback on their response according to whether it was the right or the wrong choice.

Progress is stored in the player's browser, enabling progress bars on the main screen to display the user's evolution by topic.

Table 2.12: Classification of "A mobile serious game about the pandemic (COVID-19 - did you know?): Design and evaluation study"

Source	C	BF	GP	GF	L
[16]	ON	NF	VP	F	L

Fitz et al., "A gamified mobile application for engaging new students at university orientation", 2012 [6] *Objective* This study researches the design, deployment, and initial testing of a mobile gamified application built to introduce new students to their university, helping them discover their campus, services, and people during their first few weeks.

Technical Summary With the defined goal of incentivizing the exploration of the campus in mind, multiple challenges were added to the prototype, such as collecting important items like the Student card and Semester Planner and learning about the university's services. Video game challenges and other game-like environments inspired these challenges.

During the game's initial field test, positive feedback was received from the students regarding the challenges that involved Quick response code (QR Code), therefore these types of challenges were more predominant in the following tests.

According to feedback from students, a feature where users could gain levels by completing challenges was replaced with a leaderboard, as the prior was not motivating enough.

Also a server-side was developed in Java and HTML to store and update the challenges without the need of updating the mobile application, serving as a content management system.

Classification The paper does not provide enough information to fully access the connectivity of the developed application.

Table 2.13: Classification of "A gamified mobile application for engaging new students at university orientation"

Source	C	BF	GP	GF	L
[6]	ON or PO	NF	P	NF	NL

2.6 Summary

To conclude this related work study, some key topics are enumerated:

Regarding "Organisational"studies: All analyzed studies use questionnaires as a means of gathering data and approaching the study. One splits the study into two different questionnaires with the objective of correlating responses from one with the other, analyzing dependencies in both topics (each questionnaire regarded different topics). The other submitted the target group to a questionnaire and to interviews enabling deeper conversations and topics to be discussed and analyzed.

Regarding "Mobile application"studies:

Connectivity There is a mix of approaches in the analyzed studies regarding the connectivity requirements of the proposed apps,

Beginner friendly Two out of the three analyzed studies proposed apps that were not beginner-friendly, they did not provide any initial explanation of the application itself.

This is of concern, as captivating interactions and new users are of great importance.

Game progression All of the applications analyzed developed some kind of progression for the user to chase after, two out of the three even had some kind of more visually appealing feature representing the progress made within the application.

Game feedback Two out of three applications provided feedback to the end user, making it easier to interact with the game/application, and giving better guidance to what the user is expected to do.

Localisation The majority of the applications proposed a localized application that could change its language to better adjust itself to the end user.

While there was still one study that did not specify whether the app featured localization, it is of great note that it was designed with a specific target audience in mind, being very focused on reaching the said target audience, hence the lack of translation to other languages, as the target audience is mainly speaking the language the app was designed for.

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Chapter 3.

Methodology

Contents

This section intends to clarify the methodology used during the development of the IscteSpots app 3. Section 3.1 aims to give a primer on BPMN concepts. Sections 3.2 through 3.11 describe the methodology taken in each step of development.

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Chapter 3
Methodology

This chapter describes, with the help of the BPMN diagram in figure 3.1, how the application was validated throughout the development process, it describes how feedback was collected and the multiple phases that our process went through.

We can observe that in the mentioned diagram, the flow splits in two with the parallel gateway connected to the starting node. These two flows happened simultaneously during the development process. The main flow that the IscteSpots team underwent during the whole process is present in the "IscteSpots Team"lane, the ”Python”, ”OpenAi’s Whisper” and ”MAXQDA” lanes, while the smaller flow, focused on content management and creation for use within our application is present in lanes "Google Sheets"and ”IscteSpots Questions portal”, described in section 3.11.

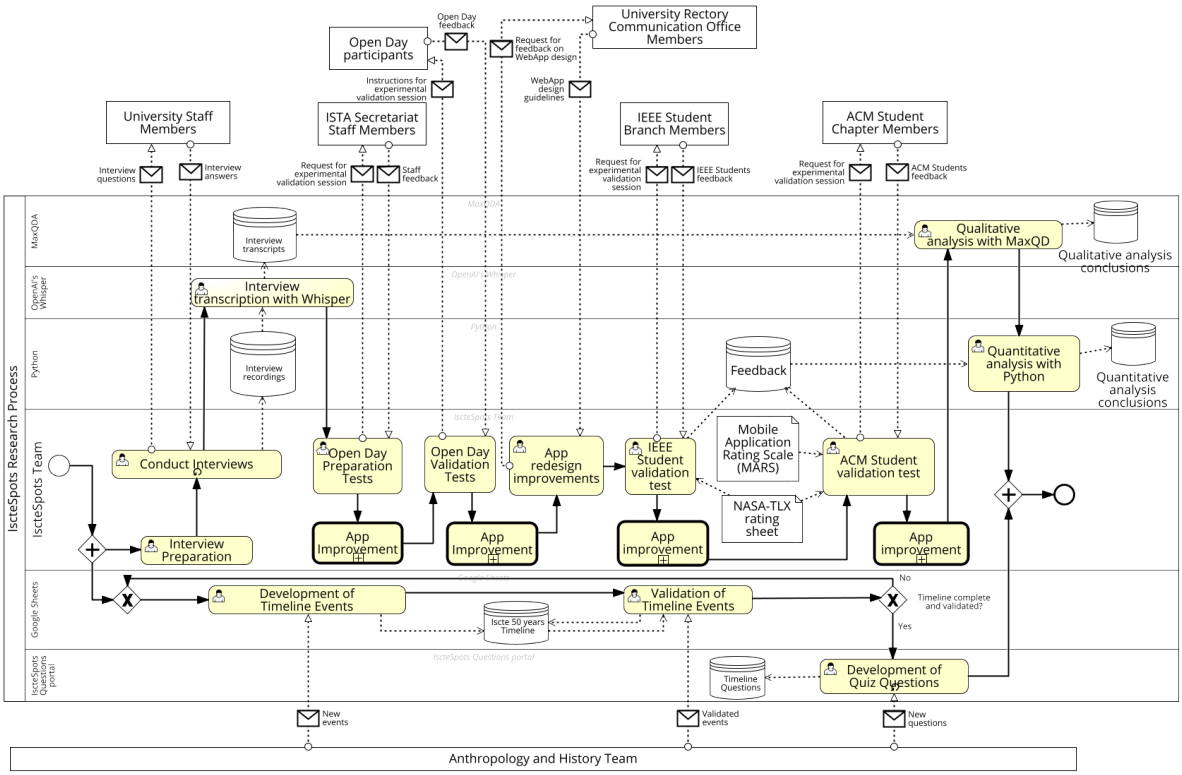

Figure 3.1: Different phases of development

3.1 Business Process Model and Notation introduction

Our methodology and subsequent chapters rely heavily upon diagrams created adhering to this notation, to ensure a basic understanding of these diagrams, their basic concepts are described below.

Business Process Model and Notation, abbreviated to BPMN provides a standardized visual representation of how work is performed within an organization clearly and understandably,

allowing business analysts, process owners, and stakeholders to communicate and analyze processes effectively. Its primary focus is to depict the flow of activities, decisions, and information involved in a business process. It allows one to map out the steps, events, and participants involved in a process, as well as the sequence of activities and the interactions between them.

The central aspect of BPMN is modelling the flow of activities in a process. Flow objects such as tasks, events, and gateways are used to represent the steps and decisions within a process. Below, several of these core concepts involved in the writing, and understanding of the referenced notation are presented.

Tasks represent the work or activities performed in a process, visible as yellow boxes. They can be manual tasks (performed by a human) or automated tasks (performed by a system). They can be representative of a subprocess if annotated with a plus sign on their bottom side, by being linked to other process diagrams,

Events represent something that happens during a process. They can be the start or end of a process, or they can occur within the process flow.

Gateways are used to control the flow of the process. They represent decision points or branching paths in the process flow, allowing different paths to be followed based on specified conditions. There are multiple different types of gateways but the main ones utilized throughout the diagrams present in this dissertation are ones that contain an "X"symbol, named exclusive (XOR) gateways, meaning that their connections are exclusive, the flow of the diagram only continues through one of its outputs, while gateways with a "+"symbol are named parallel gateways and are used to represent flows or actions that can be completed at the same time, in parallel, where the flow continues through all the outputs simultaneously.

Sequence flow is used to connect the flow objects in a process and represent the order in which activities are performed. It shows the direction and dependencies between tasks, events, and gateways.

Swimlanes are used to organize and categorize activities and participants in a process. They can represent different roles, departments, or organizations involved in the process.

Artifacts provide additional information and context to the process model. They can include annotations, data objects, and groups to enhance the understanding of the process.

BPMN diagrams can be created using various software tools that support BPMN notation. The resulting diagrams serve as a visual representation of the business processes, making it easier to understand, analyze, and communicate process improvements or changes.

Overall, BPMN is a powerful and widely adopted notation for modeling business processes, enabling organizations to optimize and streamline their operations effectively, and in the present dissertation, they were used to describe the multiple processes involved in the development and research in place.

3.2 Interviews

Interviews are a crucial and widely used research method offering valuable insights, perspectives, and information, particularly useful when studying human behavior, attitudes, opinions, and experiences.

3.2.1 Interview preparation

Script To properly prepare for these interviews a basic script was previously prepared encompassing a brief overview of the research's scope, meant as a rough draft and not to be strictly followed due to the exploratory nature of the interviews.

The draft comprises a short personal introduction followed by inquiring about the interviewees' familiarity with the history and past of the university. Additionally, a small promotional video regarding the IscteSpots app is to be presented, followed by a few questions about their impression of the video and whether they believe they or their colleagues would participate in such a competition about their university's history.

Invitation Invitations for these interviews were distributed through email in advance to selected professors and members of the University staff,

In said email a term of agreement was attached stating that participation in the interview is optional and the gathered data, namely video and sound are destined to be used in non-profit scientific events related to the University's 50^{th} anniversary.

Eventually, arrangements for the interviews' location and timing were made via email with each respective interviewee where the interviewer demonstrated complete flexibility regarding their schedule and location, aiming to provide maximum comfort and convenience for the participants, hopefully creating a relaxed environment, enabling the free flow and exchange of ideas to enhance the research and superficially validate the proposed concept.

3.2.2 Conducting interviews

Each interview was conducted in locations chosen by the interviewee, represented with task "Conduct interviews" on the diagram, marked with a circular arrow to indicate that it was repeated multiple times before allowing the flow to continue forward.

Each interviewee was presented with the option to sign a consent document where the scope and aim of the interviews were described, which allowed us to use the contents of said interviews in this dissertation and other potential material used in the scope of the fiftieth anniversary of Iscte-IUL.

The interviews were performed by the author of this dissertation as the interviewer and his girlfriend, Fernanda as the camera-woman using her smartphone as a camera to record in video format. The interviews started with giving the interviewee the option to sign the consent document followed by asking for his permission to record in video the entirety of the interview. These recordings are represented in the diagram with a Data store object named "Interview recordings"generated in task "Conduct interviews", used by task "Interview transcription with OpenAI's Whisper", explained further in section 3.2.

A total of five interviews were performed in a one-to-one setting, except for the camera-woman who was always present to record the conversation but never took part in them.

Interview Characterisation Respondents were faculty members and staff at our university, specifically chosen to have a balance between different fields and perspectives, two of which

Table 3.1: Interview Characterizations

Interview	Length	Gender	Activity	Acceptability
1	4 minutes	Female	Geography Professor	Good
2	9 minutes	Male	Online Course creator	Good
3	11 minutes	Male	Political Economy Professor	Good
4	14 minute	Female	Staff Member assistance	Good
5	12 minutes	Female	Architecture Professor, Research Group Leader	Good

were male and the remaining three were female. Table 3.1 shows the characterizations of the conducted interviews and respective interviewees.

The longest interview was around fourteen minutes long with a female interviewee working in the area of staff support in the Social Sciences, while the shortest was the first interview lasting only slightly more than four minutes, with a female professor and researcher of a Geography Institute.

3.2.3 Interview transcription

Using the recordings generated with each interview, in task ”Conduct interviews”, to feed the Whisper AI translator using the Python language we were able to transcribe them from video recordings to text.

This artificial intelligence (AI) tool from OpenAI, the creators of ChatGpt the most revolutionizing AI tool in recent times enabled us to transcribe these video recordings into text form for easier manipulation and analysis.

Whisper This whisper AI is a general-purpose speech recognition model that allowed us to automatically transform the video recordings of the interviews into written files with multiple formats of our choosing, including but not limited to JSON, srt, tsv, vtt and txt. These files are later used in qualitative data analysis using the MAXQDAsoftware.

Whisper provides multiple models to use for speech recognition that range from tiny to large, each requiring more VRAM, more parameters, and more precision in its output.

For the sake of simplicity and due to the limitations of the available hardware, the small and medium models were used in generating the transcriptions.

Due to these limitations, the outputs were not perfect, some phrases contained grammar mistakes, words that differed from the ones recorded in the video, and some were omitted, so some manual work had to be done to complete the process of transcribing the video interviews into text.

This task generated the transcription files that are represented in the diagram through a Data Store object named "Interview Transcripts"which is later used in the task "Qualitative analysis with MAXQDA".

3.3 OpenDay

The next milestone in the process is the OpenDay, an event where students from high schools all over the country come to Iscte-IUL's campus to learn more about what a university is. To do so, they participate in lectures and practical classes, and interact with students, teachers, and researchers that will assist them in all their doubts and insecurities about the world of higher education in our institution.

Usually, there is a dedicated event for each one of the different schools inside Iscte-IUL, one for the Business school, one for the Technology and Architecture school, and so on, this way each student gets dedicated lectures and more time with the people specialized in his area of interest.

3.3.1 OpenDay preparations

Before all of this could happen and before we could insert the IscteSpots app into the OpenDay as an activity for the students, we needed to perform some tests on the app, for this purpose, we gathered all the people involved in the development of the application and its backend server, as well as a number of the OpenDay staff members that shared their knowledge about how the students would react to such an app and gave extremely important feedback.

All of the feedback gathered from both the OpenDay staff as well as from within our development members included bugs, User Interface (UI) improvements, and other problems.

To highlight the most important feature implemented with the feedback from this pre-validation, besides overall stability and bug fixing was the added visual feedback provided to the user. Formerly, when completing a puzzle or scanning a QR code the application did not convey to the user the purpose or the meaning of the action he took or was about to take. With this feedback implemented, completing a puzzle now displayed confetti all over the screen in a celebratory manner, automatically showing the scan page to indicate that the user should move to the spot in the image and scan its QR code.

The gathered feedback is represented in the BPMN diagram through the message coming from the collapsed lane "ISTA Secretariat Staff Members" containing the "Staff feedback" as a message.

Such problems were correctly improved upon in the next stage of development, Improvement, represented in task "App improvement", which contains a sub-process better detailed in section 4.5.

3.3.2 OpenDay validation tests

After the app was fully tested and modified to better insert itself into the OpenDay program, it was put to the test during the event.

There were multiple OpenDay events, one for each of Iscte-IUL's Schools, three OpenDay events were performed and the app was present in two of them.

Each of these events was scheduled a week apart, providing us with a brief timeframe to enhance the app based on feedback from the preceding event. This approach allowed students in subsequent events to enjoy an improved experience, and also provided a fast feedback loop,

leading to great quality improvements in the application's quality, user experience, and stability within a relatively short period.

For participation in this event, the app had to contain a reduced set of features, firstly to avoid overwhelming the students, whose focus was exploring the university and its courses, not testing a mobile application. Secondly, the OpenDay featured many activities, finding a slot in the student's day to test the application was a difficult task that the OpenDay staff proved to be very capable and helpful in solving. Due to these limitations, the version of the application and the IscteSpots game to be tested by the students could not be too complex.

The app's flow within the OpenDay consisted of solving a predetermined puzzle, looking around the campus for the location depicted in the puzzle's image, scanning the QR code found there, getting assigned a new puzzle and the cycle repeats.

We can observe in the diagram that the task "Open Day Validation Tests" communicated with an outside lane, sending instructions for the experimental validation sessions and receiving feedback from the participants about their experience with the application.

The feedback included a question to rank the IscteSpots activity from 0 to 5 and two open questions to describe their favorite and least favorite parts of the OpenDay, where the IscteSpots activity was mentioned.

During both days of the OpenDay event where the IscteSpots activity was present, the students were initially given a simple explanation of the activity followed by some time to download the application on their smartphones, meanwhile, the IscteSpots team verified if the puzzle images in our Django back-end server matched the physical locations of the QR codes.

At this point, the application was not fully published to the application stores so it had to be installed only on Android[1] smartphones manually through an apk (Android Package Kit) file, due to iOS's[2] stricter permissions model, making it much harder to install foreign applications through direct files. This apk file was distributed through our Google Drive, we created a hyperlink available to anyone and created a short version using a free link shortener website/service.

This non-standard method of installing applications was not familiar to many of the students present in the OpenDay events which required some assistance from our team, but these issues were quickly resolved and the game could start.

The OpenDay staff suggested that grouping the students was a better alternative to every single student playing the game on his own. This way, would interact more with each other, potentially creating stronger bonds and in turn a strong positive feeling towards the university, which was one of the main objectives of the event.

To achieve this grouping we created multiple users with different passwords that would then be shared with their respective groups, that way the group members could use this same login information on their smartphones, and each member of the group could log in with these credentials and complete the puzzle, but only the last person to use the login would have permissions to scan QR codes and be validated on our backend, making them the real user while the others where simply "ghost"users, able to interact with the puzzle but not make any progress that would grant their team additional points, such as scanning a QR code.

[1] Mobile operating system based on a modified version of the Linux kernel
[2] Mobile operating system created and developed by Apple Inc.

Since these tests were short and relatively small in participant size our team and the OpenDay staff were able to closely monitor the event, so if any abusive behavior from a student towards their team were to occur we could intervene and change that group's password or remove this abusive student from the game.

For example, if a student wanted to take advantage of the system he could keep logging in to the application with the credentials to become the validated user, hindering the ability of the rest of the group to scan QR codes, robbing them of their chance to progress in the game and effectively sabotaging the group, we have to take these types of players seriously and the real application does not allow such grieving and has much more secure authentication, but since this tests were so closely monitored and were using a simplified version of the app, this was the solution we could find for the event.

While not a perfect system it was a quick change we were able to make to our authentication system that allowed the grouping function that was requested by the OpenDay staff and allowed the students to complete the puzzle simultaneously allowing every student to be included in the game and not feel like they are simply watching their colleague complete a puzzle and guide them to their next QR code.

Happily, none of the mentioned grieving happened and the tests were carried out smoothly with a general positive ambient.

3.4 App redesign

After these events, the IscteSpots team started porting the timeline present in the app to the web, which was simple to develop due to Flutter's multiplatform support, where most of the code is platform-abstract and works out of the box in all systems.

After developing a stable version of this web Timeline we decided to contact the University Rectory Communication Office to help us validate the design of the website and improve it up to the university's standards as, at the time, this website was seen as a product that could be fully integrated within the rest of the University's online presence.

This resulted in meetings realized over Zoom where feedback was given to our development team about the web app. Even with no experience in Flutter, the staff member of the Communications Office was able to help us improve the design of the app.

3.5 Mobilization for validation tests

To gather groups of students to test the full and redesigned version of the application and gather more feedback, the IscteSpots team sent out emails to contact the multiple student groups of the University. Encompassing one from Anthropology (NEA) and two from the ICT areas (IEEE and ACM local chapters).

These groups or clubs are student organized and operated by students, their reach in captivating students and their openness to participate in these validation tests are varied and optional. The social influence they have is completely dependent on their leaders, who we promptly contacted to arrange these tests.

We decided to also contact the anthropology student groups to allow for some variation in the profiles of our test users since the other two groups were already from the exact sciences fields. Unfortunately, a test session for the anthropology group was not performed due to a lack of sufficient students interested in testing our app.

This lack of engagement from the anthropology students might be also justifiable due to a possible lack of emphasis on the historical and anthropological component of the validation test and our research as a whole, creating in the anthropology students the sensation that this was simply unrelated to their area of research and therefore less captivating.

Finally, since we neither imposed any specific prerequisites for participant profiles nor intervened in the selection process, which was solely managed by the distinct student groups, we can deem the subject selection process to be random.

3.6 IEEE students test

The first validation test occurred on the 31st of March of 2023 with the IEEE student group, a total of 8 participants were present and all of them performed the test in their entirety, even filling out our optional feedback forms.

The test consisted of three phases, an initial briefing session where the IscteSpots team presented the fiftieth anniversary of the university, the research going on around this topic, the app, and then how the test was going to be conducted. The students were informed that the staff was going to be observing and taking notes about their behavior, not intending to evaluate how well each person was performing but to gather all these details and use them for this research dissertation.

At this moment, the students were instructed to utilize the full application to explore the campus, complete quizzes, and utilize every feature available, effectively mimicking what a real competition would look like and how the app and backend would behave in the real environment with real people that are seeing the app for the first time, as opposed to the previous test with the OpenDay where the app was simplified due to the lack of time and context of the event.

After the forty-five minute long session of playing the IscteSpots game, the participants reunited back at the same room used for the initial briefing for a final sit-down session where impressions were exchanged and feedback was filled using the NASA *"TLX"*, NASA Task Load Index, designed to assess the workload required by each user when interacting with human-machine interface systems.

3.6.1 NASA Task Load Index

The form is composed of six rating questions that were all manually translated into Portuguese for this validation test and a final open-ended question added by our team to gather more general feedback.

The six multiple-choice questions ask the user to rank the level of effort he put into each category, on a scale from zero to twenty-one. These categories include mental, physical, and temporal demands and levels of performance, effort, and frustration. Additionally, we included

a customized open-ended question, allowing users to provide suggestions for enhancing the app. Every participant filled out the form, totaling eight forms gathered in this validation test.

3.7 ACM students test

The second validation test occurred on the 27th of April of 2023 with the ACM student group, a total of 14 participants were present and all of them performed the test in their entirety, even filling out our optional feedback forms.

After improving the app with the feedback gathered from the first validation test performed with the IEEE student group we contacted the ACM Student group, another technology-focused group of students inside our university.

This test featured the participation of some of the Staff members of the ISTA Secretariat because the possibility of incorporating the application into the next OpenDay was discussed, therefore the Secretariat members wanted to see how far the application has improved since the previous year's test in the OpenDay and if it could be adapted again to seamlessly be incorporated into this year's open day. However, after careful consideration, both parties mutually agreed not to proceed with the inclusion, primarily due to the already full schedule of the event and the small time frame available to make necessary changes to the app specifically for this event.

The structure of the test was very similar to the one adopted for the previous test with the "IEEE"student group, an initial briefing session where the scope of the research and the activity were explained, a game session, where the students get to experience the application first hand, and a final session where opinions are exchanged, the feedback forms are filled out and participation prizes, like t-shirts and cups, are handed out to the students.

3.7.1 MARS - Mobile Application Rating Scale

In this validation test, the MARS form (Mobile Application Rating Scale), a more robust and focused form, designed specifically for rating mobile applications was used in addition to the NASA TLX form.

Again we created our version, translating the original into Portuguese and removing the last two sections of the form, leaving only the four sections, dedicated to the themes, Engagement, Functionality, Aesthetics, and Information, totaling nineteen multiple-choice questions.

This test was able to gather twenty-eight feedback forms, fourteen NASA Task Load Indexes, and fourteen MARS forms. However, compared to the previous test, this one experienced more "dropouts"from the study. Initially, around twenty participants were present, but ultimately, only fourteen attended the final feedback-gathering session

3.8 Field observations

During both validation tests, our team was dispersed across the campus taking notes about the behavior of the participants. Our objective was not to evaluate their performance while playing

the game, but rather to observe how they interacted both as a group and individually with the application and the IscteSpots game in general.

3.9 Qualitative analysis

With the transcription of the interviews in our possession, we embarked on a crucial phase of our research journey. With this data, we undertook the task of analyzing the various ideas and suggestions that emerged throughout the multiple interviews

This process not only allowed us to distill the essence of these insights but also provided us with invaluable insights into the initial feasibility and viability of the proposed concept, both the mobile application and the IscteSpots game.

The usage of MAXQDA proved very useful in the mentioned task, the software allowed a very productive and easy-to-use workflow, after some initial setup and manually linking each video with its transcription file, a simple click on each phrase starts playing the video on the time configured for that phrase. Using this feature we were able to listen to the original audio, compare it to the results of Whisper, correct any mistakes in the transcription, and more effectively analyze the gathered data. Conclusions from this data are present in section 5.1.

3.10 Quantitive analysis

Using the quizzes' answers collected by our application during both validation tests performed with students, we treated the data with Python to create a solid understanding of their performance and whether or not it motivated them to learn about the university's history and heritage. The corresponding analysis is presented in section 5.6.

3.11 Content management

At the same time that all the development within the mobile application was progressing, the IscteSpots team regularly interacted and met with the Anthropology team, responsible for gathering as much data as possible about the fifty years that the university has gone through. Creating a timeline that consists of all the events since the initial conception of the university.

3.11.1 Timeline events

The Anthropology team developed this timeline in parallel to the development of the mobile application. To easily transfer items from the internal timeline to our backend server, we created a document, using Google Sheets, designed with this specific portability in mind, data was organized into two different worksheets.

One to hold the table of events and a second for the table of contents. Each event can have aggregated multiple contents, for example, an event that represents the inauguration of a new course can have linked to it multiple pictures, videos, websites, and other types of content for the user to visit and acquire more detailed information about the event. Each event is also categorized using "Scopes"and "Topics". A Scope categorizes an event depending on whether it

regards Iscte-IUL, the whole country of Portugal, and worldwide events, performed through a column named Scope. A Topic categorizes events into pools all containing similar events, for example, one of the topics is "Infrastructure"so all events regarding the physical buildings and infrastructure are present when the user filters the timeline with this topic, furthermore, an event can be placed inside multiple topics.

These scopes and topics are used in combination with each other within the mobile and web apps to filter events based on what the user wants to see, for example, if the user only wants to see events regarding Iscte-IUL's Campus, he can select only the "Campus"topic.

This standardized way of creating new Events also created an easier workflow for the Anthropology team.

3.11.2 Validation of events

Along this process of registering new events and importing said events to the mobile application the university's rectory assigned a new member to the Anthropology team with the task of validating the events, guaranteeing that every event is based on facts and has a valid source as an origin. These sources were treated as content for the events, allowing the end users of the apps to visit them.

This new requirement created a loop where the events were constantly submitted for validation and changes to them were recommended. Due to the parallel nature of this process, improvements to the events were also discovered by the users of the app and the IscteSpots team during the development process of the app. The IscteSpots team also assisted the Anthropology team when and where it could ensure faster development of the timeline.

3.11.3 Quiz questions

After the events were deemed validated the Anthropology team started developing questions to use inside the mobile Application's quizzes.

Having quizzes on an application is a relatively easy feature to develop when compared with the effort required to make good quality questions that effectively assess and cater to the current knowledge level of the user.

To create an engaging and effective quiz, it is essential to consider several key points. Firstly, each question should have a correct answer, accompanied by multiple clever and deceiving incorrect options. Moreover, since our quiz is associated with images, integrating relevant visuals into the questions will enhance the overall experience.

Additionally, the wording of every question must be clear and concise, eliminating any potential ambiguity or confusion for the participants. This clarity ensures that users can easily comprehend the questions and respond accurately.

Finally, we also introduced different types of questions to keep the user engaged and asses his knowledge on different aspects, the majority are related to events present in the timeline but some are what we called "Self-explanatory", easy questions where the answer lies in the corresponding image and "Geo-referenced"questions where the answer is found in the physical campus with no time limit to answer.

Keeping the quality of such content to a high standard is not an easy task and as such, an iterative development similar to the one used while developing the timeline contents was adopted. The representing task inside the BPMN diagram in figure 3.1, task ”Development of Quiz Questions”, is annotated with a circular arrow to show this repeating process.

3.11.4 Questions portal

For the Anthropology team to insert questions in our database we created a web portal they could access using their user with restricted permissions.

Thanks to Django's robust user management system, we could effortlessly create an admin user with restricted access for the Anthropology team to use within our backend server admin panel. Their user could only manage the database tables related to topics and quizzes, they were able to insert new topics, and questions and link them together, answers, and images, which can be assigned to questions.

This admin panel is automatically generated based on the fields of each model defined for the database. It can be customized to feature search bars, custom fields in the new object page, and many more. Official documentation about how to customize this panel can be found here.

In the BPMN diagram in figure 3.1 task ”Development of Quiz Questions” represents the described process, it encompasses the anthropology team using our admin panel to manage all of these questions, present in the diagram through the message object received from the collapsed pool "Anthropology team", which are stored in our database and represented through the Data Store object in the diagram named "Timeline questions".

3.12 Article publishing

As we approached the culmination of our development process, a significant milestone was achieved with the publication of an academic article in the A-Mobile workshop at 38th IEEE/ACM International Conference on Automated Software Engineering (ASE 2023) conference.

This published article drew upon the foundation laid by the present dissertation and the IscteSpots app as a basis for its research, heavily focused on the cross-platform development approach used throughout our development journey, appropriately named ”Cross-platform mobile app development: the IscteSpots experience“.

Among other topics, the benefits and challenges of the cross-platform approach are discussed, as well as the choice of technological stack (Django for the backend and Flutter as a frontend) and some conclusions factoring in the results from the Validation tests performed with the University's IEEE and ACM student chapters.

Chapter 4

Implementation

Contents

This section intends to clarify the implementation and technical details of the IscteSpots app. Section 4.1 goes over our framework and language choices. Section 4.2 describes our code quality and CI/CD pipeline. Section 4.3 goes over the notation choice for our processes. Section 4.4 goes over the project's architecture and infrastructure. Section 4.5 describes the continuous development and improvement process used throughout our journey. Section 4.6 goes over logging into our application. Section 4.7 describes in detail every possible interaction between the user and the developed application in its final version.

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Chapter 4
Implementation

To capture the attention of the largest audience and consequently create the biggest engagement possible, we needed to develop the proposed application for the two most popular smartphone platforms (i.e., Android, iOS). Due to limited resources and the high costs of native development, we opted to use a cross-platform framework.

A cross-platform approach allows compilation of the same application to different target devices belonging to different platforms utilizing the same codebase, iOS and Android are examples.

Within this chapter, many aspects of our implemented solution are showcased and discussed, such as the programming framework choice, the architecture of our infrastructure through component and deployment diagrams, our application improvement and login processes, and the entire behavior of the proposed app through a BPMN diagram.

4.1 Development environment

The communities surrounding a language or framework are essential in a software development ecosystem. Therefore, its popularity conveys technology's stability and longevity, since if it is widely used, it is more likely to have ongoing development, updates, and bug fixes. Abandoned or less popular technologies may face a higher risk of becoming obsolete.

According to Google Trends (see Figure 4.1), Flutter became the most popular cross-platform framework in April 2020, a framework built on top of the Dart programming language and the Skia 2D graphics engine with a unique take on front-end development where everything is a widget. These widgets are primarily objects that represent UI as code but can contain functionality, logic, and also hold state.

