

No Thinkers - Final Report

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Politecnico di Torino



**Politecnico
di Torino**

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1. Project Information

1.1 Project Name

We chose the name 'ZLearn' for our project because of its modern appeal and simplicity. The letter 'Z', emblematic of Generation Z, combined with the word 'Learn', reflects our vision for a technologically advanced and accessible platform, transforming how students engage with computer science topics.

1.2 Value Proposition

Our value proposition is: 'The new generation way of learning computer science'. We believe that traditional education approaches may not be as impactful for the new generations of students. ZLearn is the answer to this challenge, offering a revolutionary educational experience tailored to the needs and preferences of Generation Z. With an emphasis on interactive content, and a user-friendly interface, ZLearn transcends the limitations of conventional learning.

1.3 Team Members

We are four students from the Master's Degree in Computer Engineering at Politecnico di Torino. Our names are:

- Sante Laera
- Bruno Palermo
- Alessio Rosiello
- Carlos Valeriano

1.4 Group Name

The name of our group is 'No Thinkers' which represents our dedication to approaching this project with fresh perspectives and making creativity a key element in everything we do.

2. Problem/Solution Overview

Understanding computer science topics can be really challenging initially. Our solution aims to improve the learning experience for abstract and technical concepts by incorporating visualization through augmented reality animations. Additionally, we leverage gamification to boost students' engagement, making the educational process more interactive and enjoyable.

3. Needfinding

3.1 Domain Description

Within the theme “Education & Learning”, we decided to further investigate young students between 18 and 25 years old who are enrolled in both formal (e.g. high school, university) and informal (online) computer science courses. The choice was driven by the fact that technology is a very hot topic and computer science courses are more common and required by the work industry nowadays.

3.2 Interviews

3.2.1 Methodology and Procedure

To find potential user needs, the team conducted in-person interviews to gain a deeper understanding of the user base of the application. Users involved in the interview are:

- Zakaria (immediate user) - Internship at an IT company.
- Enrico (immediate user) - Enrolled in an ECDL course.
- Gabriele (lead user) - Programmer at Blue Reply with a background from Politecnico di Torino.
- Paolo (domain expert) - Computer science professor at Liceo Volta in Turin.

After securing consent from these users, interviews were led by one team member with another taking notes. The lead interviewer presented a pre-prepared list of questions tailored to each user category, ensuring a comprehensive exploration of their perspectives.

3.2.2 List of Questions

Immediate user questions

1. How/Why did you start studying computer science?
2. Which computer science courses (also online) are you enrolled in?
3. How many hours per week does the course have?
4. How do you balance your time between computer science studies, other tasks and free time?
5. Did you have previous knowledge of this topic? If yes, do you think the course you are following has improved your knowledge?
6. Have there been prerequisites indicated for the course? If yes, were they sufficient? If not, how did you fill the missing parts?
7. Which course topic was the most complex? And the simplest?
8. Which course topic captured the most interest and which the least?
9. Which aspect of the course do you think is working better and which is worse?

10. If the course is online:
 - The course being online made the interaction with the teacher and students easier or harder?
 - Why did you choose an online course instead of an in-person one?
11. If the course is in-person:
 - Do you think the course being in person is making interaction with the teacher and students easier or harder?
 - Why did you choose an in-person course instead of online?
12. What do you do when you need clarifications or help with the course?
13. Describe a typical course lecture.
14. How would you evaluate your concentration during a lecture? Are there any distraction elements?
15. Do you prefer synchronous or asynchronous lectures? Why?
16. Which resources do you use to study?
17. How do you organize your studying materials for this course?
18. What is your studying method for this course?
 - [if they take notes]
 - In what way do you take notes during a lecture?
 - In what way do you use your notes to study?
19. What do you use to track your progress in the comprehension of the course?

Lead user questions

1. Which computer science courses have you attended?
2. In which way the study of computer science influenced your career?
3. Did you have previous knowledge of computer science? If yes, do you think courses have helped enrich your knowledge?
4. How did you balance the time between computer science, other tasks and free time?
5. Did you attend more than one course? If yes, which course did you prefer and why? Which one did you like the least and why?
6. Which course was the most complex? Which one was the simplest?
7. Which teaching method did you prefer? Frontal, theoretical, practical, interactive, etc...
8. Which study method do you prefer?
9. Which resources helped the most in studying?
10. If the courses were online:
 - Did you have a way to interact with the professor(s)?
 - If yes, how would you say the support from the professor was on a scale from 1 to 5? What do 1 and 5 mean to you?

- The fact that the course was online made the interaction between teacher and students easier or harder?
 - Why did you choose an online course instead of an in-person one?
11. If the courses were in-person:
- Did you have a way to interact with the professor(s)?
 - If yes, how would you say the support from the professor was on a scale from 1 to 5? What do 1 and 5 mean to you?
 - The fact that the course was in-person made the interaction between teacher and students easier or harder?
 - Why did you choose an in-person course instead of an online one?
12. What did you usually do when you needed help or clarifications about the course topics?
13. What recommendations and tips would you give to a person who wants to study computer science?

Domain expert questions

1. Which computer science course do you teach?
2. When did you start teaching computer science?
3. What do you like the most about teaching computer science? What's more difficult about it?
4. How do you interact with your students? Which are the things you prefer the most about the interactions and what do you think is the most difficult?
5. How many hours a week is the course that you're teaching?
6. In what way do you provide your students with studying materials?
7. Which course topic is the most complex? Which one is the simplest?
8. Does an in-person course make it easier or harder to interact with your students?
9. What are some of the challenges that your students encounter more frequently in learning new computer science topics?
10. Which are, in your opinion, the activities that students like the most?
11. What evaluation method do you prefer for your students?
12. How would you evaluate the attention of the students during a lecture? In your opinion, what could be the reason behind the lack of attention during lectures?
13. How is the workload organized and distributed among students? How many hours a week should they dedicate to this course?

3.2.3 Team Member Roles

Interview 1 - Immediate user, Enrico

- [Consent form](#)

Enrico is a 21-year-old student who took an ECDL course to get the certification in high school. He was selected from Bruno's social circle and decided voluntarily to participate in the interview. Since this was the only IT course he attended, he has unique characteristics that can make a difference in understanding the user's needs from the perspective of a novice user.

The interview was conducted online in a video meeting. For this interview, Bruno took the role of the lead interviewer while Carlos was taking notes. We used the OBS Studio software to record the video and audio of the Google Meets call and a tablet to take some notes.

Interview 2 - Immediate user, Zakaria

- [Consent form](#)

Zakaria is a 23-year-old guy who is taking on an internship at an IT company which provides a few months of learning new technologies before starting to work on a real project. He was a very good candidate for the interviews because he provided a different view of the domain. Since he didn't attend university, his view on the IT course was fresh and unbiased. He was recruited by Carlos as he is one of his friends.

The interview was conducted at Carlos' home. For this interview, Carlos took the role of the lead interviewer while Alessio was taking notes and recording the interview. A phone was used to record the audio of the interview and a PC was used to take some notes.

Interview 3 - Lead user, Gabriele

- [Consent form](#)

Gabriele is a 23-year-old programmer at Blue Reply. He was a Software Engineering student in Politecnico di Torino. He was specifically chosen by Bruno due to their mutual connections and shared interests. With a solid background of five years of university-level IT classes, Gabriele's robust knowledge and passion for learning informatics greatly contributed to our needfinding.

The interview was conducted in a room of a student residence. For this interview, Sante took the role of the lead interviewer while Bruno was taking notes and recording the session. A smartphone was used to audio record, and a PC was used to take notes.

Interview 4 - Domain expert, Paolo

- [Consent form](#)

Paolo Centaro is a 34-year-old professor who teaches computer science at Liceo Volta in Turin. He is an electrical engineer and started teaching in 2016. He was selected by Alessio, by asking at his old high school if any professors were willing to take part in an interview and Paolo accepted.

The interview was conducted in an empty classroom at Liceo Volta in Turin. For this interview, Alessio took the role of the lead interviewer while Sante was taking notes and audio recording the interview. A phone was used to record audio and a PC was used to take notes. The teacher also showed us various tests prepared for his students so we took pictures of them. At the time of the interview, he didn't have a course book on him but he told us the name of the book he uses to teach the course so that we could insert a photo of it afterwards.

3.2.4 Results

Pictures



Figure 1 - Book used by the professor in his course

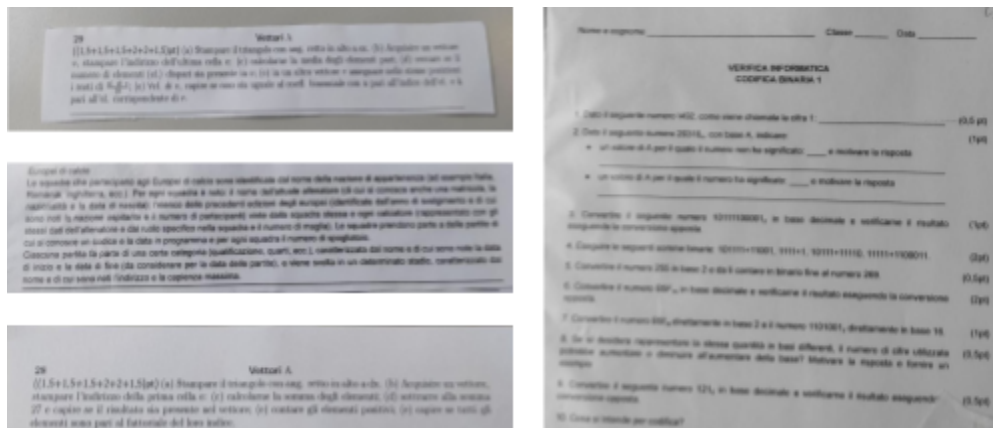


Figure 2, 3, 4, 5 - Texts (in Italian) of a test for the 4th year students

Summary of the answers

Following the interviews, the team analyzed the transcripts, the audio recording and any additional material to collect and summarize the answers of the interviewers. This was fundamental in extrapolating the key quotes and consequently the needs of our domain of interest.

