Serious game for promoting health data literacy using the Inven!RA analytics architecture

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Abstract

Currently, professors increasingly have the ambition to obtain a deeper, critical, and reflective understanding of their students' progress in activities, where the methodologies adopted are capable of constructing knowledge with the mediation of the professor to the student, in several different areas. However, these methodologies generate new challenges and difficulties, especially in the awareness of what happens during the activity. Despite the wide range of educational games currently available, a game-based learning application where teachers can actively intervene has not been yet explored.

To address this problem, the use of video games has been one of the methods increasingly used to make student learning more immersive. However, this method poses a challenge for the teacher to be able to properly monitor the student's progress in didactic activities.

The objective of this dissertation is to develop an educational game that serves as a proof of concept for the use of *learning analytics* in serious games to help teachers to monitor better and in a more granular way the progress of their students. The game was developed using the Unreal game engine and is a 'branching story' game for digital and health literacy. An activity provider was also developed to start the game and communicate with the Inven!RA platform, which allows real-time monitoring of students' progress in activities orchestrated by the teacher in immersive environments. This 'activity provider' runs on a XAMPP server and was developed using PHP: Hypertext Preprocessor (PHP) and Javascript.

This work demonstrates that it is possible to use serious games in real-time monitoring by the teacher of the student's progress throughout the didactic activities, which gives the teacher the benefits of being more aware of the progress of his students and of allowing him to intervene so that the students can meet learning objectives.

Keywords: game-based learning, serious games, immersive learning, learning analytics, learning management systems

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Resumo

Atualmente, os docentes têm cada vez mais a ambição em obter uma compreensão mais aprofundada, crítica e reflexiva sobre o progresso dos seus estudantes nas atividades, onde as metodologias adotadas sejam capazes de transferir conhecimento do professor para o aluno, em varias áreas diferentes. Contudo, estas metodologias geram novos desafios e dificuldades, especialmente na consciência do que ocorre durante a atividade. Apesar da grande variedade de jogos educativos disponíveis nos dias de hoje, não foi explorado uma aplicação baseada em *game-based learning* onde os docentes possam intervir ativamente.

Para abordar este problema, o uso de vídeojogos tem sido um dos métodos cada vez mais usados para tornar a aprendizagem dos estudantes mais imersiva. Contudo, este método traz o desafio do docente conseguir devidamente acompanhar o progresso dos estudantes nas atividades didáticas.

O objetivo desta dissertação é desenvolver um jogo educativo que sirva de prova de conceito ao uso de *learning analytics* em jogos sérios para ajudar os docentes a monitorizar melhor e de forma mais granular os progressos dos seus estudantes. O jogo foi desenvolvido usando o motor de jogo Unreal and consiste num jogo do tipo 'história ramificada' para a literacia nas área digital e da saúde. Um activity provider foi também desenvolvido para arrancar o jogo e comunicar com a plataforma Inven!RA, que permite o acompanhamento em tempo real do progresso dos estudantes em atividades orquestradas pelo docente em ambientes imersivos. Este 'activity provider' corre num servidor XAMPP e foi desenvolvido usando PHP: Hypertext Preprocessor (PHP) e Javascript.

Este trabalho demonstra que é possível usar jogos sérios no acompanhamento em tempo real pelo docente do progresso dos estudantes ao longo das atividades didáticas, o que confere ao docente os benefícios de ter maior consciência do progresso dos seus estudantes e de lhe permitir intervir para que os estudantes consigam cumprir com objetivos de aprendizagem.

Keywords: gamificação, aprendizagem imersiva, análise de aprendizagem, sistemas de gestão de aprendizagem

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José Ricardo Vieira Gomes

*"Until I began to learn to draw,
I was never much interested in looking at art."*

Richard P. Feynman

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Abbreviations

AA	Academic Analytics
AJAX	Asynchronous JavaScript and XML
API	Application Programming Interface
BEACONING	Breaking Educational Barriers with Contextualised, Pervasive and Gameful Learning
aDoS	Denial of Service
DSR	Design Science Research
EDM	Educational Data Mining
EG	Edutainment games
EngAGe	Engine for Assessment in Games
EU	European Union
GBL	Game-Based Learning
H5P	HTML5 Package
HTTP	Hypertext Transfer Protocol
IAP	Inventive Activity Plan
INESC-TEC	Institute for Systems and Computer Engineering, Technology and Science
JSON	JavaScript Object Notation
LA	Learning Analytics
LMS	Learning Management Systems
LRS	Learning Record Store
LTI	Learning Tools Interoperability
PBL	Problem Based Learning
PHP	PHP: Hypertext Preprocessor
RPG	Role-Playing Game
SG	Serious Game
SCORM	Sharable Content Object Reference Model
UML	Unified Modeling Language
URL	Uniform Resource Locator
xAPI	Experience API library
XSRF	Cross-Site Request Forgery

Chapter 1

Introduction

Chapter 1 presents the dissertation context, motivation, objectives, and research questions.

1.1 Context

The digital progress in technologies in the last two years due to the COVID-19 pandemic has accelerated, especially in the area of education, due to the need for teachers to give classes in a remote environment. In this new teaching configuration, it is more challenging for teachers to effectively monitor and have awareness of their students' progress during class activities. As such, new learning tools and technologies are needed.

Many studies conducted throughout the years have shown that the integration of serious games in the classroom as a learning tool has great potential in the learning process. This tool can improve the obtainment and retention of knowledge [15, 27]. However, games alone are not enough for teachers to monitor and be aware of their student's progress, as implementing serious games in the classroom is still limited and does not guarantee success on a pedagogical and motivational level [54, 27, 3].

Inven!RA is an architecture developed in cooperation with the Institute for Systems and Computer Engineering, Technology and Science (INESC-TEC) and by the UNISINOS Project CAPES/ PRINT "Digital Transformation and Humanities" (Brazil). It allows for online pedagogical intervention with third parties by tracking and managing distributed learning activities [18]. Inven!RA is based on the Breaking Educational Barriers with Contextualised, Pervasive, and Gameful Learning (BEACONING) project[1], which began in 2016 and is also developed at INESC-TEC [8]. Inven!RA adopted a broker-style pattern [50], similar to a 'middleman' approach between teachers, students, and the activity provider, which provides the activities for the learning sessions.

Inven!RA's main purpose is to allow third-party pedagogical activities to design activity plans without the need for a particular game narrative or having to be restricted to an approach such as

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[1]https://www.inesctec.pt/en/projects/beaconing

Game-Based Learning (GBL) [18]. One of the functions of Inven!RA is allowing education professionals to design activities with specify the learning objectives and track the planned activities, known as Inventive Activity Plans (IAPs) [17].

TRIO[2] is an active INESC-TEC project that started in February 2022. It provides relevance and rigorous requirements for digital health data literacy. It will incorporate a serious game in health education.

1.2 Motivation

Currently, teachers' awareness of their student's progress during learning activities using traditional learning methods is insufficient. The issue is exacerbated when the classes have a large number of students [6], especially during the last two years with the global pandemic, where teachers were forced to give their classes remotely, which made monitoring students very difficult for teachers to make a proper pedagogical intervention [11]. This means teachers are only aware of their student's progress at the beginning and end of the learning activities [19].

Examples of dimensions awareness by the teacher [19] include:

- student motivation throughout the learning activity process;

- sub-activity completion status;

- student satisfaction.

1.3 Objectives

The objective of this dissertation is to develop a proof-of-concept of how Inven!RA can be used to collect analytics from a serious game during learning activities. These analytics allow teachers to have a proper assessment and awareness of their students' progress during teaching activities. This awareness allows for an effective orchestration of better pedagogical interventions.

First, the relevant data analytics extracted from the serious game need to be identified. These analytics will be useful for monitoring the learning outcomes. In addition, the method used to collect this data from the serious game using Inven!RA architecture needs to be defined. Inven!RA provides a means of visualizing the data collected in order for the teacher to have a better awareness of where their students are in relation to the learning outcomes.

The main steps of this dissertation's approach will follow the Design Science research methodology:

- Design: Develop a serious game suitable for relevant data collection and integration with Inven!RA architecture for Learning Analysis.

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[2]https://www.inesctec.pt/en/projects/trio

- Demonstration: Extract the data from serious games for real-world scenarios to test the suitability of game design and the relevancy of the data analytics by using Inven!RA architecture.

- Evaluation: Measuring the effectiveness of the monitoring that allows teachers to have awareness of their students' progression and if they are in the right direction towards learning outcomes.

1.4 Research questions

In order to guide this dissertation work, two research questions were posed:

- RQ1: What relevant analytic data can be extracted from the game that is useful for teacher awareness?

- RQ2: How can this relevant data be extracted using Inven!RA architecture to perform the analytic analyzes?

1.5 Document structure

The rest of this report is organized as follows. Chapter 2 presents the state-of-the-art on educational games and teacher awareness. Chapter 3 present how the proof-of-concept system was conceptualized, while Chapter 4 details how it was implemented. Finally, Chapter 5 presents the conclusions and future work.

Chapter 2

State-of-the-art on educational games and teacher awareness

Chapter 2 presents the state-of-the-art educational games and learning analytics.

2.1 Game-Based Learning

In the current times, there is growing evidence that traditional teaching methods are not enough to engage and motivate students in learning activities. Recent research has shown that in the European Union (EU) eight out of ten students that range from first grade up to university play video games [24]. The enormous success of games that are made for pure entertainment has increased the interest of educators and researchers in the use Game-Based Learning (GBL) methods with video games as educational learning tools.

Qian and Clark [42] stated that GBL "describes an environment where game content and gameplay enhance knowledge and skills development, and where game activities involve problem-solving spaces and challenges that provide players/learners with a sense of achievement". GBL is considered a learning method where students discover portions of the game, further developing abilities while accomplishing explicit learning outcomes [4].

Using video games as a learning tool has been studied since the 80s, with these games being known as educational video games [26]. Many studies suggest that educational video games are effective in obtaining knowledge and retention while keeping students interested during the activity, as they provide the development of skills and knowledge by completing the game's challenges [51] [37] [31].GBL may also be viewed as Problem-Based Learning (PBL), on a few specific situations [20].

Educators considered the use of computer games as a highly valuable means to address many problems in the classroom [39]. In fact, a few educators took notice of the success of the game

called "PacMan", and were left wondering if "the magic of Pac-Man cannot be bottled and unleashed in the classroom to enhance student involvement, enjoyment, and commitment" [9]. For this reason, teachers believed that if they integrated video games into the classroom as a learning activity, the students would be more engaged in the lesson. Unfortunately, the opposite occurred, causing teachers to be unfavorable to the use of video games as a learning tool, with negative feedback over the effectiveness of this learning approach [39].

This sort of game uses the characteristics of entertainment video games, to build a motivational and engaging learning experience in the classroom while approaching students toward specific learning outcomes that are set by teachers in a practical educational setting. They are designed to foment cognitive skills or practice the use of such skills in a simulation environment [22]. These include edutainment games (EG) and serious games (EG).

EGs combine education with entertainment [30]. An example of an EG is "Where in the world is Carmen Sandiego?" (Figure 2.1), from 1985, which teaches the player geographical facts. This type of game marked the beginning of the first age of digital computer games in the classroom in the mid-80s to mid-90s [55]. But, by the end of the 90s, 'edutainment games' was used as a buzzword in the development of educational games [10].

Figure 2.1: Gameplay of "Where in the world is Carmen Sandiego?" [1]

Clark C. Abt was the first to define the concept of SG in his book written in 1975 called 'Serious Games' [1, 10]. However, the term SG for educational video games would only be coined in the late 90s by Ben Sawyer. This marks the beginning of the second age of video games in the classroom [7].

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[1] https://www.youtube.com/watch?v=ScvM9pecFOo

A more recent definition of SG that gathers the most consensus is "digital games created not with the primary purpose of pure entertainment, but with the intention of serious use as in training, education, and health care", as stated by Loh *et al.* [35].

SG and EG are used as synonyms in educational game development, with game developers agreeing that SGs go a step further than EGs [39], in other words, SGs are not designed with focus on entertainment [33]. SGs are also used to train high-level skills, such as training for practicing laser therapy, how to prepare for a catastrophic disaster, or practicing laparoscopic surgical procedures, then EG [13]. Design attributes desirable in Serious Games SG should have the following desirable design attributes [5]:

- Clear objectives;

- Repeatable assignments for information solidification;

- Follow students' progression;

- Stimulate more time spent on a task;

- Capable of adapting the learning level of difficulty.

With the use of SGs, students are able to develop competencies that were difficult to train with traditional methods. Studies have shown that this method improves students' skills such as critical thinking or solving complex problems [35] [25]. However, the use of SGs as a learning strategy in the classroom brings the need for a deep understanding of the effectiveness of the learning process. In other words. there is a necessity to evaluate if the SG is performing as intended as a learning tool.

Recent examples of successful SG include:

- "ARTé: Mecenas" (Figure 2.2), from 2016, a Role-Playing Game (RPG) that aims to teach historical facts about the Italian Renaissance. The game follows the historical footsteps of the Medici family and features various influential artworks of the 15th and 16th centuries, including over 130 pieces of art by more than 70 artists [52].

- "Variant: Limits" (Figure 2.3), from 2017, a 3D platformer that teaches students about limits, a fundamental concept in calculus (mathematics). The virtual world the player must traverse is divided into four zones, each one associated with a part of the game's plot and a set of topics/learning outcomes [53].
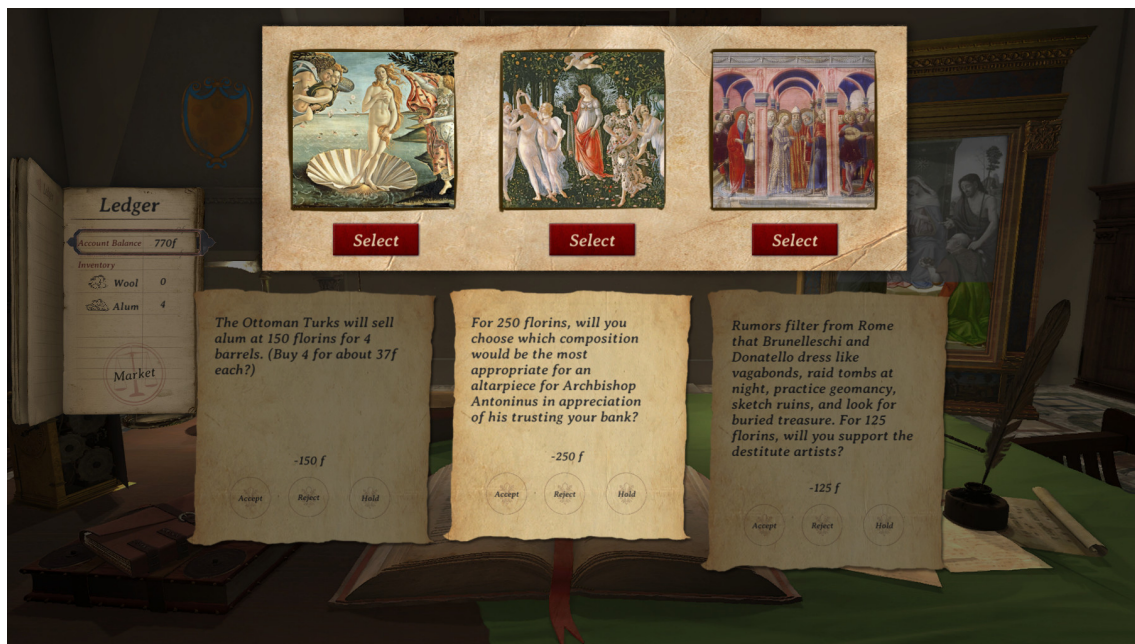
Figure 2.2: Gameplay of "ARTé: Mecenas"[2]
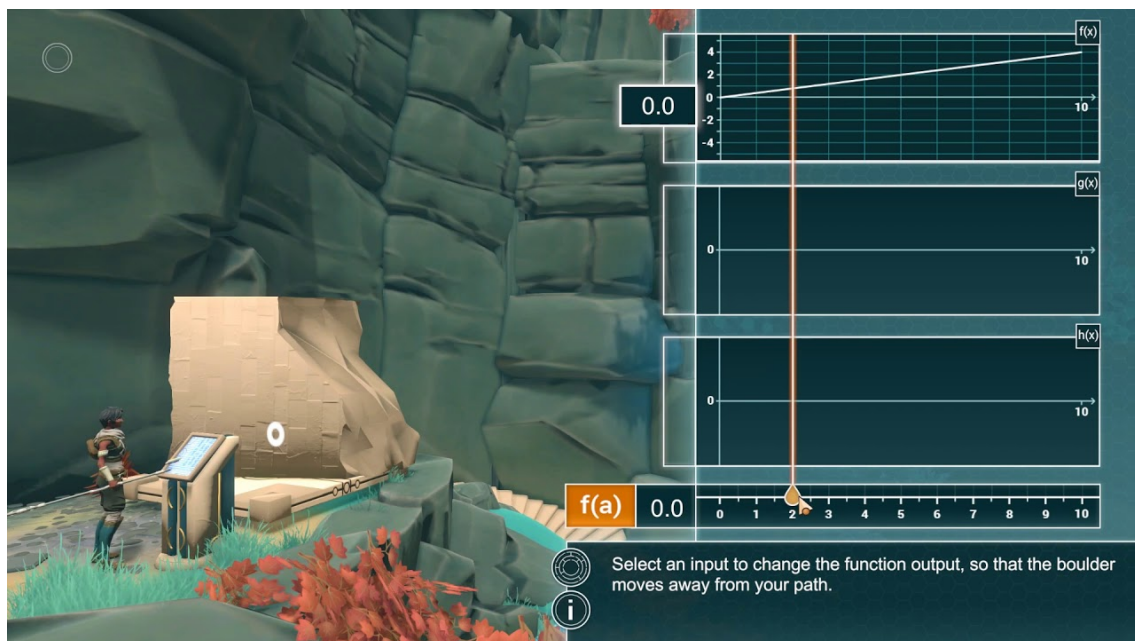
Figure 2.3: Gameplay of "Variant: Limits"[3]