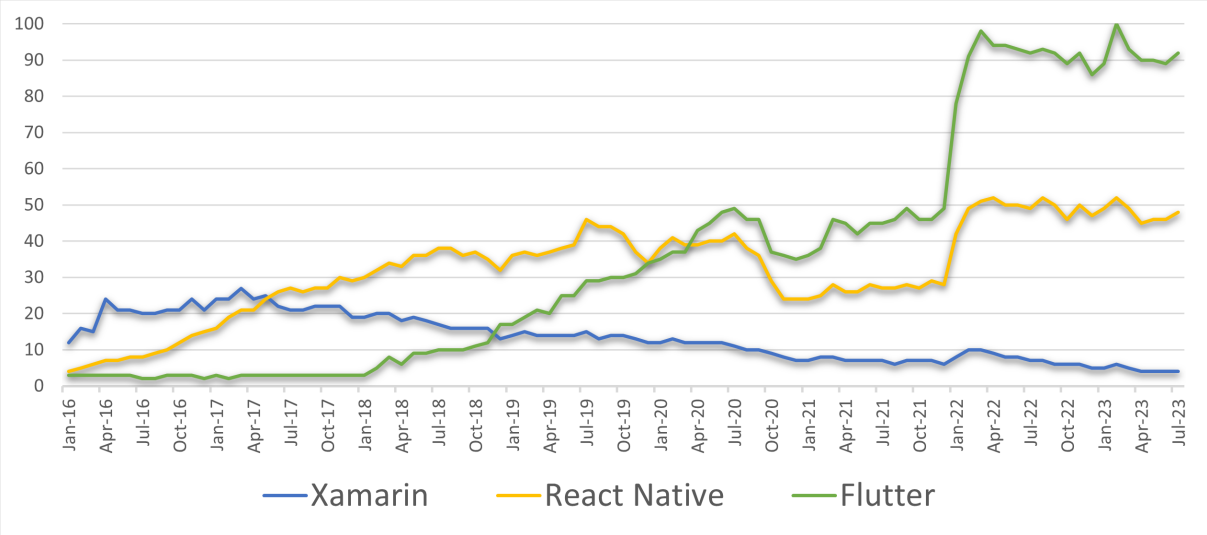

Figure 4.1: Popularity of cross-platforms worldwide (source: Google Trends)

By just focusing on the interpretation or runtime execution frameworks that account for the largest market share (React Native and Google's Flutter) we performed a quick search on SCOPUS, using the following search string: *"cross-platform development"AND "case study"AND (Flutter OR "React Native")*. We then selected the papers that provided the most interesting insights into the use of Flutter and React Native in real-world scenarios.

Khan et al. [9] compare the performance of Flutter and React Native in terms of efficiency, effectiveness, compatibility, community growth, documentation, architecture, developer productivity, and testing automation support. Zohud and Zein [20], on the other hand, compare the performance of cross-platform development compared with native app development.

Szczepanik and Kedziora [17] discuss state management approaches used for Flutter applications development and propose a combination of two approaches that solve the main problem of existing approaches related to global and local state management.

Galán et al. [7] present a multi-criteria comparison of two mobile applications built with the use of Android and Flutter SDK, showing that a mobile application written using Android SDK is often not only faster and more efficient but also has greater community support and the number of libraries available.

Cheon and Chavez [4] describe a case study of converting an existing Android app written in Java to a Flutter version to support both Android and iOS, discussing technical issues, problems and associated with such a rewriting effort.

Overall, the previous papers provide valuable insights into the use of Flutter and React Native in real-world scenarios, highlighting their strengths and weaknesses in terms of performance, state management, community support, and app conversion.

Both frameworks – Flutter and React Native – have strong online communities and a wealth of tutorials and package libraries; therefore, popularity should not be the single choice criterion. Performance on the other hand is much more important to consider when choosing a framework or language to develop with. Although React Native supports native animations that outperform other frameworks using its "useNativeDriver" option, its performance is, in most cases, outshone by Flutter as mentioned in [14] with "*In case the application is CPU intensive, a cross compiled framework such as Flutter seems to be the best option. It's performance and energy consumption is on par with the native solution. However, it may impose a non-negligible overhead on memory usage*".

We then chose Flutter due to its higher performance, rich ecosystem corroborated by its popularity, and its use of the Dart programming language, similar to the traditional Object Oriented Programming (OOP) languages like Java that the IscteSpots team was familiar with.

The Dart programming language (also made by Google), has a strongly typed nature with many modern features like null safety by default avoiding many null-related errors, cascade notation a syntactic sugar syntax that allows making a sequence of operations on the same object with more readable code, hot reloading with flutter which eases the development experience by instantly displaying the latest code changes on the screen, asynchronous programming with the "async" and "await" keywords, the pub package manager, and many more.

Effectively, Flutter is a framework, built on top of Dart and the Skia engine with a unique take on front-end development where everything is a widget, that represents a certain part of the UI, these widgets can contain functionality, logic, and can also hold state. This brings

the development much closer to the traditional OOP paradigm, allowing the instantiating of widgets and their manipulation.

In the end, we chose Flutter due to the demonstrated popularity, its use of the Dart programming language that boasts many modern features and is similar to the traditional OOP languages like Java that the IscteSpots team is very familiar with, and also due to its performance benefits compared to the other popular cross-platform frameworks.

4.2 Code quality, Continuous Integration and Continuous Development

Code quality plays a pivotal role in the realm of software development, significantly impacting the reliability of a software product, if executed correctly demonstrates several crucial benefits. First and foremost, it enhances **maintainability**, making it easier for developers to understand and extend the codebase over time. Clean, well-structured code fosters **collaboration**, and improves software robustness and stability, reducing the occurrence of defects. By adhering to coding best practices and standards, developers can create **optimized** and **scalable** code. Ultimately, ensuring great code quality results in a more stable, scalable, and maintainable software product, thereby enhancing customer satisfaction and overall project success. Furthermore "If organizations fail to take countermeasures, their long-lived software systems undergo gradual quality decay" [5] making it exponentially harder to implement new features.

High-quality code is characterized by adherence to established coding standards, readability, modularity, and an extensive test suite that verifies its functionality. Ensuring code quality not only enhances collaboration among development teams but also reduces the likelihood of introducing bugs, vulnerabilities, and technical debt into the software. Well-structured, clean code is easier to understand, modify, and extend, which streamlines the development process and mitigates the challenges associated with software maintenance. By prioritizing code quality, developers can create a foundation for efficient debugging, rapid feature development, and a positive user experience. In this light, code quality isn't just a technical concern; it is a strategic investment that pays dividends in terms of project success and long-term sustainability.

Continuous Integration and Continuous Deployment (CI/CD) constitutes a pivotal paradigm within modern software development practices, it embodies a set of principles and practices aimed at automating and streamlining the software delivery lifecycle, from initial code integration through to deployment. By ensuring frequent integration of code changes into a shared repository, CI/CD facilitates the early detection and resolution of integration issues, bugs, and conflicts. This not only promotes collaboration among development teams but also leads to faster development cycles, improved software quality, and enhanced efficiency [3]. Furthermore, the integration of automated testing and deployment processes in the CI/CD pipeline empowers development teams to swiftly release reliable and stable software updates. In a fast-paced software landscape, where rapid iterations and timely delivery are paramount, the implementation of CI/CD methodologies emerges as an indispensable practice for enhancing

development agility, reducing manual errors, and ultimately delivering valuable products to end-users.

4.2.1 CodeMagic

CodeMagic is a CICD platform specifically designed for Flutter and Dart development, offering a tailored and streamlined CICD experience, allowing developers to seamlessly integrate Continuous Integration and Deployment practices into their Flutter projects. Beyond its primary focus on Flutter, CodeMagic has extended its capabilities to include support for other frameworks and native development environments, enhancing its versatility for various software projects.

In the case of IscteSpots, where the team had no previous experience with CICD, CodeMagic's ease of use was a game-changer, allowing our team to easily initiate, configure, and successfully manage a fully operational Flutter pipeline running code analysis, tests, and code signing.

This ease of use is particularly noteworthy because it eliminates the intimidating barriers that often deter developers from adopting CICD practices. CodeMagic's intuitive setup process empowers individuals to automate their deployment workflows without requiring a deep understanding of CICD concepts. Additionally, the platform's extensive documentation and vibrant community support played a crucial role in introducing these concepts and easing the learning and configuring process.

A highly customizable configuration method via a Yet Another Markup Language (YAML)-based file, greatly facilitated the creation of pipelines compared to manual configuration methods. Traditionally, setting up CICD pipelines manually is time-consuming and error-prone but CodeMagic transforms this by enabling developers to define entire pipelines within a yaml file, streamlining setup and making configurations version-controlled, shareable, and reproducible. This yaml based approach ensures consistency across environments and reduces errors.

Such pipelines encompass crucial deployment stages including, but not limited to, static code analysis, unit tests, compilation bundle creation, app store version publishing. These pipelines automate the development process comprehensively, ensuring code quality, efficient workflows, and streamlined app deployment.

Given its specialization in Flutter development, CodeMagic offers a compelling solution for creating robust CICD pipelines tailored to Flutter apps. This specialization has led to the platform becoming a prominent choice for Flutter developers seeking to automate their build, testing, and deployment workflows.

In summary, CodeMagic serves as an accessible and effective CICD platform with a strong focus on Flutter and Dart development. Its ease of use, dedicated documentation, and community support elevate it as a powerful tool for simplifying the CICD process.

4.2.2 Sonar Cloud

In the realm of modern software development, integrating static code analysis tools holds profound importance in maintaining code quality. These tools play a proactive role by scrutinizing code without execution, identifying vulnerabilities, inefficiencies, and deviations from coding

standards. Beyond error detection, they provide suggestions aimed at enhancing code readability and consistency, ensuring adherence to best practices. This approach prevents technical debt and supports the continuous evolution of software projects.

As for the Django web server code, our selection falls upon SonarCloud, a cloud-based static analysis tool that aligns seamlessly with our requirements. It boasts a straightforward setup process, particularly valuable for our project's efficiency. Furthermore, SonarCloud offers native Python support which is an essential feature, given that Python serves as the primary language employed in Django development.

In addition to the Python codebase quality assessments, which encompass the identification of code smells, maintainability concerns, and violations of best practices, SonarCloud extends its capabilities to encompass security concerns. By detecting vulnerabilities and pinpointing potential weaknesses in the codebase, the tool significantly bolsters the robustness and security of our application. This multifaceted approach not only ensures that our code adheres to high standards of quality and maintainability but also guarantees a resilient and secure final product. As we navigate the intricacies of developing a Django web server, SonarCloud stands as an invaluable companion in our pursuit of excellence across these critical dimensions.

4.3 Why Business Process Model and Notation for software

Numerous modelling notations have been developed over the years, although they have struggled to gain significant popularity. Consequently, there exists no universally accepted and standardized notation for modeling applications within the software development landscape.

To gain a more comprehensive understanding of the current state of the field of modeling notations used to document software a quick literature review was conducted, utilizing the Scopus database. The search query employed was crafted to encompass relevant research, combining keywords such as "mobile app,""web app,""UML model,"and "BPMN model. Surprisingly, the search yielded no valid papers that directly addressed the intersection of mobile and web application development with UML or BPMN modeling techniques.

In contrast, a closer examination of the popularity landscape, as depicted in Figure 4.2, unequivocally highlights the prevalence and widespread adoption of the BPMN (Business Process Model and Notation) notation within the industry. This established prominence of BPMN further underscores its significance as a widely recognized and accepted notation.

Taking these factors into careful consideration, coupled with the collective knowledge and expertise of our research team, it became evident that BPMN emerged as a highly promising candidate for effectively modeling the entire application development process. Its industry-wide recognition and well-established framework make it an ideal choice for modeling the intricate architecture and user interface of mobile and web applications.

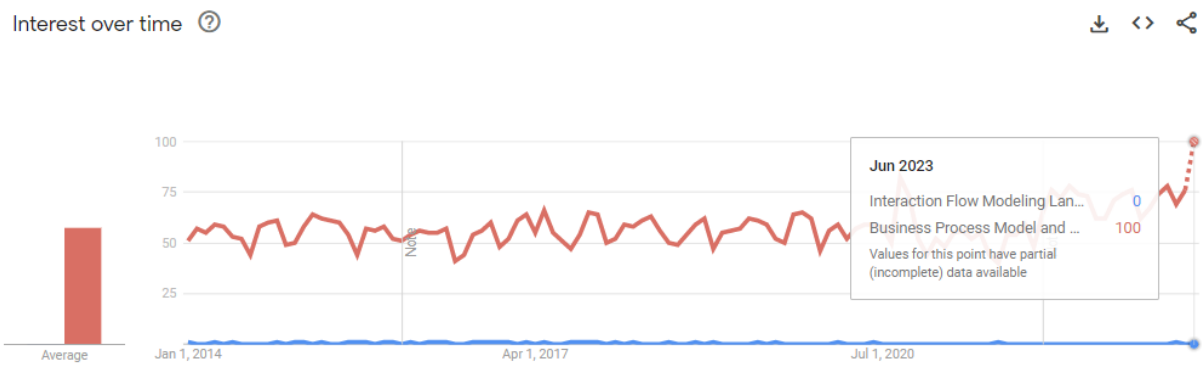

Figure 4.2: IFML vs BPMN interest over time

4.4 Project architecture

To explain all the systems developed for our solution and how they interact with each other the diagrams present in figures 4.4 and 4.3 will be used as representations of our system.

Our technology stack consists of two web servers and one mobile application deployed on both Android and iOS devices. The two web servers are the web version of the mobile application's timeline and our backend Django server.

4.4.1 Backend

Our Django server is used as the main storage and logic pillar of our whole solution, it provides a Representational State Transfer protocol (REST) API that the mobile and web applications consume to provide consistent user progression within our game.

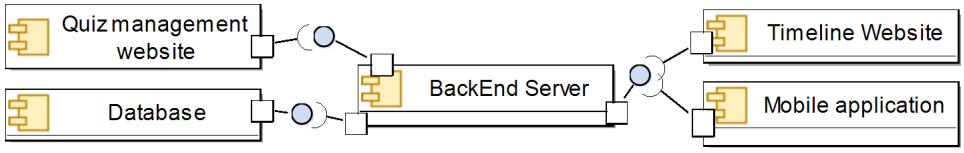

Figure 4.3: IscteSpots UML component diagram

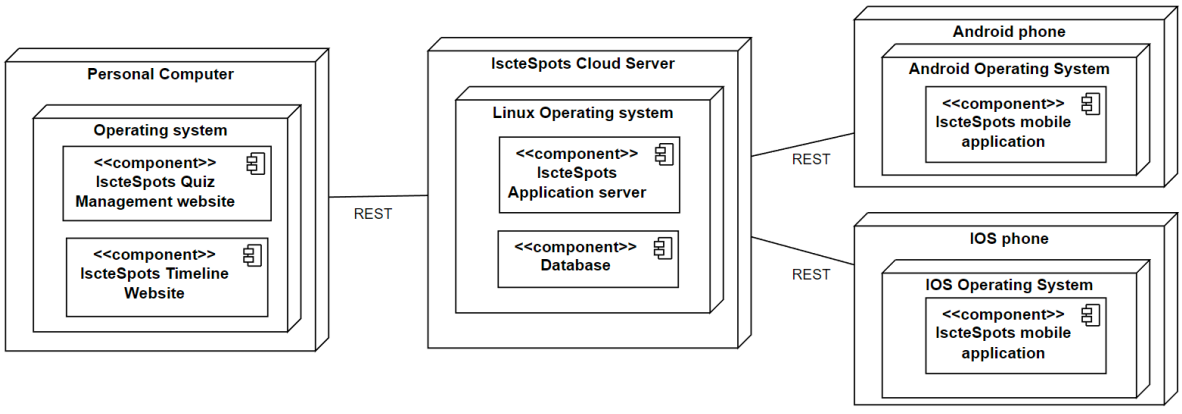

Figure 4.4: IscteSpots UML deployment diagram

Django supports several database backends, allowing the developer to switch between them without changing any code. Django's Object Relational Mapping (ORM) abstracts the SQL queries, making it easier to perform database operations using Python code and high-level database query API. With the ORM, you can define models as Python classes that represent database tables. Each model's attributes correspond to table fields, and methods allow interaction with the data.

Django offers a variety of database implementation options, such as PostgreSQL, MariaDB, MySQL, Oracle, and SQLite, to store data efficiently.

For our implementation, we decided to use a MySQL database instance, it being a user-friendly database known for its speed, reliability, and widespread adoption. Its server-client architecture is specifically designed for scalability and managing large databases with ease, making it an ideal match for our Django application. Setting up and managing MySQL is straightforward, adding to its appeal as the database backend for our project.

Applications In Django, applications can be created to divide the code and scope of certain features. Each application is created with Django's predefined folder structure and every application contains a file where all the models to be stored in the database are defined, a URLs file where all the URLs are mapped to their respective functions, a views file where all the functions that answer to the requests are coded, a serializers file where all the serializations to the database models are programmed and more. Still, these are the most influential and most tinkered with during our development process.

Our server consists of one project called "Iscte50anos"meaning Iscte-IUL 50 years and ten applications inside this root project we divided our server into the following iscte50anos, content, events, feedback, log, login, quiz, spots, topics, and users.

Besides these, we also set up a directory called "scripts"to store all of our single-file Python programs used to perform admin operations on the server and its database. For example, one of the scripts would synchronize the questions stored in the database with the questions from our Excel file which was curated by some of the members of the Anthropology team.

Inside our root project, we have the main application called, again "iscte50anos"which serves as a router to our requests, it sets up all the URLs that then redirect our requests to their respective applications, for example, it redirects all our requests to "/topics"to our topics application where the request is further broken down and eventually delivered an answer.

REST As mentioned above the backend server uses Representational State Transfer protocol (REST), an architectural style based on HTTP dating back to 2000 when it was first introduced by Roy Fielding, used in designing networked applications, especially web services, providing a standard way for different systems to communicate and exchange data over the internet. It is centered around the concept of resources, where each component is considered a resource accessed through a common interface, utilizing http standard methods.

4.4.2 Mobile application

As the main consumer of the API provided by our Django Backend, the mobile application published on the application stores for both Android and iOS devices serves as the main platform for the user to interact with our IscteSpots game.

4.4.2.1 Web application

An easier method to consult the timeline curated for the IscteSpots game was developed under the form of a website which due to Flutter's now great support for the web could be as simple as copying code from one repository to another. The only reason it was not as straightforward as it seemed was due to external packages that supported the mobile platforms but not the web, sqflite is an example, it forced us to rewrite the logic for the timeline which in turn made us rethink and redesign the Rest API provided in the backend for the contents of this page.

Implications of a port Previous to this web port the timeline page received the entirety of the timeline contents through a single endpoint and stored these on local storage, only fetching them on user request or when no content is present in this local storage.

With the new requirement of web support, which inherently lacks any significant form of local storage the previous logic was forced to be modified. Every time the page loads there needs to be content fetched from our backend server, since fetching content from each possible year of the timeline is an extreme waste of resources and network usage we rewrote our API for this page on the backend side of the architecture.

On the new version of the API, the application or website fetches the events of a single specific year, and in separately fetches the list of years available, having in this way all the data needed to display the timeline page, with its horizontal year list and its vertical event list.

Ultimately all of these changes accumulated to modifications on **27** out of 155 ".dart" files which involved changing a total of 2115 lines of code out of the entire project's 14309 lines (i.e. **14.8%** of the entire codebase).

Effectively this port emerged by creating a copy of the original repository and adapting the dependencies to accommodate this new paradigm, creating two copies of the project, the web one containing much fewer features and consequently much less source code than the mobile one, as the remaining files are the ones involved in the "timeline" feature.

In the time allocated to develop and maintain the web version, a way to keep both versions on the same repository was not found, But if eventually, we could achieve such a merge of these two current repositories, making it so they truly share code between the mobile and web versions of the app. Currently, there is still some Dart logic that differs between both versions that with such a merge would be standardized resulting in a greatly reduced quantity of differences between both versions.

4.4.3 Web content management portal

The Anthropology team, which collaborated with the IscteSpots team, created the corpora on the history and heritage of the University. Building a custom portal to edit these contents

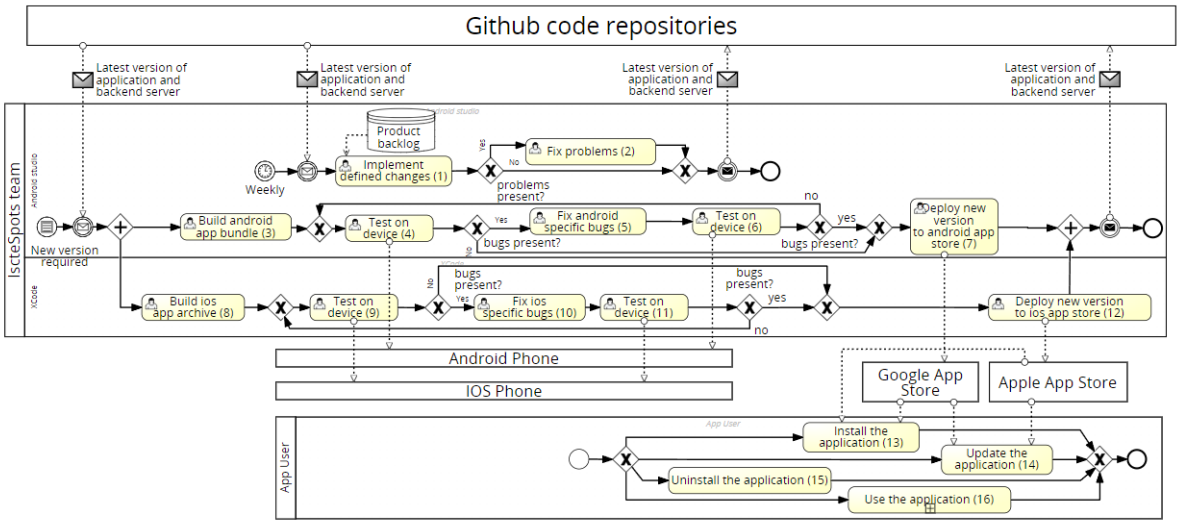

Figure 4.5: BPMN diagram describing the process of improving the presented solution

was key in building an improved repertoire of questions, images, and events to display on the IscteSpots app and timeline website. For that purpose, we used Django's Admin panel so that the Anthropology team could have editing permissions on the database tables relevant to the contents, such as the one storing the questions for the quizzes and the timeline events.

4.5 Iterative development process

The process of improving the application will be described using the BPMN diagram present in figure 4.5 as an approximation to the adopted process. If a primer on the basics of BPMN is needed, section 3.1 contains the basics needed to follow along the presented diagrams.

This diagram contains two distinct process flows, one that represents the weekly improvement and development cycle of the application and the other one that represents the more sporadic cycle of deploying the application to the application stores of both Google for Android phones and Apple for iOS phones.

4.5.1 The weekly cycle

Every week our team gathered online using Zoom to discuss the state of development and what should be focused on throughout the following week.

This process is represented in the diagram as the flow that begins with the start timer event named "Weekly"to represent its weekly period.

Following right after the starting node and as the first thing to be done when developing any feature on the app, is fetching the latest version of the code from our online repository hosted on GitHub, represented through the message-catching node that is receiving the message "Latest version of application and backend server"from the GitHub repository collapsed lane.

Implementing the defined changes is the next step in the process, represented through task number 1 and consists of fetching the assigned changes from the product backlog, hosted in our internal Trello board and the list of issues in our GitHub repository.

Trello is a free website for collaborative project management, it allows us to create groups of lists containing tasks, called boards, these tasks can be assigned to specific users and can contain a description, checklists, start and due dates, tags, and many more features, especially considering that this website supports community made add-ons that improve the experience even more and provide additional features like Gantt charts, integrations with other platforms like Slack and many more.

This website is very popular for the management of agile software development, providing our IscteSpots team with an updated and regularly maintained repository of features to be implemented and tasks to be completed.

The diagram in figure 4.5 used the Data Store object named "Product backlog"to represent our Trello board in conjunction with the issues published on our GitHub repositories.

Usually, our Trello board held the most important and high-level features like: "Build a new page"or "Page X has Y interface problem"while our GitHub issues usually contained more technical or lower priority problems that are quick to solve.

Then comes the task of actually implementing in code the defined changes. For this, we used the code editor Android Studio and its plugins for Flutter and Dart development. The main editors used for Flutter development are Android Studio and Visual Studio Code, both were given a fair chance but the preferred one came out to be Android Studio, mainly due to its improved debugging features and its emulator which allows the developer to open an emulated version of any mobile phone inside its computer without needing to use any actual phone connected via a physical cable.

After implementing the changes, the app was manually tested for bugs or errors using the mentioned emulator or even a physical phone, if any problems were found they were corrected, using task number 2 "Fix problems"as a representation, and the process was nearly over, the new version of the code was uploaded to our GitHub repository as a new commit, as can be seen with the throwing message event, sending the message "Latest version of application and backend server"to the GitHub collapsed lane, and the process ended.

4.5.2 The deploying cycle

The sporadic cycle that is represented in the lower half of the Android Studio lane in the diagram represents the deployment process, when a new version of the app is required on the public application marketplaces this process is triggered. Usually, we require a new version of the application when a validation test is to be held, for example, the process was triggered for both validation tests conducted with the students groups, mentioned in sections 3.6, and 3.7

This cycle begins with the conditional start event node named "New version required"which indicates that the flow only starts when a new version is to be deployed to the application stores for the users to download. Similarly to the weekly cycle, the first task to be done is to download the latest version from GitHub's repository, represented through the catching message event that receives the message "Latest version of application and backend server". Then the flow is

divided into two parallel lines, the upper line is dedicated to Android deployment while the lower line is dedicated to iOS deployment.

Since both of these flows are very similar their explanations will follow in parallel, first, we build the respective application compilations, the Android app bundle with task number 3 and the iOS app archive with task number 8, these tasks are represented in different lanes due to the different programs used for each one, in the Android flow we use Android Studio while on the iOS flow, XCode is used and therefore is represented by its own lane.

After building the compilations, the app is tested on both mobile phones, a personal Android phone, a "Samsung A71"with the Android app bundle in task number 4, and an "iPhone XR"with the iOS app archive and checked for any remaining bugs or errors, if anything relevant is found, it is fixed and the testing is repeated on the real devices, represented on android with tasks 5 and 6 and iOS with tasks 10 and 11. Otherwise, since no errors were found we skip directly to deploying the new version on the respective app stores, Google's Play store for Android on task number 7 and Apple's app store for iOS on task number 12.

Finally, we finish the process by uploading any code changes to the online repository on GitHub, represented in the diagram with a throwing message event sending the message "Latest version of application and backend server"to GitHub's lane.

4.5.3 The user's perspective

From the end user's perspective, he can only perform four different tasks with the application, depending on whether he owns an Android or an Apple phone he will interact with different application stores, the Google Play store for Androids and the Apple iOS store for iPhones.

These four tasks are represented in the diagram as tasks numbers 11 to 14. Starting with the eleventh task, the user can download from his respective app store the latest version of the app and install it on his device. Then, with the twelfth task, he can update his old version of the app with the latest version. Represented by the thirteenth task he can uninstall the app from his phone, an action that does not need any communication from and to the application stores.

Lastly, he can use the app and all its features, represented with task number fourteen which holds in a sub-process all the tasks that encompass the usage of the app, a sub-process that is better explained in section 4.7.

4.6 Login process

In this section, we will go over how the authentication process of the app works in conjunction with Okta OAuth and our backend server, using the BPMN diagram present in figure 4.6 as a helper to visualize and serve as a parallel to what happens in code.

The process starts when a user of our IscteSpots application wants to log in to his account, he will open the application and be greeted first with the onboarding page and then with the login page, visible in figure A.7.

To create a better experience for our university's students we have connected our internal login system with Okta Oauth, giving them the ability to log into our app using the same credentials that the students already use in our University's Fenix and Moodle systems, these

systems are what allow them to access online contents, quizzes, upload assignments and more, all prepared by their teachers.

Since our application uses this same login system, the students that use the app will feel like they are a part of a contained ecosystem, akin to what Apple has been doing for years and what other companies like Samsung and Xiaomi are more recently trying to replicate. If the student has an open session on his device on any of these systems (Moodle or Fenix), their session will crossover to the application without them needing to insert any credentials.

Now going over the authentication process itself, it starts when a user of the mobile application wants to log into his account and opens the application on the login screen, explained in detail in section 4.7.2, represented by the first task of the diagram "Show Login Screen", after which the user is prompted for his credentials and fills them out, submitting them, afterwards the app promptly sends them as a message to the Okta Oauth Servers.

After submitting the user's credentials the Okta server sends a response with the access token that the application can use to begin the process in our backend server. If the credentials are not correct then the application simply returns to the login screen showing a login error message, as can be seen by the flow returning to the "Show LoginScreen"task.

When the process in our backend server begins then the server sends the access token received from the application to the Okta server to fetch the user's info held in the Okta server to be able to create the user's profile and validate the access token received.

In our case, the user's info includes his course, name, email, department, and others. If the provided information is valid then the user's profile is created in our backend server, and an "API AUTH Token"is created and sent to the mobile application, this new token is destined for the app to use when communicating with our backend server. This approach gives us more control over the user's session, we can logout the user if needed and force him to redo his login using Okta OAuth.

On the other side of the coin, if our backend server determines that the user info is not

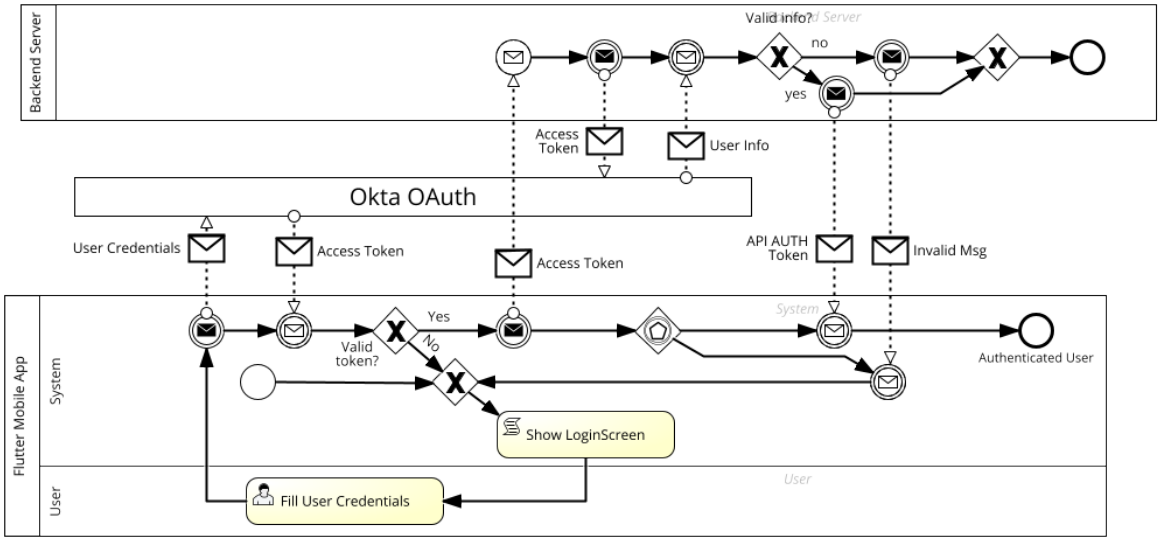

Figure 4.6: Diagram explaining the authentication process

correct, meaning for example that the Access Token received from the app is incorrect, then the app simply returns to the login screen again, with an error message.

