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Electronic, didactic, and innovative platform for learning based on multimedia assets

e-DIPLOMA

Funded by the European Union

D.5.3 System usability and validation and ergonomics evaluations

Version No. V1.4

31.07.2025

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2. Table of Contents

0. Executive summary

This deliverable presents the usability evaluation and ergonomics assessment of the three educational prototypes developed within the e-DIPLOMA project. These prototypes integrate advanced technologies such as Virtual Reality (VR), Augmented Reality (AR), and AI-driven tools in diverse learning scenarios, with the objective of fostering digital and pedagogical innovation in European education.

The evaluation followed a structured and mixed-methods approach combining standardised instruments (System Usability Scale – SUS, Simulator Sickness Questionnaire – SSQ, and Igroup Presence Questionnaire – IPQ) with qualitative techniques including thinking aloud protocols and semi-structured interviews. Across all prototypes, the main goals were to identify usability barriers, understand user experience, and propose actionable improvements to align the platform with learners' needs and cognitive ergonomics principles.

Prototype 1 focused on block-based programming and Arduino education, evaluated through five lessons using immersive video, VR, and AR. Results highlighted high usability in video-based lessons and lower usability in immersive experiences, particularly those involving complex VR interactions, which occasionally led to frustration and loss of control. AR-based lessons revealed significant interface and readability issues.

Prototype 2 addressed social entrepreneurship through narrative-driven, collaborative, and AI-enhanced games. While the concept was well-received, challenges emerged regarding language accessibility and lack of clear tutorials, which impacted the learning flow and caused user disorientation. Despite this, collaborative mechanics and game-based strategies were valued by participants once supported by additional explanations.

Prototype 3 was designed for educators and focused on the acquisition of VR teaching competencies. Lessons involving basic interaction and navigation scored moderately in usability, while advanced lessons revealed critical issues such as high cognitive load, unclear objectives, and language barriers. Disorientation and dizziness were reported in specific VR minigames, emphasising the need for clearer guidance and smoother interface design.

Overall, the study identified recurring needs across all prototypes, including:

- The implementation of multilingual support,
- The systematic inclusion of introductory tutorials,
- Optimisation of interface design and readability,
- And improvements in flow control and interaction mechanics.

These findings provide a solid foundation for the iterative refinement of the e-DIPLOMA platform and its deployment in real educational settings. Addressing the identified issues will increase user satisfaction, support pedagogical effectiveness, and enhance accessibility for diverse learner profiles.

1. Introduction

This deliverable presents the results of a structured usability evaluation of the three educational prototypes developed within the e-DIPLOMA project. The study was designed to assess the accessibility, interaction quality, and overall user experience of the prototypes, which integrate advanced technologies such as Virtual Reality (VR), Augmented Reality (AR), and AI-driven systems into educational scenarios.

The usability study was conducted as a foundational phase in the iterative development of the platform, aligned with user-centred design principles and the cognitive ergonomics of immersive learning environments. The evaluation adopted a mixed-methods approach that combined standardised usability instruments (i.e., SUS, SSQ, IPQ), observation techniques, and qualitative feedback through thinking-aloud protocols and semi-structured interviews. This methodology allowed us to capture both objective usability performance and subjective user perceptions, across diverse user profiles and technological modalities.

The main goals were to identify usability barriers, interaction breakdowns, and design opportunities to enhance system intuitiveness, engagement, and educational relevance. The insights obtained were instrumental in refining the platform's functionality and aligning it more closely with learner needs and expectations.

The structure of this deliverable follows a prototype-by-prototype analysis. Section 2 presents the overarching methodological framework, including instruments and protocols. Sections 3 to 8 detail the evaluation process for each prototype, with a focus on usability dimensions such as interface clarity, interaction fluidity, control, and cognitive load. Each section ends with improvement proposals and conclusions based on the data collected.

By focusing exclusively on the usability evaluation, this document contributes to the continuous enhancement of the e-DIPLOMA platform, supporting its alignment with educational goals and paving the way for future deployment and experimentation in real-world learning contexts.

2. Methodological Framework for Usability Evaluation

The usability evaluation conducted within the e-DIPLOMA project was designed as a fundamental phase to assess the relevance, coherence, and quality of interaction provided by the three developed prototypes. These studies were not merely conceived as technical assessments but as part of a broader pedagogical validation strategy that places the user—be it learner or educator—at the centre of the design process.

User testing is one of the main techniques within user-centred design. This methodology allows for the identification of usability problems in a product, regardless of the technology used, by observing the behaviour of a group of users during their interaction with the product (ISO. (2019). ISO 9241-210:2019) . By combining observation with data collection protocols such as semi-structured interviews, the thinking-aloud method, and questionnaires, participants can verbalise their thoughts while using the product (Nielsen, J., & Landauer, T.K.(1993). This approach enables researchers to understand both users' actions and the reasoning behind those actions.

The qualitative information obtained through this approach facilitates the identification of usability problems and the proposal of improvements and solutions to optimise the user experience.

To carry out this analysis, questionnaires were administered after each lesson, supplemented by a series of usability questions that were asked both during and at the end of each lesson. This information is explained in detail in the instruments and data collection section. This data is linked to the specific needs of the users, based on the main usability standards and the principles of cognitive ergonomics applied to virtual environments (Salvendy, G. (Ed) (2012). From this information, results will be provided that address the following issues related to:

- **Interaction**: The difficulties that users experience when interacting with the virtual environment are evaluated, specifically those arising from problems related to the means that facilitate such interaction, such as buttons, controllers or scrolling systems. The effectiveness of these mechanisms is fundamental to ensure a smooth and efficient experience.
- **Loss of control**: The phenomenon that arises when the user does not understand what actions to perform or is unable to complete them successfully, which can lead to significant frustration and non-completion of the proposed tasks. An example of this situation is when the user does not understand the goals of the task or how to achieve them, which compromises the overall user experience.
- **Narrative flow:** The interruptions or inconsistencies in the logical progression of tasks or the storyline within the virtual environment. A coherent narrative structure facilitates user engagement and task completion, while disruptions can lead to confusion, increased completion time, and reduced immersion.

- **Interface design**: Difficulties related to the visual and structural design of the virtual environment, including the user's ability to recognise objects, navigate through different scenarios, and interpret visual aids. Ineffective design may increase cognitive load and interfere with smooth interaction, ultimately compromising the immersive experience.

2.1 Objectives and evaluation logic

The primary objective of the usability studies was to systematically collect user feedback on the accessibility, functionality, satisfaction, and educational affordances of each prototype. The evaluation was designed to answer key questions such as:

- How intuitive and efficient is the interaction across different technological modalities (VR, AR, 2D)?
- To what extent do users feel immersed, engaged, and in control of their learning process?
- Are the system responses and interface elements consistent, responsive, and cognitively ergonomic?

These questions were framed within a dual perspective: assessing both the technological robustness of the system and its pedagogical usability from a learner-centred standpoint.

2.2 Instruments and data collection tools

To ensure the methodological soundness of the studies, a mixed-methods approach was adopted, combining validated quantitative instruments with exploratory qualitative techniques (see Table 1). Specifically, the following tools were employed:

- **System Usability Scale (SUS):** The System Usability Scale (SUS) is a standardized tool used to evaluate the usability of a system or product. It consists of a 10-item short questionnaire that yields a quantitative score of the user experience (Brooke, 1996). Each item is rated on a 5-point Likert scale from “strongly disagree” to “strongly agree”.

  The questionnaire assesses usability factors such as ease of use, efficiency, and overall satisfaction. Participants rate their perception of the system’s complexity, safety, and willingness to reuse it. Scores range from 0 to 100, with higher scores indicating better usability. SUS is widely used due to its simplicity, effectiveness, and reliability across different technologies.
- **Simulator Sickness Questionnaire (SSQ)**: The motion sickness questionnaire (Campo-Prieto et al., 2021) is a tool used to assess the incidence and intensity of discomfort or dizziness experienced by users during interaction with VR or AR environments. Since immersion can induce discomfort in some users, this questionnaire is essential to understand and mitigate the adverse effects of immersive technologies. The SSQ uses a 7-point Likert-type ordinal scale to assess the severity of symptoms experienced at the time of evaluation. Each item is rated from 1 (no symptoms) to 7 (severe symptoms), allowing for a nuanced, subjective quantification of

discomfort related to nausea, oculomotor strain, and vestibular disorientation. This scaling method ensures consistent interpretation of symptom intensity across participants and studies.

- **Igroup Presence Questionnaire (IPQ)**: developed by Berkman et al. (2021), measures users' sense of "presence" in virtual environments, particularly in VR and AR applications. Presence refers to the subjective feeling of being "inside" a virtual environment, perceiving it as real rather than digital. The IPQ uses a 7-point Likert-type ordinal scale to measure the subjective sense of presence in virtual environments. Participants rate each item from 1 (strongly disagree) to 7 (strongly agree), reflecting their agreement with statements related to spatial presence, involvement, and experienced realism. This scale allows for consistent interpretation of users' perceived immersion and presence across different experimental conditions.
  The current version of the IPQ consists of three subscales and an additional general item that is not part of any subscale. These subscales were developed through principal component analysis and are considered relatively independent factors:
    - Spatial Presence: Measures the sensation of physically being in the virtual environment (VE), as if the user is "inside" the space.
    - Involvement: Assesses the level of attention dedicated to the virtual environment and the degree of emotional and cognitive engagement experienced.
    - Experienced Realism: Evaluates the user's subjective perception of how realistic the virtual environment feels.

  This multidimensional approach allows for a comprehensive evaluation of the user's sense of presence, which is critical for understanding the effectiveness of virtual environments in creating immersive and engaging experiences.
- **Thinking aloud protocol** the thinking aloud method is a qualitative technique used in usability and user experience studies. (Nielsen, J., & Landauer, T.K.(1993). Participants are asked to verbalize their thoughts, emotions, and actions while interacting with a product, system, or interface.
  During testing sessions, users describe their intentions, reactions, and any confusion or frustration they experience in real-time. These data were collected on paper during the interview.This method provides deep insights into users' cognitive processes and emotional responses, helping researchers identify usability issues that might not surface through observation alone.
- **Semi-structured interview**: is a qualitative research technique used to gather detailed and in-depth information about participants' experiences, perceptions, and opinions. Unlike structured interviews, which follow a rigid, predefined format, semi-structured interviews combine a set of specific questions with the flexibility to explore additional topics that may arise during the conversation. This approach allows researchers to maintain focus while encouraging

spontaneous insights, making it particularly valuable for understanding complex behaviours, attitudes, and motivations in a nuanced manner.

The combination of these instruments ensured a comprehensive, triangulated understanding of usability issues, capturing both the measurable dimensions of interaction and the nuanced experiences of users.