- **Interview 1 - Immediate user, Enrico**

In the interview, the student was very collaborative and provided us with as many details as he could recall. He attended one of the module courses for ECDL certification and felt that the main issues concerning the lectures he attended were linked to the possibility of taking the exams each month which led him to postpone it every time due to scholastic duties and the fact that, from time to time, he was distracted because of the simplicity of some topics. He thinks that the course had a big impact, especially in the speediness with which he now takes notes on lectures. Collaboration during lectures was a key aspect of learning both with the professor and classmates.

- **Interview 2 - Immediate user, Zakaria**

In this interview, Zakaria spoke about his experience with the internship that he is taking. The internship is structured in two parts: a learning period, and a real project. He thinks that learning in a classroom is where he can be more productive as he is more focused and can solve any doubt immediately by asking for help from the teachers and tutors. He sometimes makes use of external sources of material when he feels like some concepts are unclear or lack practical examples.

- **Interview 3 - Lead user, Gabriele**

In this interview, the interviewee discusses his computer science education and its impact on his career. His passion for computer science began during high school, particularly in a coding class. His interests evolved during university, focusing more on web development, and he now works in that field. He balanced his studies, and free time by taking courses on his own schedule, optimizing his study time, and finding it easier during the pandemic when courses were online. Overall, the interviewee emphasizes the importance of practical and interactive learning methods and advises aspiring computer science students to stay consistent with their studies and leverage group work for a more rewarding educational experience.

- **Interview 4 - Domain expert, Paolo**

He feels like most of the problems in the course derive from the fact that the required syllabus is very sparse and doesn't go deep enough in certain topics. He thinks that doing practical programming and taking very good notes in class is very important and that studying at home is just a small part of the course. The lectures are better when they are

interactive and there are a lot of back-and-forth questions and answers, but peer-to-peer work is also crucial as students who have easier understanding can help those who struggle. He also said that it is very hard to keep the attention up in class, especially for a class that you haven't followed for the whole 5 years.

Key quotes

- Gabriele (lead user) - "The easiest thing to tell a novice is to learn syntax, but the hard part is getting into the mechanisms. The way a person thinks and how a program works are very different, and the contrast is a challenge."
- Enrico (immediate user) - "If there wasn't a particularly captivating subject to discuss, or conversely, if a topic was too well-trodden and unproductive to delve into, maybe my classmates and I engaged in conversation instead."
- Zakaria (immediate user) - "Human interactions are really positive for the course because they allow me to get immediate feedback on what I'm doing"
- Paolo (domain expert) - "It is hard to maintain the attention of the students because in this type of high school IT is often overlooked. If you follow a class for the whole 5 years, it's easier than for a class that you pick up halfway."
- Paolo (domain expert) - "The first programming tests are usually the hardest because theory can always be studied but programming is harder to reason about, if you study by memory the code you won't pass. The difficulty is in the fact that the test asks you to do something different than simply repeating what's done in the lecture."

3.3 Synthesis

3.3.1 Brainstormed User Needs

After having collected the results of the interviews, we identified needs (retaining the connection with the interviews and answers) by using a post-it-like voting mechanism, wherein each team member was tasked with selecting three out of the five observed user needs. This facilitated a collaborative and democratic approach, allowing each team member to contribute to the prioritization process based on their individual perspectives and insights. The outcomes of this selection process are outlined below, providing a comprehensive overview of the user needs that resonated most strongly within our team.

attention: S - B - A - C

SUMMARY: Need to capture and maintain the attention during a frontal lecture

1. Needs to be more involved in theory lectures to keep attention
9. Capture interest (be engaged) during lectures
7. Need to skip the first few topics of the course if the student already knows them to avoid getting bored at the start
16. Needs to improve the span of attention
24. Needs to capture the attention of students.
30. needs to find a way to be passionate and motivated about computer science
17. Needs to motivate students following lectures
23. Needs to motivate students attending the lectures
27. The user needs to have enough space for himself to not lose focus during a lecture

notes/materials: A - C

SUMMARY: Need to provide exhaustive material for self-studying

2. Needs to have equipment to follow live coding lectures
10. needs a way to make available lectures throughout the course
13. needs a way to speed up note writing
19. Needs to be able to cope pre-requirements of the course with appropriate materials
25. The user needs to keep the code he wrote in one place to track his progress throughout the course
26. The user needs access to relevant and reliable external sources in case the lecture material is not enough to understand a topic

interaction:

SUMMARY: Need to be able to interact, ask questions often and quickly, with teachers and students alike, privately if necessary.

6. Need a way to quickly talk and ask questions to teachers from home / not in person, emails are slow.
35. need to cooperate with other students
3. Needs to have privacy to be able to ask the teacher questions without them being heard by everyone else.
26. The user needs to have human interactions with the more experienced people in order to get immediate feedback on different problems

simplifying topics / concepts: S - B - A - C

SUMMARY: Need to be able to simplify computer science topics that are harder to grasp at first, like programming/coding, to people who are new to them

4. Need to have an easier way to introduce programming to people who are doing it for the first time
8. need a way to better clarify concepts on lectures
33. need to simplify the taught concepts
36. need to understand easier core concepts of computer science
11. needs to visualize the key concepts of the course
18. Needs to explain concepts in simple ways
37. Need to fully understand how to start coding

practice: S - B - A - C

SUMMARY: Need to apply computer science concepts that are harder to grasp at first in a practical way

12. needs a way to apply more the newly learned concepts
21. Needs to practice more with continuous feedback
25. The user needs to do as much exercises as possible in order to learn new programming languages
34. need to have a practical approach to computer science

Figure 6 - Brainstormed user needs

3.3.2 Deep User Needs

In this section, we highlight the three significant deep user needs that we identified, each followed by a list of the reasons which emerged during the interviews that led to our decision to prioritize them:

- Need to apply computer science concepts that are harder to grasp at first in a practical way.

- Immediate user 1: He was doing many coding exercises, and he said that coding was needed to verify if he understood the theoretical concepts.
- Lead user: He said that practice helps a lot since theory plays a small role in computer science.
- Domain expert: He said that students prefer lessons in laboratories.
- Immediate user 1: Before attending the course, he found difficulties in studying some arguments.
- Immediate user 2: He found difficulties in studying programming in Excel.
- Need to provide exhaustive material for self-studying.
 - Lead user: He said a course he attended didn't have any material where to study.
 - Immediate user 2: He said that following lectures asynchronously could have helped him to better manage his time.
 - Immediate user 1: He said he accessed relevant and reliable external sources in case the lecture material was not enough to understand a topic.
- Need to capture and maintain the attention during a frontal lecture
 - Domain expert: He says that it is hard to maintain the attention of the students because in Scientific high school IT is often overlooked.
 - Lead user: He said that during online courses, he often stopped the lecture to take a break. And that he has an attention span of at most one hour.
 - Immediate user 1: He said that known and easy topics for him were the main reason for his distractions.

3.4 Solutions

3.4.1 Brainstormed Solutions

Using Miro as our collaborative platform, each member of the team had five minutes to brainstorm as many ideas as possible around the previously identified deep user needs. The Miro platform provided a virtual canvas for our collective ideation process, facilitating the visualization and organization of a multitude of ideas for further evaluation and refinement.

Here's the [link](#) to the Miro board.

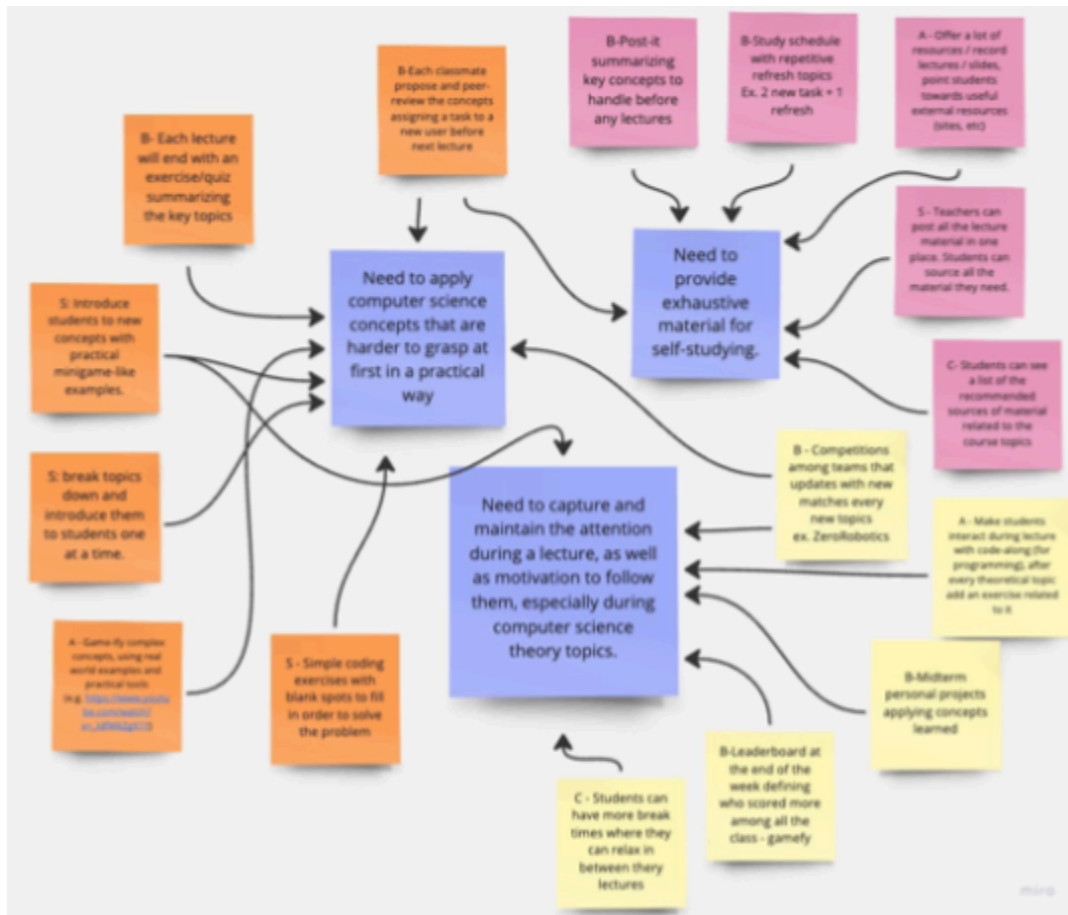


Figure 7 - Brainstorm board showing the user needs proposed solutions

3.4.2 Final Solution

Help students between 18 and 25 years old visualize and interact with abstract notions using practical examples in a visual way. Increase student engagement through gamification.