Otherwise, everything worked and the app can now use the API AUTH token to make requests to the backend server and interact with it as an authenticated user without sending the user's credentials on every request. With this, the flow is finished and the app moves on to its usual flow, explained in detail in section 4.7

4.7 Application Solution

In this section the complete application flow will be described, using the help of multiple BPMN diagrams and figures of the corresponding pages in the application. If any additional information is needed, the full source code of the application is available in our GitHub repository and a demonstration video can be found published on the following Youtube link.

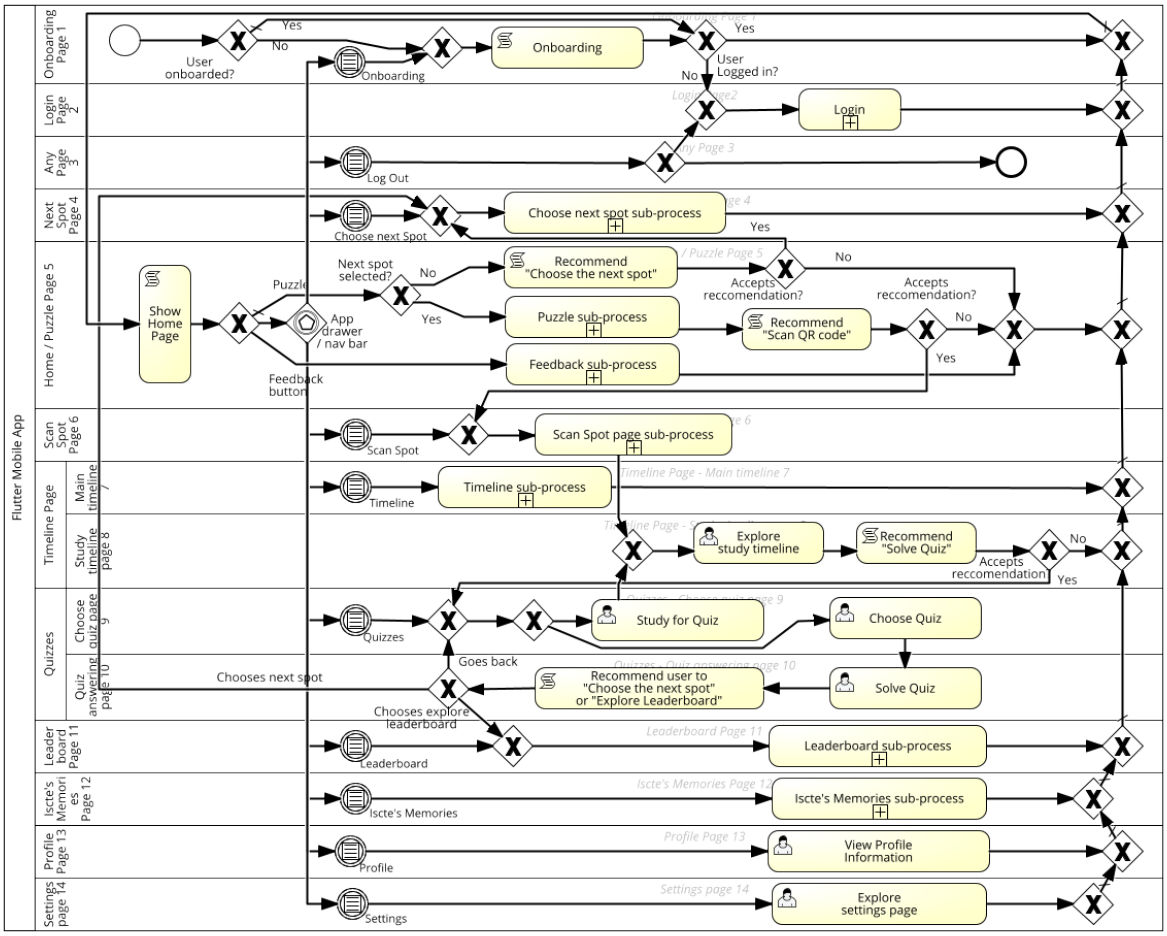

Figure 4.7: BPMN diagram describing all the application tasks and navigations possible

4.7.1 Onboarding

When the app first opens up for a user, it displays the Onboarding page, visible from figure number A.2 through A.6, composed of a series of "cards"or "tabs"that the user can horizontally scroll through to learn what the app is about and what the "IscteSpots"game consists of.

In the case that the user has never been presented with this page, the app displays it, represented in the diagram as the "Onboarding"task. On the contrary, if the user has already been onboarded or has completed the onboarding process, meaning that he viewed all the tabs in the Onboarding page and clicked on the "Get Started"button on the bottom of the last tab, visible in figure A.6, the app navigates him to the Login page, visible in figure A.7 and the corresponding "Login"task in figure 4.7.

4.7.2 Login page

The login task is collapsed, seen by its "plus"symbol at the bottom of the rectangle, meaning that it represents a sub-process represented in another BPMN diagram and explained in further detail in section 4.6. This Login task represents a sub-process due to the implementation of Okta OAuth within the app.

This page of the application can only be accessed when the user first logs into the app after installing, when he logs out of the app, as explained in section 4.7.13 or when the backend returns an authenticated error on one of the app's requests. Currently, this can only happen if the user logs into his account on another mobile phone, but can be used in the future to purposely make the users refresh their login and re-enter their passwords.

This page is made up of two choices, the "Login Iscte-IUL"button, which uses the Fenix system and Okta to carry out the Login, visible in figure A.8 or the "Admin login"which is simply to log into accounts created by the admins of the backend server, visible in figure A.9. This special admin login can and was already useful during a practical test, in the situation where a user does not have an account inside the Fenix system, one of our admins can create an account for him to use and proceed with using the app. After a successful login, the app navigates the user to the home page.

4.7.3 Application drawer

Before going any further into the app's behavior, the drawer is a very important component that deserves its own explanation. This drawer is visible in figure A.14 and is represented in the diagram as the event-based gateway named "App drawer/nav bar" that has a connection coming from the task that represents the app's home page, named "Show Home page".

It is simply an overlay containing a vertical list of buttons that navigate the user to the different pages of the app, also providing functionality to directly log the user out of his session.

Each event connected to the mentioned event-based gateway represents the user selecting any of the options present in the app drawer and the act of navigating to the respective screen.

This event gateway also encompasses the behavior of the bottom navigation bar present on the home page, and with this description, the gateway can represent every action the user can take to navigate to other screens while on the home page.

From top to bottom the buttons featured in the drawer are as follows:

A button leading to the Onboarding page that features a bus icon and its page was explained in the previous section 4.7.1, below, the C̈hoose next spot b̈utton is found and features a running person icon, its page is explained in section 4.7.5. In the third position of the list the button

leading to the Timeline page is found featuring a timeline icon and its page is explained in section 4.7.7, as fourth there is the "Quizzes"button with a question mark icon and its page is explained in section 4.7.8. The last of the plain buttons is Iscte's Memories button represented with a Book icon and its page is explained in section 4.7.10.

Account is an expansion tile in the vertical list, meaning that it can be expanded to reveal other items inside it. In our case, it reveals buttons for navigating into the user's profile, settings, and "Log out".

The profile button is represented through the usual icon for profiles, showing a grey circle as the head of a user and a bigger semi-ellipse below representing the shoulders, explained in further detail in section 4.7.11. The settings button uses the iconic gear symbol to represent definitions and settings, this screen is further explained in section 4.7.12. Lastly, the "Log out"button is represented through an arrow point left, meaning going back and leaving, further explained in section 4.7.13.

4.7.4 Home page

The home page of the app is composed of three different tabs, each one can be navigated to by using the buttons available in the navigation bar at the bottom of the screen.

The first button on the navigation bar takes the user to the puzzle page which is the default page where the app loads, explained in section 4.7.4, the middle one takes the user to the leaderboard screen, where he can see how he compares to the rest of the players using the app, further explained in section 4.7.9. Finally, the icon on the right takes the user to the scan page, where he can scan for spots / qr codes, explained in section 4.7.6

Puzzle This puzzle page is really the main page of the application, here the user can drag pieces of the selected spot around the screen and try to slot them onto their designated place, visible in figure A.10.

No Spot selected When loading the puzzle page, the app checks its local storage to determine if the user has any *spot* currently chosen, if not then the app recommends the user choose a spot and provides a button the user can click to navigate to the Spot Chooser page, instead of showing a puzzle, represented in the BPMN diagram as the *Recommend "choose the next spot"* task, if the user accepts this recommendation and clicks the provided button he is navigated

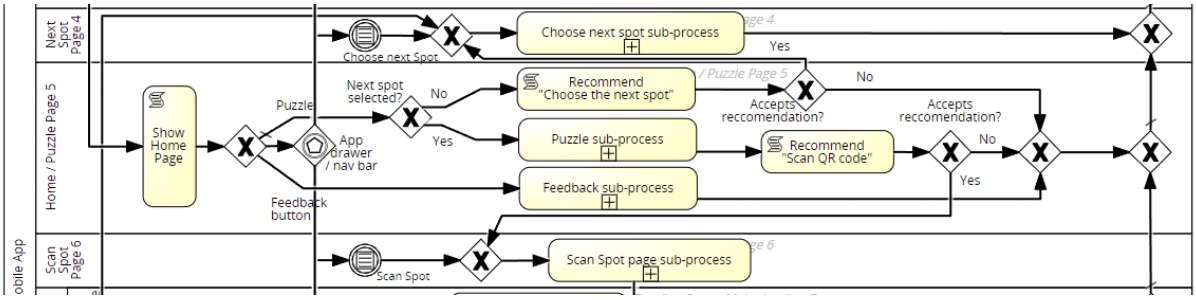

Figure 4.8: Home page section of main diagram

inside the app to the *Choose next spot* page in its corresponding lane of the diagram, visible in figure A.11.

Spot selected If the user already has a spot chosen, the app will instead show the default puzzle page, visible in figure A.10, featuring many puzzle pieces that the user can drag and fix into place when they are moved over their objective position, together they form the picture of the selected spot.

Represented in the main BPMN diagram as the *Puzzle sub-process* task, a collapsed task that contains the sub-process displayed in figure 4.9 where the interactions with this page of the applications are described in greater detail.

This sub-process shows the dragging of puzzle pieces through the *Drag puzzle piece* task and the task *Fix piece into place* represents the app slotting the piece into its place if it is in the correct place, also removing the possibility of the user moving it

Puzzle hint If the user finds it difficult to understand the puzzle image he can request help by pressing the help button on the top right corner of the home page which displays a small version of the original image for a couple of seconds, this has no cool-down and the user can request this hint as many times as he needs. This action is represented in the puzzle sub-process diagram in figure 4.9 as task *Request puzzle hint*. This task is connected to the remaining diagram through parallel gateways to represent that it can be activated at any time while the user is still performing the other tasks in this sub-process diagram. The user can request a hint in between fixing a piece of the puzzle in place and grabbing another.

Complete the puzzle The user can stay on the home page and complete the puzzle, represented as the *Puzzle sub-process* task in the main diagram, which when complete triggers the app to recommend to the user the scanning of a QR code or a Spot with the *Recommend "Scan QRCode"* task and visible in figure A.13.

If the user accepts the said recommendation, he should physically move to the spot, represented inside the *Scan Spot page sub-process* task and better explained in section 4.7.6. Otherwise, if the user does not accept the recommendation, the app simply remains on the home page, represented by connecting back to the *Show Home Page* task.

Provide Feedback The user can provide feedback about the app using the button with the icon of an exclamation mark inside a speech bubble present on the left side of the top bar of the home page, visible in figure A.10, which when pressed displays the feedback form as an overlay,

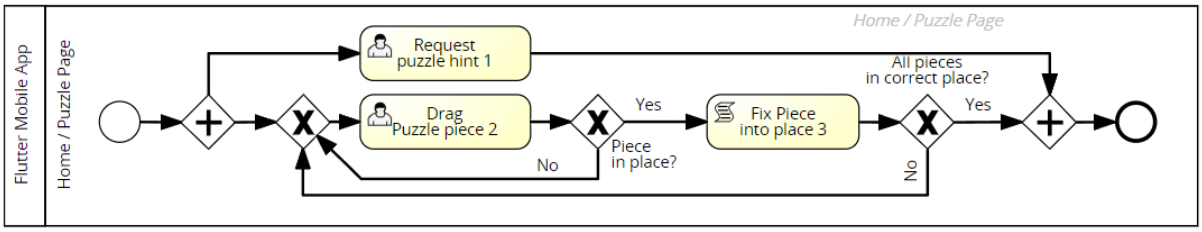

Figure 4.9: Puzzle BPMN diagram

visible in figure A.12 and represented in the main diagram as the "Feedback Sub-process"task that contains the sub-process visible in figure 4.10. In this sub-process diagram, its first task *Show feedback overlay* represents the displaying of the feedback overlay containing the form, which the user then fills represented by the *Fill feedback form* task and submits it, using the submit button of the overlay represented by the *Submit feedback* task that sends this information to the IscteSpots backend Server represented through a collapsed pool. After the submission of the Feedback data, the sub-process comes to an end, and the flow returns to the main diagram in figure 4.7 and more specifically 4.8, where the diagram connects back to the main page of the app, on the *Show Home page* task, because in reality the overlay simply disappears, showing the home page again.

The drawer/menu On the home page, the user can also use the menu icon button positioned as the first button of the top app bar on the left side, visible in figure A.10, to open the drawer previously described in section 4.7.3

4.7.5 Choose the next spot

Starting on the "Choose the next spot"event node, located in the *Next Spot* lane of the main diagram in figure 4.7, containing a single task, *Choose next spot sub-process* that represents all the functionality of this page, more detail is found in the sub-process diagram linked to this task and found in figure 4.11, which in the app corresponds to figure number A.16.

Here the user can see a mix of blurred and clear images that each correspond to a location where the user can physically find a *Spot*, in simpler terms, a QR code. Each of these images has a percentage in its top-right corner, indicating how many pieces of the puzzle the user has slotted into their respective positions out of the total of pieces of the puzzle.

An image can be displayed with zero percent completion not blurred when a user scans the QR code corresponding to the image without completing the puzzle inside the app. If this situation happened, the user is not blocked in any way and can scan the qrCode and view its contents just the same way he would with a spot after completing its puzzle. The result of this action is the non-blurry spot with zero percentage complete, as there is no benefit in blurring a picture that the user already has physically visited, he has already been to the place that the

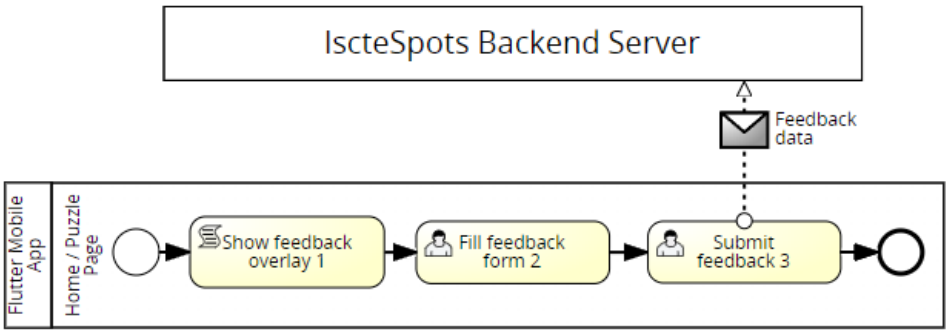

Figure 4.10: Feedback BPMN diagram

picture depicts, so the objective of the puzzle is obsolete in this situation, the user found the location so no puzzle needs to be completed.

Deliberate Spot choice If the user clicks on any one of these images he is choosing this spot as his current objective, represented through the *Choose the next spot* task of the sub-process diagram, and the app shows a confirmation dialog, visible in the figure A.17 and represented in the *Display confirmation dialog* task.

Random Spot choice The user has the option of choosing a spot at random, located as a button with an icon of arrows crossing each other on the right side of the app bar, represented as the *Choose random Spot* task of the sub-process diagram. This button shows a confirmation dialog explaining that it will replace the currently selected spot with a random one, visible in figure A.18 and also represented as the task *Display confirmation dialog*.

Help dialog This page features an explanation dialog, an overlay above the application's page explaining that the user can use the *Choose next spot* page to choose the spot he wishes to visit but firstly he will need to complete the puzzle to view the whole picture.

This dialog is present as a button on the right side of the top app bar with the icon of a question mark, present in figure A.19 and is represented in the sub-process diagram in figure 4.11 as tasks *Request explanation dialog* and *Display explanation dialog*, connected to the rest of the flow through parallel gateways, this choice of gateways was deliberate due to the fact that this dialog can be requested at any time when the user is in the *Choose next spot* page and can do this as many times as he wants, so a parallel gateway is what best describes this type of flow.

Explaining the flow of the sub-process diagram, after these 3 different tasks that the user can perform, the app shows its corresponding dialogs, with tasks *Display explanation dialog* and *Display confirmation dialog* , and the sub-process ends with the flow continuing on the main diagram in figure 4.7 where the task representing all of this behavior, *Choose next spot sub-process* connects back to the *Show home page* task because the application navigates to the home page with the new spot selected and displayed as a new puzzle.

4.7.6 Scan a spot

The scan a spot page is an integrated camera view inside the application, visible in figure A.20, it draws an overlay on top of what is being captured by the phone's camera, that helps guide

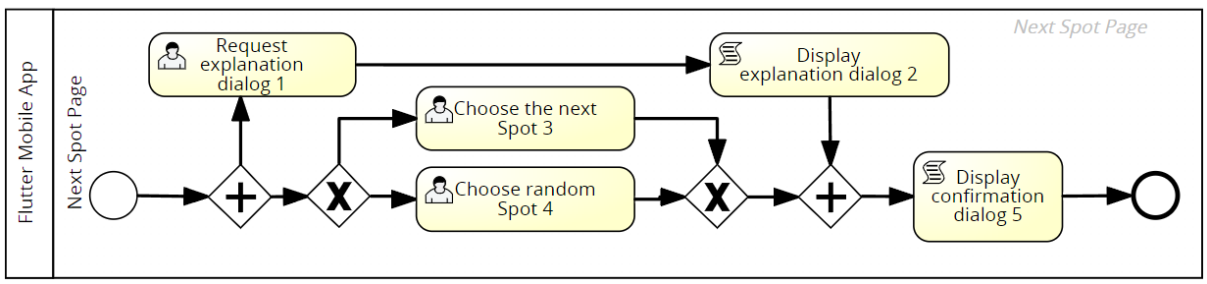

Figure 4.11: Choose next spot BPMN diagram

the user while pointing his phone at the QR code. This overlay makes it clear that the QR code should be somewhat distant from the phone and all corners captured by the camera. Below this guide, another overlay is drawn on top of the camera image with two buttons, one to turn on the flashlight for better visibility and the other to turn the camera to the front side of the phone (similar to a selfie).

In the diagram this page is present inside the *Scan spot* lane, having two points of entry, one coming from the user completing the puzzle and accepting the recommendation to scan a spot, as shown in the *Recommend "Scan a QrCode"* task and another through the navigation bar located at the bottom of the home page, represented as a button with a magnifying glass icon, visible in figure A.10, present in the diagram through the intermediate conditional event named *Scan spot*.

This lane of the main diagram features a single collapsed task named *Scan spot page sub-process* that encompasses all the behavior and interactions present in this Scan Spot page. This task is connected to a sub-process featured in figure 4.12 that represents in greater detail the flow of this page.

The *Move to the Spot* task represents the fact that the user needs to move to the spot where the qr code is physically placed, involving an action outside of the application, which then connects to the *Scan QRCode* task and represents the user pointing their phone with this page open at a QrCode. The app then sends the information of the QR code to the backend server to validate and store the scan, represented through the upward message with the *Scanned QR Code* message and then the downward facing message with the *Scan result*.

Confirmation / alert dialogs Depending on the progression of the user, multiple dialogues can be shown on a successful QR code scan. If the user has never scanned the spot, then a dialog displaying the Topic assigned to the scanned spot and asking if he confirms to continue the scan like the one featured in figure A.21 will be displayed, corresponding to the *First-time scan confirmation dialog* task.

If the user has already visited this spot by scanning its QR code, then a dialog like the one in figure A.22 will be presented, corresponding to the *Re-scan confirmation dialog* asking him if he wished to re scan the spot and revisit its contents.

These different dialogs function exactly the same and, if the user confirms the scan, the sub-process ends and the flow continues on the main diagram where it navigates to the *Study timeline* page, explained further in section 4.7.7.1

A third, slightly different dialog can be presented if the user has not yet answered his last earned quiz, blocking the user from scanning the spot and informing him that he should first complete his previous quiz. This dialog is only informational and does not provide any choice to the user, the app simply keeps on the same page when the user dismisses the dialog. This is represented through the *Last quiz not answered error dialog* task and is the reason why it connects back to the beginning gateway of the lane.

A user can earn a new quiz if he has already completed his last quiz, when he scans a new spot this information is sent to the backend server and a new quiz is assigned to the user, now also encompassing all the previous contents plus the contents of this recently scanned spot.

This sub-process ends if the user confirms the scan, returning the flow to the main diagram in figure 4.7, where it then connects to the beginning of the *Study Timeline* lane, explained in detail in section A.23.

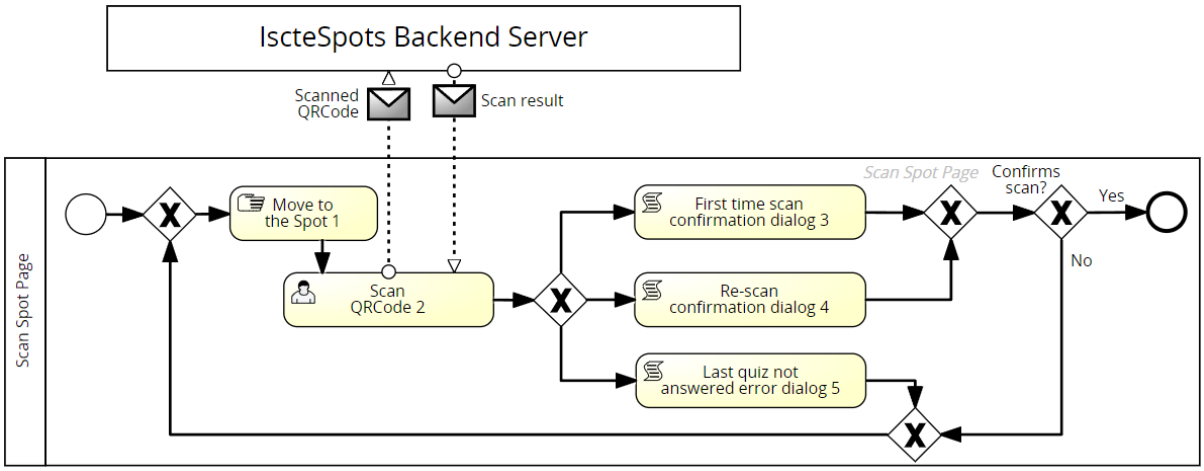

Figure 4.12: Scan spot BPMN diagram

4.7.7 Timeline

When the user navigates to this page, visible in figure A.26, he is greeted by two scrolling lists, a horizontal one on the top of the page with the list of different years that the user can choose and a vertical list containing the events from the selected year in the mentioned horizontal list.

The Timeline page is represented in the BPMN diagram as the *Main Timeline* lane. Its only entry point is through the application drawer, represented as the intermediate conditional event named *Timeline*. This lane contains a single collapsed task named *Timeline sub-process* that abstracts the behavior of this page to another diagram, a sub-process, present in figure 4.13.

The top bar of the app features a button to go back on the left and two buttons on the right, one to display an explanation/help dialog, represented by the task *Explanation Dialog* in the sub-process diagram, and a magnifying glass button that opens the filter overlay, visible in figure A.27.

Timeline Filter With this overlay open the user can choose any combination of topics and scopes he wants to be used used as a filter on the timeline, being displayed on a new screen with the same layout of the initial timeline with the two scroll lists, but now only containing the years and events that fulfill the submitted combination of scopes and topics. This page cannot be filtered again, the user can only view the details of the events or go back to the main timeline page.

The sub-process diagram is divided into two groups of tasks, the first group represents the usage of the timeline's filter, where the task *Submit selected items* sends the selected topics and scopes to the backend server through a message and receives the response from the server in the following task *Explore filtered timeline*.

While the second group of tasks represents the user exploring the default timeline, with the *Explore full timeline* task, and simultaneously requesting the explanation dialog with the *Explanation dialog* task. Where the task *Explore full timeline* receives the full timeline data from the Backend server.

We make use of the parallel gateway to represent that exploring the timeline and requesting the explanation dialog are actions that can happen simultaneously and an undetermined amount of times.

Timeline event details The user can also click any event that contains details, displayed through a simple # followed by the number of details, on the right side of each event in the vertical list of the Timeline page. Clicking on these tiles navigates the user to a new page named *Details page*, which shows these contents to the user, images, and videos are displayed right inside the app while URLs are simply displayed as clickable tiles that navigate the user to the URL in their browser. This page is visible in figure A.28, this behavior is not represented in the BPMN diagram due to its already large size.

4.7.7.1 Study Timeline

The Study timeline page is simply a filtered version of the normal timeline page (sharing the majority of their code), that only contains the events relevant to the Quiz or Spot/QrCode, it cannot be further filtered and is visible in Figure A.23.

The page's center area is identical to the normal timeline page, it consists of the same horizontal scrollbar where the user can select the year and a vertical scrollbar where all the events from the selected year are displayed. Each event is also a button for navigating into its details (if any details are available), these can be simple URLs, YouTube videos, or images that are directly displayed inside the app.

The main differences between this study timeline to the main timeline are that it cannot be filtered, it displays the topics that filter the timeline to show the current content, it has a horizontal scrollbar at the bottom of the screen with a screen wide button recommending the

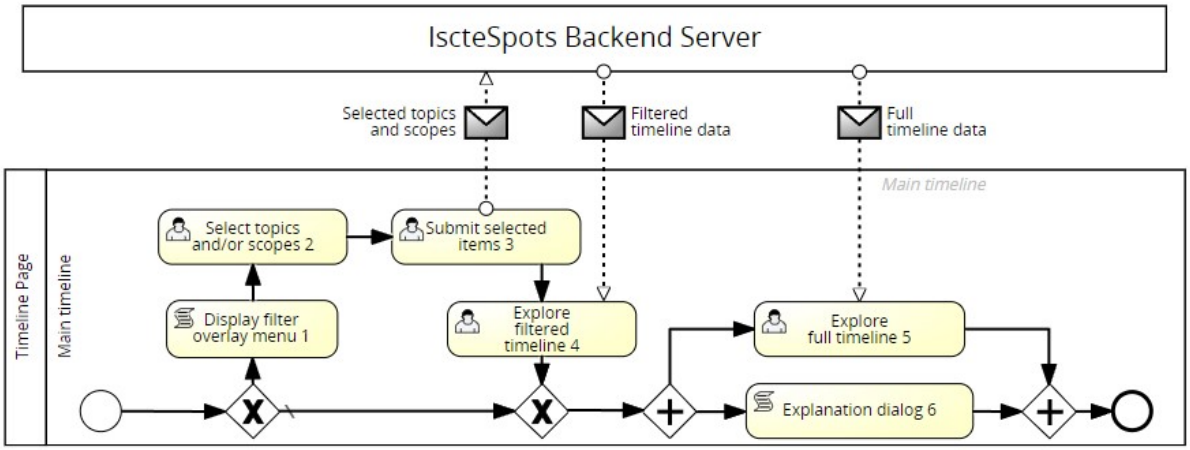

Figure 4.13: Timeline BPMN diagram

user to solve the quiz below it, corresponding to task *Recommend "Solve Quiz"* that navigates the user to the quiz list page, explained in further detail in section 4.7.8

On the diagram, this lane has two different entry points, one coming from the *Scan Spot page sub-process* task in the *Scan spot page* lane and the second one from the *Choose quiz page* lane, and task *Study for Quiz* that in the actual app is a button on the quiz list page on each quiz, this button allows the user to study all the contents related to his quiz by navigating him to this Study timeline page, as represented through task *Explore study timeline*.

More details about these pages can be found in sections 4.7.6 for the first entry point and 4.7.8 for the second entry point.

4.7.8 Quizzes

The user has two different ways of navigating to the quizzes page which can be viewed in figure A.30. The main one is through the application drawer menu, represented through the intermediate conditional event named *Quizzes*, the left-most element in the *Choose quiz page* lane. The second way to navigate to this page is through the study timeline page, explained in further detail in section 4.7.7.1, connected through an exclusive gateway after task *Recommend "Solve Quiz"*.

When the user enters this page he is greeted by a list of available quizzes, displayed through expansion tiles, similar to the Account tile present in the app drawer, explained in section 4.7.3, that each contains information about their corresponding quiz, the current points of the user, the number of tries completed and the various different topics the quiz's questions aboard. When the user expands the tile, it reveals information about their previous attempts, each obtained score, and the progress indicating how many questions were answered on each attempt.

Study for the quiz Below this list of information about the trials, there are two buttons, one with *Study for the quiz* as text and represented in the main diagram through task *Study for Quiz* that navigates the user to a Study timeline page containing only the content relevant for the quiz, explaining the connection from this task to the beginning of the *Study timeline page* lane.

Begin a new attempt The button to start a new attempt is also located below the list of trials and represented through the *Choose Quiz* task which, when triggered begins a new quiz and navigates the user to the *Quiz answering page*, having a connection in the diagram to its corresponding lane.

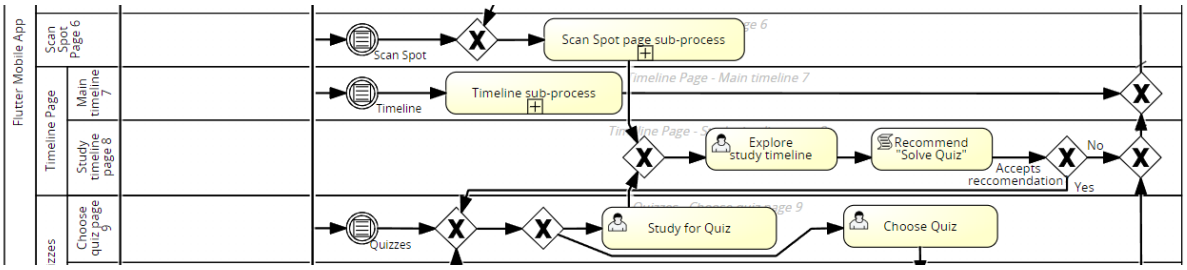

Figure 4.14: Main BPMN diagram focused on the study timeline

After an initial loading of all the questions and their images, the appdisplays to the user the first question and starts its timer.

The question page As can be seen in figure A.31, in the upper half of the page we find in order, the number of the question inside the quiz and the total number of questions, below we find the image for this specific question which is configured by the creator of the question using our backend server admin page, in the case of the referenced figure, it is a book cover but could be, for example, the face of a professor or a location inside the campus.