Table 1: Instruments and data collection tools

Prototype	Lesson	Technology	SUS	SSQ	IPQ	TA/INT
P1	L1	Immersive Video	✔	—	—	✔
P1	L2	VR	✔	✔	✔	✔
P1	L3	Immersive Video	✔	—	—	✔
P1	L4	AR (Tablet)	✔	—	—	✔
P1	L5	VR	✔	✔	✔	✔
P2	L1	VR	✔	✔	✔	✔
P2	L2	VR	✔	✔	✔	✔
P2	L3	PC (Edison)	✔	—	—	✔
P2	L4	PC (AI)	✔	—	—	✔
P2	L5	PC (Multiplayer Game)	✔	—	—	✔
P3	L1	VR	✔	✔	✔	✔
P3	L2	VR	✔	✔	✔	✔
P3	L3	VR	✔	✔	✔	✔
P3	L4	VR	✔	✔	✔	✔
P3	L5	VR	✔	✔	✔	✔
P3	L6	VR	✔	✔	✔	✔

2.3 Experimental protocol

The study's objective is explained to the participant, ensuring they clearly understand what is expected of their participation and how they will contribute to the usability evaluation of the lessons. This explanation sets the stage for the next phase: the experimental phase.

The experimental phase is divided into five parts, corresponding to the five lessons included in the application in prototype 1 and 2 and six similar phases in prototype 6. During each lesson, the "thinking aloud" technique is used, where participants are asked to verbalize their thoughts while interacting with the interface. This methodology allows for a detailed description of the user's actions and their impressions of the positive and negative aspects of the experience. This technique is key to gathering qualitative information that helps identify usability issues.

At the end of each lesson, participants are invited to complete a series of usability surveys (SUS, semi-structured interview), designed to evaluate their experience in terms of ease of use, overall satisfaction, and other key aspects of interaction with the application. These surveys provide qualitative and quantitavie data that complement the qualitative observations gathered during the experimental phase.

Finally, for the lessons incorporating virtual reality, additional questionnaires (i.e., SSQ and IPQ) is administered to assess the feeling of presence and any potential dizziness effects experienced by the user.

2.4 Data analysis strategy

Quantitative data were analysed using descriptive statistics (mean, standard deviation, score range) to identify patterns and deviations. SUS scores were benchmarked against industry standards. IPQ and SSQ subscales were analysed lesson-by-lesson to detect anomalies.

The emerging themes of interviews and thinking aloud were grouped into four domains: interaction design, narrative coherence, cognitive load, and affective engagement.

The integration of these findings across data sources enabled a holistic, evidence-based understanding of usability, forming the basis for targeted recommendations in subsequent sections.

3. Usability Evaluation- Prototype 1: Block Programming and Arduino

3.1 Description and pedagogical intent

The first prototype developed within the e-DIPLOMA framework is aimed at fostering the acquisition of basic computational thinking and electronics principles through an immersive and gamified instructional approach. Designed primarily for secondary education and vocational training contexts, this prototype introduces learners to block-based programming and Arduino microcontroller components using a carefully sequenced blend of technologies: immersive video presentations, VR, and AR.

3.2 Prototype description

The prototype is divided into five lessons:

- **Lesson 1**: Conceptual foundations are delivered through a series of immersive videos presentations generated using Edison technology, introducing learners to programming logic in an accessible manner.
- **Lesson 2**: Learners transition to a VR game where they apply programming knowledge in problem-solving scenarios.
- **Lesson 3**: Immersive video presentations provide theoretical grounding in electronics, introducing key Arduino components, information about sensors and actuators.
- **Lesson 4**: Through a tablet-based AR activity, users explore the anatomy of an Arduino board by interacting with digital replicas.

- **Lesson 5**: The final lesson consolidates acquired knowledge in a collaborative VR simulation, where learners must jointly resolve a real-world challenge.

This prototype exemplifies the "learning-by-doing" philosophy, aiming to reinforce understanding through experiential engagement and contextual application.

3.3 Sample

The sample consisted of a total of 10 participants, 5 men and 5 women. Participants ranged in age from 21 to 45 years. Considering the rule of 5 proposed by Jakob Nielsen (Nielsen, J., & Landauer, T.K.(1993) and the complexity of the prototypes evaluated in various tests during prototype development, we believe it would be interesting to double that number with a final sample of 10 users per prototype. Similarly, the data extracted from the final participants in the usability study provided little to no insight into the main changes needed, so we established the proposed sample of 10 users as sufficient. All participants had full physical mobility and had no prior knowledge with immersive technologies such as virtual reality. The average age of the men was 30.4 years, and that of the women was 31 years.

4. Results

4.1 Usability Survey (SUS)

An analysis of the data extracted from the questionnaires by lesson (see Figure *1*) showed that:
In the first lesson, the average score on the questionnaire was 72.8 (out of 100), which places it in the high range, with good usability. Despite the non-immersive lessons, this corresponded to a positive user perception, and therefore, the viewing usability must meet the questionnaire requirements. The highest scores on this questionnaire were for items such as "*I found the functions well-integrated*" or "*I think I would like to use this system often*." On the other hand, the lowest scores were for items such as "*I thought there was too much inconsistency in the system*."
In the second lesson, which involved the block programming VR game, obtained a score of 60, a slightly lower score than in the previous case. Although it is a system that, on average, is easy to implement, it has a somewhat low score, making it practical and simple. Analysing the questionnaire by item, the highest scores were found for items such as "*I felt confident in using the system*" and "*I think I would like to use the system often.*" And the items with the lowest scores were "*I thought there were too many inconsistencies in the system*", "I found the system unnecessarily complex", "*I think I would need expert support to navigate the system*" and "*I found the system very cumbersome to use*".
For the third lesson, the total score obtained was 56.8, representing the items with the highest scores were "*I found the various features of the system to be quite integrated*", "*I think I would like to use this*

system often" and "*I thought the system was easy to use*". In opposition, the items with the lowest scores were "*I thought there were too many inconsistencies in the system*" and "*I found the system very cumbersome to use*".

The fourth lesson, which involves augmented reality using a tablet, received a score of 35.3, giving the system a very low rating for user interaction and ease of use. The items with the highest scores were "*I need to learn a lot of things before I can comfortably use the system*" and "*I found the system very awkward to use*". On the other hand, the items with the highest scores were "*I think I would like to use the system often*" and "*I have felt very confident using this system*".

The fifth lesson, which was created as a collaborative virtual reality program for groups of two, received a score of 60 out of 100. Therefore, the system's usability was average. There are certain features that need to be modified, but overall, participants are able to interact without losing control of the game for the most part. The highest-scoring items were "*I think I would like to use this system often*" and "*I felt very confident in using the system*". Additionally, the lowest-scoring items were "*I thought there were too many inconsistencies in the system*", "I found the system unnecessarily complex", "*I think I would need expert support to navigate the system*" and "*I found the system very awkward to use*".

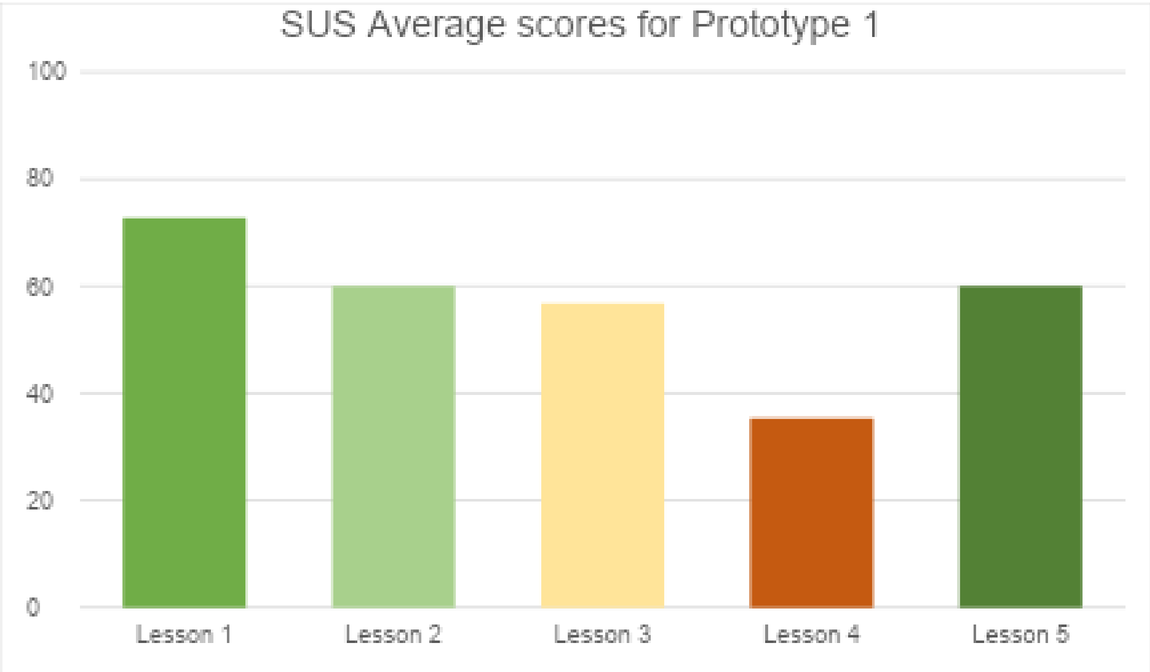

Figure 1: Scores obtained in SUS questionnaire for Prototype 1

4.2 Sickness Questionnaire

This questionnaire measures self-perceived feelings of dizziness and discomfort after playing the game in an immersive virtual experience. Responses from lessons 2 and 5 were analysed, as these are the only lessons featuring immersive virtual reality. The results show that no dizziness was felt in either case.

The average score for lesson 2 was 3.6/10 and for lesson 5 was 1.3/10 (see Table 2). Therefore, these scores indicate the absence of motion sickness in both virtual reality applications.