This choice is strictly related to the need to apply challenging computer science ideas in a practical manner. The objective of this solution is to improve the learning experience for abstract and technical computer science concepts by utilizing animations for visualization and integrating gamification to keep students actively engaged throughout the learning process.

4. Tasks and Storyboard

4.1 Task Selection

- **Simple task:** learn a new computer science topic
- **Moderate task:** see progress in knowledge of completed topics
- **Complex task:** provide feedback about poorly explained topics

In selecting our tasks, we considered their relevance to our target population and the goals of our project. These tasks were chosen to address specific challenges students face in learning computer science topics, like tracking their progress in a fun and interactive way and providing feedback to improve their overall learning experience.

4.2 Storyboard



Figure 8 - Storyboard

This storyboard was chosen because it allows us to highlight the problem of understanding computer science topics that are harder to grasp and show how our solution can be applied to help solve it.

Its main strengths are the following:

- The storyboard showcases the effectiveness of the solution because the user after studying with our solution achieves a perfect score on the test.
- It shows well that portable devices are a good fit for our solution.

Its main weakness is that the storyboard doesn't really take into consideration the whole learning process involved in understanding new topics but focuses mostly on the edges of this process.

Despite this weakness, the visual representation successfully captures the essence of our solution's effectiveness, demonstrating its potential to meet the identified user needs related to understanding and applying challenging computer science concepts.

5. Low-Fidelity Prototypes

The goal of creating low-fidelity prototypes is to lay out the main information and interactions through a set of static drawings. In this process, a team member simulates the computer's responses through pointing-for-clicking actions, while another team member, acting as a facilitator (and concurrently assuming the role of an observer), takes notes while observing the user's behavior when approaching the interface. This allows for a dynamic simulation of the application's functionalities and user engagement.

5.1 Modalities Exploration

To address the identified needs of our target audience, we decided to explore the following two modalities:

- Augmented Reality for Tablet (Android/iPadOS): [Link to Prototype](#)
- Mobile (Android/iOS): [Link to Prototype](#)

The choice of Augmented Reality (AR) for tablets was made to provide users with a seamless way to visualize and interact with abstract computer science topics. This approach leverages the immersive capabilities of AR to enhance the learning experience.

On the other hand, the mobile alternative was proposed to capitalize on the widespread use of smartphones. This platform allows for easy explanation of concepts, making the learning process more accessible through a device commonly used by the audience.

5.2 Paper Prototypes

The prototypes concretely show the main elements of the user interface with the major functionalities. These modalities were hand-drawn and printed. The navigation and task flow was illustrated using a Miro board.

5.2.1 AR for Tablet

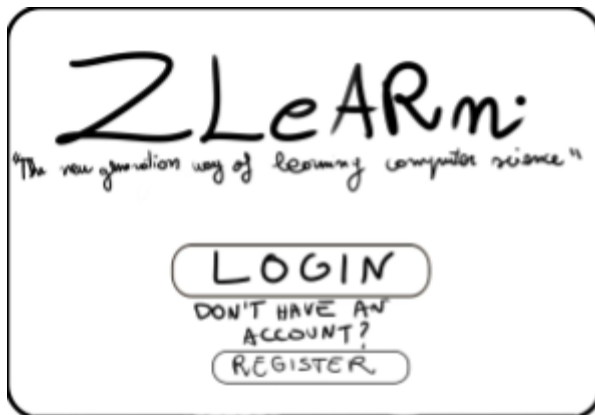


Figure 10 - Start Menu showing after app launch

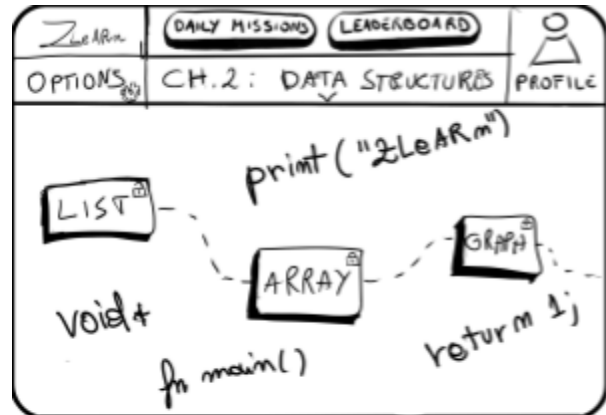


Figure 11 - Topic selection page listing the topics for the "Data structures" chapter

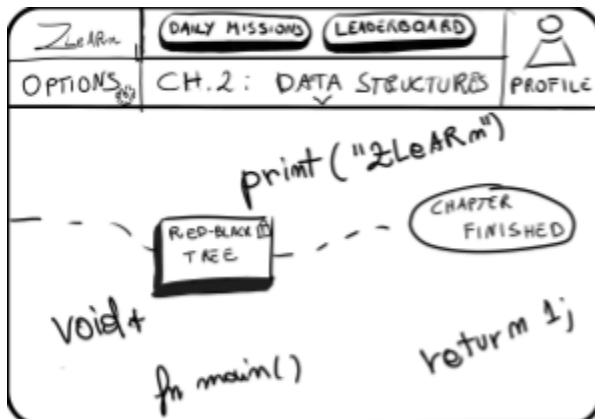


Figure 12 - Topic selection page listing the remaining topics of the chapter after horizontal scroll action

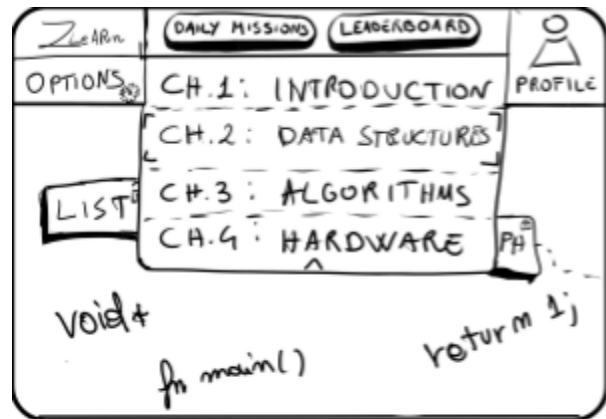


Figure 13 - Chapter selection drop down menu showing the list of chapters

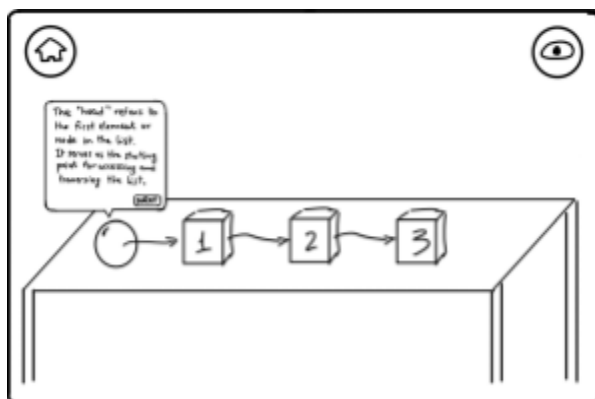


Figure 14 - AR topic explanation page with the camera pointing at a table and the navbar hidden

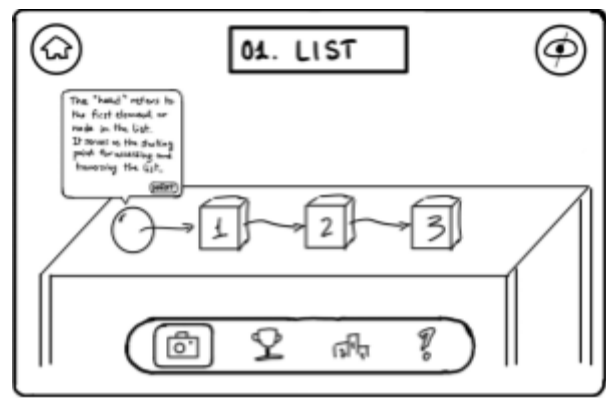


Figure 15 - AR topic explanation page with the visible navbar on the bottom

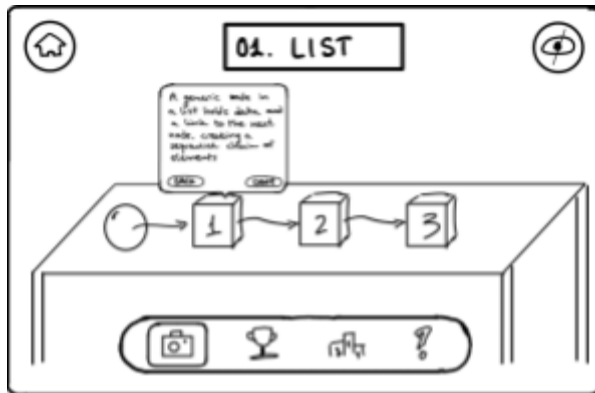


Figure 16 - AR topic explanation page after first interaction with the dialog

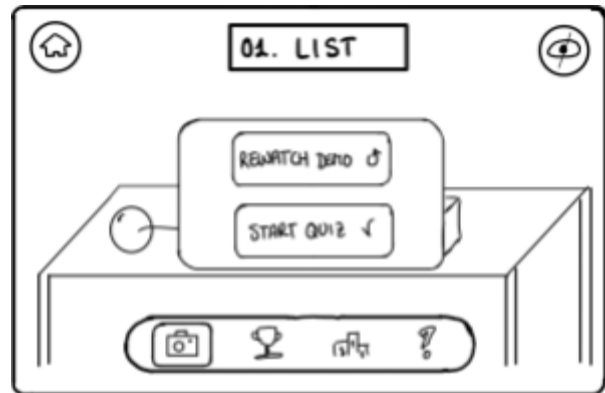


Figure 17 - AR topic explanation page after last interaction with the dialog



Figure 18 - Quiz page to test the acquired topic knowledge



Figure 19 - Quiz page dialog before quitting the quiz without having complete it

“Learning a new computer science topic” (simple task) can be done by following the showed steps reading the dialogues as well as completing the questions. A topic is referred to be learnt whenever all the quiz questions have been successfully completed unlocking the following topic/chapter.