Below the image we find the question's text, in the case highlighted in the screenshot it asks us to identify one of the authors of the magazine in the provided image, followed right below by the timer which displays to the user how much time he has left to answer the question, using a decreasing horizontal bar with a clock icon on its left to clarify that it is a timer.

At the bottom of the screen, we find the multiple answers possible, our quizzes are always multiple choice and can be configured to have a single correct answer or multiple correct answers, in the case of a single correct answer, each choice is represented through a radial button and in the case of a multi-correct-answer, check-boxes are used instead.

Lastly, at the very bottom of the page, there is the "Next"button which navigates the user to the next question.

This process is represented in the main diagram through task "Solve Quiz"which connects to task "Recommend user to "Choose the next spot"or "Explore Leaderboard""because when the user finishes answering the last question, he is navigated to a last screen, explained below.

Quiz Complete page Visible in figure A.32 that shows the user its score and recommends him to navigate to the *Choose the next spot* or to the *Leaderboard* pages.

Depending on the user's choice the app navigates him to the *Leaderboard page*'s lane or to the *Next spot page* or alternatively the user can simply use the back button on his device to navigate back into the quiz list page, as shown in the diagram, these navigations are connected to the entry points of their respective lanes.

4.7.9 Leaderboard

The leaderboard page contains three tabs within itself that the user can freely switch between through a navigation bar that sits at the bottom of the screen.

In the main BPMN diagram, there are two different entry points to the *Leaderboard page* lane. The main one is through the application's drawer, represented through the intermediate conditional event named *Leaderboard*. The second one is through the *Quiz answering page* lane, with the task *Recommend user to "Choose the next spot" or "Explore Leaderboard"*, which in the app is done through a button on the last page of the quiz, shown after the user completes a quiz, explained in detail in section 4.7.8.

The detailed behavior of the Leaderboard page can be found in a sub-process, displayed in figure 4.15 which is connected to the main diagram through the task *Leaderboard sub-process*

Global leaderboard The first page out of the three that constitute the leaderboard is the Global leaderboard.

This page of the leaderboard can be viewed in figure A.33 and features a list of the top ten players, sorted by the number of points they have. The user can see in the list, the points, affiliation, and username of the best ten players of the game at the moment of opening the page.

This page is represented in the diagram inside the sub-process diagram visible in figure 4.15 through task *Explore Global Leaderboard* that exchanges messages with the backend server to receive the data displayed on the app's page. First, the app sends a message to the server requesting the latest data and the server then responds by sending the data of each of the ten users with the most points, their usernames, affiliation and their points.

Affiliations leaderboard The second page of the leaderboard serves as a filtered view of the leaderboard as a whole. This page has a similar layout to the global leaderboard page, it features a list of tiles with the same user information as the global page, featuring two dropdown buttons above this list that filter it according to the user's Affiliation and Department, the second being dependant on the first, each affiliation has different departments. Examples of options in the affiliation button are *Student* and *Staff Member*.

If the user chooses to filter for Students using the Affiliations dropdown, the options of the Department dropdown change to include all the possible Courses in the university. This way, the user has the option to view a Leaderboard with all the students or with only the students of a specific course. The same goes for a Staff Member, but now the department dropdown features the different departments of the university's staff, for example: "School of Technologies and Architecture"or "Administrative Technical Support"and many more. All these options are customizable because they are stored on the backend server, every time the user loads this page, the app requests the list of available Affiliations and Departments.

These are generated on user login, for example, if no student from the course of Marketing ever logs into the app, this course will not show up as an option in the dropdown button. Our backend server only has knowledge about the affiliations and departments of the users who have logged into the app, when a user first logs into our system through the Fenix integration, better explained in section 4.6, their affiliation and department are imported into our database if it was not previously present.

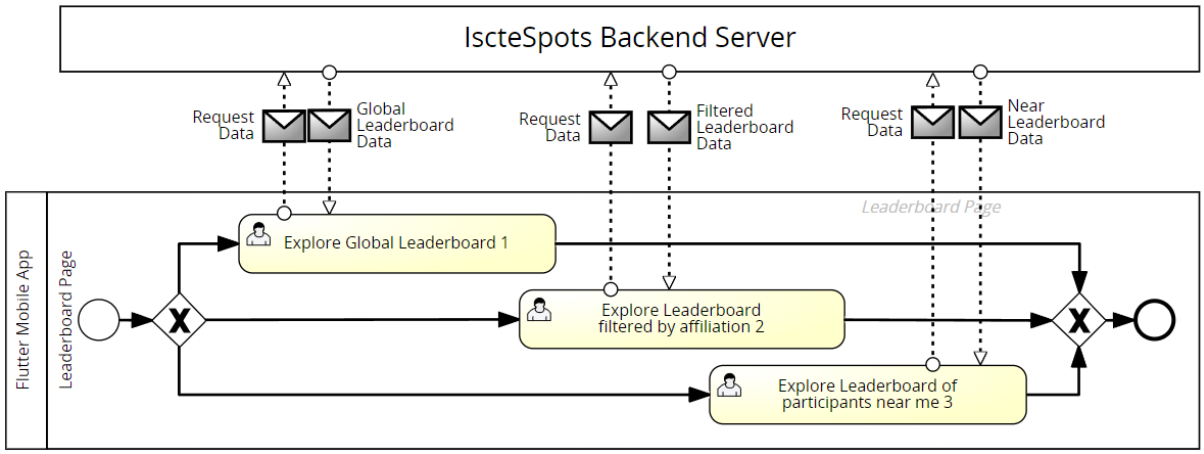

Figure 4.15: Leaderboard BPMN diagram

This page can be viewed in figure A.34 and is represented inside the sub-process for the Leaderboard page as task *Explore Leaderboard filtered by affiliation*. Similarly to the other Leaderboard sub-pages this page exchanges two messages with our backend, an initial message from the app to request the necessary data to display and a following response from the server with the updated data.

Near Me The last page out of the three that compose the Leaderboard is the Near Me page visible in figure A.35. It shows a list of the next five contestants above and five below the current user of the application in points from any Affiliation and Department.

This page is represented inside the Leaderboard sub-process, in figure 4.15 as task *Explore Leaderboard of participants near me*.

4.7.10 Iscte's memories

The Iscte's memories page is a page designed for the exploration of contents, it can be used to view photos related to the university.

This page of the app is not connected to our backend, storing and managing such important photos of the university's events is a very important task that is not included in the scope of this research.

Due to these motives, the application fetches the photos from Iscte's Flickr account, where all institutional events have their photos published.

When the user enters this page, represented in the main diagram through the intermediate conditional event called "Iscte's Memories", the user is greeted with a carousel horizontal list containing one card for each photo album. Each card contains the cover photo of the album, followed below by the album's title and description. Initially, the app only loads a predetermined number of albums to show in the carousel, currently configured to 10, only when the user scrolls past half of this configured number the app loads another "batch"of albums to show. Note that in this step, the app only fetches the metadata of the album, its title, description and cover, not the photos of the album. To view all the photos in the album the user must click on one of the described album cards.

This action of scrolling through the albums is represented inside the Iscte's Memories sub-process, in figure 4.16 through a task named *Explore List of Iscte Albums of photos* that receives

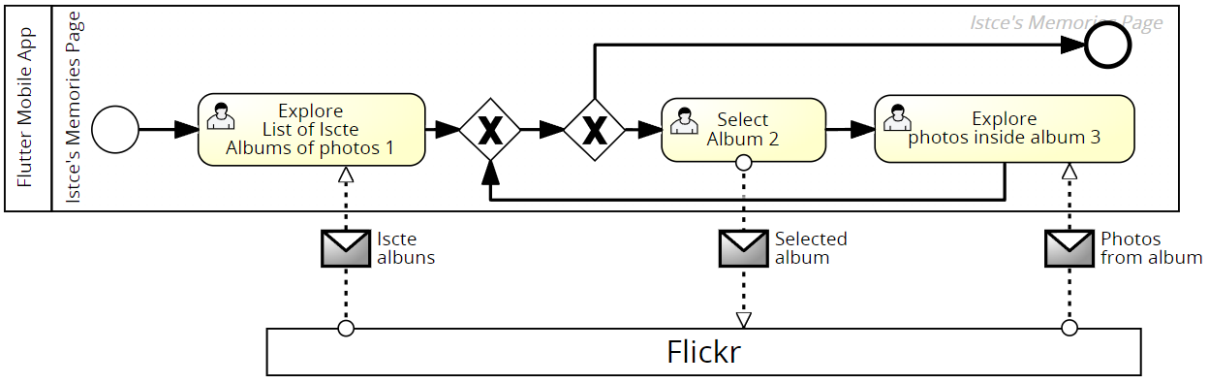

Figure 4.16: Iscte's Memories BPMN diagram

the list of albums from the Iscte-IUL profile in Flickr's servers and connects to two exclusive gateways which represent the option the user has to either go back to the main page and end this sub-process flow through the back button in the top left of the page or continue down the sub-process and view the details of an album by clicking on one of these cards, which navigate the user to a new screen shown in figure A.37 with the title of the album in the top of the screen and the images of the album as a vertically scrolling list of photos that the user can pinch to zoom in and out.

The act of the user selecting an album is represented through the *Select Album* task in the sub-process diagram, figure 4.16, and sends a message to the Flickr API with the selected album. The task directly after represents the user exploring the photos of the selected album, named *Explore photos inside album*, and receives the response to the message sent in the previous task, with the photos of the selected album. Then connects back to a gateway in the same lane that allows the user to select another album or end the sub-process and go back to the home page.

This page of the application can be seen in figure A.36

4.7.11 Profile

The profile page is only accessible to the user through the app's drawer, represented as the intermediate conditional event named *Profile*. This lane of the diagram has a single task named *View Profile information*", because this page is simply a display of information, the user cannot interact with it in any way.

The page displays the user's name and affiliation below, then two horizontal sections are displayed, the first is for displaying the user's points and level in the IscteSpots game, this basically means how many QR codes the user has scanned. The second section is for its ranking, it displays the user's position in the global leaderboard on the left and the user's position within his own affiliation, so if the user is a student, then this position is only taking into account all the users who are students.

4.7.12 Settings

The settings page is a page that was developed for any potential settings the app might have needed.

In the end, the app did not need to implement any settings for the user to change as all the potential choices remained automatic. The language of the application depends on the language of the device, therefore the user does not need to manually change this setting.

The page only has one entry point, through the app's drawer, represented through the intermediate conditional event named *Settings*.

Inside the page, the user can only see a single button: *iscte_spots* that when clicked displays an overlay dialog, with the message *About iscte_spots* followed by the current version of the app, a button to close the dialog and a button to view all the licenses of the app. This page with all the licenses is provided by the Flutter API, fetching all the licenses from a license registry.

After the user views this license page he can only go back to the settings page and from there he can also only go back to the home page of the app.

This page can be viewed in figure A.39 and is represented in the main diagram through the *Explore settings page* task.

During development this page has served to hold some debug information and buttons, for example, to reset the progress of the puzzles.

4.7.13 Any page of the app

This lane only contains the *Log out* event and no task to represent because there is no page in the app for this, the user simply selects the logout option inside the drawer and the app logs out the user, returning to the login screen.

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Chapter 5

Results discussion

Contents

This chapter discusses the gathered data throughout the multiple validation phases.

In this chapter, we present the results gathered from all the tests done on our mobile and web applications to validate our solution. Section 5.1 goes over all the data gathered in the multiple interviews performed early in development. Section 5.2, describes the feedback gathered during the OpenDay event and the changes that this first test prompted. Section 5.3, describes all the details that resulted from validating our app with one of Iscte's designers. Section 5.4, goes over the feedback received in the validation tests performed with students and our fully developed application. Section 5.5, goes over the anthropological field observations performed by the research team during the validation tests. Section 5.6, describes the in-depth analysis performed on the performance of the students in both validation tests. Finally, Section 5.7 summarizes the conclusions.

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Chapter 5
Results discussion

5.1 Interviews

All of the 5 interviewees found our proposal useful for the community and believe it will obtain a positive reaction from the latter. The fact that competition will take place was considered rather intriguing and is expected to cause more engagement, as observed by [2, 11]. Using a mobile application as a tool to learn the university's past was seen as a positive factor, in line with new generations' expectations.

An interesting point, raised by one of the interviewees, was that the app has the potential to be much more than the support to an event. He expressed that many new students, even after a few weeks of experiencing and exploring the campus still do not know, for example, where the administration offices are located, or where all the different food courts can be found. He expressed his idea of adapting the app to become a permanent part of the enrolling experience for new students, it could serve as a guide to navigating the campus and it could also guide new people inside the university in their beginning weeks of appropriating themselves with the campus.

An important worry that another interviewee demonstrated was that nowadays there are simply too many apps out there, our application needs to have a differentiation factor, it needs to earn its spot on people's phones. To deliver on this front, we aimed to incorporate inside the application the physical space of the university with its heritage and the competition support for the whole event. To achieve this objective, we aimed to integrate within the application the university's physical space, along with its rich heritage, and with integrated support for the entire competition event.

Lastly, the same interviewee offered yet another valuable suggestion, each user should have the freedom to scan the QR codes that he wants and not be constrained by a "guided tour"of some sort. There will be different types of users within our application, some want to be fully immersed in the game and all the trivia provided while others will use it more casually, maybe as a casual means of exploring the campus or simply out of curiosity. Some of these users would be greatly deterred from using our application if a guided tour through the campus was implemented as a requirement within our game, the simple interaction the user thought he was getting from our application would spur out of his initial intention possibly causing him to even uninstall the application as a result of the app's demand.

Our team recognized the merit of this feedback and decided to implement it into the final application, as we believe it will cater to the preferences of all users, making the app more versatile and user-friendly.

5.2 Open day

With overall positive feedback, and some negative references to the heartfelt during the activity and the physical effort required.

Apart from the negative references to the weather conditions and physical efforts, the application itself was well received with a rating of 3.64 out of 5 with a sample size of 33 on the first open day and an improved rating of 4.38 out of 5 with a sample size of 18 on the second open day. Two (3.9%) students mentioned that they preferred a guided tour of the campus instead of the IscteSpots activity and three (5.8%) mentioned the IscteSpots activity as their favorite of the OpenDay.

As an example of the extreme flexibility provided by the Flutter framework and iterative design process undertaken with this application, we highlight some of the changes that were requested by the OpenDay staff and promptly resolved: One of the QR codes was placed in a much more difficult to access place and therefore the students to whom it was randomly assigned were at a great disadvantage, having to spend much more time traveling to scan a single spot. In the following OpenDay, this spot was moved to a closer and much more accessible place, closing the gap in distance between all the spots. Reduce the number of QR codes to shorten the activity's length and ease the physical demand of the game on the students who were already tired after a long day of different activities. Implement visual feedback inside the application to create more engagement among the students, such as confetti being displayed as an incentive to complete puzzles.

5.3 App redesign

When updating software to a new version or copying code and running it in a new system or format, as we did with the web port, the developer must be careful as there is always the possibility of the system breaking, may it be due to a change in an old feature that no longer works in the new version, packages being incompatible with the new version, some may not support all the promised platforms by the framework, this is the case for the Sqlite package for Flutter and Dart called sqflite that only supports Android, iOS, and MacOS. Not supporting the web forced us to re-implement multiple endpoints in our backend server and changed the majority of our logic when fetching the timeline events and contents.

Initially, we were fetching all of the timeline data through a single REST Get request, which then the app stored locally, but the web version could not store all of this data due to not having database storage like the mobile systems have (Android and iOs), so we were left with a choice, either fetch all the events from all the fifty available years of history every time someone loaded the page or change our backend endpoint architecture to make more efficient requests.

After careful consideration, we decided to revamp our backend endpoint architecture, now our frontend, be it mobile or web only requests the list of years available and the list of events from the selected year, when the user selects a different year, a new request is sent with the selected year and the new list of events is retrieved and displayed.

Proposed changes Post creation of our working web timeline, as described in section 3.4, the University Rectory Communication Office was contacted to validate the design of the newly developed port.

The main changes that resulted from this design were focused on the usage of Iscte's color. Our university brands itself around a particular shade of blue and we knew this before consulting with the Communications office but we overused this color, it was present in many aspects of the app, as the color for many buttons, as the color for titles and important aspects, even as a background in some pages, which made the whole app very intense to look at. Examples of this old design can be found inside section **??** with figures A.46 and A.44 as examples.

With this feedback, the application was modified to be based on black and white, using Iscte's brand color only on highlights, important buttons, some text, and active icons, simplifying the app for the viewer and using the colors to our advantage, as it greatly contrasts to the white background.

After successfully applying these new design rules to our web timeline, these changes were also implemented in our mobile application, to improve the experience and keep it consistent between all platforms.

Examples of the redesigned application can be seen in section A with figures A.10 and A.33 as examples.

Other changes were also made regarding the icons used in the timeline page of the app, if we compare figure A.47 with A.26 we can see that the second one is much more simplified and has the important information grabbing as much attention as possible from the user

The previous icons on the left of each event are still present in the new design, just hidden when there is not enough vertical space for them, they remain in the web version and, on the mobile version only if the phone is rotated on its side. The new design removes greatly the repetition found in the older version, as you can see in figure A.29, icons are only displayed when a different icon follows a chain of similar icons, presenting the events as groups with the same icon, using vertical lines to indicate said groupings.

5.4 Validation tests

We performed two beta-test sessions with students on our campus where the Nasa Task Load Index (NASA-TLX) and the Mobile Application Rating Scale (MARS) forms where filled to provide feedback about their usage with the app.

The first test was conducted with the IEEE student chapter of our university and yielded a sample size of 8 students who filled in the TLX form, while the second test was conducted in collaboration with the ACM student chapter and resulted in a sample size of 14 students who filled in the TLX and the MARS form.

5.4.1 TLX feedback evaluation

The NASA-TLX form was created by NASA, it contains a single section with 6 questions requesting the respondent to rank the experience on a scale of 0 to 21 and an additional seventh open-ended question was added by our IscteSpots team, asking for any possible improvements to the app.

The full data can be consulted in tables B.1 and B.3 and each of the six questions is represented as an axis in the radar charts in figures 5.1 and 5.2.

Analysis In the Mental demand question, a lower score is considered better because the question accesses the amount of mental effort needed from the user while performing the activity of fully utilizing our developed application. The mean score for this question in the first validation test was 9.00 and 11.34 out of 21 on the second validation test, reasonable scores, in the middle of the scale

The Physical demand axis questions the user on how physically demanding the activity was for the user, again, a lower score is greater than a higher one because our app is not fitness nor sport-related and the users may not be expecting much physical demand, the app should serve as a companion to the student's life during the event where the quiz competition is active. With that said, the mean scores across both validation tests were 3.5 on the first and 7.93 on the second. This greater variation between the tests was not in our control, during both tests the QR codes spread out throughout the campus were not altered so maybe this variation was due to the specific people involved in the test.

The Temporal demand questions the user on how hurried the pace of the task was, again lower scores indicate a better outcome of the validation test, as it indicates that the time we allocated for the scanning of all the QR codes was appropriate for the number of QR codes set up. This question received a mean score of 8.88 on the first test, a slightly higher 10.50 on the second test, and an overall mean score across both tests of 9.91.

The Performance axis questions the user on how well they evaluate their success in the proposed task, a higher score means that the user left the test with gratification and confidence that they executed the task, and in practice played our IscteSpots game to the best of their abilities. This question received a mean score of 8.63 on the first test, 9.36 on the second one, and 9.09 across both tests. Ideally, we would like to see this score higher on the scale, taking into account that the maximum score is 21, these scores are slightly below the midpoint of the scale.

The Effort axis questions the user on how hard they worked to achieve their performance level in the proposed task. The users in the first test scored their effort levels as 11.75, in the second test as 10.71 and across both tests as 11.09. Analyzing the answers to this question may indicate why the performance scores were lower than desired. The effort levels of the users were around the middle of the scoring scale, which may indicate that the users did not feel a true sense of competition or consequence in case they performed badly and were not entirely focused on completing the task utilizing the best of their abilities.

The Frustration axis is very important to take into consideration the technical aspect of the proposed application as it questions the user on how insecure, unmotivated, angry, stressed, or bored he felt during the activity. High frustration levels indicate poor production quality or game design that steps in the way of the player instead of supporting them. With that said we are proud to conclude that this field was the best score we received out of the whole form. On the first test, the mean score was 3.13, on the second test the score was 5.71, and across both tests the score was 4.77, some very low scores, indicating that the players were not frustrated and had a smooth experience while using our application.

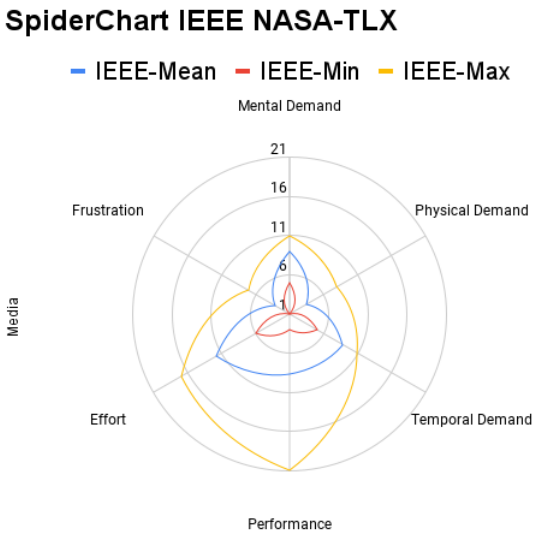

Figure 5.1: Feedback form NASA TLX filled in the IEEE validation test

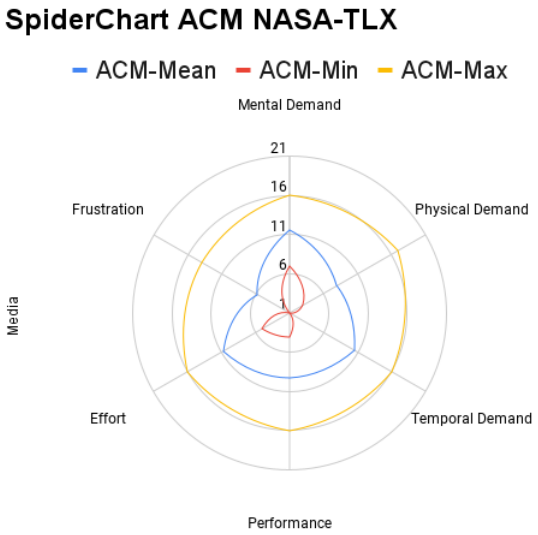

Figure 5.2: Feedback form NASA TLX filled in the ACM validation test

5.4.2 MARS feedback evaluation

Going into more detail, in figures 5.3 to 5.6 we present radar charts, each containing the maximum, mean, and minimum values for each of their questions in the form. A note regarding the use of the words "axis"and "questions", which are used interchangeably as each axis of the radar charts is representative of a single question inside the forms. The full tables with the raw data from the users in the validation tests can seen in tables B.5 to B.8.

Engagement Starting with the Engagement section of the form, visible in figure 5.3 and with the raw data in table B.5 There are five different axes on the chart, each one going over a specific question within the overall theme of the section, Engagement, the first axis is entertainment where the user is asked to rank the application in terms of whether or not he had fun using

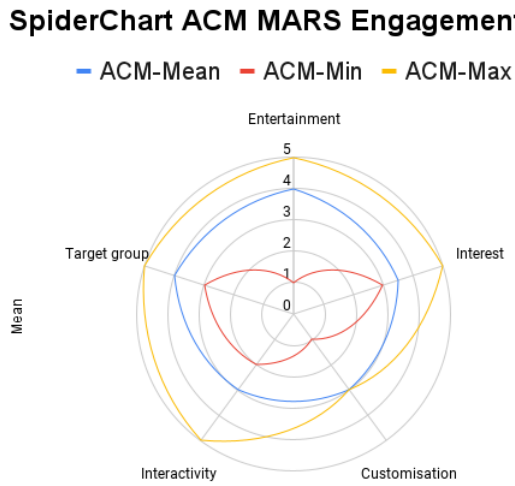

Figure 5.3: Feedback from ACM validation tests on IscteSpots app's engagement

the app, and whether the app used some kind of strategy to increase engagement through entertainment. The second axis regards whether the app is interesting to use and whether it uses any strategy to increase engagement by interestingly presenting its content. The third axis goes over the Customization that the app provides, if it offers any kind of customization regarding the app's content, sound, or notifications. In the fourth axis the Interactivity question is displayed The fifth and final axis is regarding the Target Group of the application, whether the app's contents, visual information, visual design, and language, are properly fit for the app's target group.

At least one person ranked each of the axis with the maximum score except for the customization axis, where the maximum score was 3, the mean score was 2.5 and the minimum was 1, a result that was expected and called for since the app did not have any customization options whatsoever, the only change the user could make to the app was the language, which was not an option inside the app, the user had to change the system's language to change the displayed language inside the app. The customization aspect was not our main focus and therefore did not receive any features from our part, since our main worries fell on the way the users would appropriate themselves with the contents regarding the history of the university. The mean scores of the remaining axis all hang around the 3 to 4 score mark.

Functionality Regarding the Functionality section of the form, there are four axes to be considered, visible in figure 5.4 and data present in table B.6. The Performance axis is where the user is asked about the precision or speed of the functions and components of the app such as buttons or menus. The Ease-of-use axis regarding the clarity of the menus and symbols used within the app, if their purpose is clear and simple to understand. The Navigation axis where the navigation within the app is put under inspection, are all the menus accessible and logically accessible? Lastly, the Gestural Design, questions how consistent and intuitive the interactions within all the screens are.

All the axes received a maximum score of 5 out of 5, with means between 3.7 and 4.36.

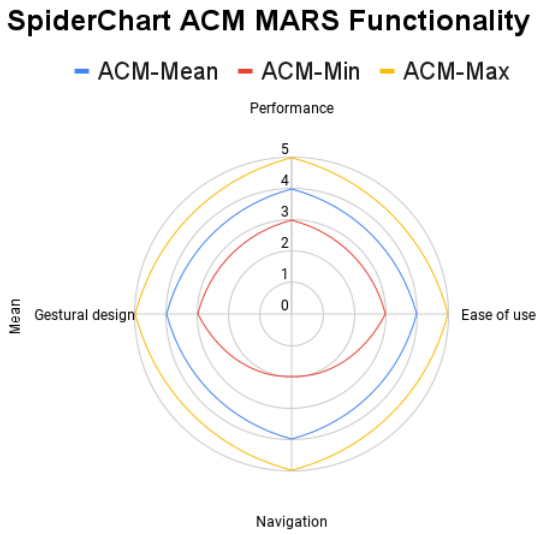

Figure 5.4: Feedback from ACM validation tests on IscteSpots app's functionality

Denoting the results flutter yielded by allowing our team to create an app well received within our tests and deemed easy-to-use (4.36) and with great gestural design(4.21), with reasonable navigation (3.86) and performance (3.79).

Aesthetics The third section goes over the Aesthetics of the application, with three different axes, visible in figure 5.5 and data present in tableB.7, each representing a question, The first question in the Aesthetics section of the MARS form is regarding the layout of the app, and whether the size and position of its buttons, menus, and icons are appropriate within the remaining UI. Secondly, the user is asked about the graphics of the application, their quality and resolution and lastly the third axis regards the Visual appeal of the app.

Regarding their mean scores, the Layout questions were ranked the highest with 4.14, followed closely by the Graphics with a solid 4.00, and lastly the Visual appeal with 3.29.

Information The last section of the MARS form goes over the Information displayed in the app, complete with five axes, visible in figure 5.6 and data present in table B.8. The first axis of the section asks the user about the Precision of the description of the app in the app store compared to what the app accomplishes. The Goals of the app, if the app has specific, measurable, and achievable goals. The correctness of the information displayed within the app is evaluated and displayed in the Quality of Information axis, as well as how well-written and relevant the information is. The quantity of information is then questioned by the user, if it is too little or too much and on the other end of the spectrum, if it is perfectly comprehensive and concise. Lastly, the user is questioned on how clear, logical, and correct the visual information used within the app like tables, images, videos, and charts.

All of the described questions received a maximum score of 5 out of 5, with mean scores of 4.31 as the highest of the five, in the Goals question, 3.62 in the Quantity of information as the lowest of the section, and the remaining questions with mean values around 4 out of 5.

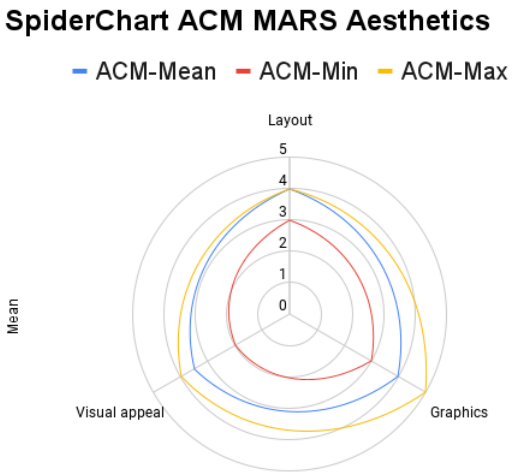

Figure 5.5: Feedback from ACM validation tests on IscteSpots app's aesthetics

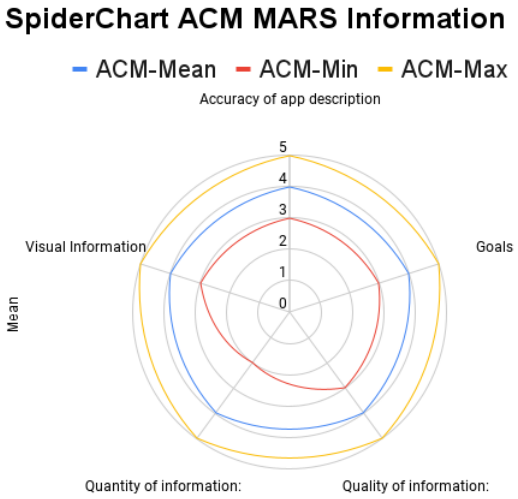

Figure 5.6: Feedback from ACM validation tests on IscteSpots app's information

5.4.3 Open ended feedback

On the first test we were able to gather valuable feedback on the application's flaws. The main point of concern expressed by the students through the forms was regarding network issues and their impact on the process of answering quizzes. These issues are only natural to occur due to the unpredictable conditions of mobile and WiFi networks.

The feedback reported that either the question timer would start before the image showed up or the image would not load at all, displaying an error, the best solution we could find was to first load every piece of data that is crucial to a quiz and all its questions, then the user could go offline while answering said questions, only needing an internet connection at the beginning to download the data and at the end to submit his answers.

Taking this feedback into consideration, the quiz answering logic was redesigned to support

more offline utilization. In the revised version, the app loads any images used in the questions before initiating the quiz, showing this progress through a circular loading icon. This process of loading the images before showing any question was the result of field testing, where we found that due to the unpredictable conditions of mobile and WiFi networks, the users experienced many hardships while answering their quizzes.