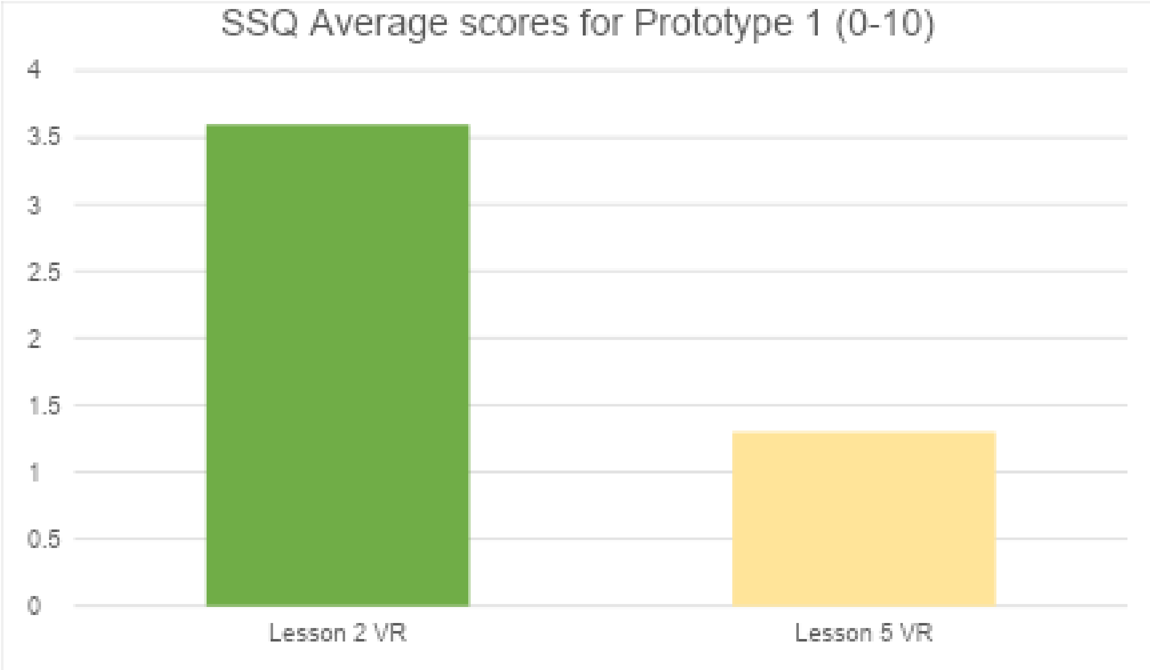

Table 2: SSQ Scores - Prototype 1

4.3 IPQ Presence Questionnaire

This questionnaire analyses the user's sense of presence in virtual environments, which refers to the subjective perception of being in a virtual environment. It is important to note that the sense of presence can be distinguished from the ability of a technology to immerse the user. While immersion is a technology variable that can be objectively described, presence is a user experience variable. Therefore, we obtain measurements of the sense of presence through subjective rating scales. This measurement is given in scores out of 100.

The responses to the questionnaires for lessons 2 and 5 are analysed, given that these are the only two lessons that include immersive virtual reality games.

In lesson 2, which is a virtual reality game, the following values are obtained:

- Spatial Presence Scale: 85.
- Involvement Scale: 69.
- Experienced Realism Scale: 50.

In lesson 5, which is a collaborative virtual reality game, the following values are obtained:

- Spatial Presence Scale: 97.
- Involvement Scale: 75.
- Experienced Realism Scale: 60.

Both lessons obtain high scores in the overall sense of presence calculation.

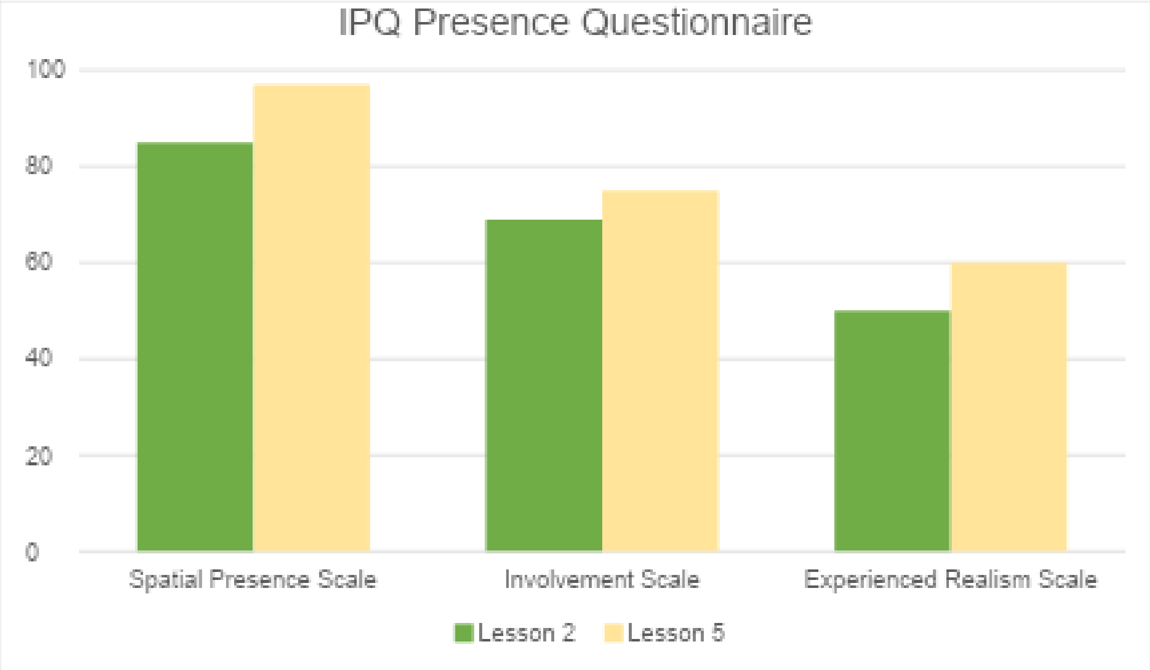

Figure 2: Scores obtained in IPQ questionnaire for Prototype 1

4.4 Thinking aloud/semi-structured interview.

The results obtained from the interview (see Annex 1: Semi-structured Interview Prototype 1) and the Thinking aloud methodology reveal a general trend of discomfort among participants when interacting with the virtual reality environments, both individually and collaboratively (lessons 2 and 5). Participants highlighted feelings of frustration, apathy, and difficulty performing actions correctly on the first attempt, attributing these problems to factors beyond their control. Thus, they mentioned challenges and difficulties experienced by participants in virtual reality. The areas they found most difficult included interaction with the blocks (mentioned by 80% of participants), lack of understanding of the game's ultimate goal (20%), and unclear instructions (30%).

The analysis of the comments shows that 90% of the observations were related to experiences of discomfort while using the game environment. However, in contrast to this trend, 80% of participants displayed a positive attitude toward the videos corresponding to lessons 1 and 3, suggesting a more favourable perception of this content. From the participants' comments, it can be inferred that, while the overall experience was largely appreciated, there are aspects that require improvement. In particular, the need to address certain issues related to loss of control and frustration generated by interacting with the game environment was identified, with the goal of optimizing the user experience and reducing associated discomfort.

Data analysis reveals that the majority of participants found the tutorials helpful in improving their overall experience, although they believe a narrative thread explaining the video's purpose is necessary. Specifically, 60% of participants indicated that the tutorial videos were beneficial, while 40% highlighted the usefulness of the Arduino-specific tutorials. However, they found the videos for the second lesson unclear. Only 15% of the comments reflected negative opinions regarding the tutorials' usefulness. On the other hand, 90% of participants indicated the need for an additional tutorial in lesson 5, suggesting a significant demand for additional support in this section of the content.

Regarding reading ability in the virtual reality experience, 90% of participants stated they were able to read correctly, although they noted some specific difficulties related to the small size of the letters or lack of clarity at certain times. In contrast, in the augmented reality environment, 100% of participants reported reading problems, mainly attributable to the type of font used.

Regarding dizziness, none of the participants reported feeling dizzy during the experience. However, 20% reported experiencing vertigo, especially when moving involuntarily within the virtual environment.

4.5 Proposals for improvement

After analysing the usability of prototype 1, a series of necessary improvements were established to ensure effective interaction and learning outcomes based on the prototype:

Lessons 1 and 3, videos made with Edison technology, have a high level of comfort, so the proposed changes are minimal:

- Visualization:
  - Ensure the programming example is always the same.
  - In lesson 3, provide a theoretical context for the concepts explained later.
  - In both videos, provide an explanation at the end of what follows, and what the objective of the video is in terms of learning development.

For **lesson 2**, Block programming in VR, the following improvements are proposed:

- Interaction:
  - Prevent individual blocks from being rotated or displaced from the target area.
  - Optimize the code box to make it easier to place the block within the code panel.
  - Limit interaction with blocks, allowing only one block to be picked up per interaction.
  - Remove bounding boxes from the environment, as they interfere with visibility and cause confusion.
  - An undo button to delete the last move made.
- Loss of control:
  - Prevent more than one block from being picked up at a time.
  - Limit the space in which the block can be moved.
  - Establish height adjustment so it can be recalibrated if it becomes misaligned or set the height to a standard average.

- Interface:
    - An undo button to be able to clear blocks in stages.
    - Visualization of controls in the virtual environment so it is easier to understand which buttons to press.
- Flow:
    - Objective and game guide to understand where to go, always have a tab to remind you of the game objective and be able to refer to it.
    - Provide the option to have hints; the button is currently there, but there are no hints.

For **lesson 4**, which is done in augmented reality, with a tablet:

- Interaction:
    - Make the buttons easier to interact with so that a person can press them and change areas without complications.
- Loss of control:
    - Need to introduce a tutorial that explains the game's dynamics and objective.
    - Explain the objective of the game.
    - Create game instructions.
    - Simplify the initial story instructions.
- Interface:
    - Clearly differentiate between study mode and game mode.
    - Instructions for use in each mode.
    - More fluid button navigation.
    - Create an undo button or explain the possibility of changing the names in the descriptions.
- Flow:
    - Possibility of introducing a video tutorial that describes the flow of action to be performed.

Lesson 5:

- Interaction:
    - Make the boundary areas invisible behind the scenes.
    - Eliminate the ability to pick up more than one block at a time.
    - Be able to undo a move without having to delete the entire code.
    - Allow recovery of blocks that exit the scene, either via undo functionality or spatial restrictions.
    - Block the rotation of blocks.
- Loss of control:
    - Explanation of the game objective and dynamics

        - Which platforms do I have to reach, highlighting those I have reached.
        - General objective of each of the 3 dynamics.
    - Creation of a tutorial that simplifies the general objective of the game.
    - Avoid height changes.
- Interface:
    - Explain the flow of action.

- Flow:
    - Enable the ability to give hints.
    - Create an undo button that allows you to delete your last move.