Figure 20 - Quiz page dialog after having completed all the questions

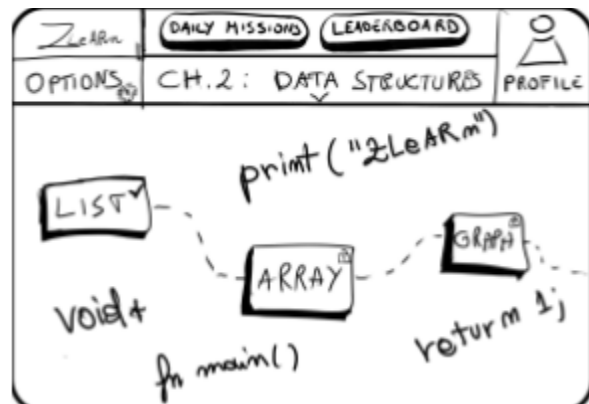


Figure 21 - Topic selection page after having completed the “List” topic and unlocked the “Array” topic



Figure 22 - Daily missions page displaying the daily goals to be completed

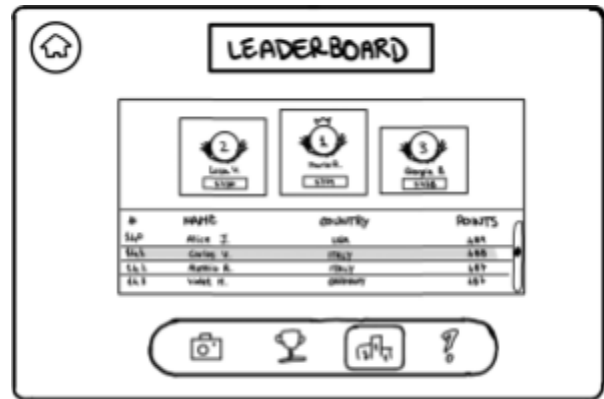


Figure 23 - Leaderboard page displaying the global rank of the user with respect to other users

“See progress in knowledge of completed topics” (moderate task) is performed by checking the provided daily missions. A daily mission is said to be completed if the tick icon is displayed and the points are obtained.



Figure 24 - Feedback page to provide useful comments on possible improvements



Figure 25 - Profile page to give an overview of the user's stats and logout button

“Provide feedback about poorly explained topics” (complex task) is done by filling and sending the form which appears after tapping the question mark icon on the question page.

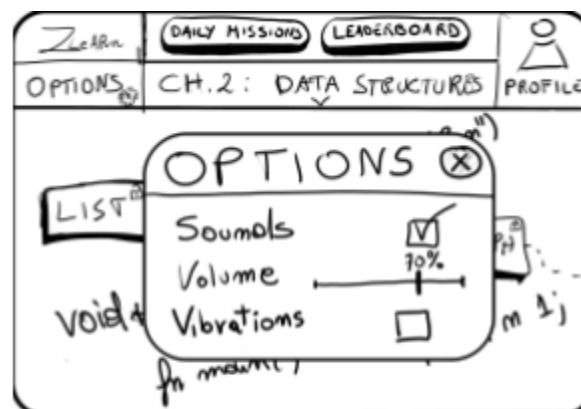


Figure 26 - Settings dialog

Overall, the project goal was reached because the questions were proposed through visual images about the abstract concepts straight after the short step-by-step explanation done in Augmented Reality. Gamification through a leaderboard and the presence of a scoring system improves the engagement of students.

5.2.2 Mobile



Figure 27 - Home page showing the logo and “Start” button



Figure 28 - Introduction page showing a character explaining the game’s goal



Figure 29 - Chapter selection page as scrollable list with a PC showing the completion status

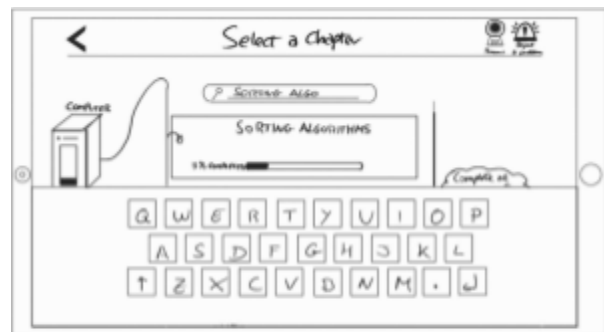


Figure 30 - Chapter selection page showing keyboard to filter the chapters by name

“See progress in knowledge of completed topics” (moderate task) is performed by checking the status of a single chapter, all the chapters and the mission’s completion. A chapter is said to be completed if all the related topics are completed (icons shown in red).

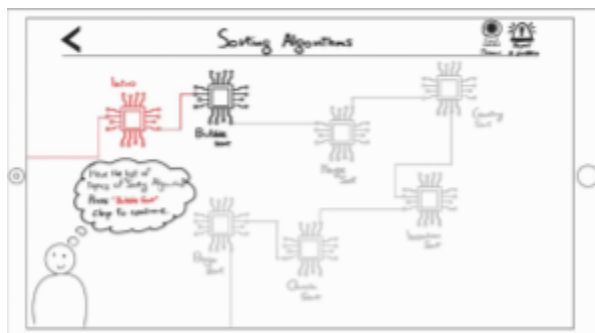


Figure 31 - Topic selection page showing the list of complete (red), unlocked (black), and locked (grey) topics related to “Sorting Algorithms”

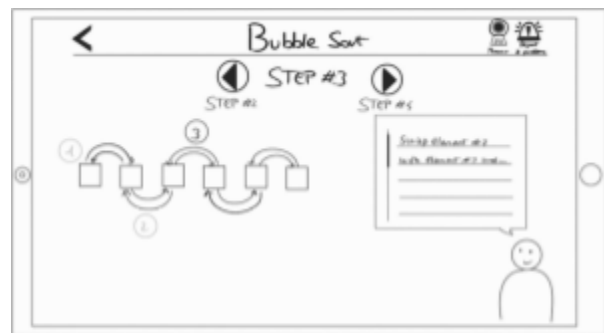


Figure 32 - Topic explanation page showing step by step dialogs illustrating the topic

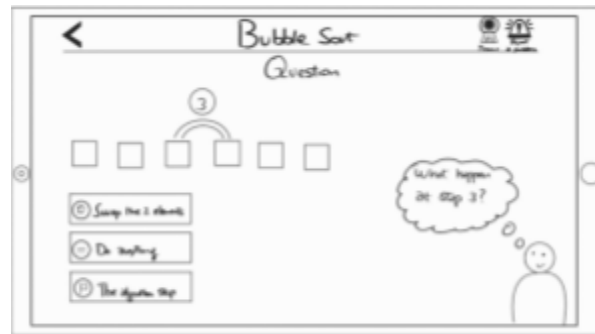


Figure 33 - Quiz page with a multiple choice question that verifies the acquired topic knowledge

“Learning a new computer science topic” (simple task) can be done by following the shown steps, reading the dialogues as well as completing the questions with the related feedback. A topic is referred to be learnt whenever all the questions have been successfully completed unlocking the following topic/chapter.

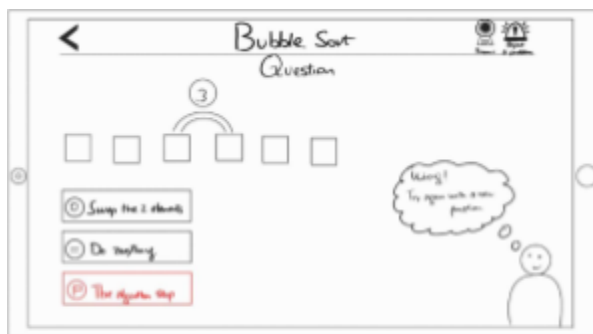


Figure 34 - Quiz page showing wrong answer feedback to the question



Figure 35 - Quiz page alert dialogue displayed when trying to exiting the quiz

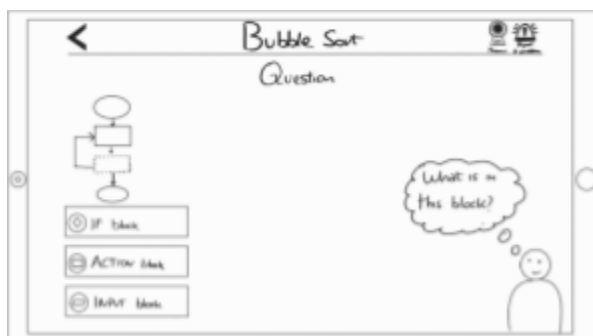


Figure 36 - Quiz page showing another multiple choice question in case previously wrong answer