[2]https://store.steampowered.com/app/934950/ART_Mecenas

However, in spite of the growing acceptance and interest in using SGs as a learning tool, they still have limitations that are preventing their integration in the classroom, such as the cost of developing and maintaining the game. One example of the cost of developing and maintaining limitations is the game "Full Spectrum Warrior", 2004, which was developed for the US Army. This game aimed to train soldiers in the army's doctrine. However, the doctrine was changed, making the game unsuitable and the cost of implementing the new doctrine was deemed unfeasible for the time it takes to implement 2.4.

Figure 2.4: Gameplay of "Full Spectrum Warrior"[4]

The largest obstacle to the use of SGs is the teachers' hesitancy in their use as a learning tool in their classroom [24]. This hesitancy is namely caused by their misconceptions when they have little knowledge about this type of game, as teachers need to feel they are in control of the classroom, in order to help their students overcome their difficulties during the learning process, and to get the desirable learning outcomes [5].

It is important for teachers to understand if their students are learning while playing. However, SGs are not an evaluation tool by themselves. Also, it is difficult to make measurements of the students' interaction with the SGs, as well as the learning progress *during* this interaction (and

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[3]https://jakelenzen.com/portfolio/variant-limits/
[4]https://coop-land.ru/allgames/strategy/509-full-spectrum-warrior-ten-hammers/tech-faq.html

not only after the interaction ends). In fact, teachers need to have awareness of their students' interaction during a SG session, so that they can have better pedagogical interventions if and when is necessary. This awareness can be attained using a method called Learning Analytics LA, which enables teachers to measure the students' progression, detect their difficulties and become more aware of the current situation of the class [14].

2.2   Learning analytics

SGs generate an enormous amount of data when students interact with the game. This data goes through established learning ecosystems, such as the eLearning platform Moodle. These platforms are also known as Learning Management Systems (LMS) [5]. They help teachers detect if students interpreted the lesson's content correctly or if they misinterpreted it. These interactions are behaviors and decisions made by the students during gameplay.

These platforms can use the LA method to analyze the data generated by the students' interaction while playing the game. This method is intended to assist teachers in understanding if students are completing the exercises. It is critical for the teacher to have the knowledge of whether a student is falling behind, in other words, of whether the student is not interpreting the content correctly or they have problems overcoming the obstacles [32].

For this reason, since teachers are concerned when it comes to planning their educational curricula, it is desirable to incite as much interaction as reasonably possible, to not make the lesson boring and uninteresting, which may cause students to not engage in the learning process.

LA offer new tools to uncover digital information from various sources, such as log records [36]. A widely accepted definition of LA, was stated by Siemens and Long [46], as it follows "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs". Most researchers believe that LA is a chance for improving the quality of the learning process.

Ferguson *et al.* [23] characterized three factors that drove the emergence of LA: big data, online learning and political concerns.

Data analysis and visualization are the most important aspects for the teacher, as they give insight into students' interactions during the gameplay session, as well as valuable assistance for a better pedagogical intervention when is necessary. Until recently, traditional methods for measuring and assessing student learning outcomes were time-consuming. They lack detailed information for teachers to assess if the lesson was going according to the expectations [21].

There are other fields associated with the processing of this data besides LA, such as:

- educational data mining (EDM), which depends mostly on automation and needs to manage the whole process of finding knowledge gathered from enormous and complex data sets from an educational ecosystem;

- academic analytics (AA), which mirrors the job of information analysis at an institutional level, recognizes patterns that will notify issues, and give noteworthy choices for academic administration [35].

2.3 Serious Games Learning Analytics

As previously discussed, the primary goal of SGs is to involve computer games in education, rather than leisure [14]. They are successful in enhancing interest in learning, and enabling the practice and assessment of student performance [47]. The main role of LA in SG is to obtain a significant understanding to perfect the game and its educational design, as well as to refine the player´s abilities and execution in order to demonstrate game adequacy. By integrating LA with SGs, it is now possible to measure how effective SGs are in the classroom during a gameplay session.

However, student interaction with a game creates a tremendous quantity of information, even in small sessions. LA are useful for filtering and aggregating the data, so that the processed data can be visualized through the customized dashboard, adapted to the teacher's needs [2]. As such, the requirements set by the teachers define how the collected data is to be processed.

To obtain this information, it is necessary to use data collection methods. These methods can be classified into two main families: ex situ and in situ. On the one hand, ex situ is the collection of information outside of the game session, such as surveys or questionnaires. On the other hand, with in situ methods, information is collected during the students' interaction with the game. This gameplay data is acquired with methods such as log files [28] or game telemetry [35], which allows the detection of flaws in the game design [44]. Log files are mapped according to a set of rules that are standard for game events or states [45].

After the process of collection of the relevant data for the teacher, the information collected is preserved in a Learning Resource Store (LRS). Afterward, the data is processed and cleaned to make the information reliable and readable, which includes eliminating information that is duplicated and irrelevant information such as computer crashes [35]. After the cleaning process is completed, the information is converted to a suitable format, usually, JavaScript Object Notation (JSON), so that platforms, such as H5P, can perform the analysis of one or more students. This way, teachers have more explicit awareness of where their students are regarding the learning outcomes, as well as their mistakes.

However, the collection of this gameplay data used to be challenging, due to concerns about data security and privacy. The reason for these concerns was that LAs integrated into SGs can gather any type of information. Fortunately, in recent years, there has been a positive development in terms of data sharing with a growing market of free applications [5].

As Petrov *et al.* [41] stated, the interaction between SG and LA occurs for two primary reasons: analysis and visualization. Analysis helps to make the collected information understandable when is visualized using graphical portrayals such as tables, diagrams [35] or dashboards, in order

to display the information in real-time [12]. A dashboard should be intuitive and versatile, to differentiate the results of each student playing the game [2]. Dashboards are typically customizable, for optimal comprehension of whether their students are acquiring knowledge as expected [34].

It is critical to consider at the initial phase of the design all the important information so that the representation of the results is evident for the teachers to make a proper evaluation of their students [5].

2.4   Existing Technologies

Some solutions were already developed to assist teachers in gaining a better awareness of a game environment during a game session, how are students progressing, and comprehending how students interact during gameplay, this solution provides valuable data about various students perspectives in the form of reports (log files), they aim to improve teacher performance of pedagogical intervention when it is necessary, being aware of where the student is in relation to the learning outcomes set by the teacher, in the learning activities.

- The Experience API library (xAPI)[5] (Figure 2.5a) is an eLearning standard for communication between the Learning Record Store (LRS) and learning content [43]. It aims to facilitate communication between learning technologies [3];

- Learning Tools Interoperability (LTI)[6] is an education technology developed to specify a method for learning systems to invoke and communicate with external and/or third-party systems. LTI can be used to host content and tools provided by external and third-party systems, with information about the student in the educational learning environment with outside systems.

- Sharable Content Object Reference Model (SCORM)[7] is a group of standards and specifications for eLearning systems, it also defines how content may be packaged into a transferable ZIP file, and it sets the rules that specify the order in which the student will use the activate. It constrains the student to follow the desired path through the activity content.

- Engine for Assessment in Games (EngAGe) (Figure 2.5b) permits designers to save a lot of time and cost, not just executing the evaluation process into the game, but as well considering it. One of the objectives of this project is to assist game designers and teachers with an instrument for evaluation as well as directives on the evaluation characteristics that must be included in the game. Importantly, EngAGe facilitate splitting of the SG mechanics and logical evaluation, making the entire framework more adaptable [14];

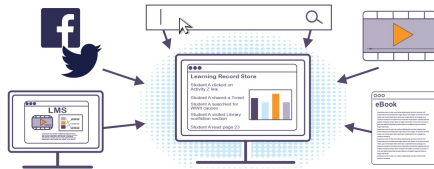[5]https://adlnet.gov/projects/xapi/
[6]https://www.imsglobal.org/activity/learning-tools-interoperability
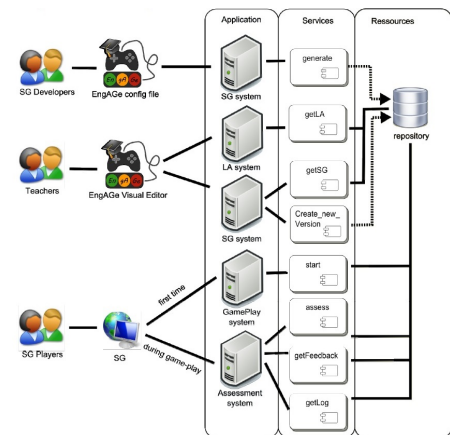[7]https://scorm.com/

(a) Architecture of Experience API library (xAPI)[8]

(b) Architecture of Engine for Assessment in Games (EngAGe) [14]

Figure 2.5: Existing Technologies Examples.

2.5 Examined Platforms

To achieve the objective of this dissertation a number of platforms were selected for review that could be activity providers (in this case educational games). First, analyze what could be extracted for Inven!RA to use, in order show to the teachers the students' learning outcomes, and second, if the data extracted is relevant for data analytics.

- WordWall[9] is interactive and collaborative. It is a student-centered learning tool in a classroom. WordWall is designed to be an interactive tool for students or others to use and contains an array of activities that can be used during writing and/or reading;

- Genially[10] is an online platform that converts presentations into interactive and animated content activities. With thousands of customized templates, it is an interactive presentation tool that presents its content dynamically and in a highly interactive manner;

- GoMeta[11] is a browser-based low-code development platform for creating web applications. Independent developers publish templates for apps and games to create new applications. Users have access to tools that allow easy manipulation of 3D models, sounds, and images. These visual abstractions are defined by the template creator in the original application bundle;

- AhaSlides[12] is an interactive classroom, meeting, and workshop platform, with thousands of templates of polls, quizzes, word clouds, etc. The data analyses are displayed in real-time in customized formats;

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[9] https://wordwall.net
[10] https://genial.ly
[11] https://studio.gometa.io
[12] https://ahaslides.com

- HTML5 Package[13] (H5P) is a free and open-source content collaboration framework based on JavaScript. It aims to make it easy for everyone to create, share and reuse interactive content, such as Interactive videos, interactive presentations, quizzes, interactive timelines, etc. The framework consists of a web-based content editor, a website for sharing content types, plugins for existing content management systems, and a file format for bundling together HTML5 resources. It uses the xAPI library method for tracking data and it is accessible to third parties.

Therefore, the problem presented is one of interoperability in learning environments with platforms such as H5P. At the present time, most of the activities used for GBL are not integrated inside of the LMS ecosystem, forcing teachers to redirect their students to platforms outside of LMS platform were teachers lecture their class´s, also forcing the student to create a profile accounts to participate in the activity, such as Kahoot!.

And so, to facilitate the use of these platforms in a LMS ecosystem there is a need to incorporate interoperability between them, Inven!RA is a solution to this interoperability problem.

2.6 Inven!RA

As mentioned, the problem at hand of interoperability for teachers and trainers during the learning game session, Inven!RA is one approach to this problem, which begs the question of "What is the role of Inven!RA in an ecosystem where applications for activity integration in Learning Management Systems, such as H5P, LTI, or SCORM exist?"

Inven!RA (Figure 3.3) is an architecture that aims to provide online monitoring and pedagogical assistance in the learning process by numerous activity providers [18]. It enables the planning of the appropriate learning activities known as IAP, and monitoring progress during the activity, while other ecosystems such as H5P do not, it was inspired by outside modules that give every activity and register the LA generated. Inven!RA architecture approach is derivative from the project (BEACONING), Inven!RA is mainly used for educational environments such as LMS platforms. the approach is to be the "middleman" that enables activity providers (third-party platforms) for pedagogical and monitoring activities with a IAP. The activity providers are responsible for hosting the activities and data collection of these activities in order to be able to perform data analyses from the interactions that students with these activities are performing, the activity providers also provide a dashboard (Figure 2.8) to display the process data that was collected from the activity. Inven!RA can also display the data analysis through the dashboard (Figure 2.7), this dashboard gives teachers the ability to better monitor their student's progress and difficulties without the need to use traditional methods of evaluation [17].
However Inven!RA imposes some constraints regarding its workflow:

- IAP must be used, with activities which come from the Activity Providers.

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[13]https://h5p.org

- The Activity Providers must make a set of calls to Web services available to Inven!RA.

- Inven!RA allows for distinct front-ends but each front-end must connect with the Inven!RA backend.

Figure 2.6 depicts Inven!RA's architecture. There are three main components:

- Inven!RA;

- the Activity Provider, which corresponds to the companies that host and collect data from the activities;

- the LMS, is a web-based application to plan educational courses, training programs, materials, or learning programs, and implement and assess a specific learning process.

The diagram shows four types of users:

- the creator, who designs, configures, and sets the learning goals for each activity set by the teacher/trainer for the IAP plan. This role can be performed by the teacher.

- the deployer, who designs the course in the LMS system, deploys the activities to the course, and decides who can access these activities This role can also be performed by the teacher.

- the active agent, who accesses the activities through the LMS system that is granted by their teachers/trainer, and is redirected to the activity by Inven!RA. This role is typically performed by the student.

- the awareness agent, who monitors the students' progress status through the Inven!RA IAP system during the performed activities to keep his awareness of the goal status. This role can be performed by the teacher or student.

2.7   Moodle

Moodle is an acronym for Modular Object Oriented Developmental Learning Environment, it is the most used learning management system in the world. It is free and distributed under an Open Source license. The MySQL database management system, and PHP programming language are used to create this architecture.

All those who are participating in the teaching and learning process, offering online courses (e-learning), or enhancing traditional classroom instruction are the target audience for Moodle. The system's primary target group is the Teachers, who may control the platform as needed. They can decide afterward on the learning environment, its specific goals, the information to be made available and in what formats, the student-accessible communication channels, and the follow-up procedures.