4.6 Conclusions

Through the analysis of data obtained from interviews, the thinking aloud technique, and the questionnaires administered, the following key conclusions were reached:

1. **Overall experience in virtual reality**: Most participants (90%) reported an experience of discomfort in virtual reality environments, both in individual and collaborative modes. Comments reflected feelings of frustration and difficulty in successfully completing tasks on the first attempt, often due to external factors such as issues with the interface or game mechanics. This finding suggests the need to optimize controls and instructions to improve the fluidity of the user experience.
2. **Positive attitude toward lessons 1 and 3**: Despite the difficulties experienced in virtual reality, 80% of participants expressed a positive attitude toward the videos in lessons 1 and 3. This data indicates that, while usability issues exist, users positively valued certain aspects of the content, reinforcing the technology's potential in education. However, adjustments are needed to mitigate frustration and improve accessibility and control in the virtual reality environment.
3. **Usefulness of tutorials**: 80% of participants found the video tutorials useful, and 60% highlighted the usefulness of the virtual reality-specific tutorials. However, 90% of participants indicated the need to include an additional tutorial in lesson 5, indicating that certain lessons necessitate additional pedagogical support to facilitate users' understanding and use of the technology.
4. **Reading ability**: In terms of reading, 90% of participants reported being able to read relatively easily in virtual reality, although some mentioned issues with font size and clarity. In contrast, 100% of participants experienced reading difficulties in the augmented reality environment attributable to typographic design issues. These results highlight the need to improve visual design and readability in both environments, with particular attention to augmented reality.

5. **Dizziness and vertigo**: No participants reported feeling dizzy during the experience, although 20% reported experiencing vertigo, especially when moving involuntarily on the virtual platform. These data suggest that, although the virtual reality implementation is adequate in terms of stability, continued monitoring of side effects such as vertigo is necessary to prevent them from negatively impacting the immersive experience.
6. **Identified usability issues**: Several problematic areas related to interaction, flow, and interface design were identified in the virtual environments. Interaction with controls and navigation tools (e.g., buttons or joysticks) proved to be a factor that hindered the user experience. Furthermore, the loss of control and difficulty understanding the tasks to be performed contributed to increased participant frustration. These deficiencies must be addressed to ensure a logical and accessible flow of the experience.

In summary, the results of this study underscore the importance of adjusting key aspects of usability, particularly in virtual and augmented reality, to improve the user experience. Recommendations include optimizing controls, implementing more comprehensive tutorials, and improving the readability and stability of the virtual environment. These adjustments are essential to ensuring a more efficient and satisfying learning experience for users.

Below is a summary table showing the problems found, classified by severity:

Table 3: Prototype 1 conclusions

Lesson	Issue	Proposed Improvement	Severity
Lesson 1	Lack of clarity about the video's objective	Explain why the video is necessary and its purpose within the prototype	Low
Lesson 2	Loss of control due to blocks moving outside the grid	Limit blocks from moving too far	High
Lesson 2	A cube appears after the start block, losing interaction with blocks	Hide walls behind the start block to limit cube movement	Medium
Lesson 2	Entire code deleted, causing frustration	Add option to undo last action	High
Lesson 2	Sudden changes in height	Set a predefined height level	High
Lesson 2	Blue blocks appear in incorrect areas and don't disappear when placed	Remove misplaced blue blocks	High

Lesson 2	Complicated position changes in the environment	Add a “fishing rod” visual cue on left controller to indicate where to go	High
Lesson 2	App crash forces restart from level 1	Add level menu at the app's start	High
Lesson 3	Overly technical language	First explain each concept clearly and concretely	Low
Lesson 4	Lack of clarity—users don’t know what to do	Include an introductory tutorial explaining game goal and steps	High
Lesson 4	Complex, unclear text	Simplify and make the information understandable at all levels	Medium
Lesson 4	Interaction problems—camera slow to refocus on next AR element	Explain that camera must focus on one item or improve detection sensitivity	Medium
Lesson 4	Unclear progress—users don’t know if actions are correct	Add a feedback marker indicating success or failure	Medium
Lesson 4	Unclear when the game ends	Add a clear game-end moment	High
Lesson 5	Users enter directly into game without understanding the objective	Add a section explaining the game’s goal	High
Lesson 5	Loss of control—users forget paths taken and blocks visited	Indicate which blocks have already been visited	High

5. Usability Evaluation – Prototype 2: Social Entrepreneurship

5.1 Description and pedagogical intent

The second prototype developed under the e-DIPLOMA initiative focuses on enhancing learners’ understanding of social entrepreneurship through interactive, context-rich scenarios that combine virtual reality (VR), digital storytelling, and collaborative decision-making mechanics.

the analysis aims to assess the effectiveness of each technology in enhancing user learning and interaction. By collecting and analysing user experience data, the study seeks to provide recommendations for optimizing lesson design, thereby promoting more efficient and accessible learning.

5.2 Prototype description

This prototype focuses on learning entrepreneurial and social business skills, covering key business functions such as sustainable entrepreneurship, urban management, human resources, marketing, and more. The prototype is divided into five lessons:

- **Lesson 1: Lodestars**

The objective is to teach sustainable and social entrepreneurship. Participants engage in virtual conversations with social entrepreneurs through a VR-based game, learning about sustainable trade. Duration: approximately 1 hour and 15 minutes.

- **Lesson 2: Heroes**

This lesson focuses on urban management, where players make decisions impacting businesses and city residents. It's a cooperative VR game requiring players to agree on building placements. Duration: approximately 30 minutes.

- **Lesson 3: Painters**

This lesson aims to apply social entrepreneurship knowledge through the practical exercise of creating a Business Model Canvas (BMC). Conducted using Edison technology on a computer. Duration: 15 minutes (to be determined).

- **Lesson 4: Allies**

A single-player game where participants take on the role of a social entrepreneur, recruiting and managing a team. They conduct interviews and assign tasks, with performance, growth, impact, and revenue assessed at the end. Conducted on a computer. Maximum duration: 15 minutes.

- **Lesson 5: Angels**

An online card game played on a computer with up to four players, focusing on financing, marketing, market research, and product positioning. The game consists of 7 rounds, lasting approximately 15 minutes.

5.3 Sample

The sample consisted of a total of 10 participants, with 5 men and 5 women. The participants' ages ranged from 21 to 45 years. All participants had adequate joint mobility and had no prior knowledge of technologies such as virtual reality. The average age of the men was 31 years, while the average age of the women was 30 years.

6. Results

6.1 Usability Questionnaire (SUS)

An analysis of the data extracted from the usability questionnaires was conducted for each of the five lessons included in the prototype. The results are as follows (see Figure 3):

Lesson 1: Lodestars, received a mean usability score of 76.6 out of 100, indicating high usability. Participants particularly agreed with statements such as *"I imagine most people would learn to use the system very quickly", "I found the system easy to use"* and *"I found the various features of the system well-integrated"*. Conversely, the lowest rated items were *"I found the system very cumbersome to use"* and *"I need to learn many things before I can use the system comfortably"*.

Lesson 2: Heroes, scored 54.1 out of 100, reflecting low usability (note: Not all participants were able to test this lesson due to technical issues). The highest-rated items were *"I think I would like to use this system frequently"* and *"I felt very confident using the system"*. On the other hand, the lowest-rated items were *"I thought there was too much inconsistency in the system"* and *"I found the system very cumbersome to use"*.

Lesson 3: Painters, obtained an average of 50/100, which means low usability. The highest-rated items were *"I think I would need the support of an expert to navigate the system", "I found the system unnecessarily complex", "I imagine most people would learn to use the system very quickly"* and *"I felt very confident using the system"*. In opposition, the lowest-rated items were *"I thought there was too much inconsistency in the system"* and *"I found the system very cumbersome to use"*.

Lesson 4: Allies, had an average scored of 72.5, a medium-high usability. The highest-rated items were *"I felt very confident using the system"* and *"I found the various features of the system well-integrated"*. On the other hand, the lowest-rated items were *"I found the system unnecessarily complex"* and *"I found the system very cumbersome to use"*.

Lesson 5: Angels, received a mean usability score of 48.1 out of 100, indicating low usability. Although participants were able to interact with the system, a notable loss of control regarding the game's objective was reported. The highest-rated item was *"I need to learn many things before I can use the system comfortably"* and the lowest-rated item was *"I imagine most people would learn to use the system very quickly"*.

In conclusion, the Lodestars and Allies lessons demonstrated satisfactory usability scores, whereas Heroes, Painters, and Angels require significant improvements. Key areas for enhancement include the absence of tutorials, perceived system complexity, and system consistency. Particular attention should be given to clarifying objectives and integrating functionalities to ensure a more seamless user experience.

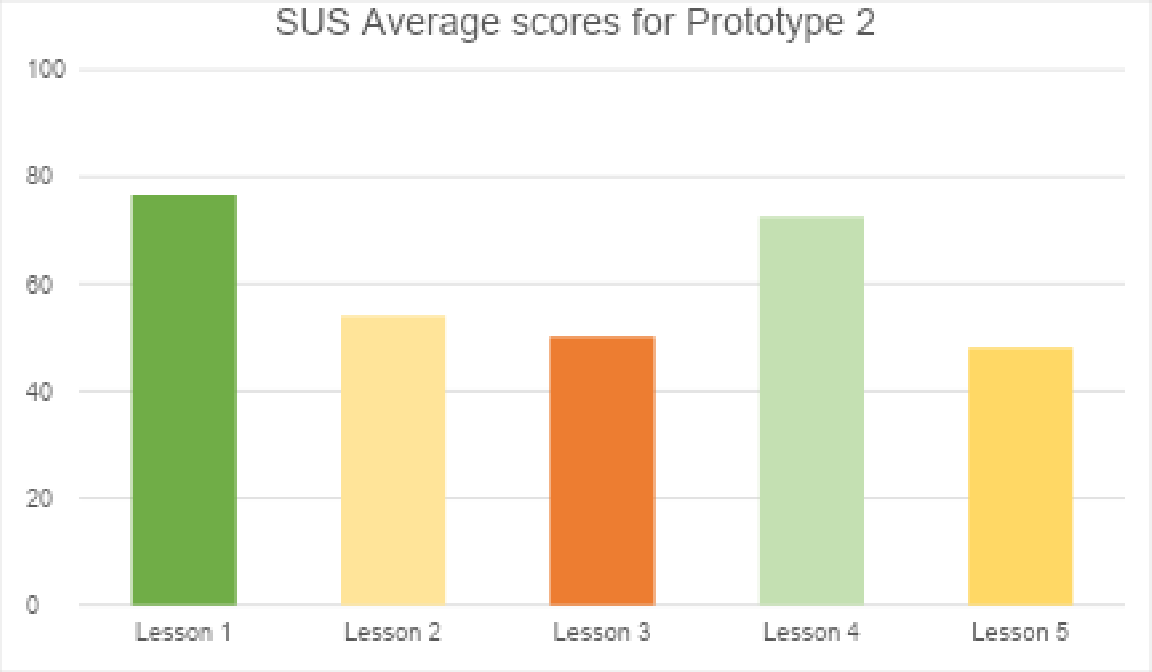

Figure 3: Scores obtained in SUS questionnaire for Prototype 2

6.2 Sickness Questionnaire

This questionnaire evaluates the self-perceived sensations of dizziness and discomfort following immersive VR gameplay. Responses from lessons 1 and 2 were analysed, as they are the only lessons featuring immersive virtual reality experiences. **Lesson 1** obtained an average score of 3.6, and **lesson 2** obtained an average score of 1.3.