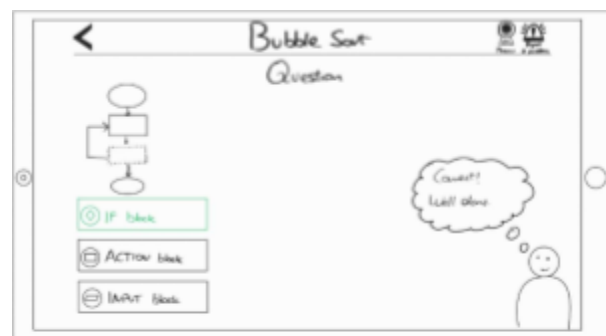


Figure 37 - Quiz page showing multiple choice question positively answered with feedback

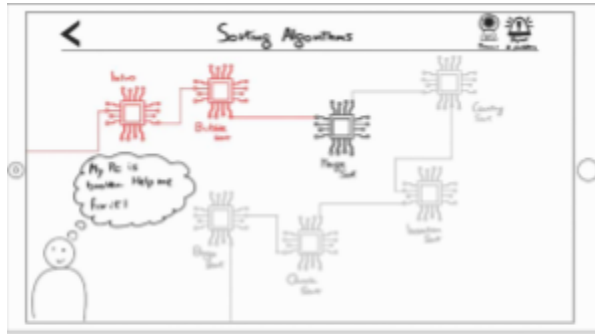


Figure 38 - Topic selection page showing completed topic



Figure 39 - Report a problem page to provide a form to send feedback comments

“Provide feedback about poorly explained topics” (complex task) is done by filling and sending the form opened by clicking the top-right “Report a problem” icon.

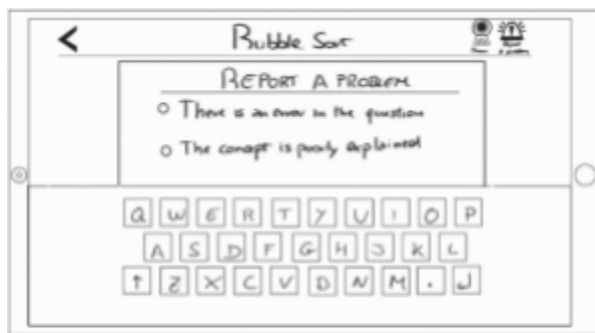


Figure 40 - Report a problem page showing the keyboard to write comments in the text area



Figure 41 - Missions page displaying the challenges to be completed

Overall, the project goal was reached because the questions were proposed with visual images about the abstract concepts straight after the short step-by-step explanation. Gamification through mission completion and the character’s story presence goal includes enriching the engagement of the student.

5.2.3 High-Level Flow

Here are the links to the high-level flows of the “screens” of both paper prototypes that were done in two separate Miro boards:

- Augmented Reality for Tablet: [Link to Miro](#)
- Mobile: [Link to Miro](#)

5.3 Heuristic Evaluations

5.3.1 AR for Tablet

The evaluators of the prototype generally praised the interfaces for being very good and intuitive, with a focus on consistency and standard errors. However, there were challenges in evaluating certain heuristics, particularly regarding system status visibility. The main recommendation for improvement is to enhance consistency across the interface by standardizing button styles, ensuring uniform navigation placement, and maintaining coherent terminology. Clearer labeling, especially for critical functions like logout, is suggested to enhance user control. Additionally, providing feedback during quizzes, such as displaying scores or summaries, is deemed crucial for user understanding and learning from mistakes.

Regarding the overall structure of the application, it is described as linear, minimalist, and easy to follow. Tasks are intuitive, and functionalities are useful and engaging. However, the homepage is criticized for appearing chaotic with an excessive number of elements. The recommendation is to split the homepage into two screens - one for the homepage itself and another for a section of the course with graphical representations of its topics. The final suggestion is to focus on improving feedback to users by incorporating screens that offer guidance on how to proceed when users find themselves without information or confused about interactions.

Here are the links to the two evaluations for the AR prototype:

- [Lenny's heuristic evaluation](#)
- [Noemi's heuristic evaluation](#)

5.3.2 Mobile

Overall, both evaluators agree that the application is well-implemented, allowing users to easily navigate through pages to accomplish main tasks. ElHelwe found no significant difficulties in understanding the workflow, despite detecting some violations with minimal impact on the user experience. One recommendation is to address issues related to user control and freedom, especially when answering questions, by providing more options instead of automatic navigation.

Francaviglia appreciates the interesting and useful idea for the chosen domain, highlighting positive aspects such as the clever concept of a broken PC getting fixed as the user learns new concepts and the themed topic section. However, concerns arise about the graphical connection between the PC and chapters in the notebook, and the presence of a character giving help makes the experience somewhat challenging. Suggestions include minimizing redundancy in character-provided information, better distinguishing between screens for theoretical concepts

and interactive questions, and providing more feedback when users answer questions incorrectly to enhance the overall user experience.

Here are the links to the two evaluations for the mobile prototype:

- [ElHelwe's heuristic evaluation](#)
- [Francaviglia's heuristic evaluation](#)

5.3.3 List of Violations

Augmented Reality Tablet application

#	Heuristic	Where	What	Why	Severity
1	H1 Visibility of system status	Quiz	The feedback about the answer is not explicit.	There's no way of knowing whether the given answers are correct or not, neither for each individual response nor at the end of the quiz to determine if it has been passed and how many questions are correct.	3
2	H1 Visibility of system status	Quiz	Once the quiz is completed, the topic is marked as completed, regardless of the score received in the quiz.	If the user has completed the quiz by providing all incorrect answers, the topic is still marked as completed. This might confuse the user as it misinterprets the topic's status, indicating it as "learned" when, in fact, it's not.	3
3	H2 Match between system and the real world	Feedback	The feedback page icon is a question mark.	The user might associate the question mark icon with a help section, they might expect another icon to indicate feedback, possibly with an image that better describes its purpose.	2

4	H2 Match between system and the real world	Camera Section	The icon to hide the bottom menu.	The user might associate the eye icon with the option to hide the AR portion from the camera's view. The chosen icon doesn't clearly represent the option to hide the menu, and its placement doesn't facilitate the understanding of its purpose.	2
5	H3 User control and freedom	Quiz	Once someone selects the answer there is no way of changing it.	It does not account for the possibility that the user might have made a mistake in their selection.	3
6	H4 Consistency and standards	Daily missions	The button to return to the home screen is represented by a house icon throughout the application, except on this screen where it appears as an arrow labeled 'back'.	The application uses different icons for the same function, leading to potential confusion.	1
7	H4 Consistency and standards	Daily missions	The design and containers of this screen differ from all the other screens accessible through the same bottom menu (leaderboard, feedback, quiz and camera).	It is not consistent with the rest of the application.	1

8	H4 Consistency and standards	Leaving page warning	In the warning description, the term 'quit' is used in the sentence explaining that no saves will occur if the user exits. However, among the buttons below, we don't find the same word to indicate the same concept; instead, we find 'cancel' or 'exit'.	Verb consistency is lacking, and users might be confused by not finding the same term indicating the action they intend to perform.	2
9	H5 Error Prevention	Feedback	There is no notification if the user presses the home button while writing the feedback.	The user might lose the text they have written up to that point.	3
10	H5 Error Prevention	Feedback	There is no confirmation pop-up after pressing the submit button.	The user might have pressed the button by mistake.	3
11	H6 Recognition rather than recall	Camera Section	The course to which the displayed topic belongs is not mentioned.	The user might not remember which course a certain topic is part of.	2
12	H6 Recognition rather than recall	Feedback	The title above the feedback window box doesn't provide information about the chapter for which the feedback is being given.	The user needs to go back to the Camera screen to get details about the topic they are providing feedback on, or they might assume that the feedback is about a general malfunction of the application rather than the specific topic.	3

13	H7 Flexibility and Efficiency of use	Camera Section	The only way to take quizzes on a certain topic is by viewing the demo first.	The experienced user might want to take quizzes without having to watch the demo (perhaps because it has already been seen).	1
14	H8 Aesthetic and Minimalist Design	Home Page	The layout and the buttons on the top bar.	The proximity of numerous elements (without an option to hide them) makes it difficult to identify clear buttons. It appears that every button holds the same importance, although on that specific screen, some might be less relevant than others.	3
15	H8 Aesthetic and Minimalist Design	Home Page	There is no indication that the lower part of the home page can be scrolled.	It is unclear, which might lead someone to never explore that part of the chapter displayed.	2
16	H8 Aesthetic and Minimalist Design	Home Page	There are many writings (representing code) surrounding the topic cards.	They make the screen confusing and aren't related to the topic cards, which should be the focus of the screen.	2
17	H10 Help and Documentation	Entire application	There are no help buttons or textual information on how to proceed, such as "start by doing this".	The user might need assistance to understand how to get started on a new screen.	2

18	H2 Match between system and the real world	Learning page	The cup icon in the bottom bar	The cup icon opens a screen with the daily missions, usually, this icon refers to a leader board, not missions or quests (a paper or a target would be more appropriate according to me). The icon cut is associated with the ranking in the “profile” popup.	2
19	H4 Consistency and standards	Topics list and learning screen	Navigation bar	The bar to change screen is often on the top and often on the bottom	3
20	H4 Consistency and standards	All screens	Buttons	There are lots of different types of button. On the topics list you have block buttons, rounded buttons, a dropdown list that could be considered as a button and on the learning screen you have icon-only buttons. It may be hard to distinguish what is a button and what is not (for example, is the logo a button?). Multiple buttons (leaderboard for example) refer to the same functionality but do not look similar.	3