Other concerns were regarding the buttons in the quizzes, the screen was composed of a ”submit“ and a ”next“ button that created confusion and did not provide clear feedback on their actions. These buttons were simplified to a single button that proceeds the quiz to the next question and performed both the submission of the answer and the progression of the quiz all-in-one. The reported bugs were fixed and the app was improved upon.

On the second test there were no clear issues that impacted every user. Some referenced the difficulty of the puzzles, wanting easier puzzles while others referenced wished they were easier. Some students experienced problems with some questions on the quizzes. Others wanted the possibility to go back to the previous question while answering the quizzes, but this is a design choice to reduce the amount of cheating by getting the answer from colleagues or the internet.

5.4.4 Summary

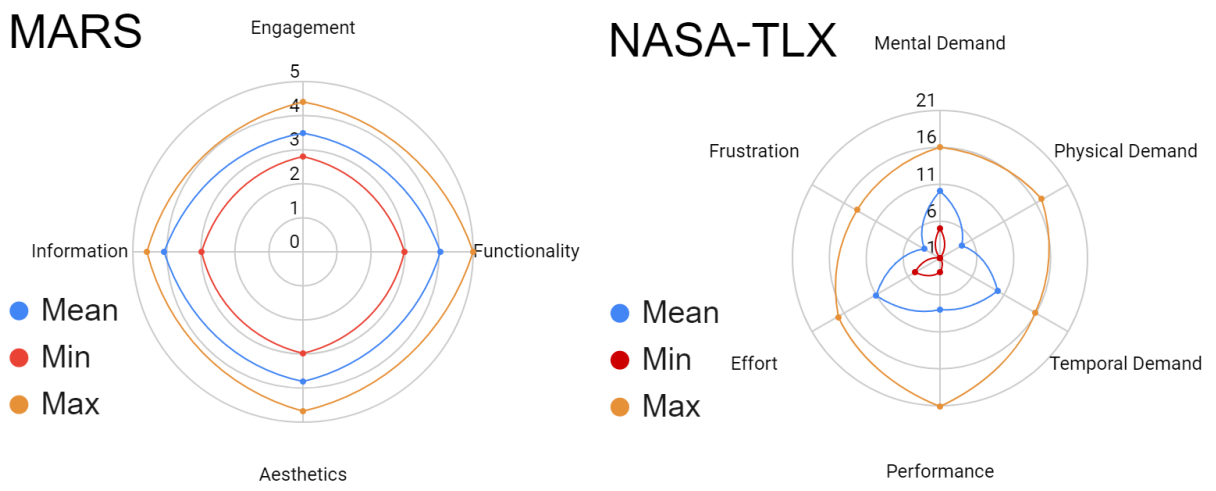

Figure 5.7: Feedback summary from all validation tests on IscteSpots app usability

Overall, this assessment exercise provided very positive feedback regarding the effort involved in using the app.

By quickly looking at the averages of the different axes evaluated by the students in figure 5.7 we see that with regards to the application's quality, in the MARS form radar chart, we consistently received above-average feedback on all axis, Engagement, Functionality, Aesthetics and Information.

The NASA-TLX form, faced more towards the experience as a whole, we see low levels of demand and frustration, good signs indicating the experience was not too difficult to complete, however, with regards to the student's performance self-evaluation we see a lower score, indicating the students did not feel very confident with their results within the app.

5.5 Anthropological field observations

During both validation tests, our team was dispersed across the campus taking notes about the behavior of the participants. Some of these notes were gathered during interactions with the participants themselves and others by observing their behavior and listening to conversations with other participants during the game.

One intriguing aspect consistently observed throughout both validation tests, which could only be discerned through an anthropological approach, pertains to the collective behavior exhibited by the participating students. Remarkably, it became evident that the students engaged in extensive collaboration among themselves, demonstrating a strong propensity to work together to attain higher quiz ratings and accelerate the completion of the activity.

An aspect consistent on both validation tests, only possible to be caught through an anthropological approach is the group behavior of the students. Across both validation tests, they collaborated heavily among each other to achieve higher ratings on the quizzes and complete the activity faster, this observation further bolsters the argument against the prevailing misconception that ethnographic research is inherently less valid than quantitative research methods, as discussed by Boellstorff et al. in their work [1].

5.5.1 IEEE test

During the application download process, all the participants exhibited high levels of enthusiasm, energy, and engagement The room was filled with interactions between the participants, all of them showing strong motivation and positive energy throughout the process.

Throughout the game, those playing solo remained concentrated while scanning the QR codes and interacting with the app, displaying confidence as they navigated the campus. As for the grouped students, they were constantly excited but still focused on the application and engaged in solving puzzles or quizzes, these even showed some degree of strategizing the game with one group that decided to initially complete all the puzzles before exploring the campus. This approach allowed them to create an optimized path through the campus, ensuring they could visit all the QR codes efficiently.

The Leaderboard page played a significant role in maintaining high engagement levels in every participant, it served as a strong motivator to actively seek and accumulate points within the game, also creating a sense of competition and encouraging the participants to achieve higher rankings, in turn contributing to sustained engagement and motivation throughout the gaming experience.

One of the participants shared that during the test, an interesting incident occurred to him when faced with difficulty locating a specific QR code, he approached a professor and a student on campus, then showed them the picture displayed in the app, asking for help finding the place depicted, both responded that they recognized the place but did not know where it was located, highlighting the intricate layout of our campus that not every member of the university knows by hand, further emphasizing the relevance and applicability of the physical exploration aspect of the IscteSpots game.

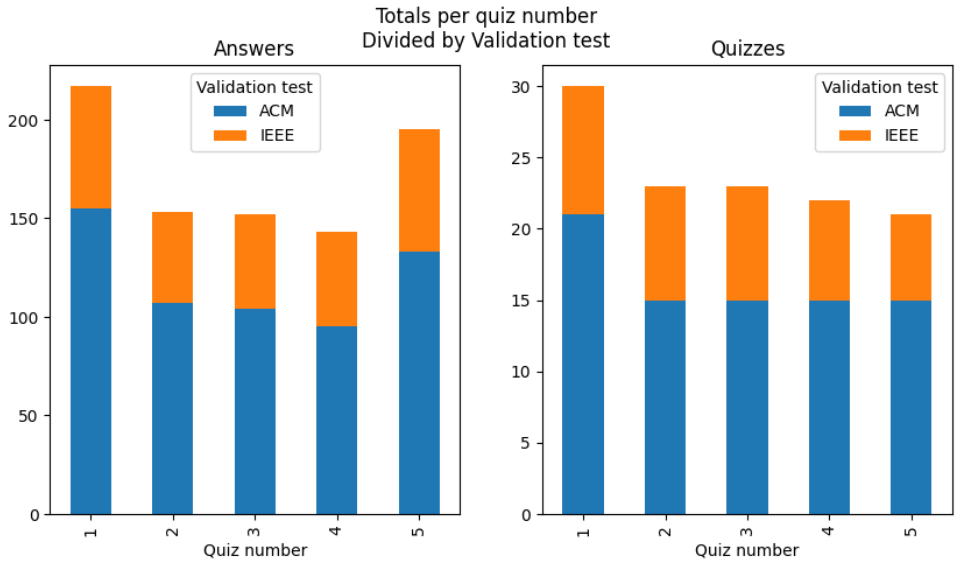

Figure 5.8: Totals separated by validation test

5.5.2 ACM test

Once again, during the activity, the students formed larger groups of 5 to 6 participants, along with several smaller groups of 2 to 3 individuals, and a few students chose to go solo. These big groups swiftly navigated the campus, scanning the QR Code faster than the other groups due to the collaborative approach, sharing quiz answers and knowledge, once the first student obtained a decent score on a quiz, he would share his answers and knowledge with the rest of the group.

We also noticed the students actively sought our staff to provide feedback on the application's faults and possible improvements they thought of, they were purely motivated to help improve the experience as a whole.

5.6 Student performance analysis

Using the Python programming language and some of its Data oriented packages such as Pandas we were able to analyze the data gathered throughout both validation tests within our application. Using this data we hope to create sound conclusions on whether the app improved the student's knowledge regarding the university's history and heritage.

5.6.1 Scale of the tests

First, we need to contextualize the tests by comparing their sizes. As referenced earlier the first of these tests was performed with the IEEE student chapter and was able to gather a sample sizer of 8 students while the second test was performed with the ACM student chapter with a sample size of 14 students, where the app benefited from some improvements compared to the previous test like the improved offline quizzes.

Both tests were configured to have 5 different QR Code available for the students to scan and consequently, 5 different quizzes for them to answer, each quiz being composed of 5 different

questions.

By looking at the data present in figure 5.8 and in table 5.1 we see that the ACM test gathered around twice as many answers and quizzes.

For example, the data on the most likely quiz to be completed by every student present in the tests, the first one shows the double of performed quizzes in the ACM test compared to the IEEE test 21 to 9, and around the same ratio for number of submitted answers, 155 to 62 respectively.

Table 5.1: Totals separated by validation test

Quiz number	Answers			Trials			Quizzes		
	ACM	IEEE	Total	ACM	IEEE	Total	ACM	IEEE	Total
1	155	62	217	32	16	48	21	9	30
2	107	46	153	22	12	34	15	8	23
3	104	48	152	21	13	34	15	8	23
4	95	48	143	19	12	31	15	7	22
5	133	62	195	27	13	40	15	6	21
Total	594	266	860	121	66	187	81	38	119

5.6.2 Performance

Our dataset contains questions with different amounts of possible answers. For example, some questions offer only two different possible answers resulting in a 50% chance of randomly choosing the correct answer. In contrast, questions with four possible answers yield a 25% chance of a correct answer through a random selection. In our application, the user was awarded the same amount of points regardless of the number of possible answers

To conduct a thorough analysis of the dataset we had to create an alternative approach to calculate the amount of points awarded by each question, a method that would take into consideration the difficulty of each question and benefit the users able to answer such difficult questions.

The new Points formula With this in mind, we started by calculating the random chance of choosing the correct answer, by dividing the number of possible answers by the number of correct possible answers, for instance, a question with 4 different answers with 2 correct answers has a chance of 2/4 or 0.5. We then invert this chance to calculate the number of points awarded by the question, if the user answered correctly he will gain 1/0.5 points, 2 points. Another example is our most common case of a question with 4 possible answers and only one correct answer, using the same formulas, if answered correctly this question awards the user 4 points. In all cases, the user receives 0 points for choosing one of the wrong answers.

Using this method, questions that are hard to answer by random chance give much more reward to the users who can answer them correctly.

Context on the quizzes When given the possibility to answer a new quiz, the user has 3 attempts to answer the quiz in total, each with different questions within the same knowledge topics. Every quiz is marked with a quiz number, the first quiz the student answers is marked with quiz number 1, the second with number 2, and so on, this number represents the difficulty

of the quiz, equivalent to a quiz level. Each quiz contains all the topics the user has previously scanned, and is therefore progressively harder due to the increased quantity of content and broader scope, meaning the user has to memorize exponentially more content each time they answer a new quiz.

By analyzing the plots present in figure 5.9 we can see that the scores obtained during the second test performed with the ACM student chapter outperformed the test with the IEEE students in every aspect, be it across quizzes or attempts. The values depicted in the attempts plot are computed through the average of every attempt's score, which is simply the sum of the points given by the questions of each attempt. Likewise, the values shown in the quiz plot represent the average scores derived from the multiple trials associated with each quiz number.

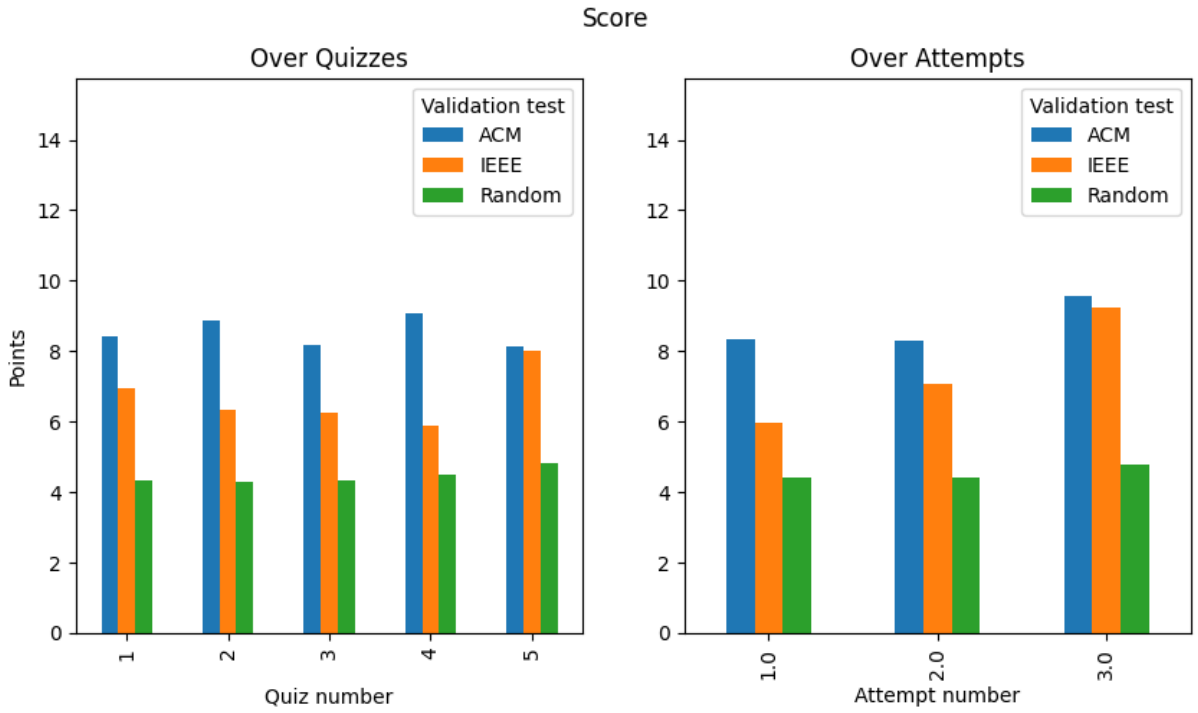

Figure 5.9: General scores of each quiz number and trial

In green, we can see the average score someone would receive by simply choosing a random answer in each question. The scales of both plots go up to around 15 points, this is the average maximum score each attempt can give to the user, we calculated this by adding the scores if a user would answer every question correctly. Because each attempt can have a different maximum score we used the maximum possible score out of every attempt performed and used it as the maximum value for the y-axis as a reference to visualize the overall performance of our users.

With this in mind, we can see that at first glance, our users did not perform all that well, but considering all the facts, such as the limited time frame of our validation tests that did not allow for much studying of the contents by the students, the overall difficulty of our questions, the difficulty of our later quizzes, as each quiz contains questions regarding all the previously studied content from the user, each quiz is progressively harder than the last. Finally comparing the performance of our users with the random reference scores, we observe that they had a very

Table 5.2: Data on the scores of each quiz

Quiz number	IEEE	ACM	Overall	Random
1	6.94	8.41	7.92	4.34
2	6.33	8.86	7.97	4.30
3	6.23	8.19	7.44	4.32
4	5.89	9.09	7.85	4.47
5	8.00	8.11	8.07	4.81

Table 5.3: Data on the scores of each trial

Trial number	IEEE	ACM	Overall	Random
1	5.96	8.32	7.57	4.39
2	7.05	8.31	7.73	4.42
3	9.25	9.55	9.45	4.78

admirable performance.

The random scores for each quiz and attempt sit around 4 to 5 points while our users were able to obtain around 6 to 8 points in the first test and 8 to 9 points in the second, while the maximum score sits around 15 points this performance is noteworthy.

We can also see that in both validation tests, the performance of the students is improving along with their attempts, scores obtained in the 3rd attempts are better than the ones in the 2nd and 1st attempts, especially noticeable in the IEEE test.

Regarding the scores obtained over the quiz numbers we can see that while there is no clear trend on the ACM test, the IEEE test was clearly on a downward trend from quiz numbers 1 through 4, on the last quiz the score suddenly jumps and matches the overall better scores obtained in the ACM test.

Table 5.4: Data for scores over quizzes and attempts

	IEEE			ACM		
Attempt	1	2	3	1	2	3
1	5.89	8.60	7.50	7.95	8.12	11.25
2	5.71	6.50	10.00	8.87	8.00	10.00
3	6.00	4.33	10.00	7.27	10.75	10.00
4	5.38	6.60	Nan	9.95	3.67	8.67
5	7.00	8.25	9.67	7.82	8.62	8.27

This sudden jump could be justified by a very specific reason that is, the IEEE test students gathered at the allocated classroom for the introduction of the activity after the 1 hour they were given to use the application, and while waiting for the arrival of the IscteSpots staff they might have answered to their last quiz using the additional attempts provided by the app as a group, using their group knowledge to obtain much better points that they could individually. As stated in section 5.5 we observed many individual students within this study and that might be an indicator of the overall lower scores in this study, it also featured a smaller sample size of only 8 students which probably reduced the amount of knowledge shared in group environments, as the possible groups that could be formed had much fewer members.

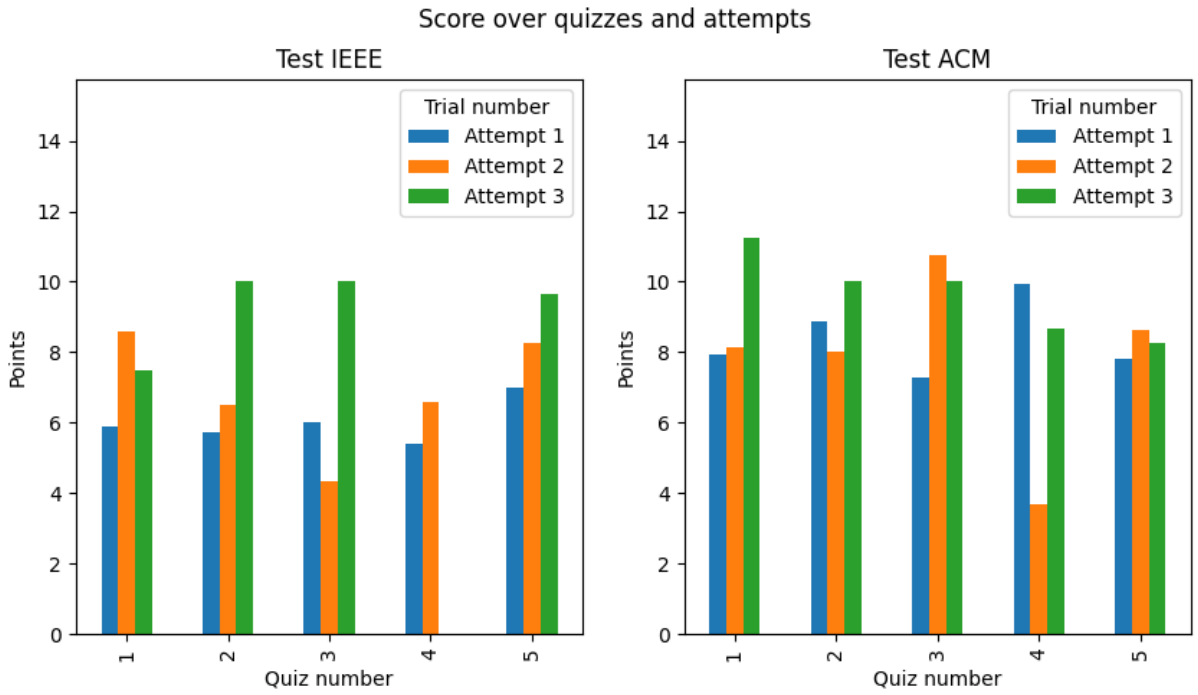

Figure 5.10: Scores over every quiz and attempt number separated by validation test

A deeper analysis can be made by looking at the plots present in figure 5.10 where the average scores for each attempt in each quiz number can be seen for each one of the two validation tests separately.

In general, with a few exceptions, we can see that the third attempt always tends to result in higher scores than the others.

5.6.3 Question categories

By analyzing the plot in figure 5.11 with data from table 5.5 we see all the question categories ranked by their difficulty, meaning the average scores obtained from questions within each category.

We see that on the IEEE test, the daily life category was the category with the most points per question, being the easiest in the test, while chronology is the one granting the least points, the hardest. On the ACM test, things differ, georeferencing is the easiest, while daily life is the hardest category.

This shift in difficulty, especially in the case of the Daily Life category being the easiest in one instance and the hardest in another, is justified by the fact that this category had few submissions in both validation tests. While analyzing our database, we found that only two questions were classified in this category. Such a small number of questions in a category leads to extremely volatile results and therefore this category is discarded in further analysis.

Besides the daily life category, the easiest category in both tests becomes the georeferencing and the hardest becomes the chronology category in the IEEE test and the dimensions category in the ACM test.

Before performing this analysis we were hopeful that there was one category that greatly

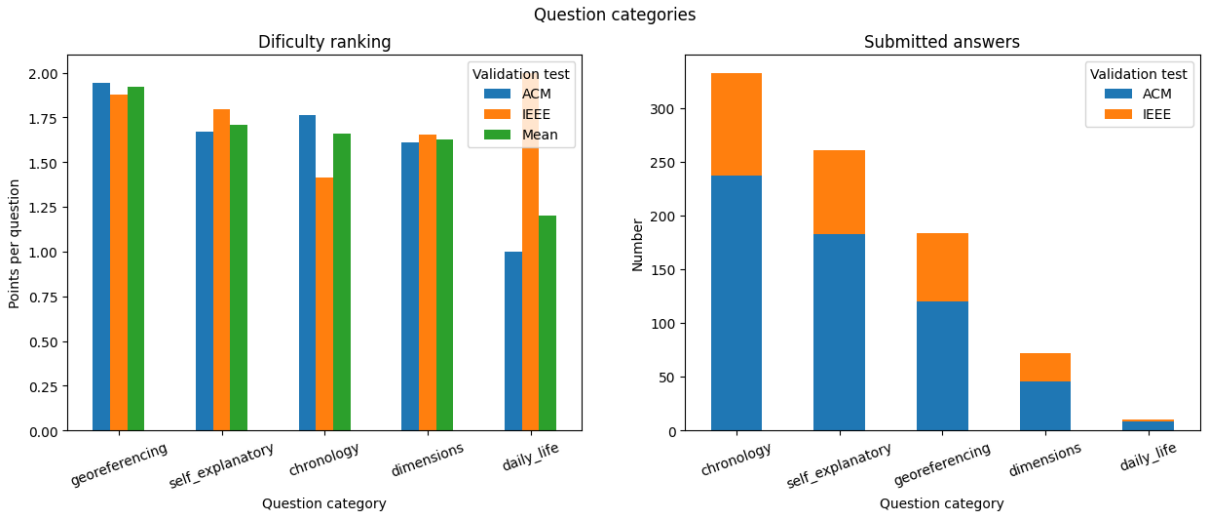

Figure 5.11: Difficulty of each question category

outperformed or underperformed the others, as no such case can be found, we can conclude that in general our question categories are balanced in terms of difficulty. The amount of questions is, in contrast not balanced at all, there needs to be created much more questions for the daily life category, to bring it up to the standards of the "chronology"and "self-explanatory"categories, as for the dimensions category, there are only a total of 11 questions present in our database, an aspect in need of improvement, and the final category, "georeferencing", there are a total of 39 questions present so the problem is the frequency of the questions, but since this is the category which awards the most points to the users, their frequency is balanced.

The case of the "georeferencing"category was deliberate, before conducting our validation tests our staff already knew the apparent easy difficulty of this category and fixed a quiz to always have a single question of this category, both to incentivize the physical exploration of the campus and to give a fighting chance to the less fortunate in the competition. Since this number would be fixed, no one player would benefit more or less from the questions in this category, keeping the overall balance of our game controlled.

Table 5.5: Data on each question category

Question category	Ranking			Amount of answers		Choice count
	ACM	IEEE	Mean	ACM	IEEE	
Georeferencing	1.94	1.88	1.92	120	64	3.12
Self explanatory	1.67	1.79	1.71	183	78	3.12
Chronology	1.76	1.41	1.66	237	96	3.40
Dimensions	1.61	1.65	1.62	46	26	2.72
Daily life	1.00	2.00	1.20	8	2	3.62

5.6.4 Questions

By computing the easiest and hardest questions in the validation tests, present in figures 5.6 and 5.7 we can identify potential weakness points in the quality of our quizzes and can use this knowledge to better the quiz for the future versions of the app.

We can conclude that questions revolving around personalities and their governmental activities are hard questions that the students struggled to answer correctly, 6 students tried to answer the question "Eduardo Ferro Rodrigues foi ministro de ...", which translates to "Eduardo Ferro Rodrigues was the minister of...", and failed which could indicate the lack of knowledge or interest coming to the students regarding governmental positions, or could indicate a flaw in our app in communicating such knowledge to them effectively and engagingly. In any of the above cases, the performed tests gathered a small sample size, so extrapolating conclusions on such specific aspects is I'll advised, but still these conclusions could serve for future investigation on question-set and their answers.

Table 5.6: Hardest questions

Question text	Points	Answers	Correct answers	Category
Eduardo Ferro Rodrigues foi ministro de...	0.0	6	0.0	chronology
O que é o Iscte-IUL?	0.0	5	0.0	chronology
Quando e constitui o INDEG?	0.0	5	0.0	chronology
O Iscte-IUL esteve integrado na Universidade Nova de Lisboa?	0.0	4	0.0	chronology
O Professor Luís Filipe Pereira foi ministro de...	0.0	4	0.0	chronology

Table 5.7: Easiest questions

Question text	Points	Answers	Correct answers	Category
Quando se criou o Criação do Vitruvius FABLAB?	44	17	11	chronology
A que se refere esta imagem?	30	16	10	self explanatory
Quando foi inaugurado este edifício?	30	13	10	self explanatory
A inauguração deste edifício permitiu melhores condições de funcionamento. Qual é a área deste edifício?	27	12	9	dimensions
A se refere esta imagem?	27	11	9	self explanatory

5.6.5 Takeaways

Concluding this analysis, we noted that the scores obtained by the students throughout the two separate validation tests are indicative that they are improving their knowledge of the University's history due to the increasing difficulty of each quiz and the overall stability of the obtained scores despite this increased difficulty.

The multiple attempts provided possibilities for the students to reinforce their knowledge and improve their scores by revisiting contents and questions related to the same topics as their respective quizzes.

The validation test with a bigger sample size outshone the performance of the smaller test, potentially highlighting the benefits and advantages of group play for individual performance, i.e. multiple people completing quizzes and discovering new locations faster than the individual

ever could, the multiple members exploring the questions in the quizzes and familiarizing themselves with the contents before spreading their knowledge.

5.7 Summary

Overall these validation phases were crucial in crafting a refined experience for our users, they helped achieve and maintain a professional level of quality.

The initial interviews allowed for early validation of the proposed application. The Open-day event allowed for early validation of the physical exploration and qr code scanning aspects, while the two tests with the IEEE and ACM student chapters enabled the refinement of the experience and gathering of such important data that positively validated the experience and concept of an application that connects the users to the history of a University.

The redesign performed after contact with the Communications Office greatly elevated IscteSpots's visual appeal and consistency.

The field observations gave us invaluable insight that simply could not be gathered by other means.

Finally, the performed statistical analysis on the performance data verified the effectiveness of the application in bridging the gap between the students and the heritage of the institution.

Chapter 6

Conclusion

Contents

This chapter summarizes all the work developed in this research. In Section 6.1, it is stated the conclusions that are taken from the developed work. Section 6.4 identifies the limitations of the work and elaborates research opportunities for the given route generator algorithm systematized.

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Chapter 6
Conclusion

6.1 Conclusions

This dissertation presents the development and iteration process involved in the conception of a mobile cross-platform application from beginning to end, extensively documented using BPMN and other diagrams. This research focuses on how we were able to utilize this cross-platform application to bridge the gap between the campus community and their university's alma mater, its history, and its heritage.

With this in mind, two research questions are proposed, RQ1 and RQ2, a carefully crafted search string was applied to the Scopus repository, where 85 papers were obtained and after applying our inclusion, exclusion criteria, and quality assessment 5 remained.

Regarding RQ1 "Can a gamified mobile application connect students with the past of their university?", we conclude that our application can create such a bridge, our data from both validation tests highlights the good performance of the students concerning their knowledge of the University's history despite the limited time frame that did not promote content exploring and studying. We believe that with a bigger timeframe, i.e. an event spanning multiple days or weeks, with compensation for the winners of the competition, the heritage of our university would spread effectively.

Regarding RQ2 "Can a mobile application increase public interest in a university's event?" we conclude that a mobile application can effectively increase public interest in a University-related event. Through our validation tests, even though the students received participatory prizes such as ISCTE-branded t-shirts, pens, and cups these were not communicated beforehand. This decision was made intentionally to avoid influencing their behavior during the testing process. By not revealing the presence of these prizes beforehand, we ensured that the gathered test subjects were purely interested in participating in the improvement and validation of a mobile application devoted to their University's history. Therefore we conclude that such an application, if well marketed and in the context of a bigger event would aid in increasing engagement and general public interest.

On another note, mobile app development presents a multitude of challenges, ranging from platform fragmentation and varying device capabilities to optimizing user experience across different screen sizes and addressing security concerns. Balancing functionality with performance, ensuring seamless offline capabilities, navigating through app store guidelines, and maintaining user engagement through frequent updates further compound the intricacies.

Within this dissertation, we described our journey in the development of the IscteSpots app where the adoption of cross-platform development enabled us to effectively tackle the aforementioned challenges. The primary advantages that we can present, with the aspiration of inspiring fellow researchers and professionals confronted with mobile app development, are as follows:

Enhanced Code Reusability and Resource Efficiency – Writing code once and deploying it across multiple platforms substantially reduced our development timeline and efforts, while

also diminishing the necessity of maintaining distinct code bases.

Expanded audience reach –By targeting multiple platforms, we were able to engage users across various operating systems whether they preferred mobile apps (iOS and Android) or web browsers on Windows, MacOS, or Linux.

Consistent user experience – Our ability to provide consistent user interfaces and functionality across different platforms ensured a seamless and harmonious user experience.

Throughout the development process, Flutter allowed us to rapidly iterate over concepts and features, Dart's flexibility and user-friendliness accompanied by Flutter's vast online community with packages for practically every developer challenge, along with a wealth of tutorials including those from the Flutter team detailing their framework's different widgets and their uses further emphasized its excellence.

To validate IscteSpots, we conducted tests using two assessment instruments: the NASA Task Load Index, and the Mobile Application Rating Scale. Twenty-two subjects participated in these tests as surrogates of the final users. The feedback garnered from these validation tests was very positive, highlighting the high quality of the IscteSpots app. We credit this success to a combination of factors: (i) the aforementioned potentialities inherent to Flutter/Dart itself, (ii) the iterative development approach with users' feedback in each cycle, (iii) the shared understanding of the intended app behavior, where the BPMN models were a cornerstone and, last but not least (iv) the adoption of an automated CI/CD pipeline with embedded quality assurance tools.

The presented work and its findings were published and presented in the A-Mobile workshop of the 38th IEEE/ACM International Conference on Automated Software Engineering (ASE 2023) conference, The published article focused on our development approach and named Cross-platform mobile app development: the IscteSpots experience, can be found here.