The results indicate that no significant motion sickness was reported in either lesson. Both scores are notably low, suggesting that the immersive VR applications are well-tolerated and do not induce discomfort or dizziness among participants.

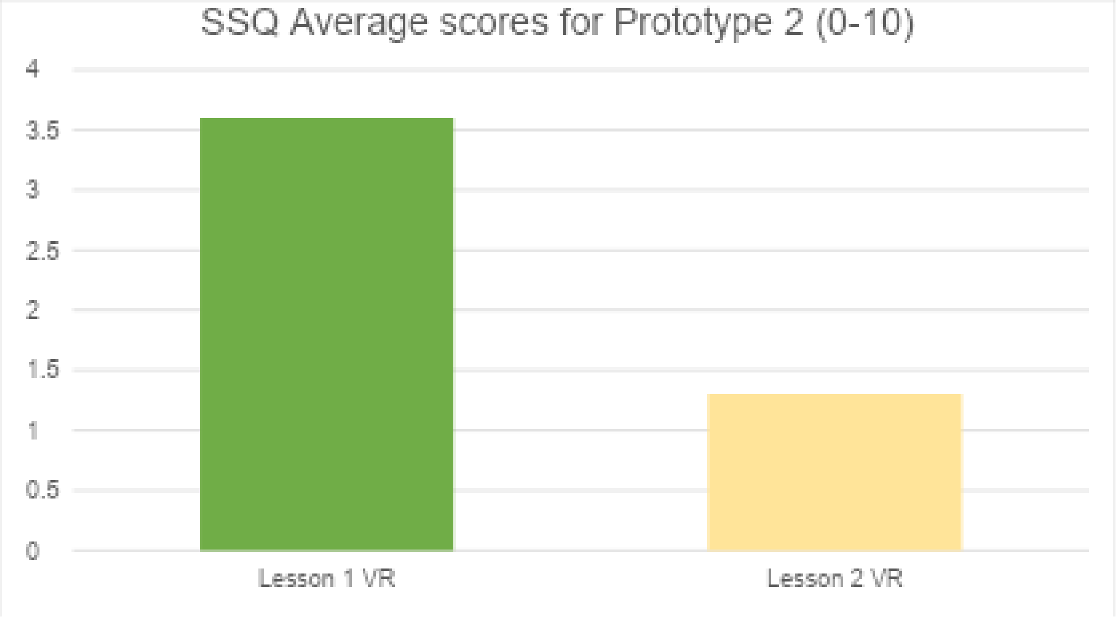

Figure 4: Scores obtained in SSQ questionnaire for Prototype 2

6.3 Presence Questionnaire IPQ

User presence in virtual environments refers to the subjective perception of "being" in a virtual space. It is crucial to differentiate between **presence** and **immersion**: while immersion is an objective measure related to the technology's capability to envelop the user, presence is a subjective user experience variable. Presence is typically measured using self-assessment scales, with scores ranging from 0 to 100. The analysis focuses on responses from lessons 1 and 2, as they are the only ones featuring immersive virtual reality (VR) games. The Presence Scores in VR Lessons were:

- **Lesson 1 (VR game):**
  - Spatial Presence Scale: 85.
  - Involvement Scale: 69.
  - Experienced Realism Scale: 50.
- **Lesson 2 (Collaborative VR):**
  - Spatial Presence Scale: 97.
  - Involvement Scale: 75.
  - Experienced Realism Scale: 60.

Both lessons achieved high overall presence scores, indicating that participants felt significantly immersed in the virtual environments. Notably, Lesson 2, featuring collaborative VR, received higher scores across all scales, particularly in spatial presence, which suggests that interactive and cooperative elements may enhance the sense of presence.

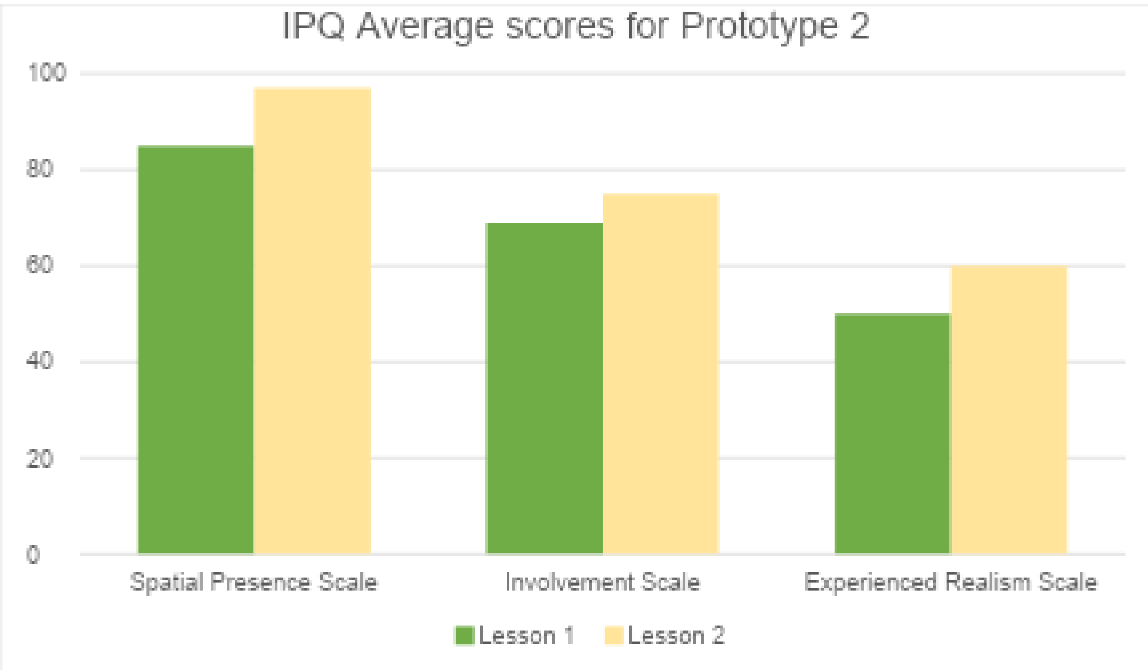

Figure 5: Scores obtained in IPQ questionnaire in Prototype 2

6.4 Thinking aloud/Semi structured interview.

Before proceeding with the analysis, it is important to note that Lesson 2 "Heroes", did not function properly during the usability sessions, so it was not possible to gather information from the structured interview for this lesson.

The results obtained from the interview (see Annex 2: Semi-structured Interview Prototype 2)and the "thinking aloud" methodology reveal a general sense of well-being with the overall game experience among participants when interacting with the virtual reality environment, both in individual and collaborative modes. However, there was also a clear tendency towards discomfort due to the lack of tutorials and language barriers. Participants highlighted feelings of comfort and ease of use (after receiving instruction from the experimenter) on the one hand, a sense of lack of control and difficulties performing actions correctly without prior explanation. They attributed this to the need for an introduction and a tutorial explaining the game's objective and development, as well as issues stemming from external factors beyond their control.

In lesson 1, lodestars, the most challenging aspects for them were interacting with the avatars (60% cited language issues, and 37% said it was because they didn't know what to ask), not understanding the final game objective without an explanation (90%), and the lack of a tutorial (100%).

Analysis of the comments shows that 90% of the observations were related to discomfort during the game environment use due to the language barrier, as all games were developed in English. Most participants did not have sufficient English proficiency to successfully navigate the lessons. However, with the experimenter's explanation of the game and assistance in translating activities, 90% of participants reported feeling comfortable with the game's development at a practical level, suggesting the game was perceived positively once the language and tutorial issues were addressed.

Based on participant feedback, it is concluded that although the overall experience was rated positively, specific aspects need improvement. Primarily, issues related to loss of control and discomfort during interactions in a non-native language must be addressed, and the implementation of tutorials in each lesson is crucial to optimize the user experience and minimize the risk of not understanding the game or its objectives.

Regarding the tutorial issue, 90% of participants did not understand the game before the experimenter provided any instructions. Only 10% managed to grasp something through trial and error. All participants agreed on the need for an introduction to the game in each lesson, including an explanation of the game's objective and detailed information on how to use the controls, particularly for Virtual Reality or how to operate computer applications (Painters, Allies, Angels).

In terms of reading capability during the virtual reality experience and with the IA and Edison games on the computer, 100% of participants stated they could read the text correctly and found the font size adequate. However, in the "Painters" lesson, 25% of the participants indicated that some information was difficult to read due to the small text size. In addition, in the "Angels" card game, 75% of participants said they could read the text correctly, although 25% noted that the information on the cards and each round (located in the upper left and right corners) was too small. Additionally, they found it difficult to locate this information as they did not intuitively look towards the corners.

Regarding the sensation of dizziness, none of the participants reported feeling dizzy during the experience.

6.5 Proposals for improvement

Following the usability analysis of Prototype 2, several critical improvements are proposed to ensure that the intended learning outcomes are achieved:

Lesson 1: Lodestars

- Loss of Control: Tutorial
  - Game Contextualisation: Introduce a concise statement summarizing the game's objective.
  - Objective Clarification: Provide clear instructions on the purpose of the conversations with the avatars, emphasising that the dialogues are meant to engage with social entrepreneurs. Without this, users may not realise the learning objective.
- Loss of Control: Language
  - Language Implementation: Add Spanish (or other languages besides English) to make the game accessible to users with limited English proficiency.

Lesson 2: Heroes

- Loss of Control
  - Control Tutorial: Develop a tutorial to teach users how to navigate the environment, use controllers, and open menus.
  - Game Objective Clarification: Clearly explain the final objective: what needs to be achieved to complete the task successfully.

Lesson 3: Painters

- Loss of Control: Tutorial
  - Game Contextualisation: Clarify the final objective of the game.
  - Objective Clarification: Explain what a Business Model Canvas (BMC) is and how users can interact with it. Provide guidance on button functionalities and their purposes.
  - Topic Explanation: Include detailed explanations about the BMC and related concepts.
- Loss of Control: Language
  - Language Implementation: Include Spanish (or other languages) to enhance accessibility for non-English speakers.
- Interaction

- Simplify Interactions: Make button interactions more intuitive, e.g., how to place a sticky note on the BMC.
- Increase Label Size: Enlarge BMC labels for better readability, especially when the canvas is fully expanded.

- Flow
  - Tutorial Video: Consider adding a video tutorial describing the action flow for better guidance.