21	H4 Consistency and standards	Learning screen	“next” button	The first button is “next” and once I click on it, I can see other buttons but this one to pass to the next step is now “done”, how is it different from the previous button? The second popup only refers to the first node and I can see other nodes, are they the same?	2
22	H3 User control and freedom / H4 Consistency and standards	Profile popup	The logout button is not labeled and not easily findable	The logout icon may not be so understandable and findable. There is no label and it’s on the same line as statistics.	3
23	H7 Flexibility and efficiency of use	Topics list screen	Dropdown to select a chapter	A dropdown is easy to use until there are lots of chapters. If your application has 30 chapters, it will be hard to browse the chapters and find the right one. The navigation becomes less easy. You could try to add a way to search the right chapter.	4
24	H7 Flexibility and efficiency of use	Topics list screen	See the progression as you navigate through the chapters	When you open the chapters dropdown you may want to know directly which chapter has been completed and which has not. In this prototype you have to click to see the chapter, notice there are no more exercises and browse the chapters again	3

Mobile application

#	Heuristic	Where	What	Why	Severity
1	H1 Visibility of system status / H3 User control and freedom	After tapping to Start at the beginning, the screen with the character saying “My PC is broken. Help me fix it!”.	The screen provides no information about what is happening. There’s no way for the user to move from this page forward or backward	The user may not know how to interact with this screen, whether to read quickly, tap on the screen, or wait for something to happen. If it’s not the first time the user used the app he doesn’t want to read the greeting message again especially if the predefined wait time on this page is so long	2
2	H1 Visibility of system status	Question	The total number of questions and the current question number are not specified.	The user might want to know how many questions they need to answer and at what point they are in the questionnaire.	3
3	H1 Visibility of system status	Question	The user receives no feedback about the end of the questions when they answer the last question.	The user may not know how to proceed, as they have to tap on the back arrow on their own to return to the topic menu and discover that they have completed the current topic.	2
4	H2 Match between system and the real world	On every screen except the first two.	The rosette symbol used as the icon for ‘missions’ does not evoke the concept of mission.	The user might be confused because without reading the word ‘Missions,’ they wouldn’t associate that symbol with missions.	1

5	H3 User control and freedom	Question	When the answer is wrong, the next question is automatically shown.	If the user taps by mistake an answer or wants to change the answer, they can't. The user may prefer to review his answer, understand his mistake, or take a moment to think before moving on to the next question	3/2
6	H3 User control and freedom	Report a problem.	The 'back' button is missing.	The user might want to go back without sending any feedback, but they can't.	3
7	H3 User control and freedom	Going back when answering a question.	The role of the buttons "Yes" and "No" is not specified.	If the user taps on the 'yes' button, they don't know where they will end up, and they are unsure if the progress will be saved. If the user presses 'no,' they don't know what happens because it is not explained by the written sentence.	3
8	H3 User control and freedom	Select a chapter	The 'back' button in the "Select a chapter" screen brings the user back to the first screen.	Returning to the first screen serves no practical purpose.	1
9	H4 Consistency and standards	Missions	The symbol identifying the 'Missions' section displays a rosette, while each milestone has a trophy as its associated symbol.	If the user sees a rosette, they might expect to collect rosettes. Therefore, when they tap on the rosette and encounter trophies instead, they could become confused.	1

10	H4 Consistency and standards	Missions. Report a problem.	The ‘missions’ and the ‘report a problem’ screens have different structures: the ‘report a problem’ screen features a little figure and opens in a window on top of the precedent, while the ‘missions’ one opens in a new screen.	This diversity might disorient the user, as they need to alter their screen-viewing approach in the two scenarios.	2
11	H4 Consistency and standards	Everywhere	The little character’s position constantly changes in the various screens: sometimes it’s in the center, sometimes on the right, and sometimes on the left.	The user might be disoriented because they have to search for the character every time.	3
12	H4 Consistency and standards	Sorting algorithms. Before and after completing the Bubble Sort topic.	The text inside the balloon is different before and after completing the bubble sort topic.	It’s an inconsistency since it’s the same screen with the same purpose in the two screens.	2

13	H5 Error Prevention / H1 Visibility of system status	Report a problem	After pressing the 'Send' button, no confirmation is given to the user. The user is redirected to the previous page without any feedback	the button could have been unintentionally pressed by the user. The problem is reported without giving any feedback to the user so he might think nothing happened and his report is not sent so he might repeat the action.	3
14	H6 Recognition rather than recall	Bubble sort. Task: Learn a new computer science topic.	The "Chapter" of the selected topic, e.g. Bubble sort, is not visible in the topic window.	The user might forget what chapter he is working on since it's not written on this screen.	2
15	H6 Recognition rather than recall	Question	The question number the user has reached is not specified.	The user must keep in mind the question number they have reached, as it is not specified on the question screen.	2
16	H8 Aesthetic and minimalist design / H2 Match between system and the real world	Question	The icons on the possible answers. The icon corresponding to each option is misleading and hard to understand the correlation between the icon and the option, for example, the icon related to "Do anything" in the first question.	They don't have an intuitive and immediate meaning, and they distract the user from reading the actual answers. Misleading icons that might confuse users when answering	3

17	H8 Aesthetic and minimalist design	Everywhere	The presence of the little character that gives help to the user.	Having to read the balloon is distracting, and the information provided is not always useful, as it can be inferred from other elements on the screen. For example, "Here's the list of topics of Sorting Algorithms. Press Bubble Sort chip to continue" is implied information.	3
18	H8 Aesthetic and minimalist design	Select a chapter	Inconsistency of graphical elements: a PC and a notebook with chapters.	The user might get confused, as the computer illustration and the list of chapters written in a notebook lack any logical connection.	1
19	HN Non-heuristic issue	2nd and 3rd page	The sentence "My PC is broken. Help me fix it!" and "Complete all chapters to fix my PC".	It is misleading on the real purpose of the application. It suggests that the goal of the application is to fix the PC, but the real goal is to learn new topics.	1
20	H3 User control and freedom	Select a chapter page, when the keyboard is open	In the keyboard there is no button to delete what he had written	User does not have the possibility to correct errors so it's an important lack of control	4

21	H4 Consistency and standards	Select a chapter page, when searching for a chapter	When the user finishes typing the name of the chapter there's no button other than the arrow button inside the keyboard to click on to perform the search	If the user closes the keyboard without clicking on the arrow button there's no way for him to search so it's better to add another button next to the search bar. The arrow button is not clear enough, could be also changed to "search"	3
22	H10 Help and documentation	Select a chapter page when all chapters are listed	The user knows only the big title of each chapter and is not provided with any further details.	Provide a short description of each chapter so the user can choose which chapter to start with since all chapters are unlocked from the beginning.	1
23	H6 Recognition rather than recall	Sorting algorithms, the page where all topics are available	The percentage of the chapter already done should be presented on this page	On the previous page (where all chapters are listed) we can see the completion percentage of each chapter. However, this information is not available on each chapter's specific page. So, if a user completes a topic, they can not easily check the progress unless they navigate to the previous page.	2
24	H3 User control and freedom	When working on a topic (at any step in "Bubble sort" for example)	When leaving the page the user will have to restart from step 1 when he re-enters the topic	Users should preserve their achieved progress and have the option to restart if needed.	2

25	H2 Match between system and the real world	Question page when the question is presented	The question is placed at the right side of the page and the optional answers are placed on the left side.	There's a convention of placing questions or headings on the left side and corresponding content or answers on the right side. This convention is based on the typical left-to-right reading pattern. The used pattern might confuse users.	2
26	H4 Consistency and standards	Missions page	The "Missions" icon that navigates the user to the "Missions" page is still shown as it is in the header.	Since the user is already on the "Missions" page, the icon in the header should be highlighted otherwise it may cause confusion.	2
27	H4 Consistency and standards	Missions page	The mission "Solve 3 exercises with no errors" while before the terminology "Question" was used.	Two terminologies were used to describe the same functionality which can be confusing for the user.	2
28	H4 Consistency and standards	"Report a Problem" page	The "Report a Problem" icon that navigates the user to the "Report a Problem" page is still shown as it is in the header.	Since the user is already on the "Report a problem" page, the "Report a problem" icon in the header should be highlighted otherwise it may cause confusion.	2
29	H7 Flexibility and efficiency of use	Report a problem page	The user cannot choose more than one problem when choosing from the list of predefined problems	Limiting the user to select only one option from the list is less flexible than allowing them to select multiple options if applicable.	1

30	H6 Recognition rather than recall	Report a problem page when the keyboard is open	When the keyboard is open it's blocking the text box where the user is writing	The user will need to memorize what he wrote and cannot check the output unless he closes the keyboard.	4
31	H5 Error prevention	Report a problem page	The user can send a report without selecting a problem or writing anything in the "Tell us more" input box	The button "Send" could be disabled when none of the options is selected or when the "Something else went wrong" option is selected and nothing is written in the "Tell us more" input box	2
32	H1 Visibility of system status	Report a problem page when the send button is clicked	The user is redirected to the previous page without any feedback.	The problem is reported without giving any feedback to the user so he might think nothing happened and his report is not sent so he might repeat the action.	3

5.4 Selection

The team opted for the Augmented Reality for Tablet prototype solution, integrating key features from the mobile prototype. By leveraging the screens of the AR tablet prototype for topic explanation, topic selection, and mission and leaderboard pages, we enhanced the user experience. Addressing certain violations encountered in the tablet prototype, we incorporated the mobile prototype's "Chapter Selection" page, introducing a navigation bar at the bottom of chapter and topic selection pages for seamless navigation between application sections.

To further enrich the user experience, we integrated the "Feedback" page from the mobile prototype into the AR prototype, refining the feedback form and resolving identified violations. This strategic blend of features from both prototypes aims to optimize usability and address potential shortcomings.

Beyond functionality, we selected the AR prototype for its innovative approach to explaining and presenting computer science topics, providing a distinctive perspective on the problem at hand. This choice adds a unique and forward-thinking dimension to our project, aligning with our goal to offer a solution that stands out in its effectiveness and presentation.