6.2 Limitations

There were multiple possible limitation factors throughout our development journey, but the main limitation factor was the small sample size of the validation tests, due to time limitations, only two validation sessions were performed, totaling 22 students, which may not be indicative of the entire campus community.

The low amount of articles analyzed in the systematic literature review phase of our work, possibly including results from other sources or changing the search string to include more and more similar work are possible solutions.

The second is the low amount of interviews performed, more interviews and even user studies in the beginning phases of research could have accelerated user interface development and would allow for an even better final experience.. Also, these were the first and only instances the interviewer conducted interviews, with a more experienced interviewer more information and ideas may have been exchanged during each interview and more feedback may have been gathered. The fact that the first interview was much shorter than all of the others may be a consequence of this inexperience.

6.3 Ongoing work

Nei2023 In the last month of the development of this dissertation project our staff was presented with the possibility of representing our research center ISTAR in the European Researchers Night in Lisbon, a yearly event spanning many European countries focused on spreading knowledge, providing visibility for researchers and generally promoting science, with this years mote being "Ciência para Todos – Inclusão e Sustentabilidade"which translates to "Science for everyone - Inclusion and Sustainability".

We accepted the opportunity and once more benefited from Flutter's flexibility, extensibility, and cross-platform approach, where within a single week we were able to recycle our app into a new version used within the event.

It was appropriately named ScienceSpots instead of IscteSpots, since the event called for a much more science-related activity it was decided that our topics would be converted into the main fields of Science like physics and chemistry, mathematics, human and social sciences, technology, literature, architecture and more. This new version was stripped of some features from its previous self, the timeline and the flicker album viewer were removed while the other aspects were adjusted for the event. New puzzles were set up on our backend, each one focused on a science field instead of a physical space, this connection between puzzle and physical location disappeared and now the puzzles were a new means of gathering additional points, a solution we found to the limitation of our new paradigm.

With such broad topics and with the organization of the event itself we would constraint ourselves if a QR code was configured with a predetermined physical location, with our new approach where the puzzle is not an indication of where the QR code is located and simply an additional task for the user, we gained more flexibility throughout the event, we were able to adjust the location of the QR code "on the fly"to be able to increase their visibility and engagement rate.

We used Bing Image Creator to generate the images used in the puzzles, each depicting a field of science, with a very consistent theme and color scheme to create a new engaging experience for our event users.

6.4 Future work

The application's effectiveness in communicating the university's heritage could be put to the test by supporting an official event spanning multiple days or weeks, as it was intended initially, allowing for comparison of the knowledge of a user before and after a long period of use with the app.

One of the suggestions received in the interviews was that the app could be expanded to not only communicate the historical contents but also help connect the students more with the physical space, giving them directions and maps, possibly utilizing some form of location detection, GPS for the outdoors and Bluetooth beacons for indoors for example.

The contents and their topics could be reworked, refined, and possibly even filtered to focus on the learning path the users take through the app.

A deeper usability study could be performed on our web and mobile applications, creating an understanding of how they are used and how they could be optimized and improved to better fit our users' needs, as *Mobile apps likely face rejection from users if these are not user friendly*[15].

As proposed in [18], a usability analysis could be performed, using the logs of our application, with the intent of segmenting our user base, leveraging the power of neural networks, similar to the one performed by [10], and creating features with this knowledge in mind. Analyzing the segmentation of our user base could help further the development of new and current features we could discover what contents are most consumed and which need focused improvement Additionally, analyzing the behavior within our timeline could enable us to conclude how much our software is motivating connections between the students and the university's history.

The European researcher's night proved that our developed application and the framework used for its development are very flexible, in future research, this adaptability could enable us to reuse it as a base to support other events, for example, the Iscte's Open Day and FISTA. Most of its functionality could be abstracted so that an open-source template is created and provided to other universities or organizations for them to adapt, expand, and benefit from, enabling them to foster their history and heritage within their community. Tutorials or guides could also be developed and provided as part of this open-source contribution, easing the process of adapting and expanding our template.

Finally, we have almost four thousand international students within our campus, therefore expanding the set of languages supported by IscteSpots could prove beneficial as it would increase its adherence by the community. To achieve this, we could expand the current internationalization approach to support more languages by making use of emerging Large language models to translate the base application and the contents that populate it such as the timeline and quizzes.