Lesson 4: Allies

- Loss of Control: Tutorial
  - Objective Clarification: Explain the goal of recruiting and managing employees. Provide clear guidance on button functionalities and their respective purposes.
  - Final Objective: Detail the ultimate objective of the game.
- Loss of Control: Language
  - Language Implementation: Add Spanish (or other languages) for better comprehension. Although some avatars occasionally respond in Spanish, consistency across the game is needed.

Lesson 5: Angels

- Loss of Control: Tutorial
  - Game Contextualisation: Provide context at the beginning of the game.
  - Objective and Mechanics Clarification: Explain the game's purpose and the mechanics of each round, detailing the use and purpose of each card before starting the game.
- Loss of Control: Language
  - Language Implementation: Integrate Spanish (or other languages) to facilitate understanding for non-English speakers. Current explanations are sparse and in English.
- Interface
  - Interface Design Optimization: Improve the visibility of round explanations, currently placed in a corner and displayed in a colour that lacks prominence. Consider repositioning and enhancing the colour contrast for better clarity.

6.6 Conclusions

This usability study has identified several areas for improvement in the design and implementation of lessons developed using virtual reality (VR) technologies and AI-integrated games. Based on the data gathered from interviews, the thinking-aloud technique, and various questionnaires, the following key conclusions have been reached:

1. **General VR experience**

The majority of participants (90%) reported a comfortable experience in both individual and collaborative VR environments, despite issues with language and lack of tutorials. While participants expressed frustration and difficulty understanding the game due to language barriers, they also reported positive feelings regarding the gameplay mechanics. This finding highlights the need for clear instructions to enhance the fluidity of the user experience.

2. **Positive attitude toward computer games**

Similar to their VR experience, participants noted enjoyable experiences with computer-based games, except for language-related challenges. This indicates that while there are usability issues, users appreciated certain aspects of the content, reinforcing the educational potential of the technology. However, adjustments are essential to reduce frustration and optimize accessibility and control within the VR environment.

3. **Lack of Tutorials**

All participants (100%) emphasized the need for tutorials explaining both the game objectives and mechanics to help them navigate and perform tasks more effectively.

4. **Reading Capability**

In VR environments, 100% of participants reported being able to read text easily, although some mentioned issues with font size and clarity. In contrast, 25% of users encountered reading difficulties in the Painters and the Angels lessons due to small or unclear text.

5. **Motion Sickness and Dizziness**

None of the participants reported experiencing motion sickness, dizziness, or discomfort during the sessions.

In summary, the results of this study emphasize the importance of addressing key usability aspects, particularly the implementation of tutorials, to improve the user experience. Additionally, recommendations include enhancing text readability and interface design in certain lessons and providing contextualisation for each lesson. These adjustments are essential to ensure a more effective and satisfying learning experience for users.

Below is a summary table with the problems encountered classified by their level of severity:

LESSON	***PROBLEM***	***IMPROVEMENT***	***IMPORTANCE***
Lessons 1, 2, 3, 4 y 5	Loss of control, losing the objective of the game	Make a tutorial	**HIGH**

Lessons 1, 2, 3, 4 y 5	Language	More idioms during the game	HIGH
Lesson 3	Loss of control because the BCM disappears	Limit it and fix it in the dashboard	MEDIUM
Lesson 3	Non-intuitive and unnecessarily difficult buttons	Make button interactions simpler to make them more intuitive to people	MEDIUM
Lesson 4	Game closes with 5 minutes left	Fix this error so that they can time out completely.	HIGH
Lesson 5	Interface	To go to the tutorial of the cards any time you need it	LOW

Table 4: Prototype 2 conclusions

7. Usability Evaluation – Prototype 3: VR for Educator

7.1 Description and pedagogical intent

The third prototype of the e-DIPLOMA project is designed as a comprehensive training module aimed at educators—both active and in training—seeking to incorporate Virtual Reality (VR) technologies into their pedagogical practices. The objective of this module is not only to provide technical skills in VR interaction but to encourage reflective use of immersive environments in instructional design, content delivery, and learner engagement strategies.

The aim of this study is to evaluate the usability of different lessons, which have been designed and implemented using virtual reality. This analysis seeks to identify the effectiveness of virtual reality in improving learning and user interaction. Through the collection and analysis of user experience data, it aims to provide recommendations for optimising lesson design and facilitating more efficient and accessible learning.

7.2 Prototype description

This prototype aims to teach, research, and inspire the use of virtual reality (VR) in education, enabling current and future educators to explore its advantages, disadvantages, and practical applications. Through various games, participants learn basic concepts of VR. The prototype is divided into six lessons:

- **Lesson 1. Interaction**

The objective of this lesson is to teach interaction with virtual objects through a series of minigames set in a daycare environment. It includes five main activities focused on grasping, “telegrasping”, rotations, and gesture-based interaction. The approximate duration of this lesson is 20 minutes.

- **Lesson 2. Navigation**

This lesson introduces navigation techniques in VR through four interactive minigames, where users, acting as shepherds, must guide sheep indirectly in a virtual environment. The game, which includes several levels, utilizes navigation methods such as smooth movement, teleportation, minimaps, and flying, helping users develop practical navigation skills. The approximate duration of the lesson is 20 minutes.

- **Lesson 3. Visualization**

This lesson addresses how light sources and materials affect appearances in 3D environments. It begins with an overview of basic lighting and object appearance, followed by an interactive activity where users position and illuminate a car, experimenting with various settings, including non-realistic representations. The approximate duration is 15 minutes.

- **Lesson 4. Collaboration**

This lesson explores how to facilitate interaction and learning in VR when users do not share the same physical space. It begins with an introduction to avatars and techniques for guiding attention. Users then practice mimicking and recalling movements performed by a "ghost instructor." The approximate duration is 10 minutes.

- **Lesson 5. Demonstration**

This lesson uses VR to teach physical concepts interactively. Users explore different planets by testing how balls bounce under variables such as gravity, weight, size, and elasticity. The simulation allows users to adjust time and perspective, encouraging exploratory learning about forces acting on objects. The approximate duration of this lesson is 10 minutes.

- **Lesson 6. Builder (Optional)**

In this final lesson, users apply what they have learned by designing their own 3D environments in VR. They can create layouts, build walls, customize colours, add objects and light sources, and define navigation metaphors such as teleportation or flying. The design process is conducted on a large scale, allowing users to gain a comprehensive view of the environment and iterate at each stage. The approximate duration of this lesson is 20 minutes.

7.3 Sample

The study included a total of 10 participants, comprising 6 males and 4 females, with ages ranging from 21 to 45 years.
All participants demonstrated adequate joint mobility and had no prior knowledge of handling technologies such as virtual reality. The mean age of the male participants was 32 years, while the mean age of the female participants was 31 years.

8. Results

8.1 Usability Questionnaire (SUS)

An analysis of the data extracted from the questionnaires by lesson shows that:
Lesson 1: Interaction obtained an average of 73.3/100, a good usability. The highest-rated items were *"I found the system easy to use"* and *"I found the various functions in this system were well integrated"*. In opposition, the lowest-rated item was *"I needed to learn a lot of things before I could get going with this system"*.
Lesson 2: Navigation obtained an average of 55.5/100, a marginal usability. The highest-rated items were *"I think most people would learn to use this system very quickly"* and *"I found the system easy to use"*. Contrarily, the lowest-rated items were *"I found the system very cumbersome to use"* and *"I thought there was too much inconsistency in this system"*.
Lesson 3: Visualization obtained an average of 57.3/100, indicating marginal usability. The highest-rated item was *"I found the system easy to use"*. In opposition, the lowest-rated items were *"I thought there was too much inconsistency in the system"* and *"I found the system very cumbersome to use"*.
Lesson 4: Augmented Reality Interaction obtained an average of 59.4/100, which means marginal usability. The highest-rated items were *"I think I would like to use this system frequently"* and *"I felt very confident using the system"*. On the other hand, the lowest-rated items were *"I needed to learn a lot of things before I could get going with this system"* and *"I found the system very cumbersome to use"*.
Lesson 5: Collaborative Virtual Reality obtained an average score of 56.0, which means marginal usability. The highest-rated items were *"I think I would like to use this system frequently"* and *"I felt very confident using the system"*. Contrarily, the lowest-rated items were *"I thought there was too much inconsistency in the system"*, *"I found the system unnecessarily complex"*, *"I believe I would need the support of an expert to use the system"* and *"I found the system very cumbersome to use"*.
Lesson 6: Advanced Collaborative Virtual Reality obtained an average of 41.3, reflecting low usability. The highest-rated items were *"I think I would like to use this system frequently"* and *"I felt very confident using the system"*. In opposition, the lowest-rated items were *"I thought there was too much inconsistency*

in the system", *"I found the system unnecessarily complex"*, *"I believe I would need the support of an expert to use the system"* and *"I found the system very cumbersome to use"*.

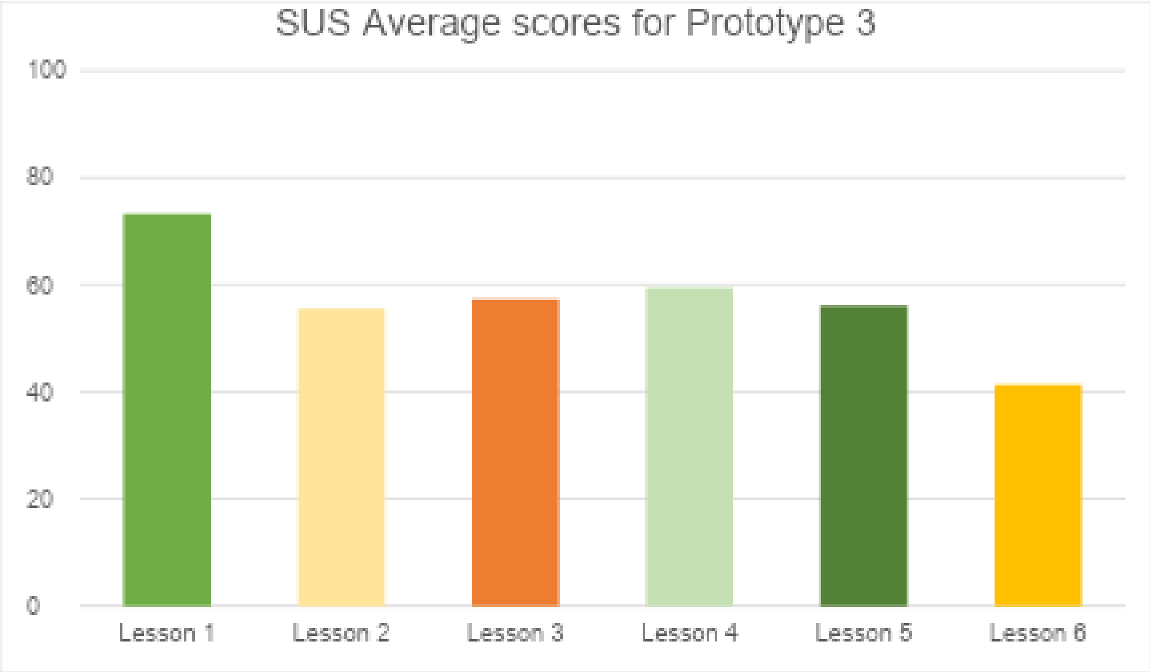

Figure 6: Scores obtained in SUS questionnaire for Prototype 3

8.2 Sickness questionnaire

This questionnaire measures self-perceived feelings of dizziness and discomfort after playing the game in an immersive virtual experience. The responses from lessons 1 to 6 were analysed, with the scores in most of the lessons being very low, reflecting a lack of dizziness in almost all the lessons.
Expanding on this, the following scores are observed:
The first lesson obtained an average score of 1.6, so the existence of dizziness was negligible, the second lesson obtained an average score of 3.8 out of 10, and lesson 3 obtained a 2,84/10, so the existence of dizziness has to be considered, although this perceived sensation is low. Participants report a loss of balance and general discomfort during lesson 2 (as described later in the semi-structured interview section). However, no participants reported nausea or vomiting.
In the subsequent lessons, the scores obtained from the dizziness questionnaire show a lack of dizziness, with a averaged scores of 1,1/10 for lessons 4 and 6, and 1,3/10 for lesson 5.