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[13]https://info.library.okstate.edu/c.php?g=741859&p=5306929
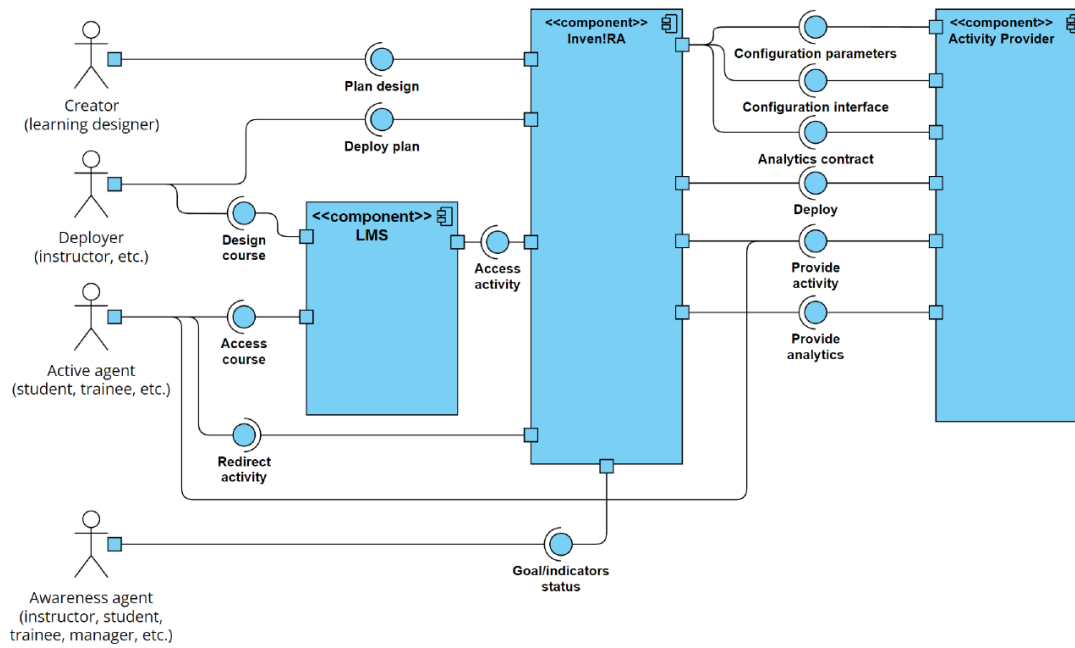
Figure 2.6: Inven!RA architecture overview

2.8 Summary

This chapter began by explaining the concept of Game-Based Learning (GBL). Then, educational video games were presented: the older edutainment games (EGs) and the more recent serious games (SGs). Afterward, Learning Analytics (LA) were presented in a general setting, before focusing on their integration with SGs and presenting some existing projects on LA integrated into SGs. The chapter concludes with the description of Inven!RA and Moodle.

Figure 2.7: A LA an Inven!RA qualitative analytics report. [17]

Figure 2.8: A LA example of dashboard from a website [16]

Chapter 3

System conceptualization

This chapter presents the conceptualization of the system developed in this thesis. After presenting the main goal of this work and the research methodology, the system's requirements, architecture, and workflows are presented.
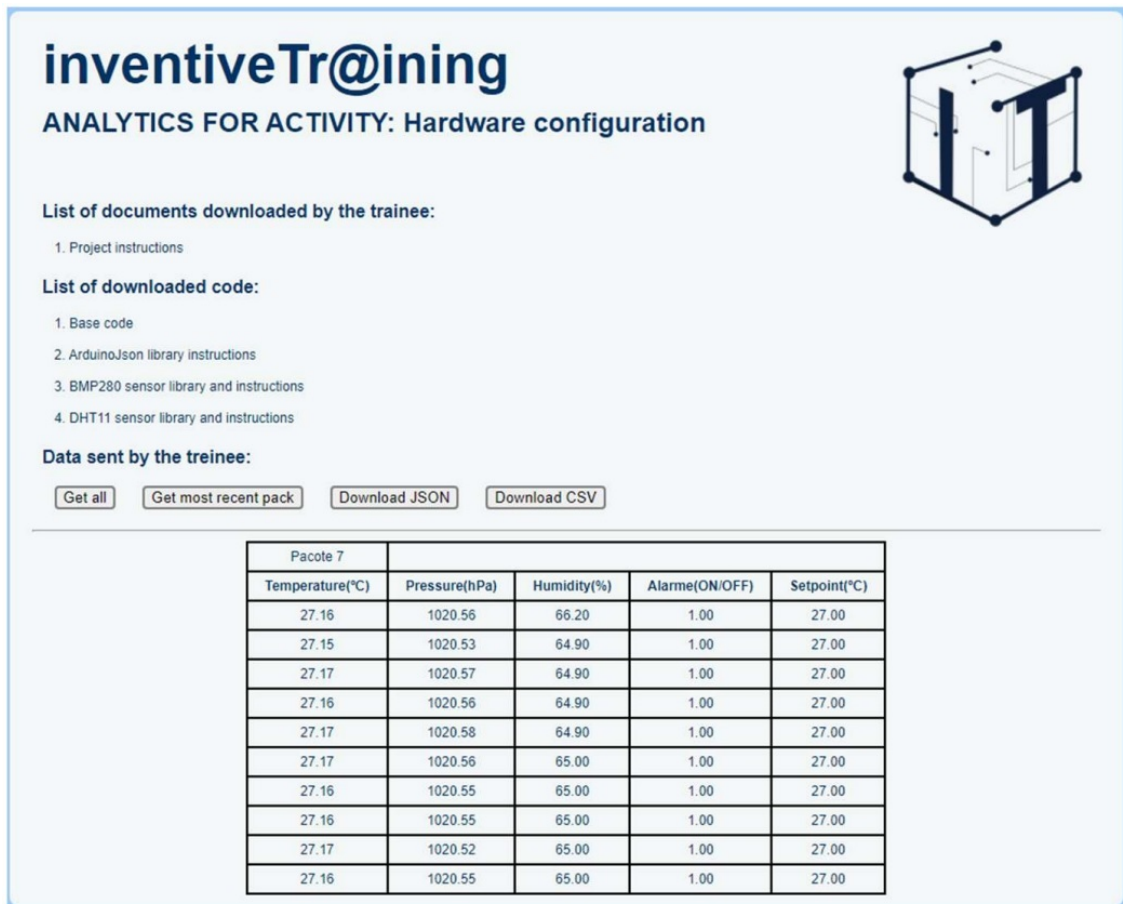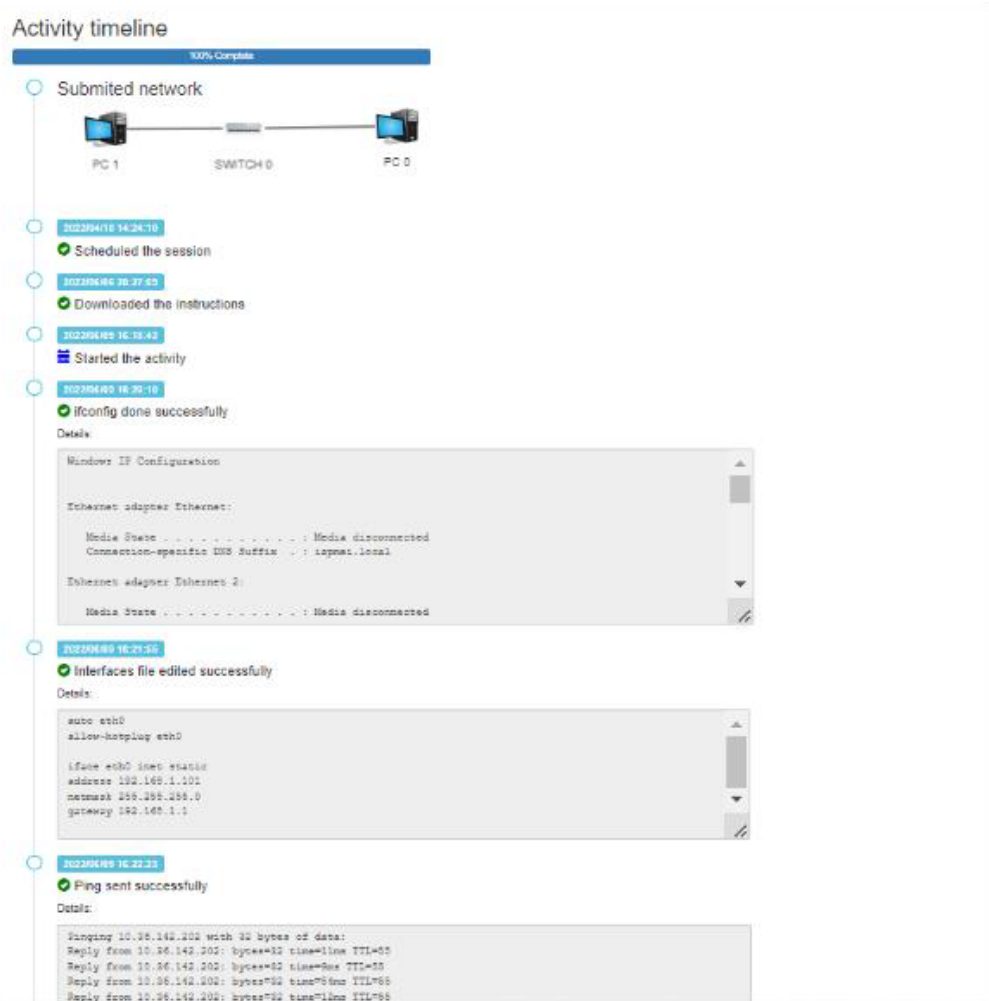
3.1 Main Goal

The primary objective of this dissertation is to develop a prototype that serves as a proof-of-concept of how Inven!RA can be used to extract Learning Analytics (LA) from a serious game. These LA provide teachers with real-time monitoring and awareness of their students. In fact, as discussed in Chapter 1, this dissertation addresses the significant challenge of the absence of suitable tools to accurately assess students' progress during an activity, thereby emphasizing the need for effective monitoring and awareness mechanisms.

To achieve this goal, the research conducted follows the Design Science Research (DSR) methodology, as presented in the next section.

3.2 Research Methodology: Design Science Research

The Design Science Research (DSR) methodology consists of the development of an artifact from a scientific standpoint. According to Hevner *et al.* [29], DSR has several advantages when it comes to helping businesses with real-world problems due to its pragmatism.

Figure 3.1 presents the model proposed by Hevner *et al.* [29]. This model consists of three cycles:

- the *rigor cycle*, which makes sure that the research is in accordance with the required theoretical and methodological standards.
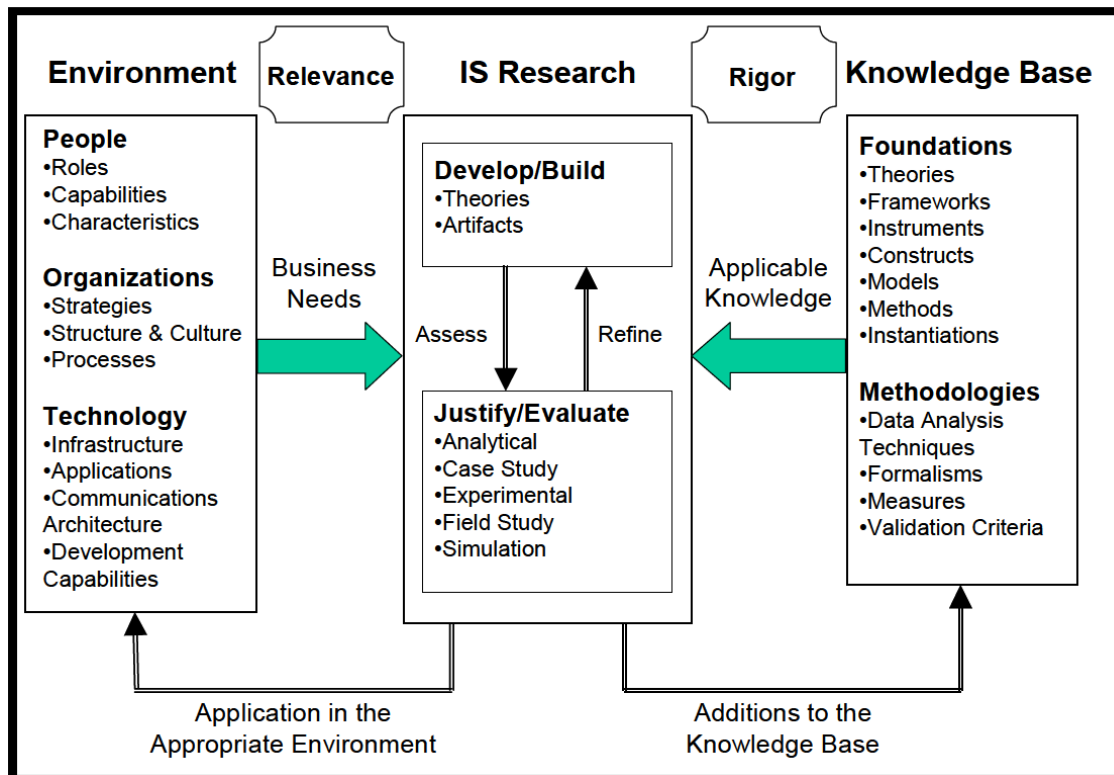
Figure 3.1: Design Science Research model proposed by Hevner *et al.* [29]

- the *design cycle*, which produces an artifact that will address a real-world problem for a specific situation, where this artifact will be put into practice.

- the *relevance cycle*: which establishes the requirements for the analysis conducted by the use of this artifact.

Peffers *et al.* [40] described the DSR process in detail, as depicted in Figure 3.2. The process consists of six activities. As shown in figure 3.2 activities two to six are done in a cyclic fashion. The six activities consist of:

1. **Identify the problem and motivate**: defines the particular research that breaks down the problem so that the solution may adequately reflect its complexity. The problem's description will be used for the development of an artifact that can provide an appropriate solution successfully. This activity is helpful for understanding the current status and the significance of the solution to the problem.

2. **Define the objectives of a solution**: establishes the goals for a potential solution, based on the problem description and specifications of what is practical and attainable by the researcher's knowledge. A description of how a new artifact is intended to provide answers to problems that have not yet been addressed is one example of a qualitative objective. Objectives can also be quantitative, where a desirable solution is preferable to the existing ones. So the goals should be logically deduced from the problem description and specifications.
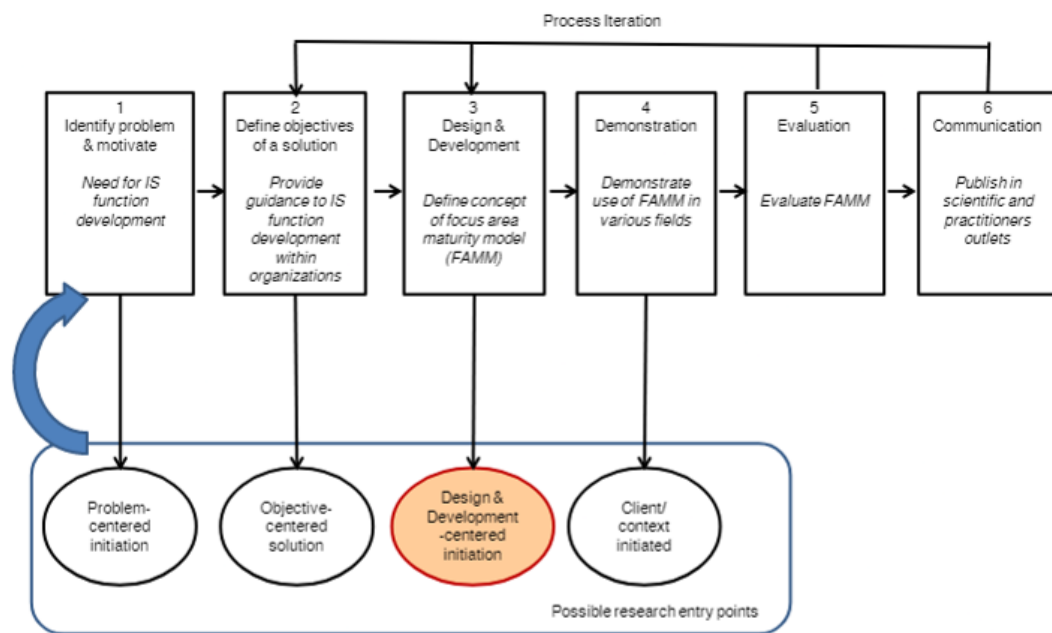
Figure 3.2: Design Science Research model process proposed by Peffers *et al.* [40]

3. **Design and development**: consists of the creation of an artifact, which can consist of constructs, models, methods or instantiations. This artifact might theoretically be any created object in which a research contribution is included. This activity entails deciding on the architecture and expected use of the artifact before its creation. The ability to apply theory to a problem is one of the resources needed to go from the objectives to design and development.