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Appendix A

Application screens

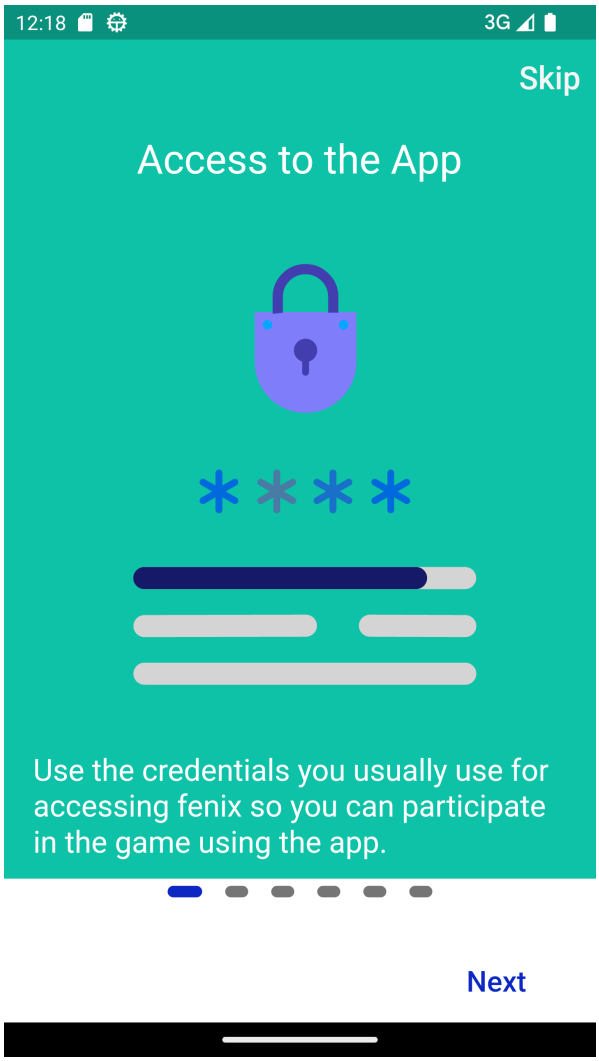

Figure A.1: Onboarding page of the app: access - 4.7.1

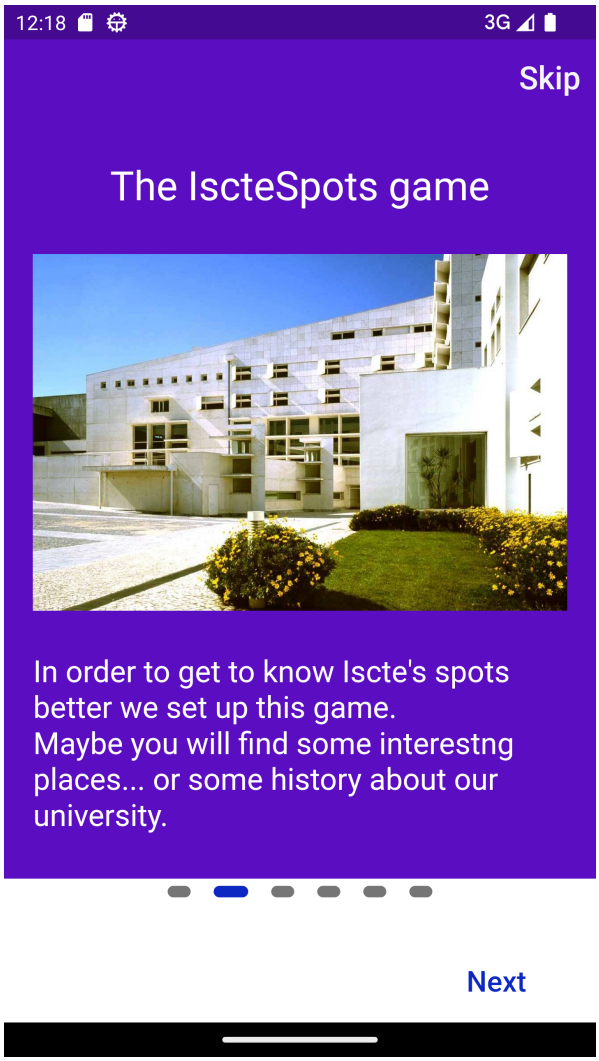

Figure A.2: Onboarding page of the app: the game - 4.7.1

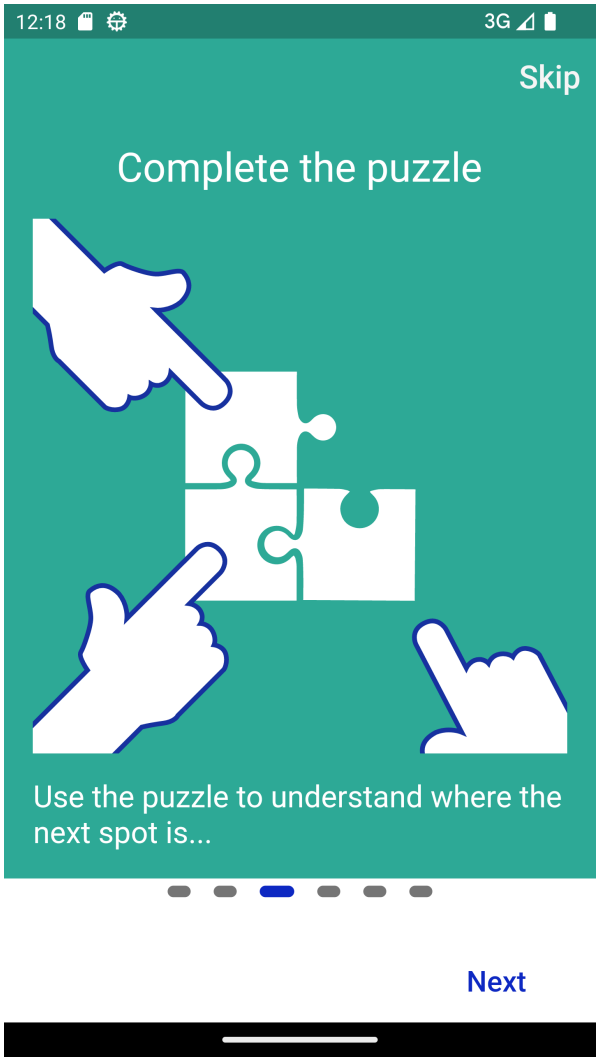

Figure A.3: Onboarding page of the app: puzzle - 4.7.1

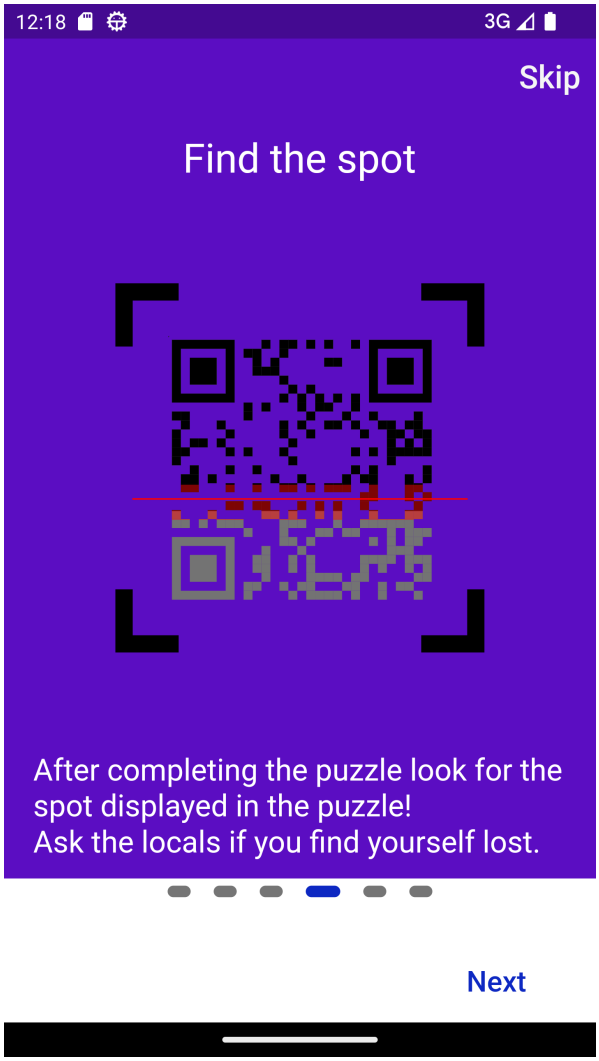

Figure A.4: Onboarding page of the app: qr_code - 4.7.1

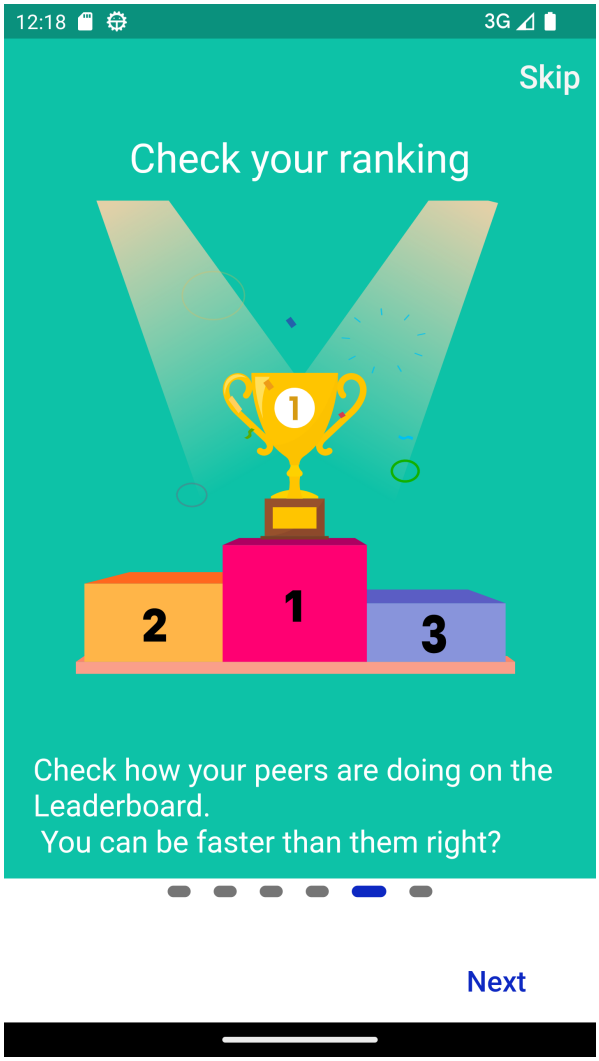

Figure A.5: Onboarding page of the app: leaderboard - 4.7.1

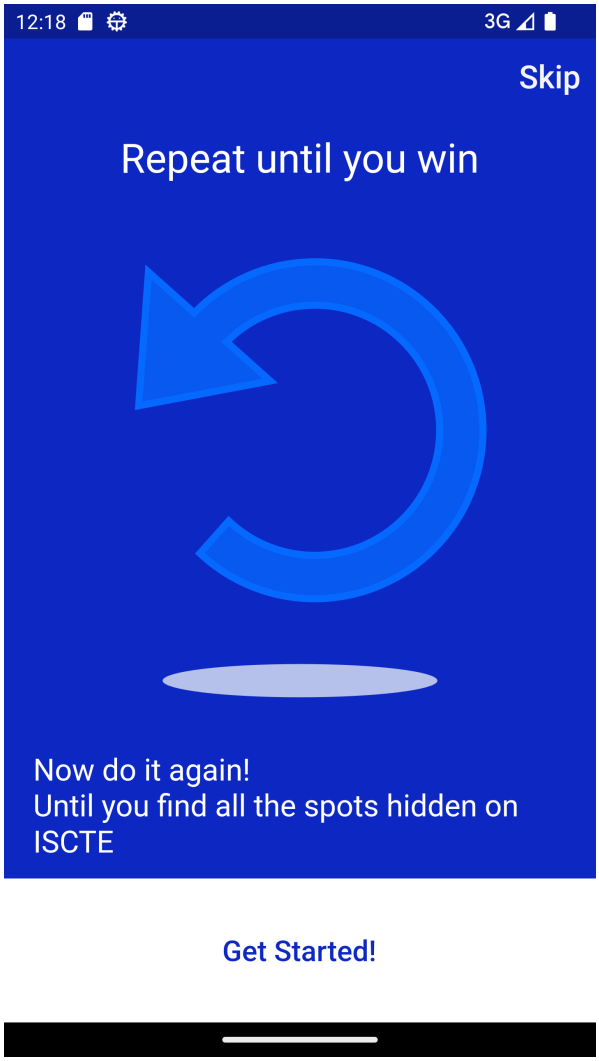

Figure A.6: Onboarding page of the app: repeat - 4.7.1

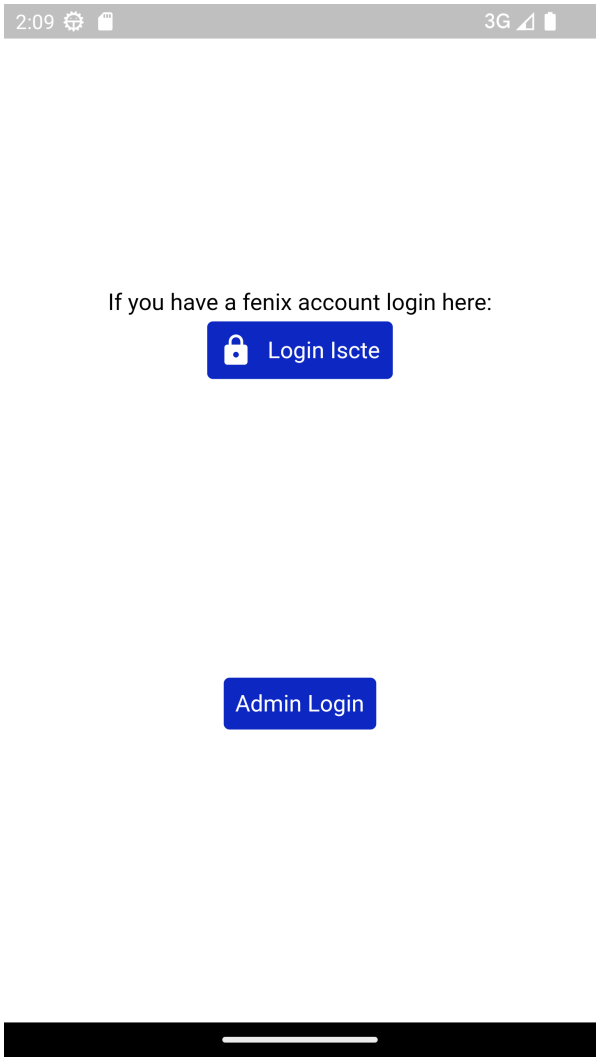

Figure A.7: Login page of the app - 4.7.2

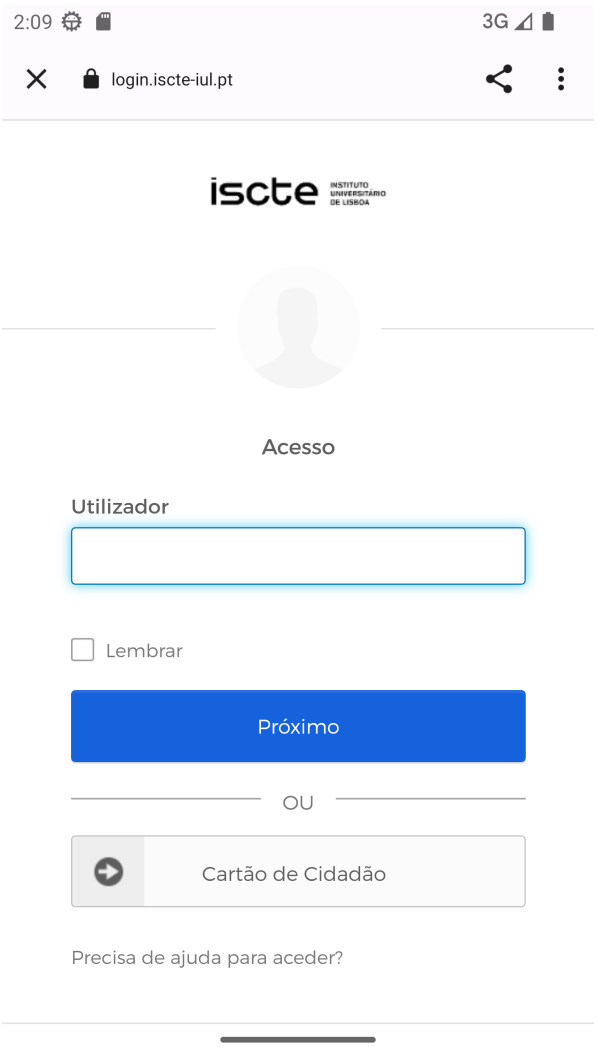

Figure A.8: Login page of the app - 4.7.2

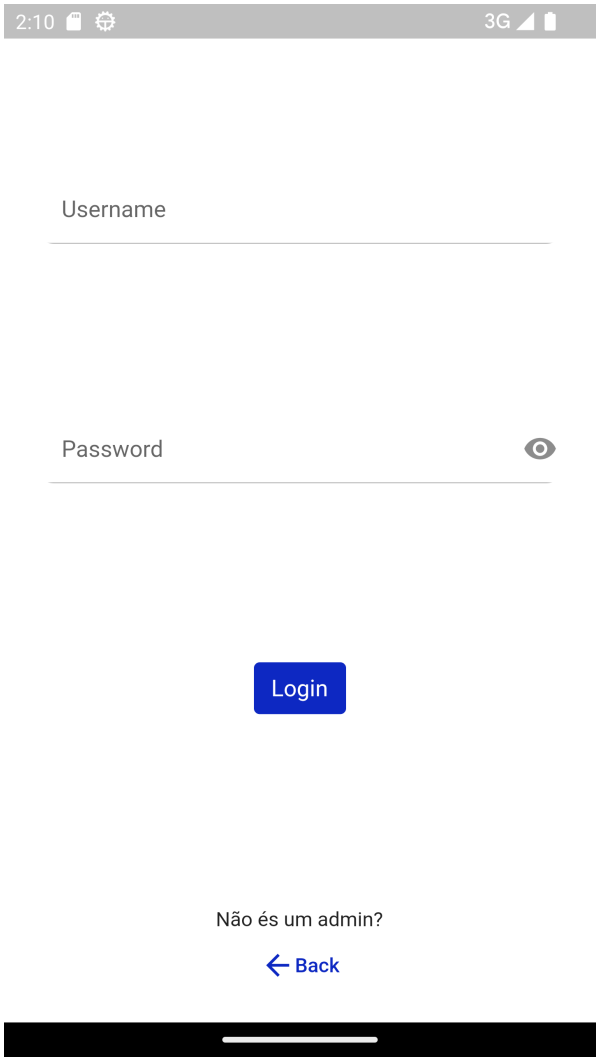

Figure A.9: Login page of the app - 4.7.2

Figure A.10: Home page puzzle - 4.7.4

Figure A.11: Home page recommending choose spot - 4.7.4

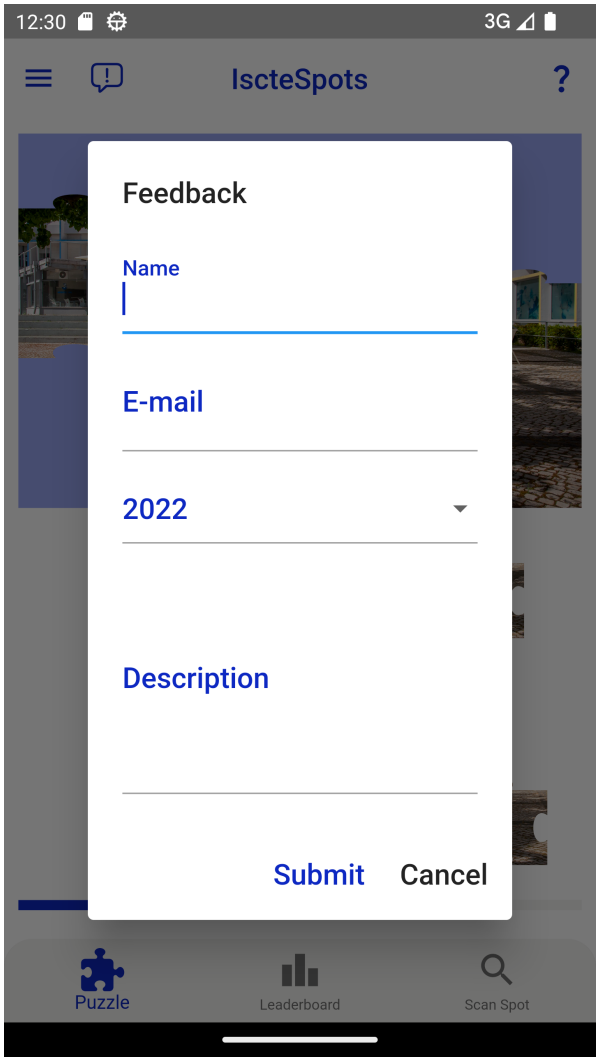

Figure A.12: Home page feedback overlay - 4.7.4

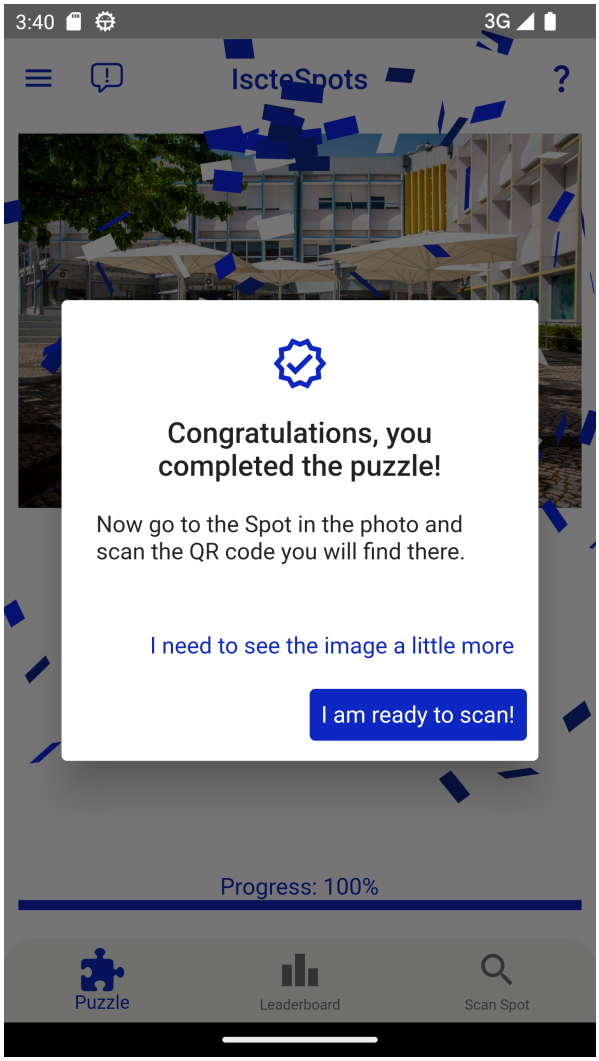

Figure A.13: Home page scan spot recommendation - 4.7.4

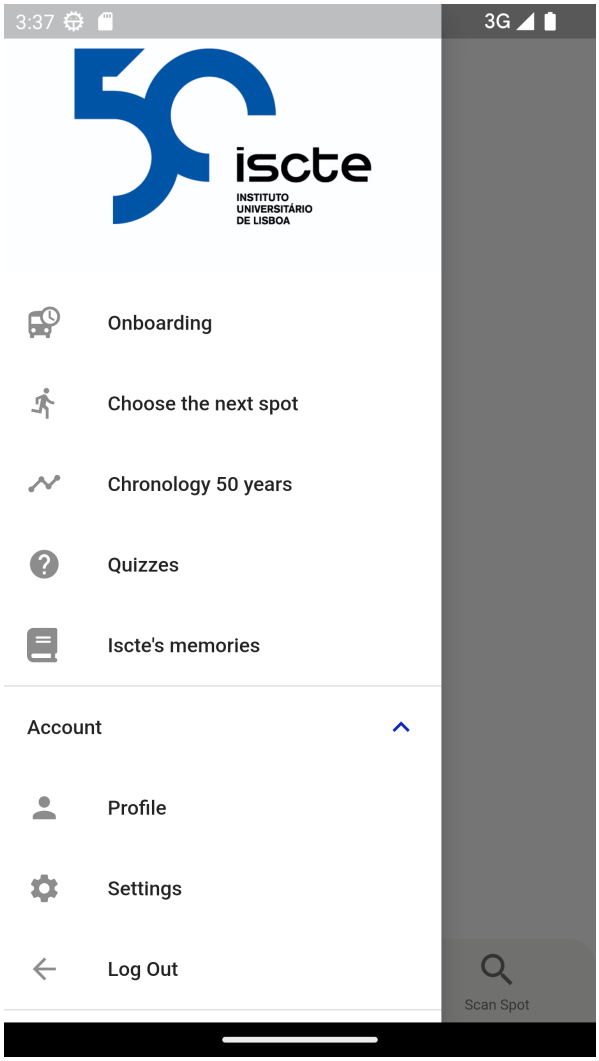

Figure A.14: App drawer - 4.7.3

Figure A.15: Scan a spot page - 4.7.4

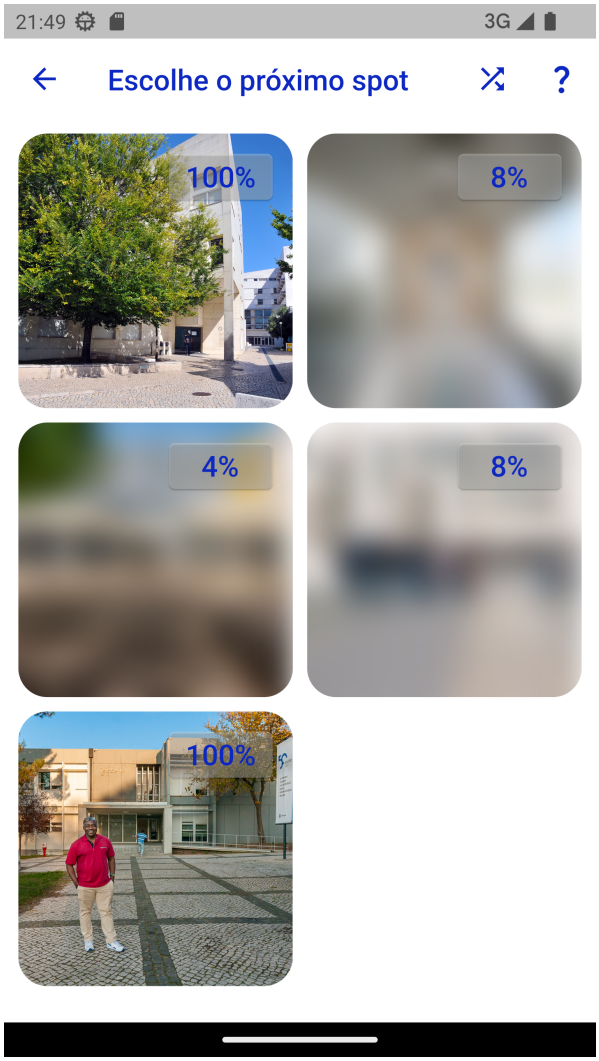

Figure A.16: Next spot page - 4.7.5

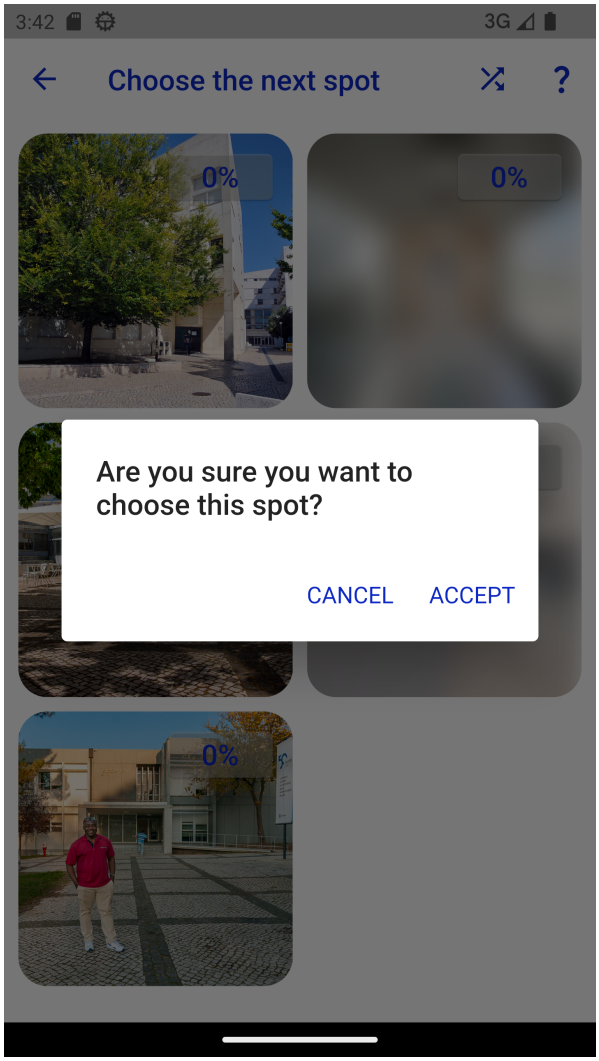

Figure A.17: Next spot confirm dialog - 4.7.5

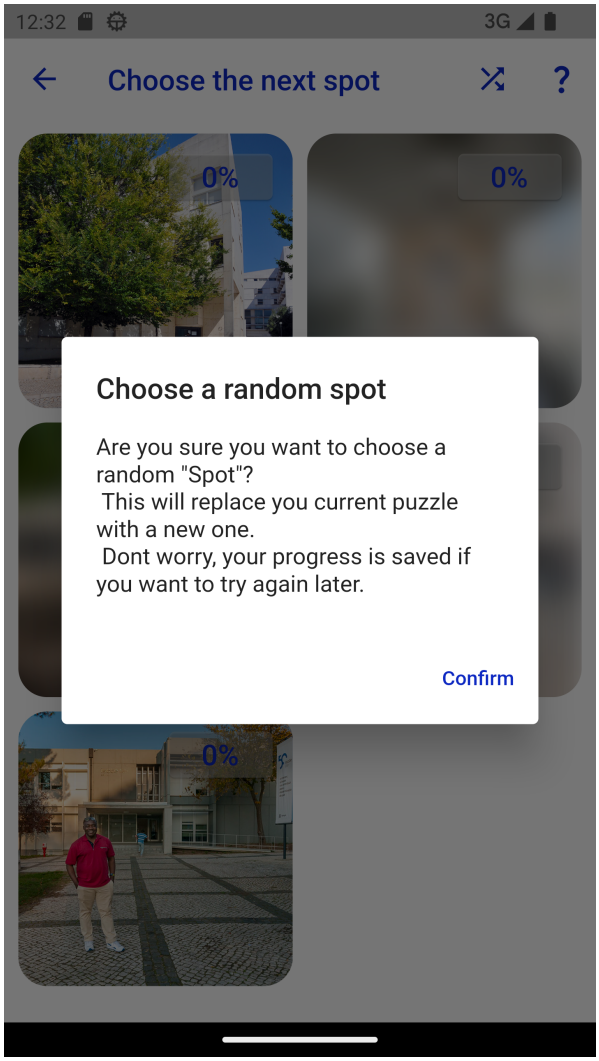

Figure A.18: Next spot random dialog - 4.7.5

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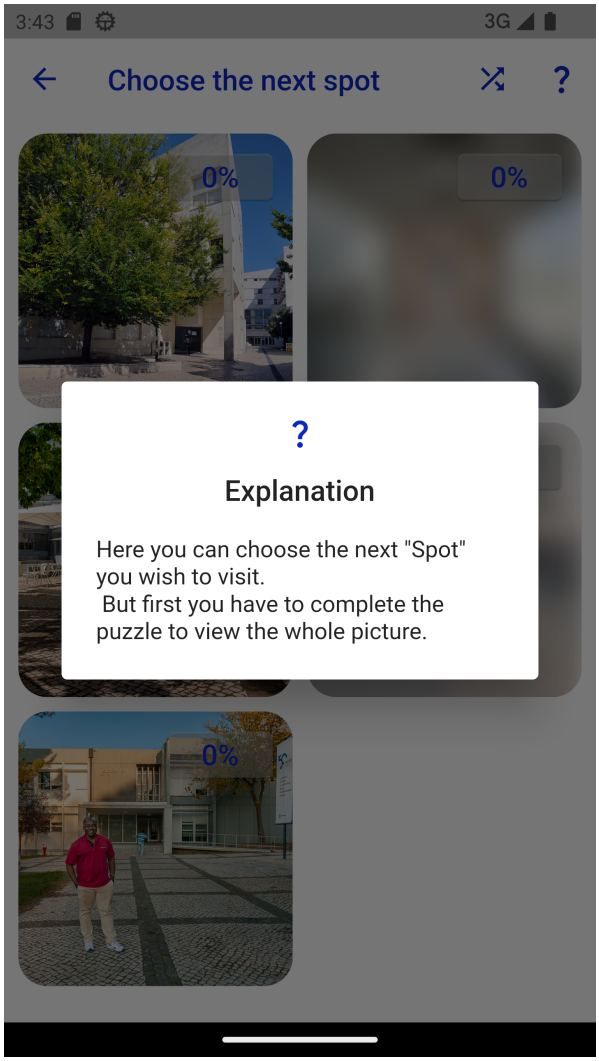