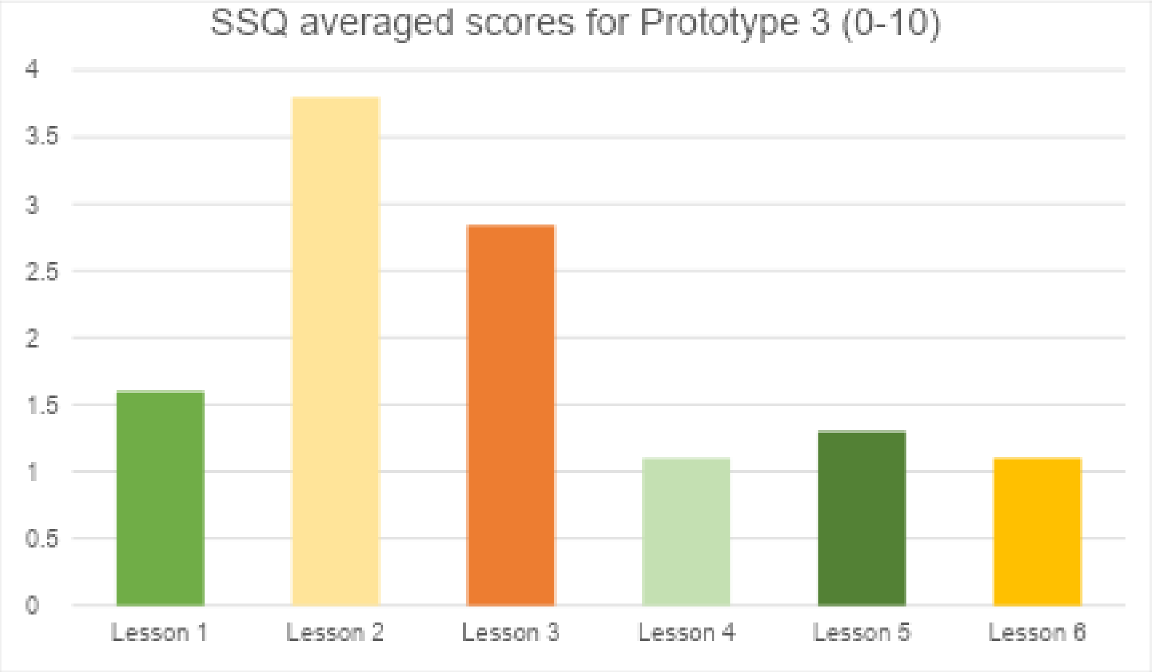

Figure 7: Scores obtained in SSQ questionnaire for Prototype 3

8.3 Presence questionnaire IPQ

This questionnaire analyses the user's sense of presence in virtual environments, which refers to the subjective perception of being in a virtual environment. It is important to note that the sense of presence can be distinguished from the ability of a technology to immerse the user. While immersion is a variable of the technology that can be described objectively, presence is a variable of the user experience. Therefore, we obtain measures of the sense of presence through subjective rating scales.

Scores on the presence scale are high, with a high mean, where scores reach 10 points in the first two lessons, and the lowest scores are 6.4 out of 10, resulting in a highly immersive experience.

However, somewhat lower scores are observed in the sense of realism, where the score drops to 3.2 on a scale of 10. Finally, on the scale of involvement, the scores remain constant with an average of 6 out of 10 in all modules.

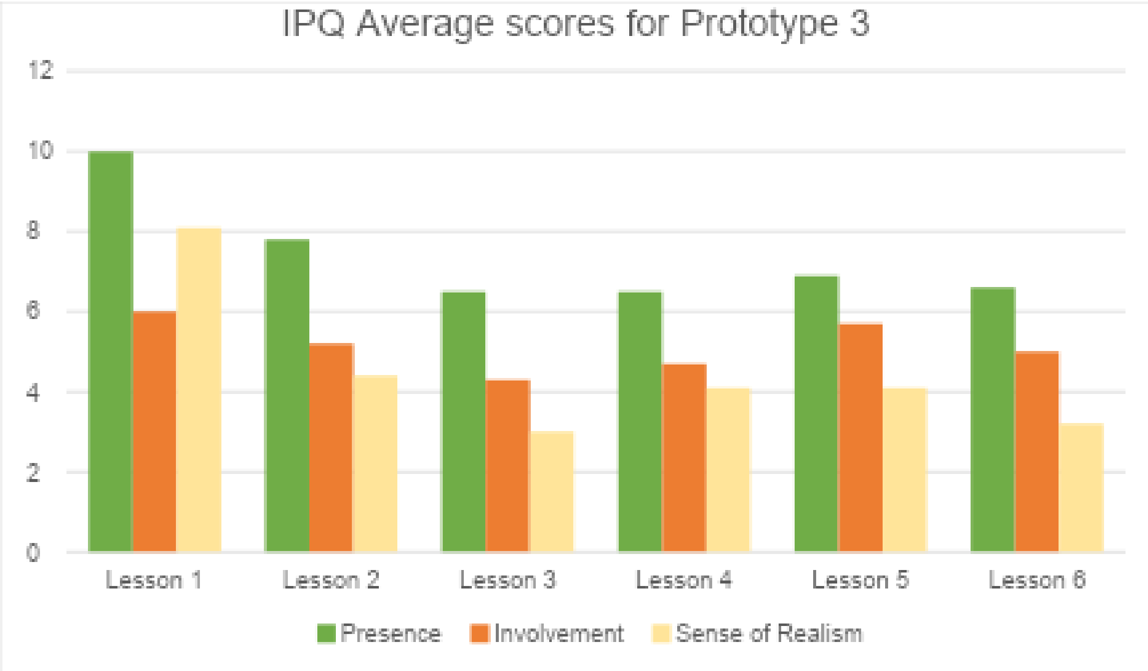

Figure 8: Scores obtained in IPQ questionnaire for Prototype 3

8.4 Thinking aloud/Semi structured interview.

The results obtained from the interview (see Annex 3: Semi-structured Interview Prototype 3) and the thinking aloud methodology reveal a general tendency among participants to report feeling comfortable during the first two lessons (interaction and navigation), while an increase in discomfort is observed in the last four lessons, with the last one (extra-building museum) being the one in which the discomfort is greatest. In these last four lessons, a difficulty in carrying out the actions correctly is highlighted, as well as a feeling of disorientation, attributing these problems to factors outside their control, such as a lack of knowledge of the objective of the task to be carried out.

Discomfort was greatest in lesson 6, where 80% of the participants highlighted a feeling of lack of control and difficulties in carrying out the lessons correctly, as well as a feeling of disorientation. They attribute these difficulties to not having a guide to explain the objective of the game and how to continue with the flow of the game.

In the second lesson (navigation), there is a general difficulty in controlling the interaction with the sheep (60% of the participants) with level 2 being the level with the highest number of losses of control and high frustration. It is notable that, during this level, in the navigation lesson, 70% of the participants experienced a feeling of dizziness.

In lesson 3, 50% of the participants reported a loss of control in the game because they did not know what the objective of the game was, and this problem was repeated in lesson 4, in 60% of the cases, and in lesson 5, in 60% of the cases.

The analysis of the comments shows that 80% of the observations were related to discomfort during the use of the game environment due to the language barrier: most of the participants did not have a sufficient level of English to successfully navigate the lessons and they needed help in translating and understanding the games. On the other hand, large losses of control were highlighted in the last 4 lessons due to problems in understanding the objective and actions needed to successfully complete the lesson levels.

Based on participants' comments, it is concluded that, although the overall experience was rated positively, there remain areas that require significant improvement. In particular, problems related to loss of control and discomfort during interactions in a non-native language were identified. In addition, it is crucial to implement specific tutorials in each lesson to optimise the user experience and reduce the risk of confusion about the game.

This was particularly evident in lessons 4, 5 and especially 6, where a considerable percentage of participants (60%, 60% and 100%, respectively) reported not understanding the purpose of the game due to the absence of a clear explanation of the objectives and the use of the controls. These difficulties resulted in feelings of disorientation, frustration and apathy towards the game. Improving these aspects could therefore minimise perceived discomfort and enhance usability and user satisfaction.

In relation to readability during the VR experience, 80% of the participants reported being able to read the text correctly and considered the font size to be adequate. Only 20% reported finding the font blurry, a problem that was solved by adjusting the glasses appropriately, allowing them to read without difficulty.

Regarding the feeling of dizziness, 70% of the participants reported experiencing this symptom when moving within the virtual environment during lesson 2, especially in the second smooth motion mini-game (60%) and in the fourth flying mini-game (50%).

8.5 Proposals for improvement

1. **Lesson 1: Interaction**

This lesson displayed high usability and user control, with participants clearly understanding the game's objectives. However, the language barrier posed a challenge. The recommendation is to implement a language change feature to enable users to select their native language. This will foster greater autonomy and allow participants to fully comprehend the integrated aids in the virtual environment without requiring additional explanations.

2. **Lesson 2: Navigation**

While participants were able to navigate autonomously through the levels, specific issues were. The recommendations are:

- In level 2, there were high levels of discomfort and dizziness were reported due to fast movement speeds, so it's recommended to reduce movement speed to alleviate discomfort and improve user experience.
- Language barrier: the inability to interact in the participant's native language disrupted the activity's flow. Incorporate a language selection option to enable intuitive and barrier-free interaction could be a solution.