4. **Demonstration**: shows how the artifact may be used to solve one or more instances of the problem. This can entail using the artifact for an experiment, a simulation, a case study, a demonstration or another applicable task. It is crucial to have an effective understanding of the use of this artifact in order to solve the problem demonstrated. This step is pivotal for developing a serious game that is not only adept at gathering relevant data but also seamlessly integrating into the Inven!ra Learning Analytics architecture. In this step, we will extract game data from real scenarios and thoroughly assess the suitability of the game design, as well as the relevance of data analysis through Inven!ra.

5. **Evaluation**: assess the artifact's ability to aid in finding a solution to the problem. This task entails contrasting a solution's goals with the outcomes that were actually obtained when the artifact was used in the demonstration. It is necessary to have familiarity with pertinent measurements and analytic methods. The evaluation can take many different shapes depending on the artifact and the problem venue. It could consist of things like a comparison of the artifact's functionality with the solution goals from the second activity (*i.e.* definition of the objectives). Conceptually, such an assessment may contain any pertinent logical or empirical support. At the conclusion of this activity, the researchers can choose to go

on to communication and leave further development to the following projects, or they can
go back and try to increase the efficacy of the artifact in the third activity (*i.e.* design and
development of the solution). Whether or not such repetition is possible may depend on
the nature of the study environment. Measure the efficacy of the monitoring process, which
enables teachers to stay informed about the progress of students and their alignment with
the learning objectives.

6. **Communication**: explain the problem and its significance to the pertinent audiences, as
   well as the artifact's utility, uniqueness, and efficacy. Researchers may use a similar nominal
   structure of an empirical research process, which is a typical structure for empirical research
   papers, to structure the paper in scholarly publications.

3.3   System architecture

A general view of the architecture of the system to be implemented is depicted as a UML com-
ponent diagram in Figure 3.3. This diagram is based on an architectural diagram of Inven!RA by
Morgado *et al.* [38]. The elements developed in this thesis are highlighted in blue.
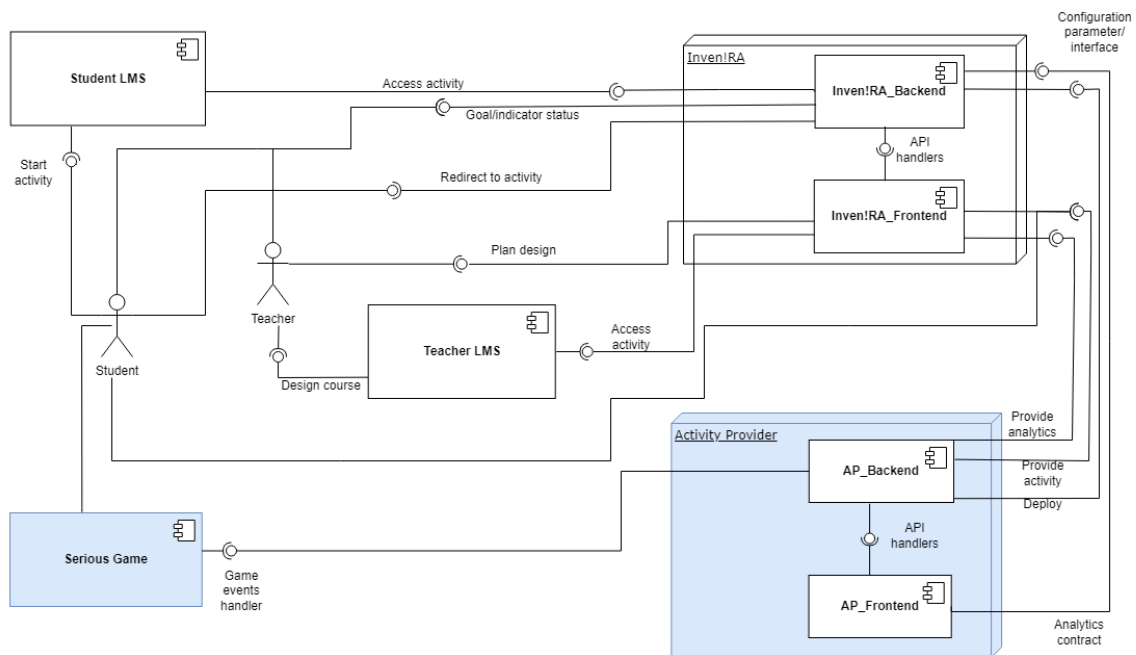
Figure 3.3: UML component diagram of the architecture overview

With respect to the original architecture presented in Figure 2.6, the system developed in this
thesis was simplified to only encompass two actors, presented in Table 3.1.

Teachers will create the desired IAPs, which are then stored at an activity provider using
Inven!RA. Inven!RA functions as the broker between the teacher and the activity provider, by
creating an Uniform Resource Locator (URL) for each IAP stored in the activity provider.

Table 3.1: Description of the actors of the system

Name	Description
Teacher	The user that is teaching the class. They configure the learning activities and monitor the analytics.
Student	The user that is enrolled in the class. They partake in the learning activities in order to accomplish the learning outcomes

Next, the teacher deploys the IAPs and assigns it to the students that are participating in the activity, which access it via the LMS and request to start the activity session. Afterward, Inven!RA will request the IAP deployment's URL to the activity provider, which sends the requested IAP to Inven!RA. In turn, Inven!RA sends the activity to the LMS. After receiving the requested activity, the LMS proceeds to start the activity session.

During the activity session, the activity provider will be collecting the data of the captured events and performing the LA process. Teachers can monitor their students during the activity session by using the dashboard generated by Inven!RA. To generate this dashboard, Inven!RA requests LA data to the activity provider, which after receiving the request, searches for the activity data and sends it to Inven!RA, which in turn processes the data to generate the dashboard for the teacher.

3.4 System requirements

This section will detail the requirements that both components developed in this thesis (the activity provider and the serious game) must satisfy. The requirements can be divided into functional and non-functional requirements.

Functional requirements declare services that an application must provide and how it should react given an input or situation [48]. This type of requirement will be presented as user stories in the following section. A user story consists of a sentence with the following format "As a <role>, I want to <capability>, so that <goal>." and with three components:

- Role: the name of the actor that has access to the feature of the user story.

- Capability: the feature of the user story.

- Goal: what the feature enables the user to accomplish.

During the development of this thesis work, each user story was assigned a priority level, reflecting the importance of fulfilling specific requirements for the correct functioning of the system. Non-functional requirements, encompassing aspects like usability and scalability [48], serve as constraints on the application's services and features. Before delving into the requirements of both components, a subsection will be provided to explain the requirements elicitation process, shedding light on how the requirements were determined.

3.4.1 Requirements elicitation

The functional and non-functional requirements of both components were obtained through a series of interviews conducted with Professor Maria Van Zeller, as coordinator of the TRIO project, a project from INESC-TEC that will incorporate a serious game in health education, as mentioned in Chapter 2. These interviews are presented in Appendix A. Each interview was conducted face-to-face and lasted between 30 minutes and 1 hour.

For each interview, a set of questions were posed. These questions were categorized according to the interrogative word (how, where, when, who, what).

In order to properly document how the interview connects with the system's requirements, an ID is given to each question-answer pair and will be associated with its respective functional and non-functional requirements in the upcoming sections.

3.4.2 Requirements for the serious game

Summarizing the interview with Professor Maria van Zeller, the serious game was designed to improve digital health and data literacy for adults in a fun and interactive way. The game should have various multiple-choice questions in a branching scenario. Participants will access the game through a browser, and the interface should be user-friendly for people with less experience with technology. The game should provide feedback on correct answers, and participants can review their results after completing the game. Learning analytics to be collected include answers, timestamps, and media usage.

Only the student actor will interact with the serious game that is hosted by the activity provider. Table 3.2 presents the functional requirements as user stories for this component.

Table 3.2: Description of the user stories for the serious game

Identifier	Name	Priority	Description	Question from interview
US1-1	Register	High	As a student, I want to register in the game, so that I can play the game.	25
US1-2	Group	High	As a student, I want to register the group that I am a part of, so that it can be registered before the game starts.	24
US1-3	View current question	High	As a student, I want to view the current question I am on in the branching scenarios game, so that I can select an answer and advance in the game.	27
US1-4	View question media	High	As a student, I want to view the image or video associated with the current question, so that I view the audiovisual content of the question.	31

The non-functional requirements are presented in Table 3.3.

Table 3.3: Description of the non-functional requirements for the serious game

Identifier	Name	Priority	Description	Question from interview
NF1-1	Compatibility	High	The serious game must be compatible with the most commonly-used Web browsers: Google Chrome, Mozilla Firefox, Microsoft Edge and Opera.	20
NF1-2	Usability	High	The game must be playable by people who have little to no digital literacy. Therefore, the game's user interface must be intuitive, i.e. the users must be able to interact with the game with no external help.	25
NF1-3	Scalability	High	The system must be able to handle between 30 to 40 users playing the game simultaneously without slowing down.	22

3.4.3   Requirements for the activity provider

According to the interview, the activity provider platform aims to create and manage serious game activities. The questions and answers can be edited, and the number of questions and answers can be customized. Media like images and videos can be used in questions.

Only the teacher actor will interact with the activity provider. Table 3.4 presents the functional requirements as user stories for this component.

Table 3.4: Description of the user stories for the activity provider

Identifier	Name	Priority	Description	Question from interview
US2-1	Create activity	High	As a teacher, I want to create activities, so that students can access them to learn.	32
US2-2	Edit activity	High	As a teacher, I want to edit activities (namely their name and the first question), so that I can fix incorrect details or update them.	33
US2-3	Delete activity	Medium	As a teacher, I want to remove activities, so that they are no longer accessible by students.	34
US2-4	Add question	High	As a teacher, I want to add questions, so that they are accessible in the branching scenario of an activity.	35

US2-5	Edit question	High	As a teacher, I want to edit questions (namely the text of the question), so that they are accessible in the branching scenario of an activity.	33
US2-6	Delete question	High	As a teacher, I want to delete questions that are not necessary in the branching scenario of an activity.	35
US2-7	Add extra answer	High	As a teacher, I want to add an extra answer to a question, to the branching scenario of an activity.	37
US2-8	Edit answer	High	As a teacher, I want to edit the answers (namely the text of an answer), so that I can fix incorrect details or update them.	33
US2-9	Delete extra answer	High	As a teacher, I want to delete the extra answer, that is not necessary in the branching scenario of an activity.	37
US2-10	Add/Edit media to question	High	As a teacher, I want to add an image or video to a question, so that students have access to visual information that is important for them to select their answer.	39
US2-11	Choose answer destination	High	As a teacher, I want to choose the next question that an answer will connect after this question is selected as the answer to the current question.	38
US2-12	View analytics	High	As a teacher, I want to view all the analytics collected during an activity, so that I can monitor the student's progress.	41
US2-13	Filter analytics	High	As a teacher, I want to filter the analytics of an activity (namely by the student's identifier), so that I can more easily access specific information of the student's progress.	42

The non-functional requirements are presented in Table 3.5.

Table 3.5: Description of the non-functional requirements for the activity provider

Identifier	Name	Priority	Description	Question from interview
NF2-1	Compatibility	High	The activity provider pages must be able to function with the most commonly-used Web browsers: Google Chrome, Mozilla Firefox, Microsoft Edge and Opera.	43
NF2-2	Usability	High	The activity provider must have an intuitive and simple interface for the creation and editing of activities. It must also provide an easily-readable interface for displaying analytic data that was collected in the activities.	38

NF2-3	Scalability	High	The system must be able to support a large number of activities, a large number of users accessing the activity as well as their respective data analytics collected by the users participating in the event.	41

3.5 System workflows

This section will detail the system's workflows using sequence diagrams. These diagrams are used to validate and document the flow of data in an information system, allowing for a careful analysis of the progression of data inside a framework [49]. The diagrams that will be presented next are based on Morgado *et al.* [38] and adapted to both components: the serious game and the activity provider, each one accessed by a distinct kind of user.

3.5.1 Workflow for IAP creation

Figure 3.4 shows the workflow for a IAP creation in the Inven!RA side.
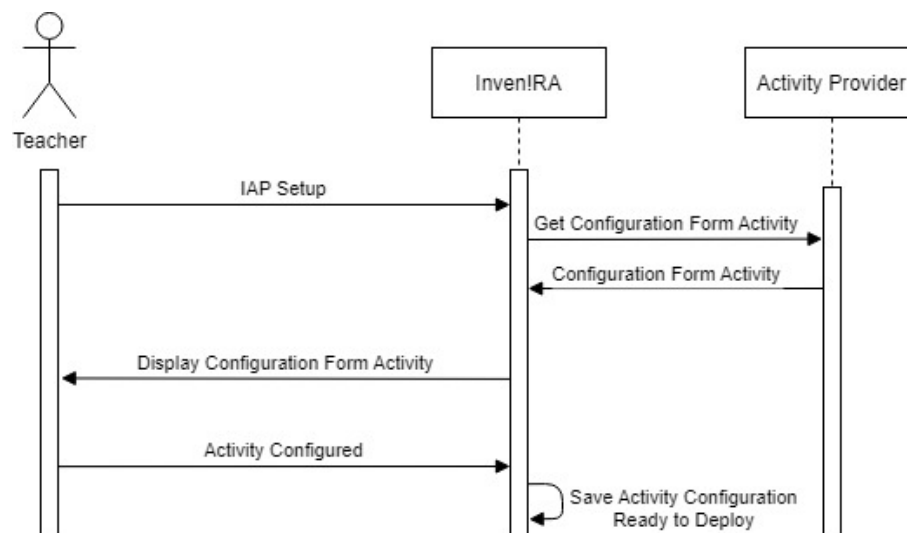

Figure 3.4: Sequence diagram for IAP creation in Inven!RA, adapted from Morgado [38]

Once the activities are created in the activity provider, they become available to be included in the IAP. The teacher sets up the IAP in Inven!RA and includes the desired activities in the IAP.

A configuration window is displayed after an activity from the activity provider is included in the IAP. When the configuration is completed with the desired activities, the IAP is stored in Inven!RA, making it accessible for use.