Figure A.19: Next spot explanation dialog - 4.7.5

Figure A.20: Scan spot page - 4.7.6

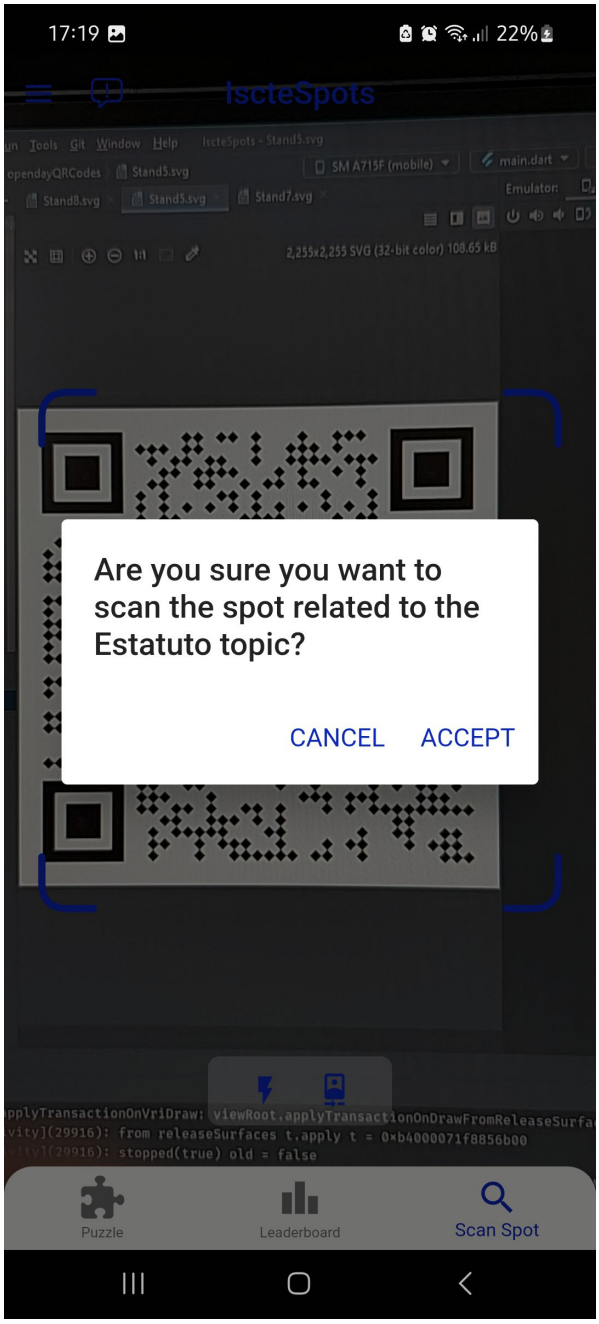

Figure A.21: Scan spot visit dialog page - 4.7.6

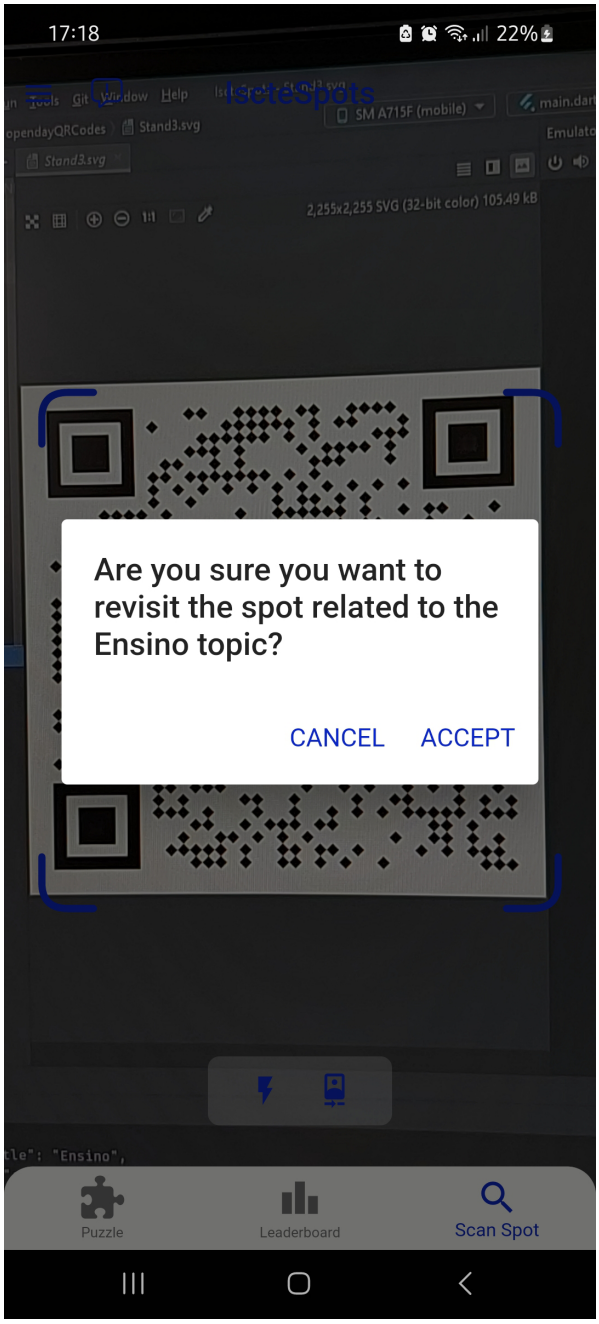

Figure A.22: Scan spot revisit dialog page - 4.7.6

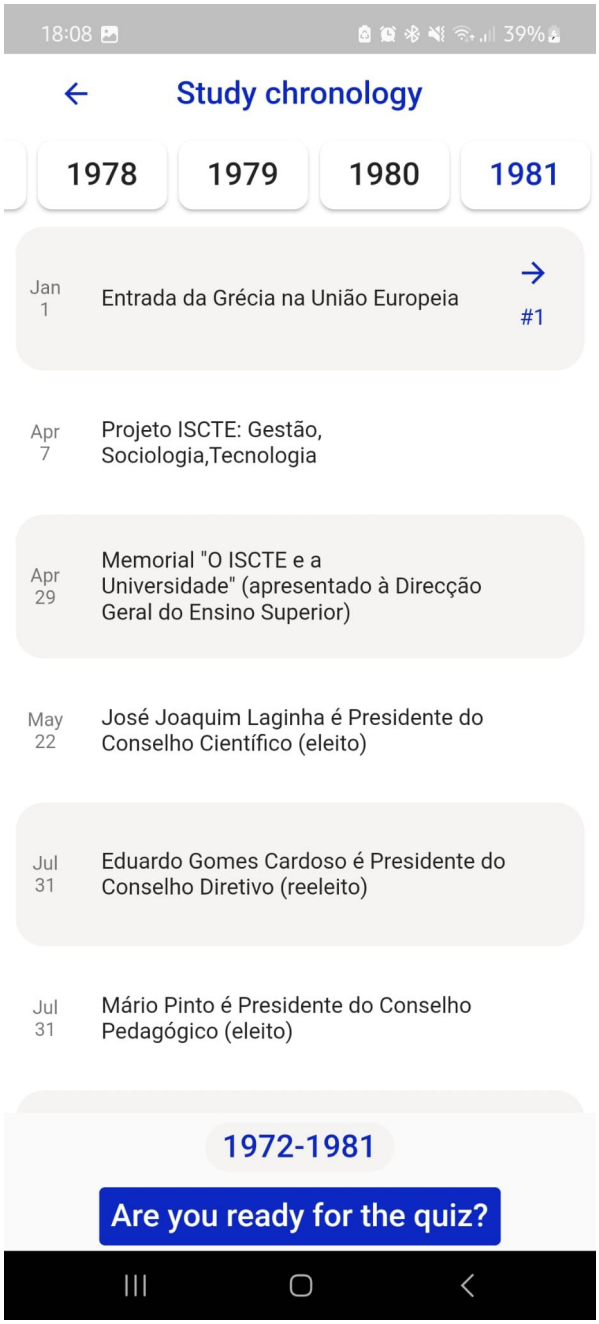

Figure A.23: Study timeline page - 4.7.7.1

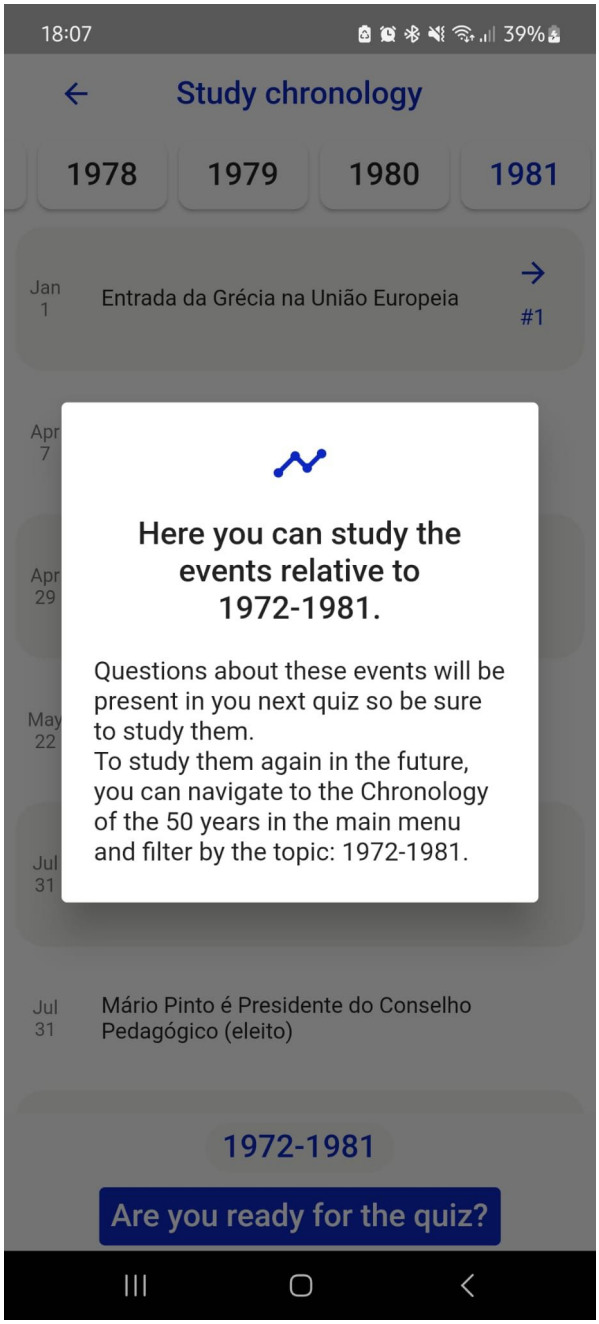

Figure A.24: Study timeline explanation dialog page - 4.7.7.1

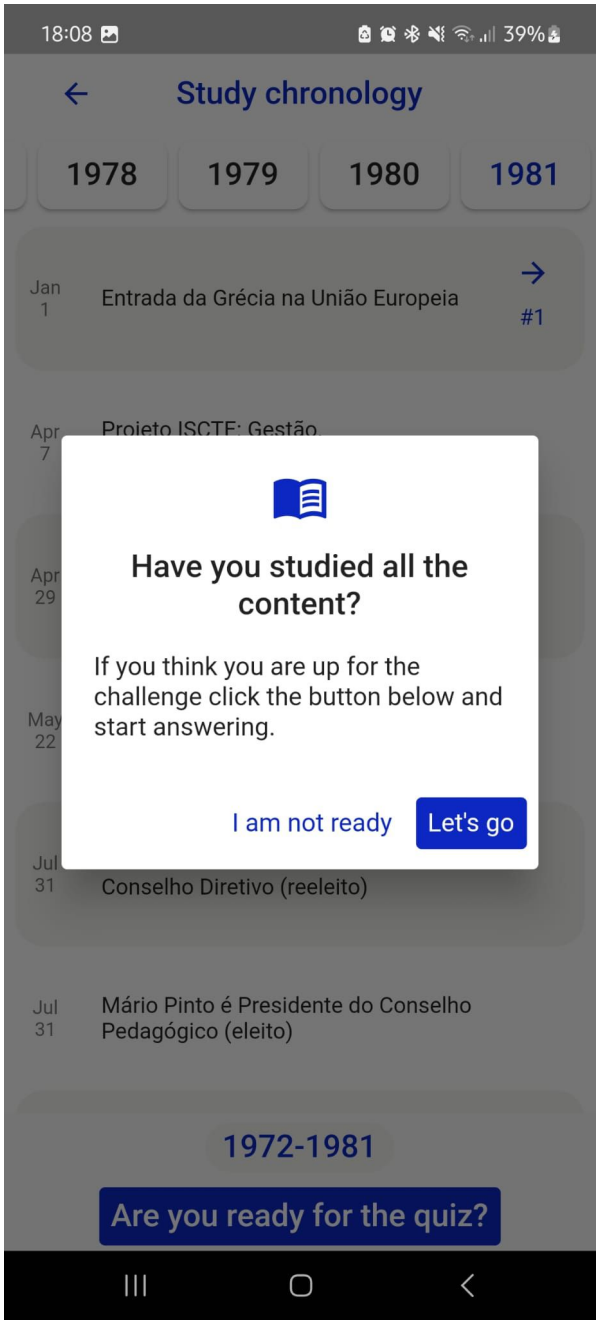

Figure A.25: Study timeline answer quiz confirmation dialog page - 4.7.7.1

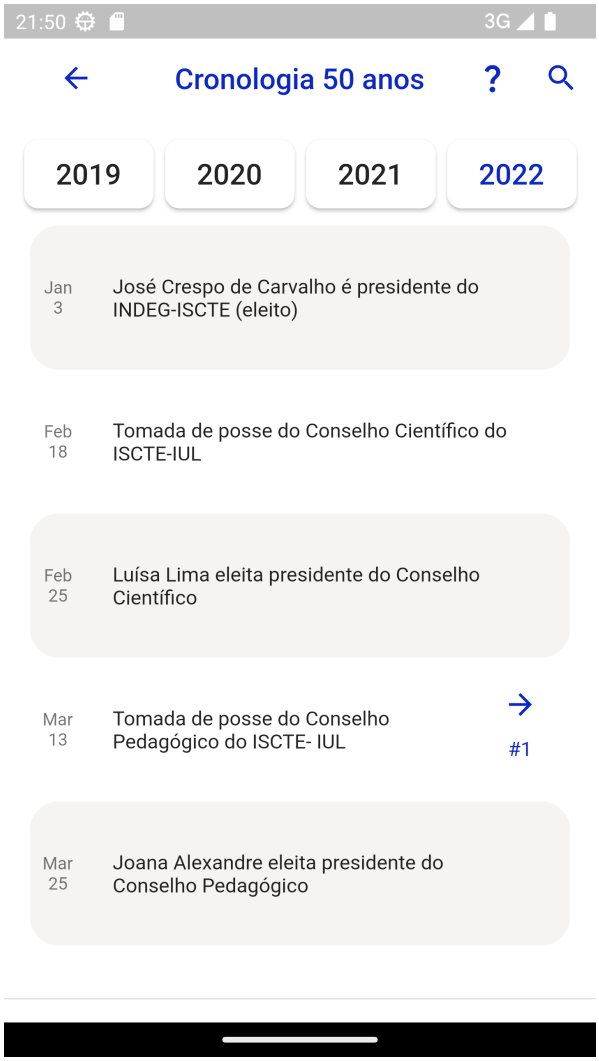

Figure A.26: Timeline page - 4.7.7

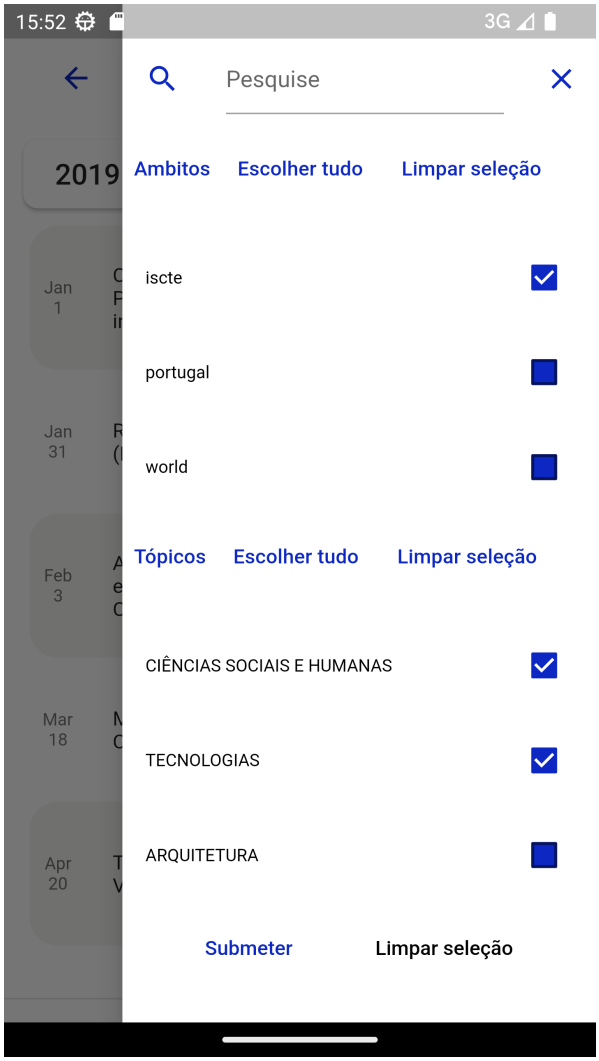

Figure A.27: Timeline filter overlay - 4.7.7

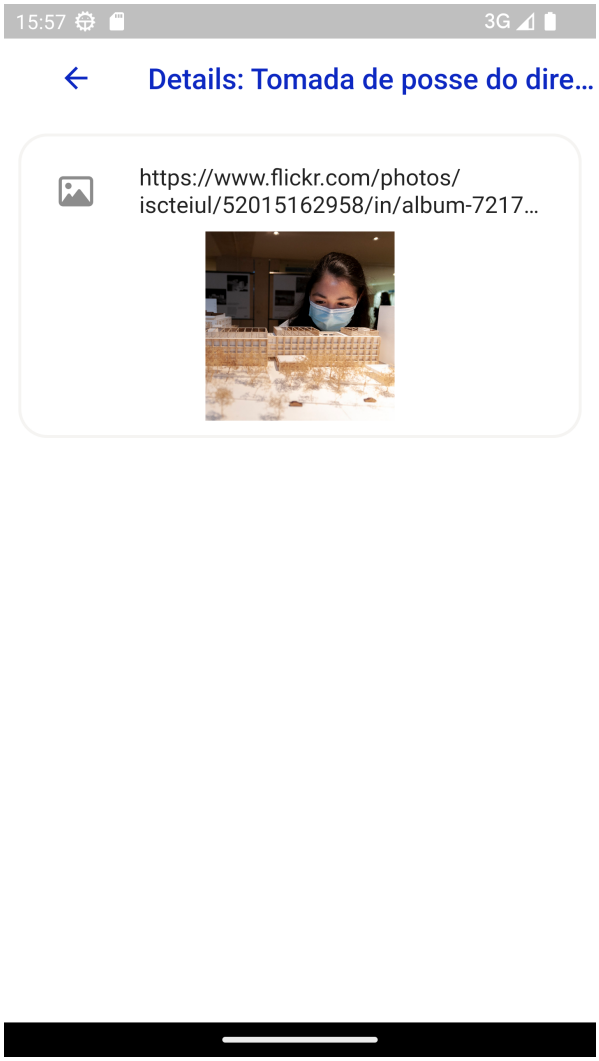

Figure A.28: Timeline event details page - 4.7.7

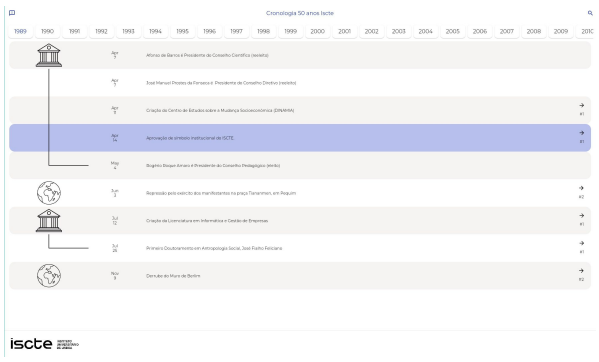

Figure A.29: Web timeline page page - 4.7.7

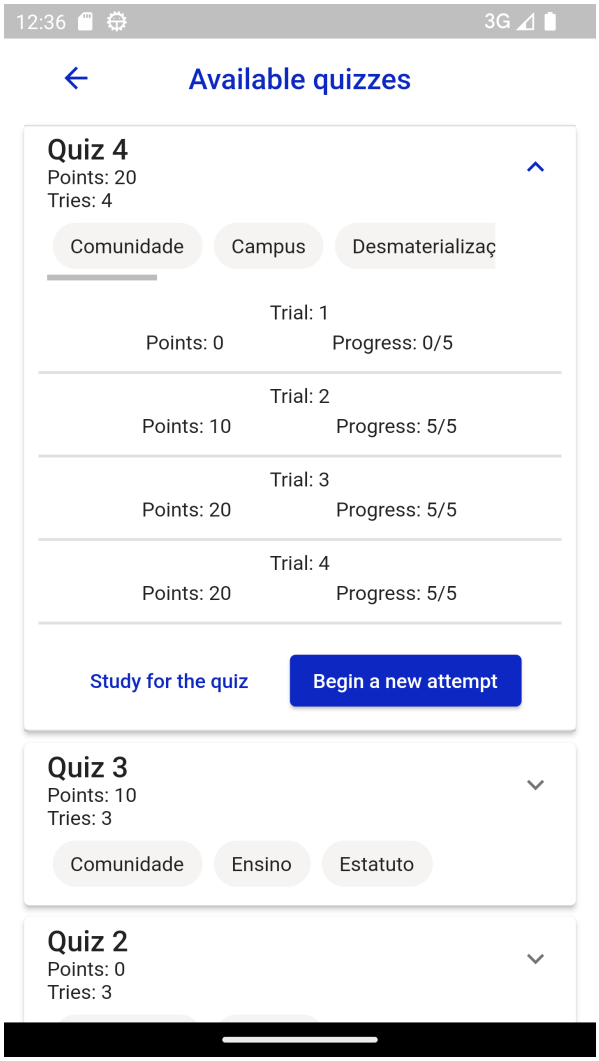

Figure A.30: Quiz list page - 4.7.8

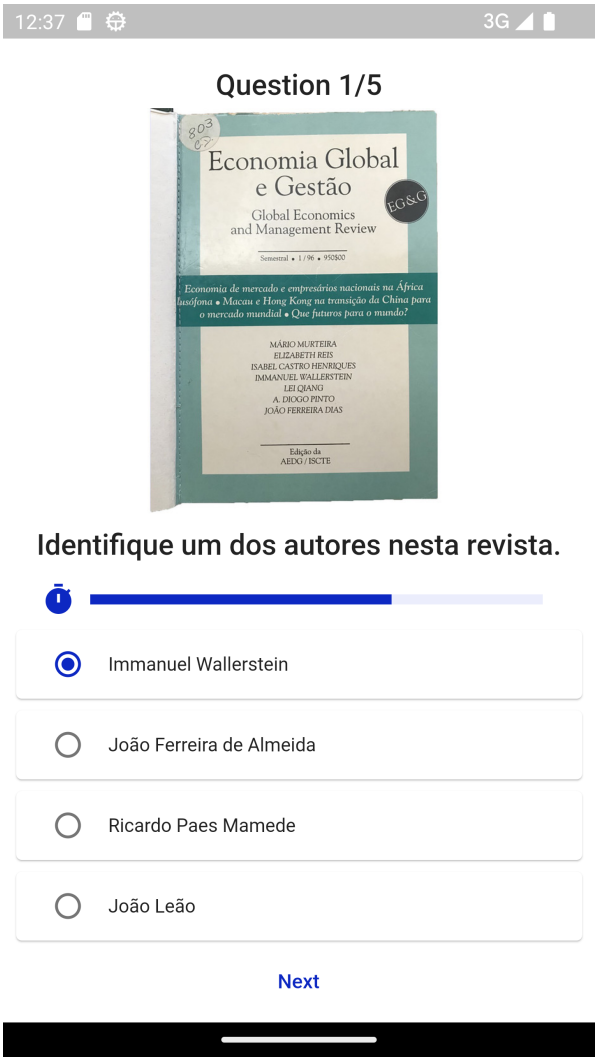

Figure A.31: Quiz question page - 4.7.8

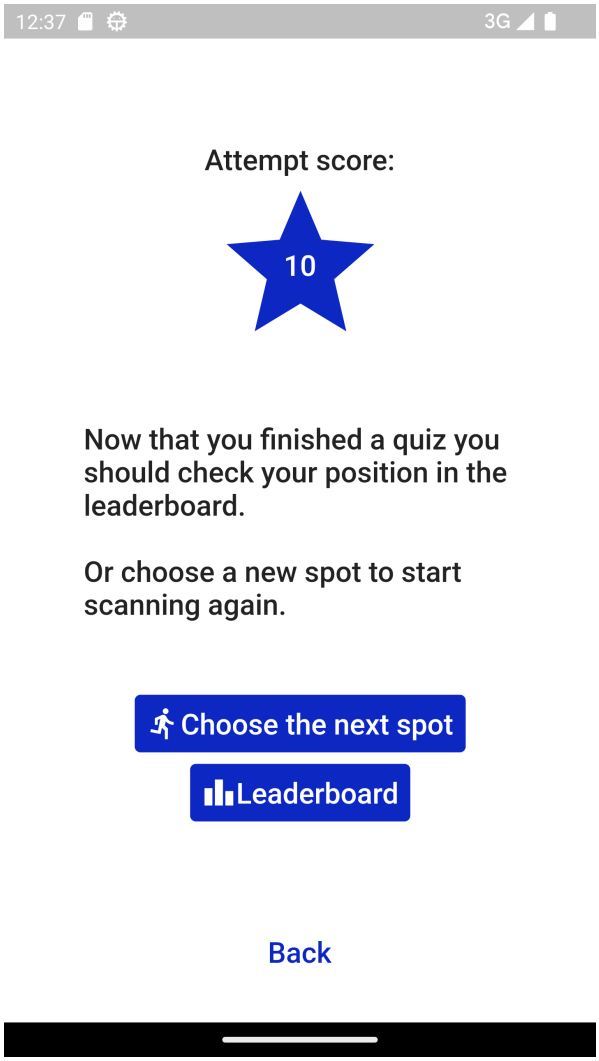

Figure A.32: Quiz complete page - 4.7.8

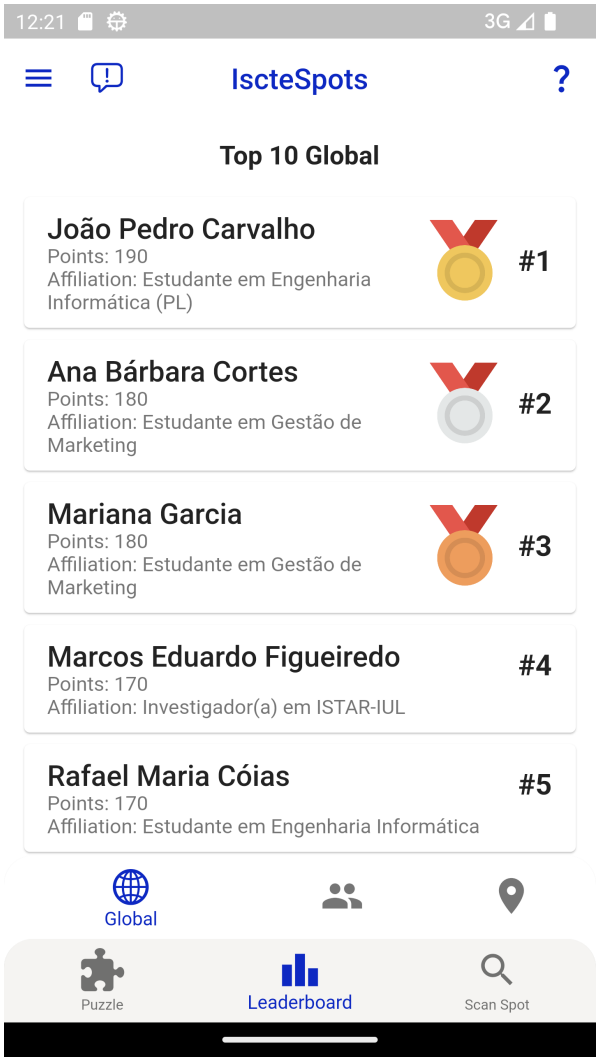

Figure A.33: Leaderboard global page - 4.7.9

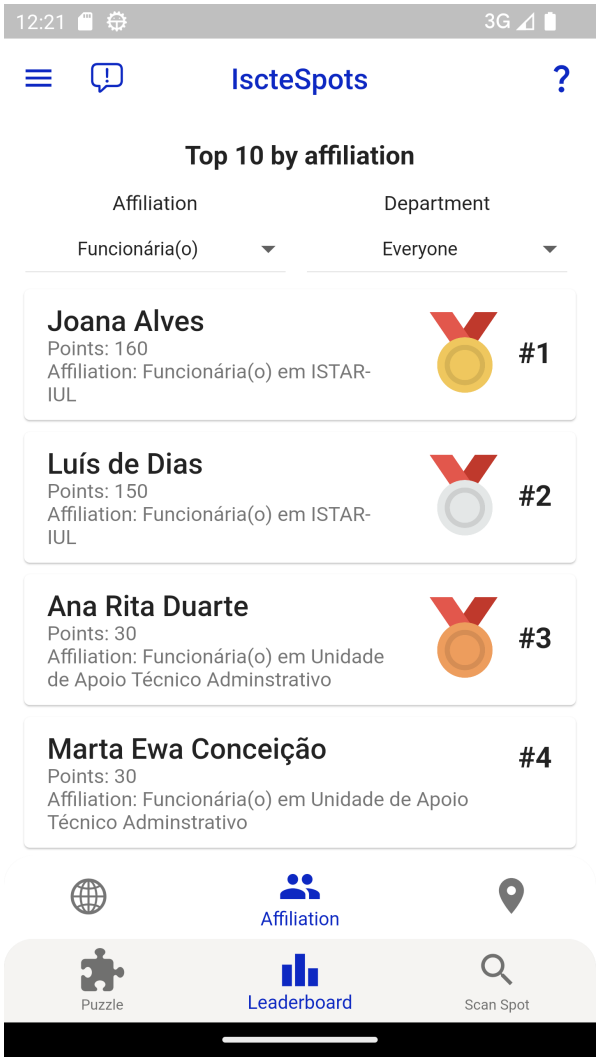

Figure A.34: Leaderboard affiliation page - 4.7.9

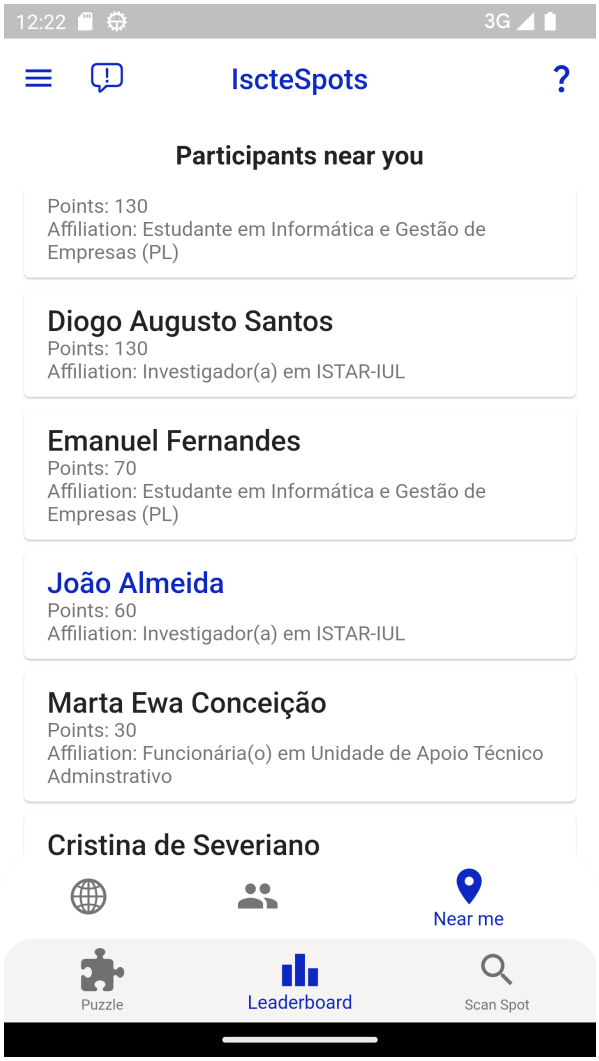

Figure A.35: Leaderboard near me page - 4.7.9

Figure A.36: Iscte's memories albums page - 4.7.10

Figure A.37: Iscte's memories photos page - 4.7.10

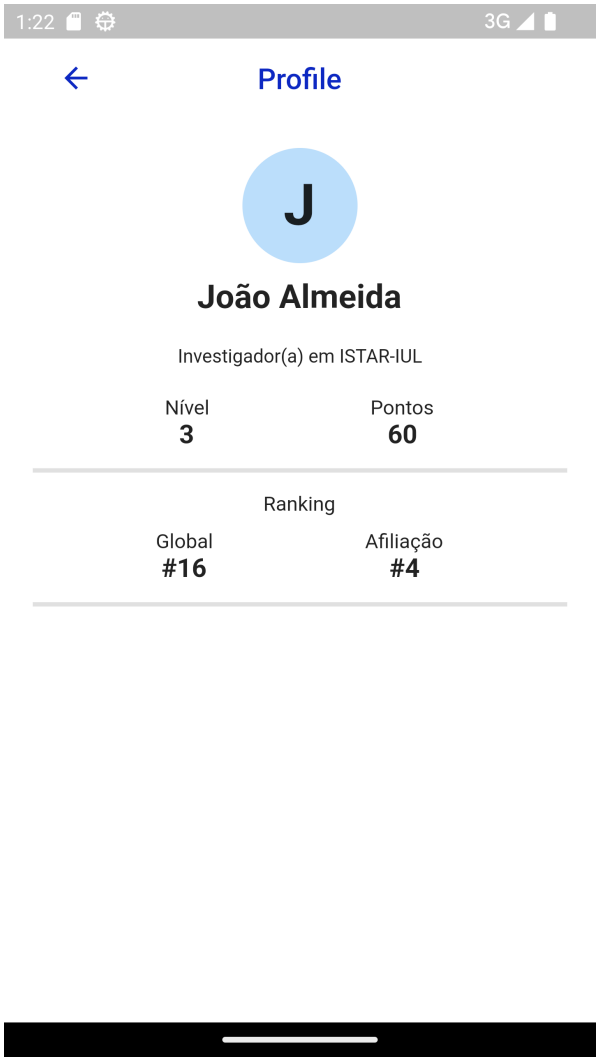

Figure A.38: Profile page - 4.7.11

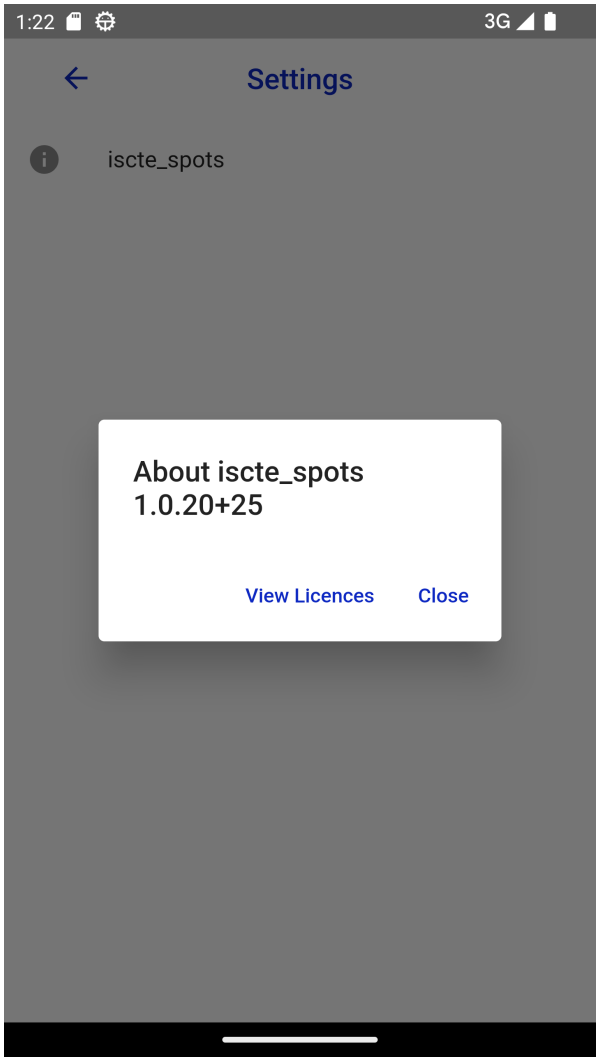

Figure A.39: Settings page - 4.7.12

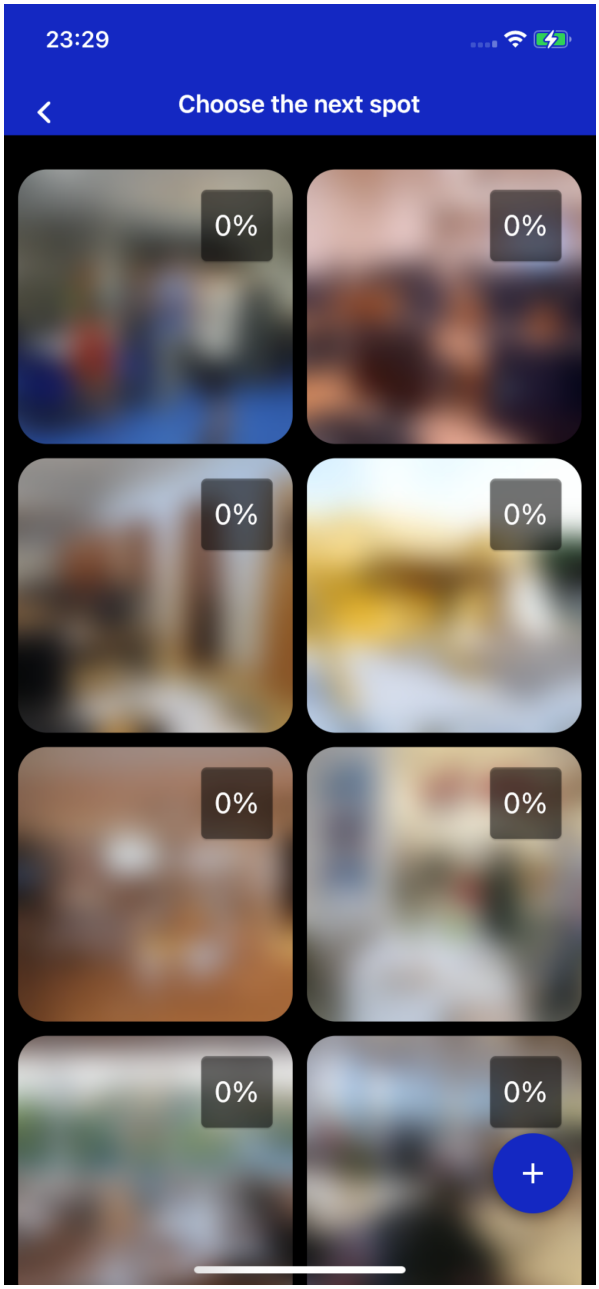

Figure A.40: Old choose next spot page

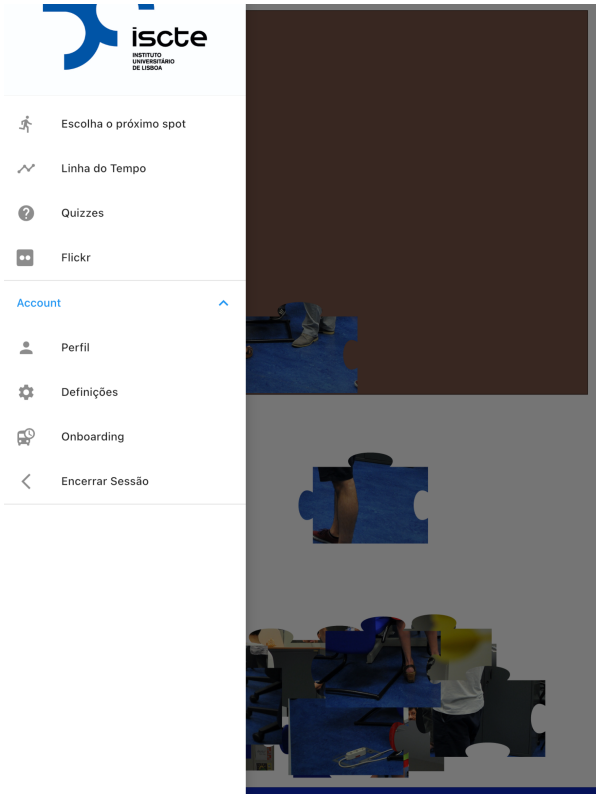

Figure A.41: Old drawer

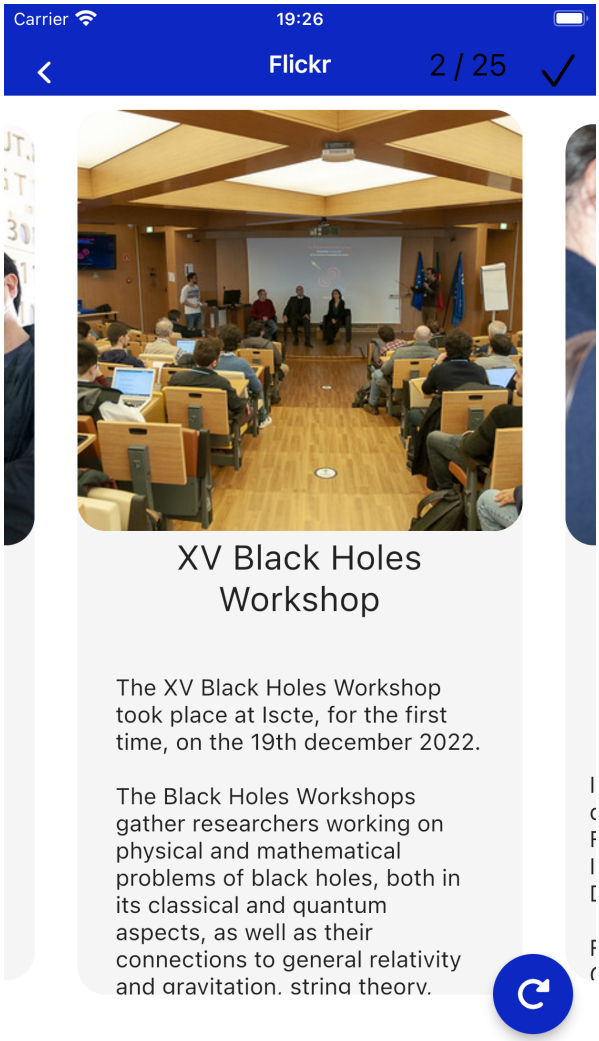

Figure A.42: Old Flickr/Iscte-IUL memories page

Figure A.43: Old album inside Flickr page

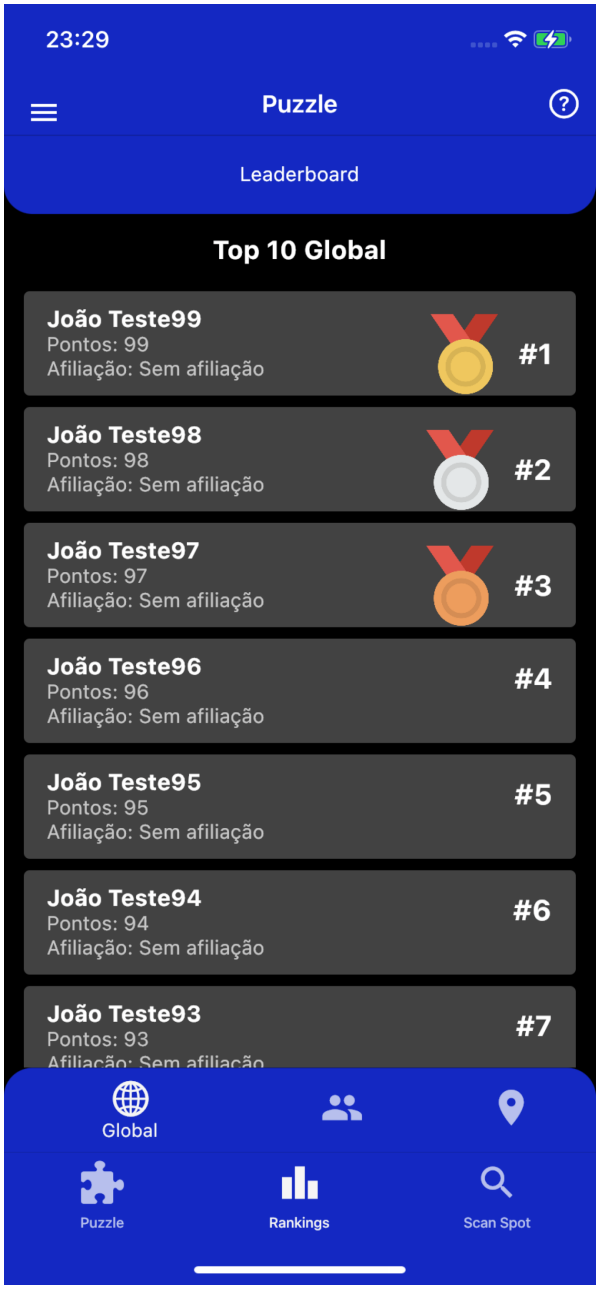

Figure A.44: Old leaderboard page

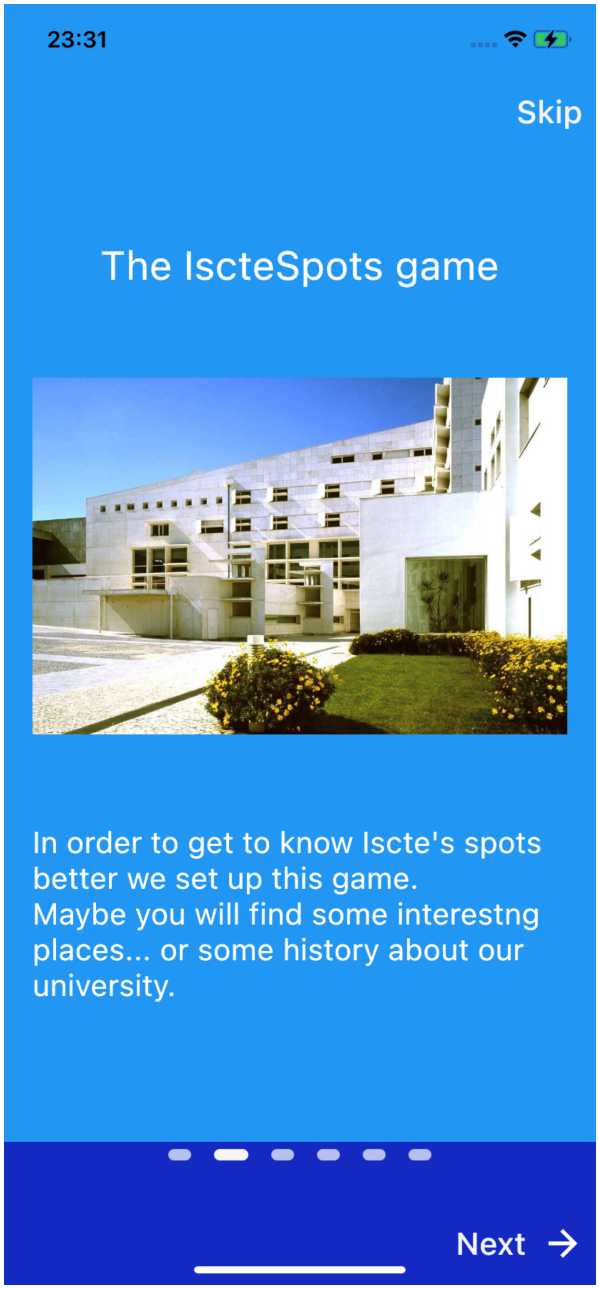

Figure A.45: Old onboarding page

Figure A.46: Old puzzle page

Figure A.47: Old timeline page

Figure A.48: Old timeline event page

Appendix B.

Feedback tables

This Appendix presents tables for every plot displayed in section 5.4.

B.1 TLX forms results

Table B.1: IEEE TLX feedback results (scale 0 to 21)

ID	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
1	13	1	10	10	7	2
2	5	3	9	4	13	7
3	10	8	11	7	15	2
4	9	8	9	21	6	1
5	8	1	8	8	17	1
6	6	3	10	3	10	2
7	13	2	5	8	14	3
8	8	2	9	8	12	7
Mean	9,00	3,50	8,88	8,63	11,75	3,13

B.2 MARS forms results

Table B.2: IEEE TLX open ended feedback

ID	Improvement Suggestions
1	A app podia ter localmente as imagens , perguntas e resposta. Quando tivesse acesso à net, enviava os resultados dos inquéritos e recebia a classificação global.
2	Poder fazer zoom na fotografia, depois de feito o puzzle. Filtro “todos” em vez de “*” no Departamento ->visualização da pontuação
3	No ato das perguntas, não aparecer opções “responder” e “seguinte”.Não está muito intuitivo. Não permitir repetir quiz ou pelo menos não dar a cotação total nas tentativas seguintes.
4	Falhas no botão submenter/responder. ->Talvez tenha sido só depois do submeter a resposta em branco. Fazer zoom na imagem depois do puzzle. Depois do login aparecer um separador diferente do login.
5	Puzzle inicial (splash screen) não aparece muito bem ou de forma igual em diferentes modelos de telemóvies. Nem sempre as imagens carregavam e por vezes a resposta nao era imediatamente submetida. A interface podia ser mais intuitiva (“responder” e “seguinte” um bocado confuso). Os puzzles desfaziam-se / voltam ao estado inicial.
6	(incompleto -letra dificil de ler)Seleção de puzzle. Na primeira utilização poderiamos ter um tutorial indicativo de onde carregar para ir até certo sitio.
7	Apenas algumas perguntas com imagem incorreta
8	Não é 100% intuitiva (eg. ao selecionarmos a opcção que consideramos correta, o “seguinte” devia permitir logo submeter a resposta + avançar - sem que houvesse necessidade de haver 2 botões : “responder” e “seguinte”). O puzzle inicial devia ficar centrado e não ir para um canto.

Table B.3: ACM TLX feedback form results (scale 0 to 21)

ID	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
1	10	3	1	11	8	1
2	8	16	14	5	14	3
3	7	17	14	9	8	4
4	9	4	11	12	9	2
5	14	6	10	7	10	4
6	11	10	16	4	5	10
7	11	14	14	13	11	14
8	14	6	12	8	16	4
9	15	5	11	5	13	3
10	10	11	11	6	11	4
11	10	10	14	11	11	12
12	15	3	7	16	16	3
13	13	3	6	14	5	6
14	16	3	6	10	13	10
Mean	11,64	7,93	10,50	9,36	10,71	5,71

Table B.4: ACM TLX open ended feedback

ID	Improvement Suggestions
1	Pergunta com uma imagem e opções Campo Grande ou Avenida da Reppública apareceu repetida muitas vezes. Quando acabamos o quizz acho que devia ir automaticamente para os puzzles ou para o ranking
2	Existem alguns bugs nos quizzes, por exemplo, faltam algumas informações na parte antes dos quizzes e algumas imagens
3	Foto perto da biblioteca estava do angulo contrario onde estava o QR Code. De resto a minha experiencia foi bastante positiva
4	Perguntas repetidas. Perguntas sem imagem.Puzzles podiam ser mais intuitivos e mais desafiantes.
5	Uma pergunta não tinha imagem e era necessária. Puzzles tinham demasiadas peças.
6	Dar par andar para a questão anterior nos quizzes. Dar para fazer Log In sem ser aluno do Iscte-IUL (por exemplo s/login-ghostuser)
7	Falta de informação em algumas perguntas
8	A adequação do quiz à informação mostrada ... podia ser melhorada
9	Existia perguntas repetidas. Existia perguntas em que as respostas dependiam de uma imagem e a mesma não aparecia. Sugestão: Diminuir o numero de peças dos puzzles.
10	Fotografias não apareciam em algumas perguntas. Numa pergunta ouve uma correspôndencia falsa entre a fotografia e a pergunta (Audax/Ala autonoma). No inicio não percebi muito bem onde começava. Devia haver um botão no final do quiz para ir para o próximo spot.Acho que ninguém vai fazer download dos decretos-lei...
11	No quizz, ao final voltar para o Home. Indicar qual o local para estudar cada quizz antes de iniciar.Notificações de QR, assim que aceitar não voltar a enviar.
12	Fazer o sus online ao invés de papel. Permitir versão web, para fazer pelo windows. História pode ser um anime, manga, storytelling.
13	Aumentar a dificuldade do puzzle, era possivel arrastar as peças aleatóriamente até elas se encaixarem sozinhas.
14	Aumentar a dificuldade dos puzzles, deixar mais intuitivo

Table B.5: ACM MARS feedback section A results scale 0 to 5

ID	Entertainment	Interest	Customization	Interactivity	Target group
1	3	3	3	3	3
2	1	4	3	3	4
3	3	4	2	2	3
4	5	5	3	4	5
5	4	3	3	3	4
6	5	5	2	4	4
7	4	3	3	2	4
8	4	3	2	4	4
9	4	4	3	2	5
10	4	3	1	3	4
11	4	5	1	5	4
12	3	3	3	3	5
13	4	3	3	4	5
14	3	4	3	4	5
Mean	3,64	3,71	2,50	3,29	4,21

Table B.6: ACM MARS feedback section B results scale 0 to

ID	Performance	Ease of use	Navigation	Gestural Design
1	3	3	3	3
2	3	4	5	3
3	3	4	3	3
4	4	4	4	5
5	3	5	4	4
6	3	5	5	4
7	3	4	3	5
8	4	4	3	4
9	5	4	4	5
10	4	4	4	5
11	5	5	2	4
12	5	5	5	5
13	4	5	4	5
14	4	5	5	4
Mean	3,79	4,36	3,86	4,21

Table B.7: ACM MARS feedback section C results scale 0 to

ID	Layout	Graphics	Visual appeal
1	3	3	3
2	3	3	3
3	5	3	2
4	4	5	4
5	5	5	4
6	4	4	4
7	4	4	2
8	3	4	2
9	5	4	4
10	3	3	3
11	5	4	4
12	5	5	4
13	4	4	4
14	5	5	3
Mean	4,14	4,00	3,29

Table B.8: ACM MARS feedback section D results scale 0 to

ID	Accuracy of app description (app store)	Goals	Quality of information	Quantity of information	Visual information
1	3	3	3	3	3
2	4	5	3	3	4
3	3	4	4	5	4
4	4	5	5	4	5
5	4	4	4	4	5
6	4	5	4	4	4
7	5	5	5	3	3
8	4	3	5	4	5
9	4	4	4	4	3
10	5	5	3	3	4
11	4	4	3	4	5
12	4	5	5	2	5
13	5	4	4	4	5
14	5	-	4	-	-
Mean	4,14	4,31	4,00	3,62	4,23

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