3. **Lesson 3: Visualization**

Participants faced difficulties understanding the goals and requirements of the lesson. Some suggestions are:

- Clarify game objectives: Add an initial section that explicitly states the purpose and specific goals of the activity, including numerical targets necessary for completion.
- Language: As in previous lessons, provide a language change feature to enhance accessibility and comprehension.

4. **Lesson 4: Augmented Reality Interaction**

Participants expressed a need for more detailed guidance at the start of the activity. Some recommendations are:

- Initial tutorial: Create an introductory tutorial that explains the actions flow of the activity and the overall game objective and steps to achieve it.
- Language: Ensure the activity is available in the participant's native language to remove linguistic barriers and improve immersion and understanding.

5. **Lesson 5: Collaborative Interaction**

Challenges similar to Lesson 4 were observed in collaborative settings. Recommendations are:

- Initial Tutorial: Include a comprehensive tutorial to guide participants through the flow of the collaborative actions required and the overall game objective and how to achieve it as a team.
- Language: Support native language options to facilitate smooth collaboration and understanding among participants.

6. **Lesson 6: Advanced Collaborative Interaction**

This lesson mirrored issues seen in Lesson 5 but required even more support to ensure effective interaction. Some suggestions are:

- Initial Tutorial: Add a detailed tutorial to help participants navigate the advanced flow of collaborative actions and the objectives of the game and how to achieve them in a collaborative context.
- Language: Enable native language support to remove barriers and ensure better group interactions.

General Observations Across Lessons

- The recurring language barrier highlights the importance of implementing a multilingual interface to improve usability and participant autonomy.
- Comprehensive tutorials and clear explanations of objectives are critical in guiding users effectively, especially in more complex and collaborative activities.
- Adjustments to movement speed and interface consistency will significantly enhance comfort and user satisfaction.

Addressing these recommendations can lead to a smoother, more intuitive experience for participants, increasing overall engagement and satisfaction with the system.

8.6 Conclusions

The analysis of SUS scores and qualitative data collected through the Thinking Aloud methodology and questionnaires allow us to draw the following conclusions:

1. **Summary of overall usability**:

The first lesson (interaction) demonstrated favourable usability, attaining a score of 73.3/100, whereas the second lesson (navigation) exhibited marginal usability with a score of 55.5/100, partially attributable to dizziness induced by system movement. Lessons three through five maintained marginal usability levels, with scores ranging between 56.0 and 59.4. Notably, lesson six revealed a substantial decline in usability, scoring merely 41.3/100, indicative of pronounced challenges in accessibility and clarity. These findings imply that increasing task complexity exacerbates issues related to system inconsistency, complexity, and the necessity for expert assistance, thereby adversely impacting overall user experience.

2. **Discomfort and interaction barriers:**

During the last four lessons, an increase in discomfort was observed, particularly in Lesson 6, where 80% of participants reported disorientation and difficulty completing tasks due to the lack of clear guides and defined objectives. The language barrier was a critical limitation, affecting 80% of participants who required assistance to understand instructions presented in English. This negatively impacted the fluidity and autonomy of their experience.

3. **Specific issues identified:**

- Dizziness: In Lesson 2, 70% of participants experienced dizziness, particularly during minigames involving smooth movement (60%) and flying (50%).
- Disorientation: Between 50% and 60% of participants in Lessons 3 through 5, and 100% in Lesson 6, did not understand the objectives of the activities, leading to frustration and loss of control.
- Text Legibility: While 80% of participants considered the font size adequate, the remaining 20% encountered difficulties, mainly due to improper adjustment of the VR headsets.

4. Participant feedback:

Participants frequently highlighted a lack of clarity in objectives and the absence of specific tutorials. Feedback emphasized the need for the system design to address language barriers and provide a more structured guide, particularly in advanced lessons.

5. Improvement Recommendations:

- Language: Implement multilingual options for all systems and lessons.
- Initial Tutorials: Introduce clear explanations regarding the objectives and flow of each activity.
- Movement Optimization: Reduce the speed of virtual navigation to mitigate dizziness, especially in Lesson 2.
- Text Legibility: Ensure proper adjustment of VR headsets for all participants.

In summary, this study underscores the importance of focusing on usability and accessibility in advanced lessons, with special attention to the design of clear tutorials and the elimination of language barriers. These improvements are essential to ensure users can effectively interact with the system and enjoy a positive and satisfactory experience.

The following table outlines a summary of the identified issues, classified by severity level:

LESSON	***PROBLEM***	***IMPROVEMENT PROPOSAL***	***LEVEL OF IMPORTANCE***
Lesson 1-6	Language barrier	Create instructions in all the idioms where the pilots are going to be made	**HIGH**
Lesson 3-6	Instructions of the game objective	Brief explanation about the game objective	**HIGH**
Lesson 3-6	Loss of control	Instructions of the goal that is needed to be achieve	**HIGH**
Lesson 4	When is the goal achieved	Put a timer or a clear number where the goal is achieved	**HIGH**

Table 5: Prototype 3 conclusions

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Annex 1: Semi-structured Interview Prototype 1

- **Lesson 1:**
  - Did you have time to understand and structure the video content?
  - Do you think the image quality is good?
  - Do you find the examples clear enough?
  - The language used is useful?
  - What would you add?
  - What would you remove?
  - Did you feel comfortable with the experience?
- **Lesson 2:**
  - Was the tutorial useful?
  - What would you add to improve the experience after the lesson?
  - What would you remove from the tutorial?
  - Do you think the content could be presented in a different, more useful way in the tutorial?

  During the lesson:
  - Did you feel dizzy or physically uncomfortable during the training?
  - Did you manage to clearly understand the objective?
  - Interaction: Were you able to interact with the elements easily? If not, how would you do it?
  - Were you able to read clearly during the session? Is the writing small or blurry?
  - Are the instructions clear? If not, how would you add them?
- **Lesson 3:**
  - Have you had time to understand and structure the video content?
  - Do you think the image quality is good?
  - Do you find the examples clear enough?
  - The language used is useful?
  - What would you add?
  - What would you remove?
  - Did you feel comfortable with the experience?
- **Lesson 4:**
  - Was the tutorial useful?
  - What would you add to improve the experience after the lesson?
  - What would you remove from the tutorial?
  - Do you think the content could be presented in a different, more useful way in the tutorial?

During the lesson:

- Did you feel dizzy or physically uncomfortable during the training?
- Did you manage to clearly understand the objective?
- Interaction: Were you able to interact with the elements easily? If not, how would you do it?
- Were you able to read clearly during the session? Is the writing small or blurry?
- Are the instructions clear? If not, how would you present them?

- **Lesson 5:**
  - Was the tutorial helpful?
  - What would you add to improve the experience after the lesson?
  - What would you remove from the tutorial?
  - Do you think the content could be presented in a different, more useful way in the tutorial?

During the lesson:

- Did you feel dizzy or physically uncomfortable during the training?
- Were you able to clearly understand the objective?
- Interaction: Were you able to interact with the elements easily? If not, how would you do it?
- Were you able to read clearly during the session? Is the font small or blurry?
- Are the instructions clear? If not, how would you present them?

- Collaborative section
  - Compared to the individual lesson, is this similar? What would you add? Was it easier, more convenient, or more useful?
  - Why?

Annex 2: Semi-structured Interview Prototype 2

- **Lesson 1: Lodestars (VR – Dialogues with Entrepreneurs):**
    - Did you find the dialogue with the avatars useful? Did you understand its purpose?
    - What would you add to better contextualize the story or the characters?
    - Did you feel comfortable with the language? Would it have helped to have the option in your native language?
    - Did you find the content relevant and inspiring? Did it motivate you?
    - Would you change anything about the interaction?
    - Did you feel lost at any point during the experience?
    - How would you rate the visual and auditory quality of the experience?
- **Lesson 2: Heroes (VR – Cooperative Urban Planning Game):**
    - Was the initial tutorial sufficient to understand what to do?
    - What would you add or change to feel more oriented in the task?
    - Was it easy to collaborate with the other participant?
    - Did you feel a loss of control or lack of information during the session?
    - Did you experience dizziness or physical discomfort?
    - Do you think you understood the overall objective of the game? How would you clarify it?
    - Were the instructions clear? If not, how would you rephrase them?
- **Lesson 3: Painters (PC – Business Model Canvas):**
    - Did you fully understand the objective of the activity?
    - Was using the canvas intuitive or complex?
    - Did you encounter difficulties with the language or technical vocabulary?
    - What would you improve to make interacting with the canvas more natural?
    - Was the visual organization clear to you?
    - What would you add or remove to make the process easier?

- **Lesson 4: Allies (PC – Entrepreneurial Team Management):**
    - Did you find the interface clear for managing the team?
    - Was it clear what decisions to make and why?
    - How would you rate the game's difficulty?
    - Were the characters' responses understandable and helpful?
    - Would you change the way the results are presented at the end?

- **Lesson 5: Angels (PC – Multiplayer Card Game):**
    - Were the game rules easy to understand?
    - What tutorial or advance help would have been helpful?
    - Was the interface clear so you knew which card to use?
    - Were the instructions well-positioned and visible?
    - What part of the game caused you the most doubt or confusion?
    - Would you change anything about the design to make it more accessible?

Annex 3: Semi-structured Interview Prototype 3

- **Lesson 1: Basic Interaction (Daycare):**
  - Was the purpose of the proposed activities clear to you?
  - Did you feel comfortable with the controls and environment?
  - What would you add to make the introduction more understandable?
  - Was the feedback received sufficient?
- **Lesson 2: Navigation**
  - Did you feel dizzy or uncomfortable with the movements?
  - Which navigation method felt most natural to you?
  - Was it easy to understand what to do in each level?
  - Were the maps or visual cues helpful?
- **Lesson 3: Visualization and Lights:**
  - Was the relationship between lighting and appearance clear to you?
  - What would you add to make the visual concepts easier to understand?
  - How would you rate the experience in terms of realism?
- **Lesson 4: Asynchronous Collaboration (Ghost Instructor):**
  - Was it easy to follow the ghost instructor?
  - Did the activity help you understand how to guide attention in VR?
  - What would you improve about the avatar interaction system?
- **Lesson 5: Physics Demonstration (Planets):**
  - Did you find the simulation environment intuitive?
  - Were you able to experiment and test freely?
  - What would you add to improve understanding of physics concepts?
- **Lesson 6: Builder – Advanced Environment Design**:
  - Did you feel creative freedom in designing the environment?
  - Were the tools sufficient for customization?
  - What difficulties did you have when building or navigating your environment?
  - Would you like a more detailed tutorial at the beginning?

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