3.5.2 Workflow for IAP deployment

Figure 3.5 depicts the workflow for IAP deployment to a Moodle system.
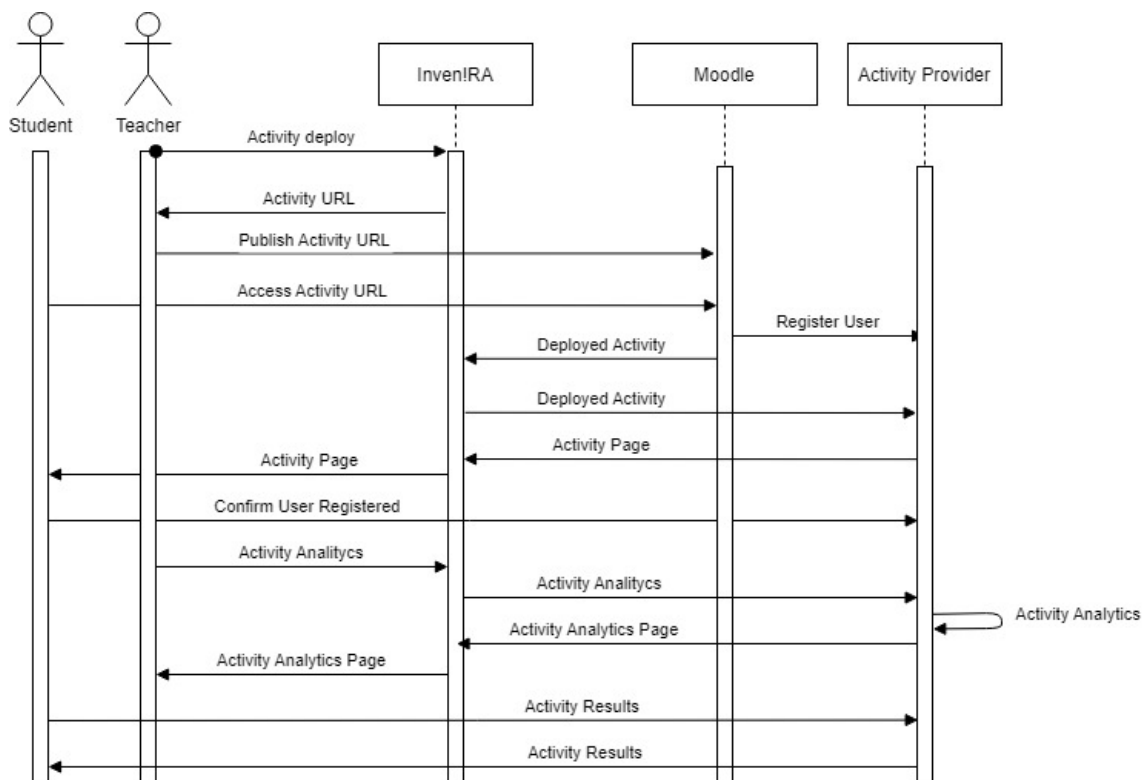
Figure 3.5: Sequence diagram for IAP deployment in Inven!RA, adapted from Morgado [38]

An IAP can be deployed by a teacher via Inven!RA's interface. The deployment produces an URL with the format `http://<domain_name>/deploy-activity-activityID`. This URL can then be configured on Moodle by the teacher, so that students have access to a personalized URL that includes their unique identifier on Moodle.

When a student accesses their unique URL through Moodle, Inven!RA receives the student's Moodle identifier, creates a unique internal identifier on Inven!RA and sends a POST request to the activity provider to add the new student to the activity. The student is then redirected to the activity's page, where they receive a code that grants them access to the branching scenarios via the serious game's mobile app. It should be noted that Inven!RA uses an internal identifier for privacy reasons.

The teacher can then keep track of students' progress on the learning objectives during and after the activity. These objectives' data are collected by the activity provider during the learning activity. The teacher can access this data through the Inven!RA dashboard. Accessing this dashboard triggers a GET request from Inven!RA to the activity provider, which returns a JSON document with the analytics. An example of this JSON is depicted in Figure 3.6. The URL to perform these requests has the format

`http://<domain_name>/analytics-activity-<activityID>.`

```
[
    {
        "inveniraStdID":"64a724111abd5e66a0c8a763",
        "quantAnalytics":[
            {
                "order num.":"2",
                "question text":"Pode uma imagem 3D ajudar-me a perceber a localizacao do figado?",
                "answer text":"O figado fica no peitos.",
                "dificulty level":"Higher",
                "timestamp":"2023-07-06 21:33:41"
            },
            {
                "order num.":"2",
                "question text":"Pode uma imagem 3D ajudar-me a perceber a localizacao do figado?",
                "answer text":"O figado fica no peitos.",
                "dificulty level":"Higher",
                "timestamp":"2023-07-06 21:33:41"
            }
        ]
    },
    {
        "inveniraStdID":"64a728a51abd5e66a0c8a764",
        "quantAnalytics":[
            {
                "order num.":"1",
                "question text":"Aonde fica o joanete?",
                "answer text":"No dedo grande.",
                "dificulty level":"Medium",
                "timestamp":"2023-07-06 21:49:01"
            },
            {
                "order num.":"3",
                "question text":"Como se chama a arteria principal do corpo humano?",
                "answer text":"Azul",
                "dificulty level":"Medium",
                "timestamp":"2023-07-06 21:49:03"
            },
            {
                "order num.":"4",
                "question text":"Para que serve a iris do olho.",
                "answer text":"Para ver as cores.",
                "dificulty level":"Medium",
                "timestamp":"2023-07-06 21:49:05"
            }
        ]
    }
]
```

Figure 3.6: Example of a JSON with analytics

3.5.3   Workflow for the serious game's gameplay

Figure 3.7 portrays the workflow of the students' interaction with the serious game.
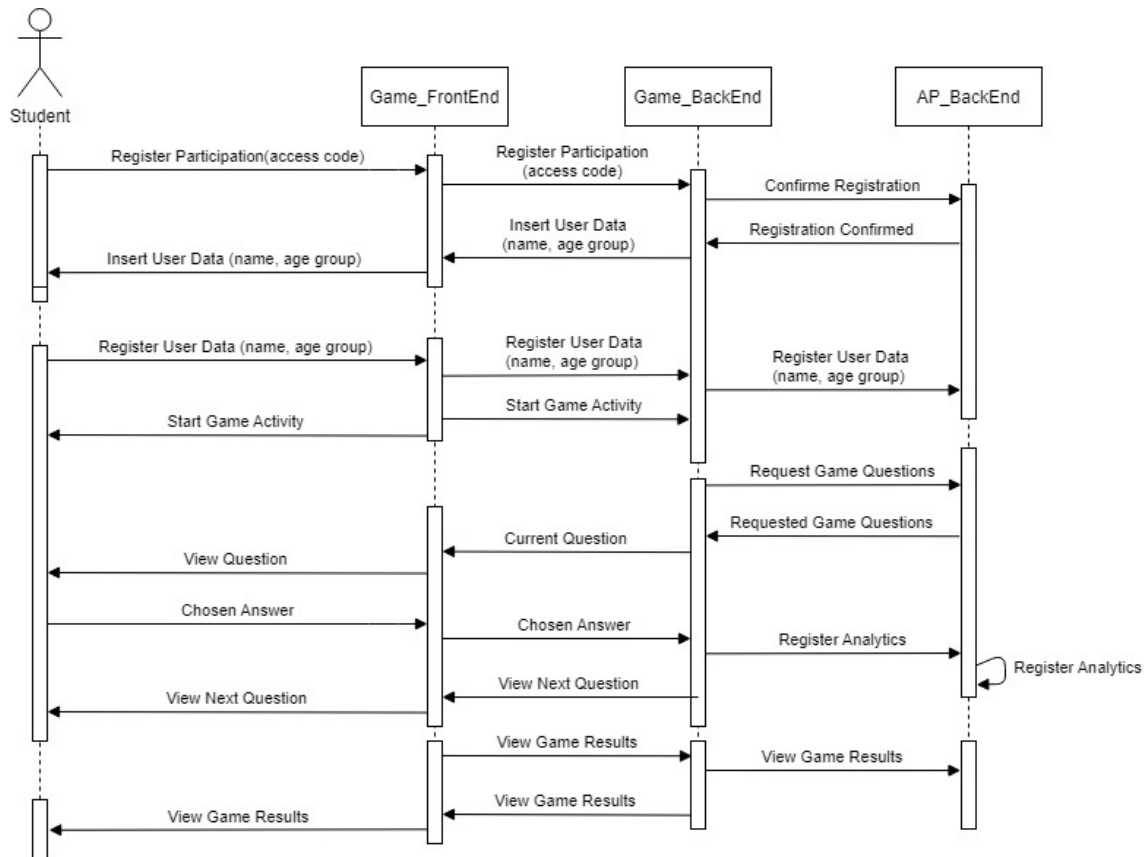

Figure 3.7: Sequence Diagram for the serious game's gameplay

The student registers their participation in the activity that was assigned to them and selects their age group (18 to 25, 26 to 50, or 51+). Then, the student begins the game activity and each of their interactions with the game (frontend) are recorded in the backend.

3.5.4 Workflow for activity creation

Figure 3.8 presents the workflow for activity creation in the activity provider.
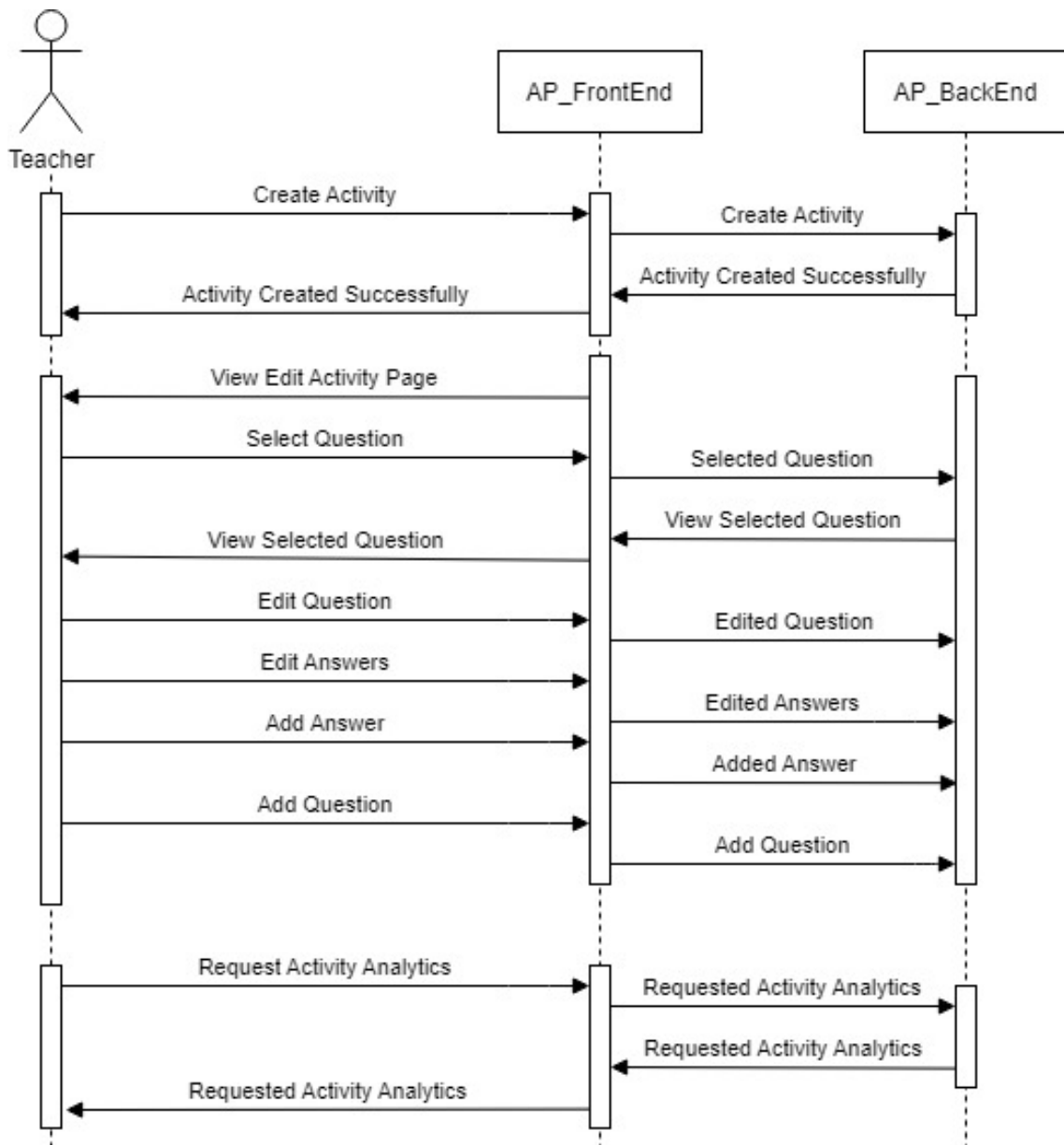
Figure 3.8: Sequence diagram for activity creation in the activity provider

The teacher begins the activity creation process in the frontend, which issues a command to the backend. The backend then notifies the teacher whether the activity was created successfully or not. The teacher then proceeds to the configuration page of the activity, where they can edit questions. After editing each question, the modifications are stored in the backend's database.

The teacher can access the activity provider to access their students' analytics via a dashboard.

3.6   Summary

This chapter began by presenting the main goal of this dissertation, followed by the research methodology based on the Design Science Research (DSR). The chapter then detailed the system's requirements, architecture and workflows.

Chapter 4

System implementation

This chapter presents how the proof-of-concept's system was developed. First the system is thoroughly described, then the implementation steps are detailed. Finally, an evaluation of the prototype using a survey is presented.

4.1 System description

4.1.1 Database structure

The interview with Professor Maria Van Zeller aided in the definition of the database used to support the activity provider. Figure 4.1 depicts the database's structure using a class Unified Modeling Language (UML) diagram.
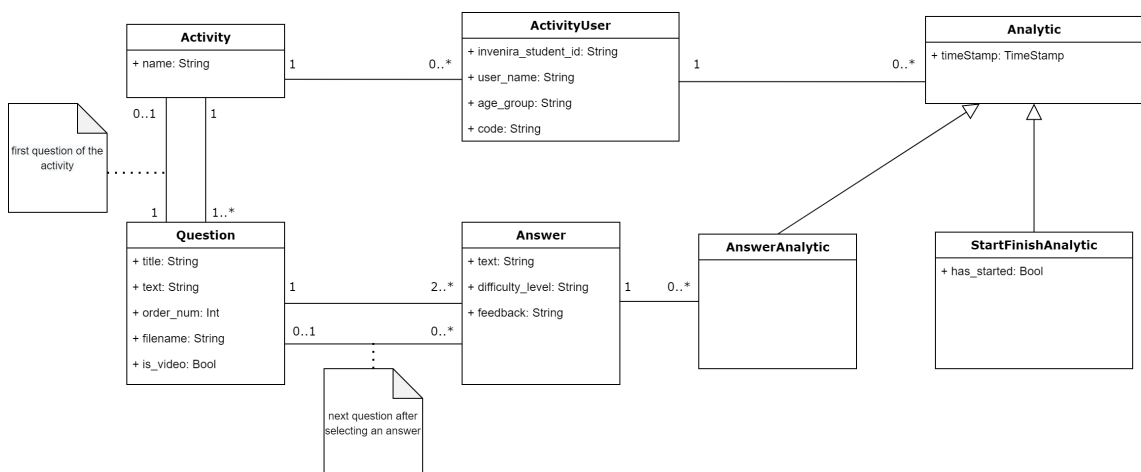
Figure 4.1: Class UML diagram for the activity provider's database

The database is in the Third Normal Form and in the Boyce-Codd Normal form to avoid redundant or repeated information.

The data related to each question (namely the title, text and media) is stored in the Question table. Each question has a set of associated answers, each representing an instance of the Question table). Each user (represented by an instance of ActivityUser) is connected to multiple analytics (associated with the Analytic class). Derived classes were used to allow the analytics to have multiple subtypes, each with their own fields, but with all instances having two common fields: the time instant when the analytic was recorded and the associated user identifier. Finally, the Activity table is used to store the created activities which in turn enables Inven!RA to deploy the activities. Each activity contains a set of parameters that the third-party provider selected for Inven!RA has access to, via the teacher, when creating a IAP.

4.1.2   Description of the activity provider

The activity provider that was developed is a part of the proof of concept. The activity creation page of the platform is shown in figure 4.2. This page allows teachers to create and edit activities.

Figure 4.2: Create Activity, List of available activities

After clicking on the edit button on the activity that the teacher wants to modify, they are directed to an edition page where the list of questions can be found, as shown in figure 4.3. This page allows the teacher to create new questions and change their order by dragging and dropping them. It should be noted that changing this order only affects the visual presentation on the website (to help the teachers organize their activities better). The actual sequence of questions the students will have access to is defined by editing the questions, given that this sequence is non-linear: different questions are accessed according to the answers given to the previous questions, which is the main mechanism of a branching scenario game.