6. Medium to High-Fidelity Prototype

The screens proposed to be the representatives of the medium-fidelity prototype are the "Topic Selection" page and the "AR Explanation" page. These were designed using Figma, a collaborative design and prototyping tool that enables teams to work seamlessly on digital projects in real-time.

The "AR Explanation" page was selected because it encloses the main goal of the application: learning a new computer science concept in a visual and animated way. Using AR, indeed makes the explanation more interactive, capturing the attention of the learner.

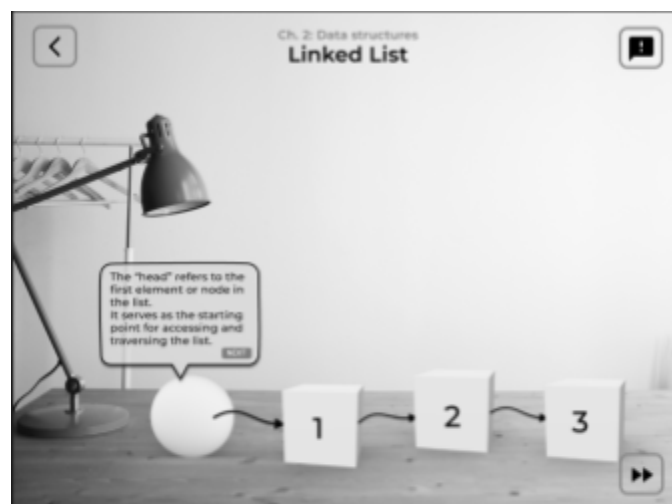


Figure 42 - AR Explanation page

Instead, the “Topic Selection” page provides a goal-oriented illustration to complete a chapter which makes the progressive learning mechanism more engaging.

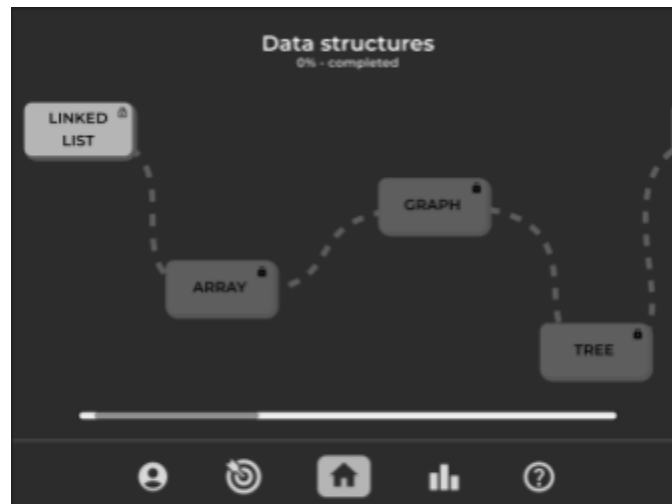


Figure 43 - Topic Selection page

Here's the link to our mid-fi prototype project on Figma: [Link to Figma Project](#).

6.1 Violations Resolution Plan

In developing our violations resolution plan, we adopted a systematic approach tailored to the screens chosen for implementation in the high-fidelity prototypes combining AR and mobile screens. This strategy ensured a targeted and effective resolution of identified issues, aligning with our goal to enhance the overall usability and user experience of our project.

Chapter selection - Mobile prototype

- Heuristic violation #8 - Mobile
How to solve: The button is removed
- Heuristic violation #20 - Mobile
How to solve: The delete button is added to the keyboard
- Heuristic violation #21 - Mobile
Disregarded: This violation is disregarded because it is standard for mobile applications to close the keyboard on screen simply by tapping outside of its border or by clicking the “enter” key, therefore adding a “close keyboard” button would just break consistency with established standards.

- Heuristic violation #22 - Mobile

How to solve: A short description under each chapter title will be added to the chapter selection list.

Topic selection - AR tablet prototype

- Heuristic violation #16 - AR

How to solve: A minimalistic view is instead shown with no decorations.

- Heuristic violation #15 - AR

How to solve: A scrolling bar is now displayed, and the user can use it to explore the whole chapter

- Heuristic violation #14 - AR

How to solve: The top bar is removed. A simplified bottom bar is added to the page

- Heuristic violation #24 - AR

How to solve: Progression through the chapters is visible in the subtitle at the bottom of the title of the chapter.

AR Explanation page - AR tablet prototype

- Heuristic violation #4 - AR

How to solve: The button associated with the hidden menu and the related menu is removed

- Heuristic violation #11 - AR

How to solve: The current chapter is now displayed above the topic name.

- Heuristic violation #13 - AR

How to solve: A “skip button” (double right-oriented arrow) is used to skip the explanation of the topic.

- Heuristic violation #18 - AR

How to solve: A dart icon is placed instead of a cup one.

- Heuristic violation #21 - AR

Disregarded: This violation is disregarded because it is standard behavior when advancing through multiple screens to have a button labeled “next” until the end where it changes and becomes “done” (e.g. multi-step installers, tutorials, processes).

Mission page - AR tablet prototype

- Heuristic violation #6 - AR
How to solve: The “left arrow” button on the top left of the page referring to the “go back” action is used instead of the 2 different options previously used.
- Heuristic violation #7 - AR
How to solve: A unique design and containers are instead implemented.

Question page - AR tablet prototype

- Heuristic violation #1 - AR
How to solve: For each question the given answer will be colored in a different way if it is right or wrong. At the end of the quiz, a report of all questions with the correct and wrong ones will be displayed.
- Heuristic violation #2 - AR
How to solve: At the end of the quiz, a summary of the answers will be displayed. If the user achieves more than 60% of the correct answer, a text will be displayed saying, “More than 60% of the answers are correct; you have completed the topic” with a button to go to the next topic. Otherwise, it will be displayed, “Less than 60% of the answers are correct; try again the quiz” with a button to try again the quiz.
- Heuristic violation #5 - AR
How to solve: Allow the user to change their selection by double tapping the currently selected answer.
- Heuristic violation #8 - AR
How to solve: When the leaving page warning is displayed, the same verb, “exit”, is used both in the text and in the buttons.

Leaderboard page - AR tablet prototype

The leaderboard page did not receive any heuristic violations.

Profile - AR tablet prototype

- Heuristic violation #22 - AR
Disregarded: This violation is disregarded because the icon that was used for the logout is the standard icon (open door with an arrow pointing outside), and it is widely used to indicate the logout action.

Feedback - mobile prototype

- Heuristic violation #13 - Mobile
How to solve: After the feedback is submitted a popup is displayed to confirm the submit.
- Heuristic violation #28 - Mobile
How to solve: The icon will be highlighted when the report a problem popup is opened
- Heuristic violation #29 - Mobile
How to solve: The user will be able to select multiple options
- Heuristic violation #30 - Mobile
How to solve: We changed the layout so that the keyboard doesn't cover the textbox
- Heuristic violation #31 - Mobile
How to solve: The “send” button will be disabled when none of the options is selected or when the “Something else went wrong” option is selected and nothing is written in the “Tell us more” input box

Miscellaneous violations

- Heuristic violation #17 - AR
How to solve: An ‘?’ button is displayed in the topic selection displaying the information to proceed.
- Heuristic violation #19 - AR
How to solve: The navigation bar is fixed on the bottom of the screens, and hidden in the explanation page.
- Heuristic violation #20 - AR
How to solve: A single button style is used throughout the entire application.

7. High-Fidelity Prototype

7.1 Prototype Details

We chose to develop our application using Unity, a versatile game development engine, leveraging the AR Foundation library for implementing augmented reality interactions. The selection of Unity was driven by its robust capabilities in creating immersive and interactive experiences, aligning with our vision for an engaging AR learning platform.

Additionally, we employed the UI Toolkit within Unity to craft the entire frontend interface. This choice was motivated by the UI Toolkit's efficiency in designing user interfaces within Unity, providing a streamlined and intuitive development process. The framework's compatibility with Unity ensures a cohesive and integrated development environment.

To program the application's logic, C# scripts were employed, as dictated by Unity's scripting framework. Unity utilizes C# as its primary scripting language, making it the natural and default choice for programming within the Unity development environment. The use of C# facilitated efficient coding practices, allowing for the seamless integration of logic components into our application.

In addition to these tools, we utilized Blender for the creation of 3D models within our application as Sante, one of the team members, was already familiar with the tool.

Here's the link to our GitHub repository containing the full code of the prototype: [Link to GitHub repository](#).

7.2 Significant Screens

Chapter Selection Page

This is the first page the user sees in the home tab and it is the place from where the user can search for a chapter she/he would like to start learning. This screen is fundamental to give the user an idea on what the app has to offer in terms of learning content and also about the chapter's progress.

Topic Selection Page

This page, featured in our mid-fi prototype, stands out as one of the most important screens in our app. It allows users to choose a topic within the selected chapter, representing our primary task. Here, topics unlock gradually as users successfully complete the respective quiz with more than 60% of the questions answered correctly.

AR Explanation Page

This screen holds significant importance in our app, as it provides users with the opportunity to view 3D models accompanied by detailed, step-by-step explanations of the topic. Additionally, users can choose to skip the explanation and provide feedback through a pop-up window featuring a user-friendly form.

Quiz Page

The quiz page becomes the user's destination after completing an AR explanation. This page holds major importance in our app, as here users can assess their knowledge by testing themselves. Upon completion, a summary of their responses is provided, including insights into any mistakes made, along with the correct answers for reference. When the quiz is completed, the user can either rewatch the topic explanation or, in case more than 60% of the questions were answered correctly, go straight to the next topic.

Profile Page

This page provides a comprehensive overview of the user's statistics. It displays the user's name, and rank within the global leaderboard, and provides percentages for chapter completion, topic completion, AR quizzes answered correctly, and an overall percentage score, which combines the previous three metrics. Additionally, users have the option to log out and return to the app's start menu. The importance of this page lies in the fact that it allows the user to get an overview of the progress made throughout the app.