The top of the activity edition page contains a form to allow changing the activity's name and selecting the first question, as shown in figure 4.4.
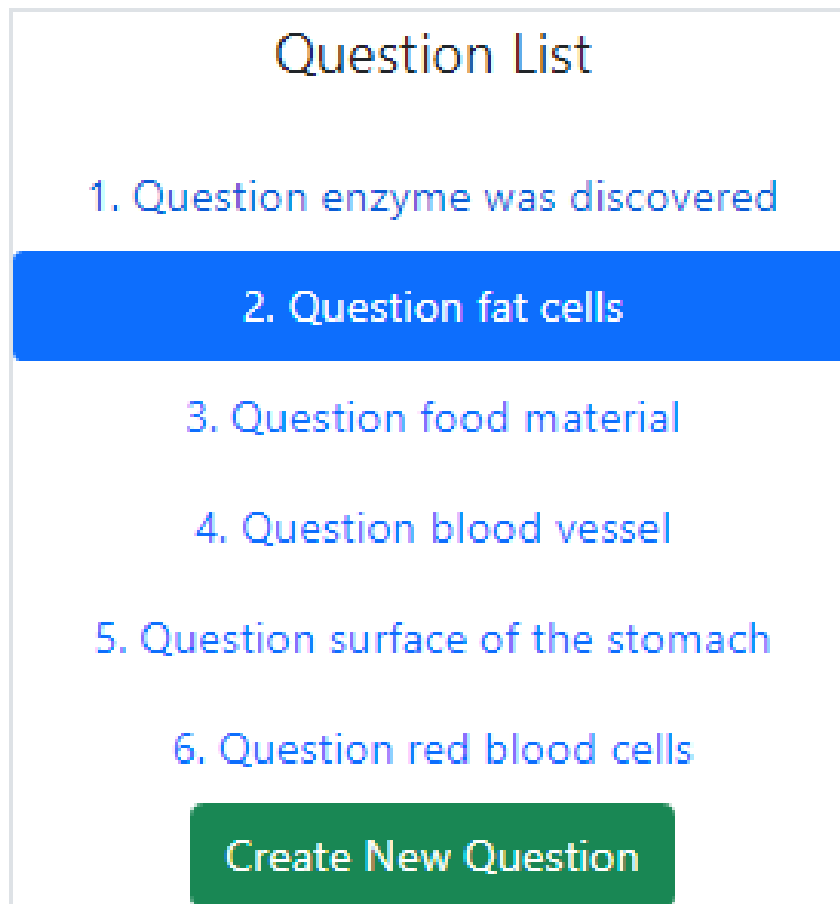
Figure 4.3: Question List

Figure 4.4: Activity Edit

For each question, teachers can edit the question's title and text as well as upload media, which can either be an image or a link to a YouTube video, as shown in figure 4.5.

Each question can have between 1 and 3 answers. 1-answer questions are used to pass additional information to students and to segment activities into parts, with comments or guidelines for the students delimiting each segment. The form also allows the teacher to define which is the

Figure 4.5: Question edit

next question after the student selects a specific answer, as portrayed in figure 4.6. Any answer can also be set to lead to the conclusion of the activity by selecting the "End" option.

Figure 4.6: Answer Edit

The platform also has an analytic dashboard to show the teacher their students' progress after

an activity game session is finished, as shown in Figure 4.7. This dashboard has a separate tab for each type of analytic. It is possible to filter the analytics by the student's name and/or a time interval for when the analytic was collected. Given that hundreds or even thousands of analytics may be collected, the analytics are divided into pages and teachers can set how many analytics should be shown per page. All the results are shown in decreasing order of the timestamp field.

Figure 4.7: Platform Analytics Dashboard

4.1.3   Description of the serious game

The developed game is also part of the proof of concept. It consists of an interactive form branching scenario-type game. The game revolves around a set of questions, each containing a set of answers that vary from one to three that will make the player follow one of the paths that were determined by the teacher. The answer given in each question determines which path the player will follow as is shown in Figure 4.8.
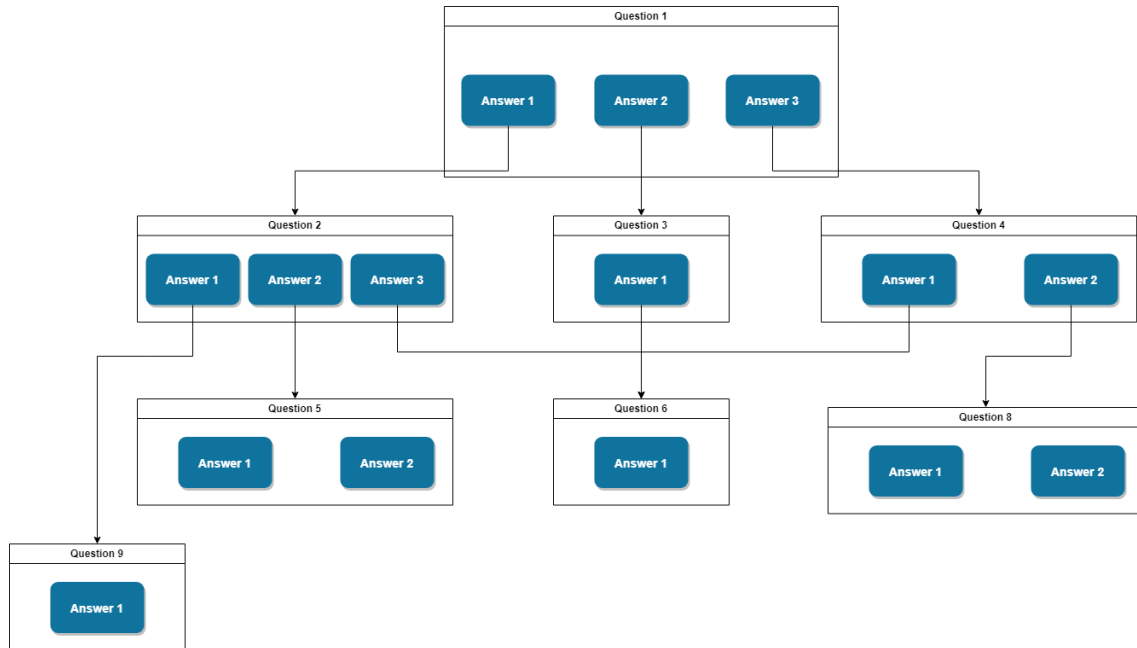
Figure 4.8: Game Flow Diagram

To begin playing the game, players must insert their name and choose the age group they belong to, as depicted in figure 4.9.

Figure 4.9: Game Initial Screen

When the game starts, the player will view the activity's first question, including the question's text, any media attached to it (image or video) and the possible answers. Figures 4.10a and 4.10b provide an example of a question with an image and a Youtube video, respectively.

(a) With Image Screen

(b) With Youtube Video Embedded Screen
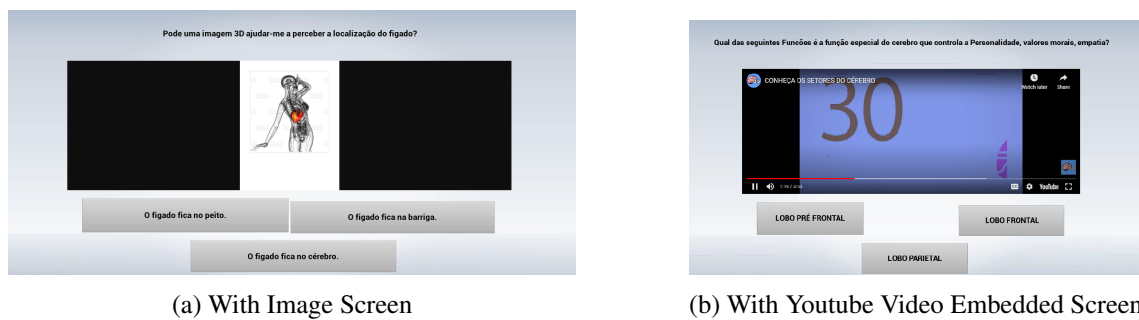
Figure 4.10: Game Question.

4.1.4 Description of the learning analytics

The activity provider collects several game data analytics that are provided for the teacher. The analytics can be divided into two main types:

- Start activity analytics: a single analytic that is created for each student when they start an activity. It records the timestamp for when the student initiated the activity.

- Answer analytic: an analytic that is created when the student answers each question. It records the selected answer and the timestamp.

The analytics are sent by the activity provider to Inven!RA via a HTTP. Inven!RA's dashboard presents not only the elementary information of both types of analytics, but also the following derived data (as presented in Figure 4.11 and 4.12):

- total time elapsed on the activity;

- average time per question;

- question that took the most time to be answered;

- question that took the least time to be answered.

Analytics for "Health Literacy Activity" activity

Analytics dashboard on the activity provider: Link

Student ID - 64a724111abd5e66a0c8a763

order num.	question text	answer text	dificulty level	timestamp
1	Which enzyme was discovered by William Maddock Bayliss and Ernest Henry Starling in the year 1902?	protease	Medium	2023-07-06 21:33:42
2	Which of the following is connective tissue made of fat cells?	epithelial tissue	Medium	2023-07-06 21:33:42
4	The inner surface of every blood vessel is lined by a thin layer of cells known as the:	endothelium	Medium	2023-07-06 21:33:43
5	The inner surface of the stomach is lined by a mucous membrane known as the:	gastric mucosa	Higher	2023-07-06 21:33:43
3	The undigested food material from the small intestine is received by the:	peritoneum	Medium	2023-07-12 23:36:47

Total time elapsed:

187 seconds

Average time per question:

18.36 seconds

Longest Question:

Text: Which enzyme was discovered by William Maddock Bayliss and Ernest Henry Starling in the year 1902?
Time: 24 seconds

Shortest Question:

Text: Which of the following is connective tissue made of fat cells?
Time: 10 seconds

Figure 4.11: Inven!RA Dashbaord Example 1.

Student ID - 64a728a51abd5e66a0c8a764

order num.	question text	answer text	dificulty level	timestamp
4	The inner surface of every blood vessel is lined by a thin layer of cells known as the:	veins	Medium	2023-07-06 21:49:05
4	The inner surface of every blood vessel is lined by a thin layer of cells known as the:	endothelium	Medium	2023-07-06 21:49:08
1	Which enzyme was discovered by William Maddock Bayliss and Ernest Henry Starling in the year 1902?	secretin	Medium	2023-07-06 21:49:10
5	The inner surface of the stomach is lined by a mucous membrane known as the:	mesentery	Lower	2023-07-06 21:49:13
1	Which enzyme was discovered by William Maddock Bayliss and Ernest Henry Starling in the year 1902?	protease	Medium	2023-07-12 23:36:43
4	The inner surface of every blood vessel is lined by a thin layer of cells known as the:	veins	Medium	2023-07-12 23:36:45
3	The undigested food material from the small intestine is received by the:	peritoneum	Medium	2023-07-12 23:36:47

Total time elapsed:

153 seconds

Average time per question:

12.29 seconds

Longest Question:

Text: The inner surface of the stomach is lined by a mucous membrane known as the:
Time: 30 seconds

Shortest Question:

Text: Which enzyme was discovered by William Maddock Bayliss and Ernest Henry Starling in the year 1902?
Time: 2 seconds

Figure 4.12: Inven!RA Dashbaord Example 2.

4.2   Implementation

4.2.1   Iterations

4.2.1.1   First iteration: November 2022 - December 2022

The "Design and development" step of DSR process was performed with the collaboration of Ph.D. Maria Van Zeller. This step consisted of the development of a serious game and a third-party activity provider platform to create and modify activities related to health education. These activities are used in a serious game developed specifically for these activities. The game has a data collection, to be integrated with Inven!RA to perform adequate learning analyses for the teacher.

Using the DSR methodology, an initial interview was conducted with Ph.D. Maria Van Zeller on November 8, 2022. On November 14, 2022, a demonstration of this nonfunctional prototype for both platform and serious game was presented, as shown in Figure 4.13 and Figure 4.14. This prototype was evaluated by Ph.D. Maria Van Zeller, who suggested improvements to the activity provider and serious game, namely:

- on avoiding reloading the page after modifying the information associated with a question, to make the interface more user-friendly;

- allowing for the user to drag and drop the elements of the question list to change the order in which they are presented, to facilitate the construction of more complex branching scenarios;

- introducing images and videos on the serious game, to allow the creation of more engaging questions.
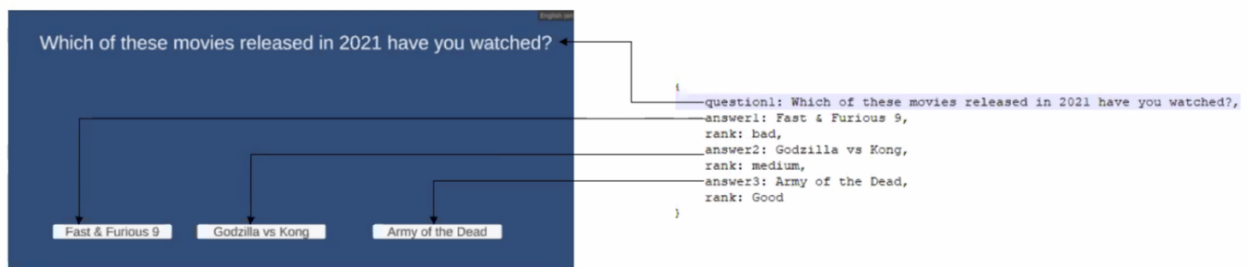

Figure 4.13: Platform prototype

Figure 4.14: Serious game prototype

4.2.1.2 Second iteration: January 2023 - February 2023

In the second iteration, the platform was developed in PHP, a scripting language geared towards Web development. This language was chosen since it is user-friendly and flexible, which allows developers to have more control over the project compared to other programming languages that are bogged down by long, complicated scripts. Asynchronous JavaScript and XML (AJAX) was used on the activity provider to allow users to perform actions on the platform without a compulsory page reload.

The serious game was initially developed with a well-known game engine called Unity, because of its user-friendly, its effectiveness in rendering 2D scenes for game development, and its built-in analytics, which helps to collect data necessary for our proof concept. It was also detected that the game can be accessible with a device with Android/iOS system after the student clicks on the link of the activity that is deployed, the platform will check if the game is installed on the device, if the game is installed the game will startup, if not the platform will redirect to the link to the game to install (ex: Google Play Store). During the evaluation of this second iteration, it was noticed that it is not possible to embed Youtube videos in Unity games without buying plug-ins that did not offer any guarantees of being compatible with the serious game's requirements. This motivated a change in the framework used to develop the game.

4.2.1.3 Third iteration: March 2023 - July 2023

In the third iteration, the game had to be remade in a different game engine that allowed to use of Youtube video links. The engine that was chosen for this requisite was Unreal Engine 4, this engine editor is a bit more complex to use than Unity engine but it provides more features and plugins such as the Web browser that allows using both images and Youtube video links without the need of third-party programs as it is shown in Figures 4.10a and 4.10b, during the demonstration and evaluation, it was made a few suggestions such as change question order by drag and drop.

In this final iteration, the activity provider was also integrated with Inven!RA. This proved to be time-consuming as the version that was worked on for Inven!RA had several issues that needed to be overcome:

- The frontend was not connected properly to the backend. While the backend uses a MongoDB non-relational database stored on disk, the frontend was using a SQLite3 relation database that was stored in memory. Thus, the frontend code had to be adapted to access the backend and use the MongoDB database.

- Understanding Inven!RA code structure was not trivial at certain times as different libraries were being used to accomplish similar tasks. While Javascript was used as the programming language, Node.js as the runtime environment, and React as the underlying framework, different libraries were being used to perform (HTTP) requests: Axios[1], Node Fetch[2] and React Request[3].

The integration is further detailed in subsection 4.2.2.

4.2.2   Inven!RA integration

Inven!RA is integrated with the platform using a service that performs all interactions between the activity platform and Inven!RA, this service provides the deployment and analysis operations.

The activity provider is one of the main components of Inven!RA. It is responsible for the creation and supply of the activities, it is also responsible for storing the analytics for those activities and feeding these analytics to Inven!RA that is not an internal system to Inven!RA architecture.

According to Cota *et al.* [17], in order to register an activity in Inven!RA, the architecture must receive a configuration file. As seen in Figure 4.15, this file is a JSON type file that will need to follow the following configuration parameters:

- *name*: It is the name of the activity provided by the activity provider.

- *config_url*: URL of the Activity Provider website where the activity can be configured.

- *json_params_url*: URL for a Web service that produces a list of items in JSON format listing the configuration page's components where Inven!RA may gather the configuration settings specified there.

- *user_url*: URL for a Web service that permits activity deployment and takes as a parameter an Inven!RA instance identity.

- *analytics_url*: URL for a Web service that accepts a parameter and provides the analytics values for each user of an activity instance in Inven!RA.

- *analytics_list_url*: URL for a Web service that gives a list of the analytics that the Activity Provider will gather.

---

[1] https://www.npmjs.com/package/axios
[2] https://www.npmjs.com/package/node-fetch
[3] https://www.npmjs.com/package/react-request

```json
{
    "name": "Health Literacy Activity",
    "config_url": "http://localhost:80/server/inveniraChooseActivity.php",
    "json_params_url":"http://localhost:80/server/Parametros.json",
    "user_url": "http://localhost:80/deploy-activity-7",
    "analytics_url": "http://localhost:80/analytics-activity-7",
    "analytics_list_url": "http://localhost:80/server/ActivityListParams.json"
}
```

Figure 4.15: Activity Provider Configuration JSON File

4.2.2.1 IAP creation

The Teacher can begin developing a (IAP) after all activities are ready. Every time the learning designer adds an activity, a window with the corresponding configuration page is presented since an IAP is made up of one or more activities as it is shown in Figure 4.16.
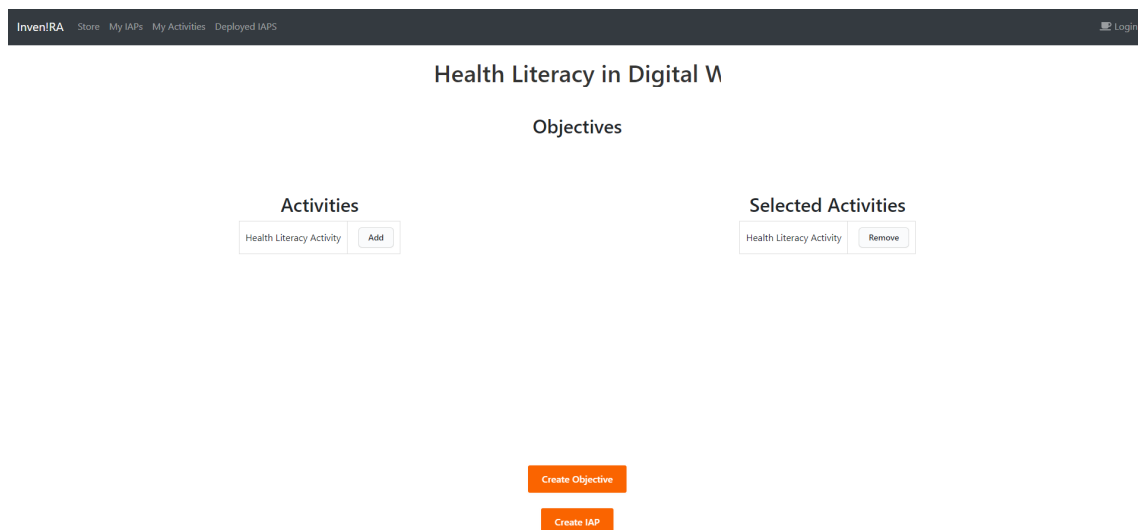
Figure 4.16: Creating IAP

Inven!RA gathers the filled-in data after filling out and storing the configuration data. The setup JSON for the Health Literacy Quiz activity is shown in Figure 4.15. The configuration JSON file provided in the $json_params_url$ field is the foundation for this recording. Reading this JSON identifies the fields, and in this example, the summary and instructions fields' text entries are gathered.

4.2.2.2 IAP deployment

Activity plans are ready for deployment after being created by the teacher. Inven!RA gives an URL that should be published on the LMS platform when the instructor publishes an activity as it is shown in Figure 4.17.
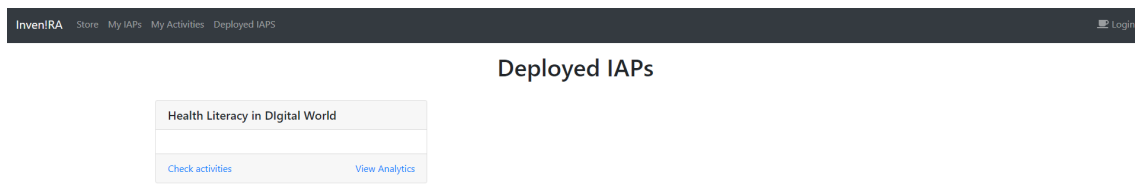
Figure 4.17: IAP Deployed Screen

The last stage in the creation of an activity plan is to obtain the deployed IAP. As it is shown in Figure 4.18 demonstrates how the deployed link for the IAP was created by the teacher, the teacher proceeds to copy this link to a LMS platform, where the student will use it to access the activity of the IAP.
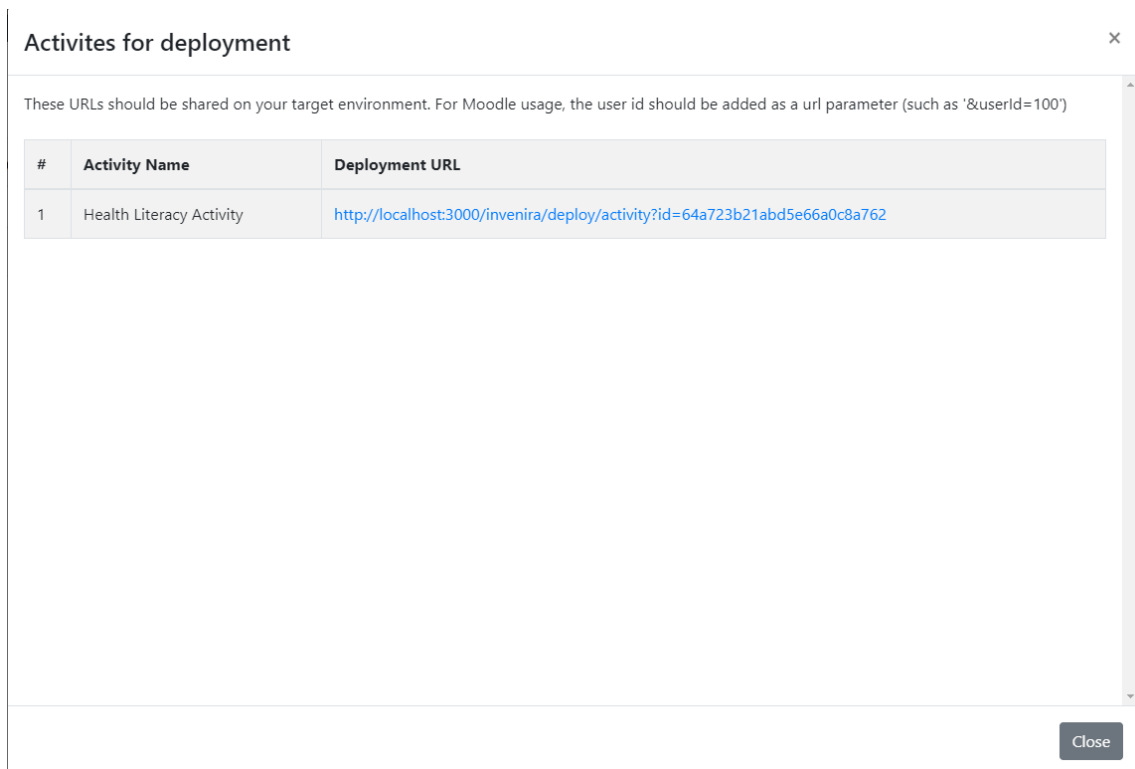
Figure 4.18: Creating IAP

4.2.2.3 Moodle installation and configuration for Inven!RA

The generation of the deployment URL is the next step in the execution of integrated tests. To do this, Moodle was locally installed together with XAMPP, a free and open-source cross-platform Web server solution that incorporates the Apache Hypertext Transfer Protocol (HTTP) Server. The supporting database was developed in MySQL initially it was developed using MariaDB, but was later changed due to better support for JSON by the former database system). The XAMPP server also includes interpreters for scripts written in the Hypertext Preprocessor (PHP) and Perl programming languages.

Four users with student profiles and one with a teacher profile were created to manage the integrated assessments. There is now a course on Digital Health offered as is shown in Figure 4.19.
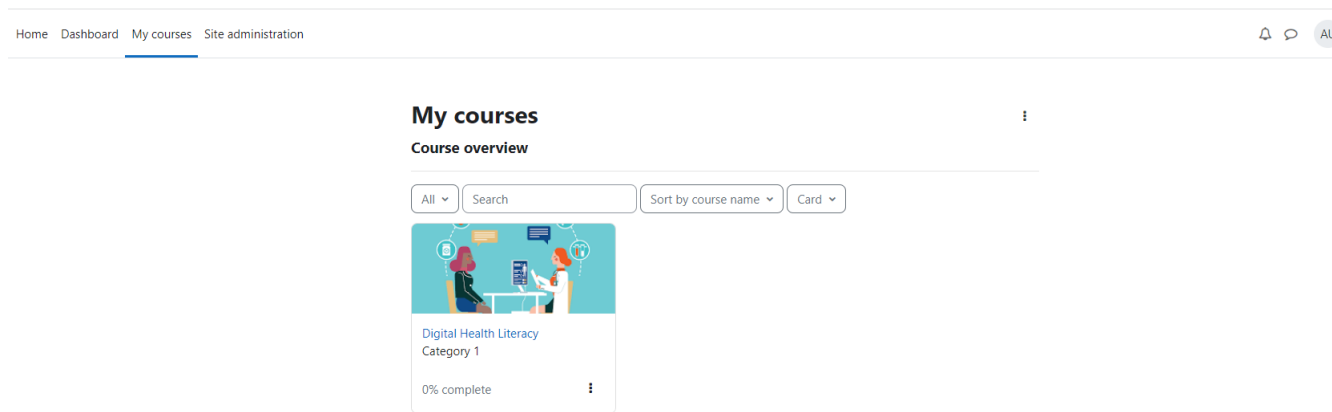

Figure 4.19: Moodle Course

One practical Moodle activity with a Digital Health theme was created in the respective course, where the teacher sets the activity using the external (URL) option where the (URL) provided by Inven!RA is inserted to be available to the students that are enrolled in the course, as it is shown in Figure 4.21 and Figure 4.20.

The teacher then setups the userId in the (URL) variables option, as shown in Figure 4.22. The deployment URL plus userId variable will be generated by Inven!RA was made available in the activity.

This completes the setting of the activity for the students, URL that is shown in the Moodle activity shows that the userId variable is generated and filled with the student's ID and added to the URL provided by Inven!RA. The students have access to the URL `http://localhost:3000/invenira/deploy/activity?id=64a5fe2128185006687c38aa&userId=5` in the Moodle activity page as it is shown in Figure 4.23 when the student clicks on the link.
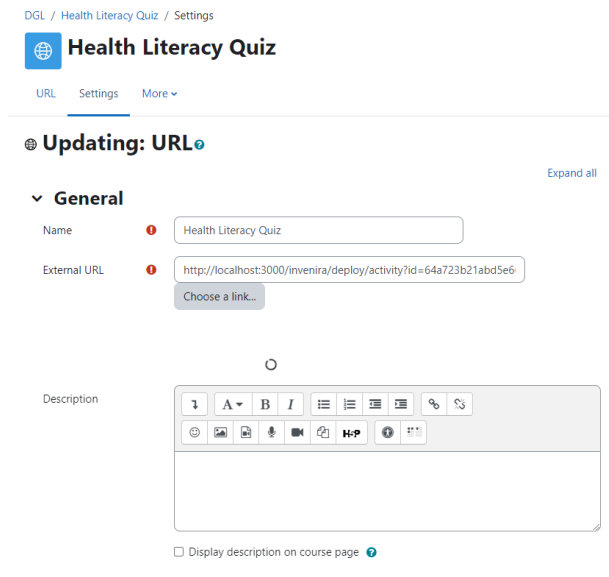
Figure 4.20: Inven!RA Link Moodle
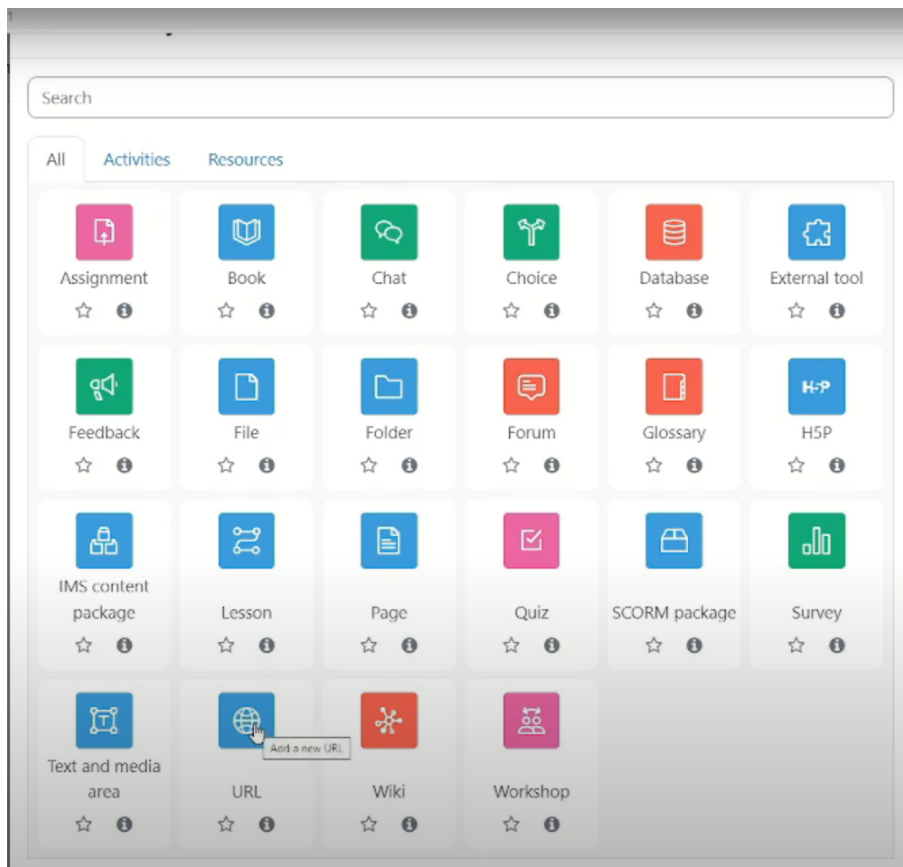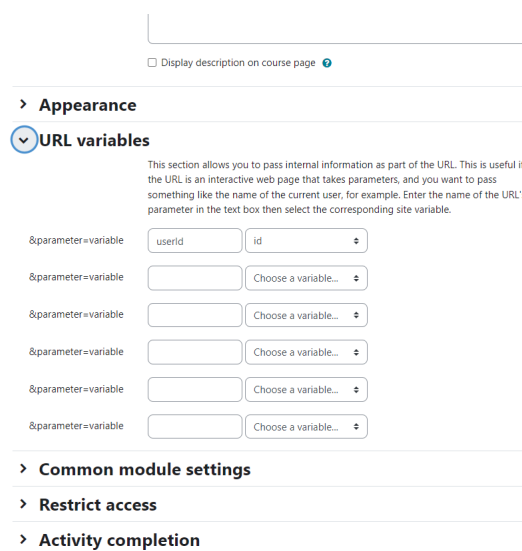
Figure 4.21: Creating Moodle Activity External (URL)

The student is redirected to the page that was provided by the activity provider to Inven!RA in

Figure 4.22: Setting User ID in Moodle
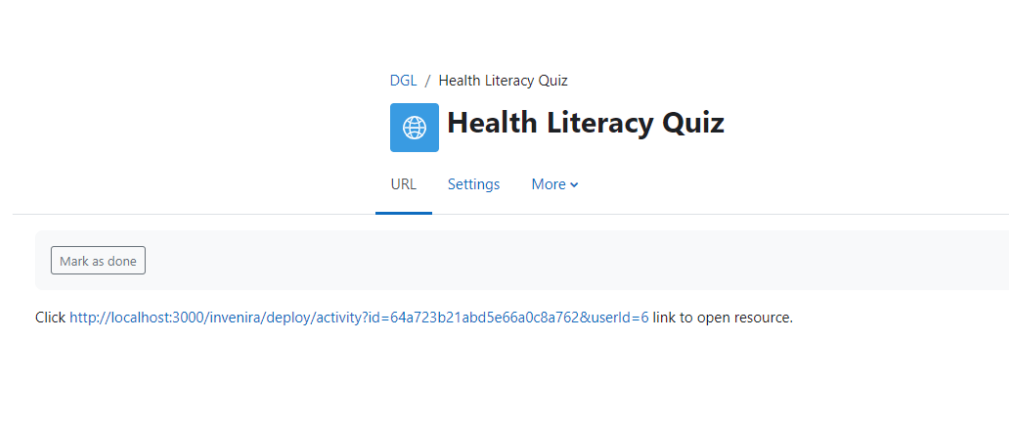
Figure 4.23: Inven!RA Link Moodle

the configuration file in the *user_url* field (Figure 4.15). This page shows the student their unique code that is exclusive to the student to access the activity game as it is shown in Figure 4.24.

Figure 4.24: Student Access Code for the Activity

The student then proceeds to install the game, then the student proceeds to copy the activity access code and insert it in the game's initial screen to proceed to the activity as shown in Figure

4.25.

Figure 4.25: Student Insert Access Code in the Game Activity

4.3   Prototype Evaluation

To validate the prototype, a narrated video[4] was prepared to showcase all of the functional requirements presented in section 3.4 for both the activity provider and the serious game. The video presents all of the system's workflows, including the corresponding steps in Moodle and Inven!RA.

A survey[5] on Google Forms was prepared to assess whether the prototype fulfills all of the functional requirements. It is divided into two parts, one for each main component: activity provider and serious game. In each of these parts, two sections were included in the survey:

- a set of questions asking the user to rank from 1 to 5 whether each of the functional requirements (presented as user stories) were present in the prototype. The lowest score (1) represents that the user story was not implemented at all, while the highest score (5) signifies that the user story was completely and correctly implemented.

- an optional free-text question asking for additional feedback about the component.

Due to the limited amount of time during the thesis work, it was only possible for one person to answer this survey: Ph.D. Maria Van Zeller, who plans to use this work in workshops in the future, according to the first interview in Appendix A.

The following subsections detail the feedback for each of the components.

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[4]https://drive.google.com/file/d/1vyv2A5hXLvyAhHRC9dsannmDiqtjw4O-/view?usp=drive_link
[5]https://drive.google.com/file/d/1AAbdxkRnQEUq14IamHcucz_Ufpxb59Pl/view?usp=drive_link

4.3.1 Evaluation of the serious game

Table 4.1 presents the scoring by Ph.D. Maria Van Zeller for the functional requirements of the serious game. All of the functional requirements achieved the maximum score of 5.

Table 4.1: Feedback of the user stories for the serious game

Identifier	Name	Score (out of 5)
US2-1	Register	5
US2-2	Select age group	5
US2-3	View current question	5
US2-4	View question media	5

In the free-text question, additional feedback was provided:

- Ph.D. Maria Van Zeller commented that she would like to view the progression of the game in a more visually appealing manner. One idea that the author of this thesis suggests is adding a progress bar.

- For future work, it was suggested to thoroughly experiment with playing the game on mobile devices with screens of different sizes, to confirm that the game's interface is responsive.

- It was advised to add options to make the app more accessible, such as increasing the font size or changing the colors (for color-blind people).

From these results, it can be concluded that the serious game completely fulfilled all of the basic requirements identified during the requirements elicitation phase, with some ideas of how the game be improved in the future.

4.3.2 Evaluation of the activity provider

Table 4.2 presents the scoring by Ph.D. Maria Van Zeller for the functional requirements of the activity provider. Most (11) of the functional requirements attained the maximum score of 5, with only a few of them (2) obtaining a score of 4.

Table 4.2: Feedback of the user stories for the activity provider

Identifier	Name	Score (out of 5)
US1-1	Create activity	5
US1-2	Edit activity	5
US1-3	Delete activity	5
US1-4	Add question	5
US1-5	Edit question	5
US1-6	Delete question	5

US1-7	Add extra answer	5
US1-8	Edit answer	5
US1-9	Delete extra answer	5
US1-10	Add/Edit media to question	5
US1-11	Choose answer destination	5
US1-12	View analytics	4
US1-13	Filter analytics	4

In the free-text question, additional feedback was provided:

- Ph.D. Maria Van Zeller commented that she did not find it very clear how to read the collected information in Inven!RA's dashboard and suggested adding a progression line (such as a chart) to make the progression of each student more explicit. This feedback is the likely cause as to why the two user stories related to the analytics obtained the sub-optimal score of 4.

- It was suggested to add the age group of each student to the dashboard.

- Some usability improvements were detailed:

  - Improving the clarity of the different stages of the creation of an activity.

  - Saving the progress during activity creation in a more user-friendly manner than having to click to save the fields.

  - Adding a hierarchical view (for instance with a graph) of the paths formed by the questions within an activity.

  - Adding a button to show a summary of the whole activity.

- On the video, it was suggested that it was not clear how a teacher creates a JSON to set up an activity.

From these results, it can be concluded that the activity provider is suitable for the previously defined objectives and requirements, with some clear lines of how to improve it for future work.

4.4   Summary

This chapter began by describing in detail the proof-of-concept's system, followed by the implementation's iterations and the integration with Inven!RA. The chapter concludes by explaining how the prototype was evaluated with the aid of a survey. The results show that the developed prototype respects the previously-defined requirements.

Chapter 5

Conclusions and Future Work

Conclusions

After examining the state-of-the-art, one can conclude that there has been a significant increase in the past couple of years in using games for education, namely GBL. However, there is still no clear answer to how LA can be applied effectively to a serious game to extract useful data to increase teaching awareness.

The contributions of this dissertation include:

- A serious game based on branching scenarios on a mobile app. The game was developed using the Unreal game engine.

- A server that functions as an activity provider for Inven!RA. The server includes an interface that allows teachers to define their own instances of the serious game by configuring the activity's questions. The interface includes its own dashboard to view the students' analytics throughout the learning activity. The activity provider was developed using PHP and Javascript and the server runs using XAMPP.

- Improvements to the Inven!RA framework, so that its frontend and backend communicate correctly and so that the developed activity provider can communicate with it.

A brief answer can now be provided to the research questions posed during this dissertation:

- *RQ1: What relevant analytic data can be extracted from the game that is useful for teacher awareness?*

  The serious game that was developed is able to register which answer was selected by the students for each question on the branching scenario, as well as a timestamp for when the answer was given. In addition, the game records the timestamp from when students begin the activity. This data, though elementary, allows more complex information to be extracted from the activity, such as the average time taken per question and which questions require the least and most time to be answered, which can reflect which parts of the activity require more thought.

- *RQ2: How can this relevant data be extracted using Inven!RA architecture to perform the analytic analyzes?*

  Chapter 4 detailed how Inven!RA was integrated with the serious game, to serve as a proof-of-concept. This integration shows how Inven!RA can obtain the learning analytics produced by the serious game using HTTP requests. The positive results of the survey in section 4.3 highlight that the serious game and its activity provider have enough quality to serve as a suitable proof-of-concept.

In a nutshell, this dissertation work provides a contribution to the state-of-the-art regarding the use of educational games as a learning tool to provide greater awareness for teachers in monitoring their students during the learning process.

Future Work

This work leads to several lines of future research.

First of all, all of the improvements enumerated by Ph.D. Maria Van Zeller for the serious game (section 4.3.1 and activity provider (section 4.3.2 should be incorporated in the next iteration of the system's prototype. These suggestions will improve the accessibility and usability for both the students and the teachers.

Secondly, the author strongly believes that conducting usability studies with actual students and teachers would have greatly benefited the project, regardless of whether the prototype fulfills its original objectives. By engaging real users, valuable insights could have been obtained regarding their engagement with the prototype and its ability to meet their requirements and expectations. These studies would have provided the opportunity to gather user input, identify areas for improvement, and refine the prototype based on real-world usage scenarios.

Lastly, it will be interesting to develop other types of serious games to integrate with Inven!RA. Despite the game developed in this thesis serving as a proof-of-concept that learning analytics can be collected in real-time, it will be very enriching to compare how the learning analytics of different activities interact in Inven!RA, and to identify which analytics are common to both games.

Appendix A

Interviews with Professor Maria Van Zeller

First interview

The first interview was conducted in order to determine the requirements for the serious game and activity provider. The questions were categorized according to their type.

How?

Q 1 How will the serious game be used?

A: It will be used in workshops. It will be composed as a set of questions and answers about digital literacy.

Where?

Q 2 Where will the users be able to have access to the serious game?

A: The user will have access to the serious game through TRIO's Moodle, which belongs to INESC-TEC.

Q 3 Where will the results be stored and they will be visible to the user?

A: The results may be accessible to the user, and the data will be stored in a game server.

When?

Q 4 When does the data collect from the serious game need to be available to the activity creator?

A: The data needs to be available during and after the event.

Who?

Q 5 Who will be creating the serious game activities?

A: The presenter of the event.

Q 6 Who will do the serious game activity?

A: The users that will participate in the event, this users will be divided into groups of 18-25, 26-50, and 51+ groups.

Q 7 Who will have access to the serious game analytics of the activities during the event?

A: Only the presenter of the activity and administrator should have access to the analytics data of the activities.

What?

Q 8 What physical location is the user in to use the serious game?

A: To play the serious game the user will need to be in the event that he will participate.

Q 9 What will be the phases in using the serious game?

A: The serious game will be used in three phases, each phase will have 2 questions and will be about different digital literacy areas.

Q 10 What is the use of the serious game in the environment where it is inserted?

A: The serious game will be used to promote digital illiteracy in digital environments.

Q 11 What is TRIO's objective?

A: Is a project that aims to develop ways to improve digital health and digital data literacy for adults of all ages.

Q 12 What are the expectations?

A: It is to develop a model approach with a complete curriculum and toolset for educators, supporting a teaching platform that ensures the flexibility to adapt to users.

Q 13 What options will the end user have at their disposal?

A: The options will be, enter the game with your user profile, start the game, answer the questions and see the results.

Q 14 What data should be extracted for analysis?

A: The data to be extracted will be the answers that the player will give to the questions, the current level if it reached the end and the result of the game.

Q 15 What infrastructures are intended to be used?

A: The infrastructures will be those of INESC-TEC

Q 16 What tools can be used in the development of Serious Game?

A: The developer is free to choose what tools are appropriate for the development of the Serious Game.

Second interview

This second interview was conducted in order to consolidate and rectify some of the requirements missed in the first interview, this interview was divided to better comprehend the division between the serious game and the activity provider platform.

Questions about the serious game

Q 17 Which purpose will the serious game serve?

A: The serious game will serve as a vehicle to improve digital health and digital data literacy for adults of all ages, in a fun and interactive way.

Q 18 How should the serious game be structured? Should the serious game be a normal quiz or be more complex like a branching scenario?

A: The serious game structure should be more complex than a normal quiz, it can take the approach like a branching scenario, with a number of questions, and each answer can proceed to a different question, for example, question 1-answer1 proceed to question 2 and question-answer2 proceed to question 3.

Q 19 Should the questions be divided into phases?

A: The serious game should be divided into three phases where each phase will have a minimum of two questions for each phase for the participant to answer.

Q 20 Will the serious game be used in an online or offline environment? If it is online, should it be accessible via a browser? If so, which browsers should it be compatible with?

A: The serious game is expected to be used in an online environment, the serious game should be able to be played with the most used browsers (Google Chrome, Mozilla Firefox, Microsoft Edge, and Opera).

Q 21 Who will be participating in the activity?

A: The participants are people that have low literacy in the topics of digital health and digital data literacy, they are 18+ years old.

Q 22 How many participants are expected to participate in a single activity?

A: The number of participants that are expected to participate in an activity in an event that will perform an activity is 40 people.

Q 23 Will the participants be divided into groups? If so, according to which criteria should the users be divided?

A: The participants are to be divided into 3 different types of groups (example: group 1 = 18-25, group 2 = 26-50, and group 3 51+),

Q 24 Which options should be available for the participant to interact with the serious game?

A: The participant should register his/her participation, choose the activity that it is supposed to participate and start the serious game.

Q 25 How should the game's interface look like so it is intuitive for people with less experience with technology?

A: The interface should be the most user-friendly possible, taking into account universal design concerns, for example, devices that have enabled the increased size of the character type.

Q 26 Should the game have a feedback system for the participant? If so, how should it work?

A: The most suitable feedback that can be given to the participant should be to show which answer is the correct answer.

Q 27 Should the results of the activity be shared with the participant? If so, which results should be shared?

A: Yes, the participant should be able to see the question and respective answers at the end of the serious game.

Q 28 What type of information should be extracted from the serious game, which may be considered useful for the teacher?

A: The information that should be recorded is the activity name, the timestamp of every interaction, the question, the answer selected by the participant, and if it starts and finishes watching a media file.

Q 29 Can a user select a specific language for themselves or will all participants play the game in the same pre-determined language?

A: The user should not be able to select other languages that are not predefined by the activity file.

Q 30 Which security threats should the game be robust against? (examples: prevent the unauthorized participation, multiple open sessions from the same participant ...)

A: The game must not allow for the participants to open more than one window session, it also should prevent cheating, for example, running third-party software to now the correct answer.

Q 31 How should a question's media be shown to a user? For videos, can the media be replayed? Does the video start once the new question is shown or only after pressing a play button?

A: If the question has a video to be displayed, the video should start playing before it displays the question to the participant, it also should able to be replayed.

Questions about the activity provider

Q 32 Who will create the serious game activities?

A: The activity will be created by the host of the event/workshop, it should be also able to delete the activity.

Q 33 Can the user edit the text of a question and its answers?

A: Yes the user that creates the activity should be able to edit the text of both questions and answers.

Q 34 Can the user create more than one activity? Or can they only create one instance of the serious game?

A: The user should be able to create, and delete as many activities as it deems necessary.

Q 35 Should the number of questions in an activity be customizable by the user? If so, what is the minimum and maximum amount of questions?

A: Yes, the minimum number of questions for an activity should be six, and should give the user the ability to increase or decrease the number of questions if it deems necessary.

Q 36 What will be the appropriated number of answers for a question by default?

A: Each question should have at least two answers.

Q 37 Should the number of answers be fixed or should the user have the option to add/delete answers from a question? If so, what is the minimum and maximum amount of answers per question?

A: If the should be able to add at most one more answer to a question, it should also be able to delete this extra answer if deems necessary.

Q 38 How should the user configure the question a participant goes to next? What should the interface look like? Is the next question fixed and based only on the answer to the previous question?

A: The user should have a user-friendly interface that should be able to easily choose what question should be connected to the answer (excluding the question that the answer belongs to).

Q 39 Will the user be using media for the activity questions? If so what type of media should be expected? (examples: images, videos...) If videos are used, what is the maximum duration (in seconds) and size (in MB) for a video?

A: Yes, the user should be able to use media such as images, videos, or gifs, the videos should be at most three minutes long, and should be embedded in the game like a video stream.

Q 40 What type of analytics data should the system collects? What fields should each instance of an analytic have?

A: The information that should be recorded is the activity name, the timestamp of every interaction, the question, the answer selected by the participant, and if it starts and finishes watching a media file.

Q 41 When should the analytics data be available to the user? During the activity (when participants are still playing the game) or only after the activity ends?

A: The information should be available to the user when the activity starts, during the activity, and after the activity is performed.

Q 42 Which criteria should be used to filter the analytics data? (examples: timestamp, user ID . . .)

A: The information should have the following filters, activity data and time, activity name, and participant name.

Q 43 Which browsers should the activity provider be compatible with?

A: The activity provider should be compatible with the most used browsers (Google Chrome, Mozilla Firefox, Microsoft Edge, and Opera).

Q 44 Which security threats should the activity provider be robust against? (examples: prevent the unauthorized participation, SQL injection. . .)

A: The activity provider platform must be robust against attacks such as SQL Injection, Cross-Site Request Forgery (XSRF), Denial of Service (DoS) and unauthorized user access.

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