7.3 Limitations

Pre-stored data

Currently, the application pulls all the required data for chapters, topics, questions and achievements from read-only JSON files embedded in itself, this means that if we wanted to add things such as new topics or new chapters, we would need to recompile the entire application after changing said files, however, this also means that most of the data is proper and not just mock data.

Although the chapter and topic names are complete, the quiz data exists only for the topics that also have AR scenes ready.

Mock and hard-coded features

Even though the application works as if a user was logged in, there is no login functionality, the application just opens using a mock account with no saved data, unless the app was used before, in which case the last state of the application will be restored.

The other two features that are being mocked currently are the leaderboard page and the feedback dialog. The leaderboard page is partially dynamic, it updates correctly after the user gains points from completing achievements and the user can climb the leaderboard, however, all

other users are just hard-coded in the application. In the feedback dialog, the “submit” button doesn’t send the feedback anywhere and silently ignores it.

Current limitations

The app only has support for 3 AR scenes, as they are crafted and animated by hand, so the user can watch and explore just those 3 topics, this means that during the demo and the usability testing, the users will only be able to access and complete fully just the first chapter, as other topics do not have AR scenes associated with them and the camera will open but no models will appear. The user can still proceed to the quiz but as explained previously, there will be no questions to answer and the topic will be considered as completed.

Moreover, all saved data, such as current topics completed, current chapters completed, quiz information and achievement tracking, is saved locally to a JSON file, using Unity’s persistent storage feature, this means that if the user decides to swap devices there is no way to move save data from one to another except for manually copying the file.

8. Usability Testing

8.1 Preparation and Run

The testing protocol that was used to conduct the usability testing is available [here](#) as a script.

8.1.1 Tasks

The set of tasks that the participants were asked to complete during the testing is the following:

#	Text of the task	Success criteria	Methodology
T1	Complete the AR explanation to understand the topic Computer Architecture	The user successfully completes the AR explanation.	None
T2	Complete the quiz test related to the topic Computer Architecture	The user successfully completes the quiz	None

T3	Complete the mission named “Learning bit by bit”	The user claims the points of the completed achievement	None
T4	Complete the chapter Introduction	The user successfully completes all the topics in the chapter.	None
T5	Verify your overall progress percentage about AR Quizzes completion	The user opens the profile page	None
T6	Look up the progress of chapter Introduction.	The user goes to the chapter list and see the progress bar OR chapter overview and see the progress bar	None
T7	Report feedback about the AR explanation of the topic Binary conversion.	The page shows a confirmation message stating that the problem/feedback has been reported.	None
T8	Revalidate your knowledge with a topic you have already completed.	The user skips the explanation and start the quiz	Think aloud

8.1.2 Usability Tests Details

First test (Nicolò C.)

- [Consent form](#)
- [Questionnaires](#)

Nicolò was the first person chosen for our usability testing which was held in Carlos' home. Nicolò is a 19-year-old student of the Computer Engineering bachelor degree at Politecnico di Torino and he was selected because he's currently enrolled in the computer science course so he fits well in our target user category. Carlos took the role of main facilitator, reading the script out loud, while Alessio helped as an observer of the test session.

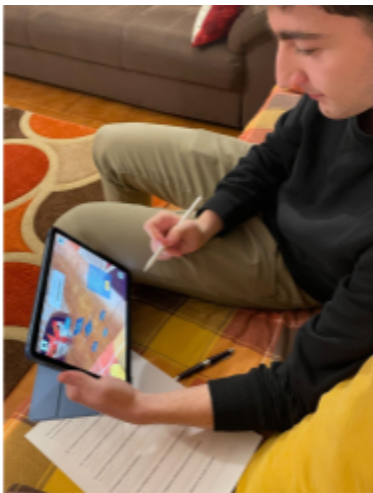


Figure 44 - Nicolò C. viewing the flowchart explanation in AR

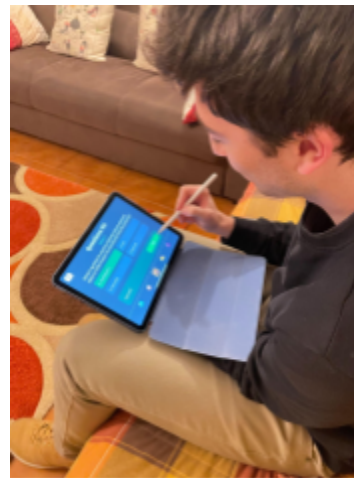


Figure 45 - Nicolò C. completing a quiz

Second test (Giulia)

- [Consent form](#)
- [Questionnaires](#)

Giulia was our second participant for the usability testing session, conducted in an empty room with a simple table setup. Giulia, a 21-year-old student at UniTO, was a fitting choice for our test due to her academic background in a technical school and her enrollment in an IT course aligning with our target user category. Sante assumed the role of facilitator whereas Bruno was the observer.



Figure 46 - Giulia viewing the topic select screen

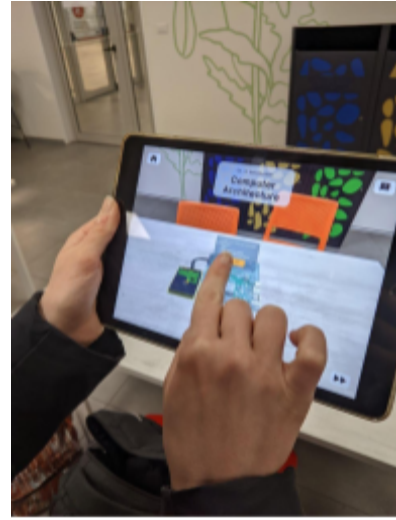


Figure 47 - Giulia interacting with an AR model

Third test (Nicolò Z.)

- [Consent form](#)
- [Questionnaires](#)

Nicolò was our third participant for the usability testing, the session was done in an empty room at Politecnico di Torino, using the app installed on an iPad and school table as a surface to point the device to. He was chosen because he is a 22-year-old university student who also follows an online computer science course in his free time, which makes him a target user for our application. Alessio assumed the role of facilitator and Carlos was the observer.



Figure 48 - Nicolò Z. reporting feedback on the application



Figure 49 - Nicolò Z. completing a quiz.

Fourth test (Tommaso)

- [Consent form](#)
- [Questionnaires](#)

Tommaso was our last selected participant for the usability testing. In this case, the setting was an empty room furnished with a table. Tommaso is a 20-year-old student who studies computer science at University making him a fit choice for our target user population. Taking on the role of the main facilitator was Bruno, who guided Tommaso through the test scenario by reading the script aloud. Concurrently, Sante assumed the role of observer, taking notes throughout the session.



Figure 50 - Tommaso signing the consent form

8.2 Results

8.2.1 Summary

During the usability testing sessions, we took notes and received feedback from the testers, summarizing all the results, we can see that overall most of the tasks were completed successfully, with a success score averaging 86.22%.

The tasks that didn't cause many concerns were related to the completion of the topics as well as the overview of chapter-related statistics. A point of notice is the gap between the tasks related to the main features of the application and the ones about statistics and mission completion. The first indeed achieved on average more than 74.75% while the seconds no more than 70.5%.

On the other hand, the task's duration concerned many factors such as the complexity, the user's familiarity with the application, and any time the user restarted the task. It is important to note that the task "Revalidate your knowledge with a topic you have already completed" was performed using a "think aloud" methodology which implies the time was affected by the time the user took to explain his actions.

Additionally, the results of the tasks show as pain points the difficulty found in performing the task of reporting feedback, consulting the user statistics, and completing the mission. Those tasks were also the longest with the maximum mean time of 2:19 min for the T3 task. Probably the elongated time is caused by the difficulty of finding the correct button to press or the correct page to visit. This led us to the conclusion that highlighting those features could provide better user feedback becoming more intuitive.

8.2.2 What we discovered and learned

Overall the app user experience seems smooth. In particular, users found the quiz page and quiz summary page to be both functional and intuitive. However, some features did not meet the desired level of intuitiveness, such as the missions not being immediately recognizable, the statistic completion being a bit confusing, and the difficulty in identifying the feedback button. On the positive side, the AR feature is very Interactive and effective and appreciated by the users, despite occasional technical errors. Finally, the app's user experience and user interface could benefit from improvements in certain areas to make features more user-friendly.

8.2.3 Problems and solutions

Problem	Solution	Feedback or actions from users that generates it
Users didn't understand the navigation bar icons meaning	Add a text under the icons to help user to understand what icon to click	Users did not easily find the mission page
It is not clear at first when a Chapter is finished.	Add a popup on the screen that advise the user that the chapter is completed	Users didn't understand immediately that the chapter was finished
Progress statistics are hard to find. It isn't clear that the user page contain information about the completion percentage	Add a button in the home page that opens a popup with the statistics about the completed topics	Users searched the percentage of completion in the home page not in the user page

It is possible to give a feedback only on the AR explanation page	Add a feedback button also on the bottom navigation bar, which is accessible from all the pages. If the report popup is opened from this page it should be optionally possible to select a chapter of a topic that the feedback is about	Users didn't find how to report feedback at first.
The skip explanation button isn't clear	Add a text under that button	Users didn't use it
Sometimes faulty plane detection can cause models to move and/or not spawn.	Don't just rely on plane detection, use some kind of "marker" system to identify where to spawn models	N.A.
Searching for topics requires opening all chapters	Apply user feedback	One user provided the following feedback: "Make the search bar not only search the chapter name but also inside single chapters for topics".
During the AR view, the banner with the topic name and chapter name sometimes obscures the view of the model	Apply user feedback	One user provided the following feedback: "Shrink the text and the entire banner to make it smaller".

9. Conclusions

9.1 Main Insights

Attending the course “Human-Computer Interaction” shaped our knowledge of usability and User Experience (UX) principles with hands-on activities applying these to our project. The course provided progressive interactive laboratories with feedback sessions that guided us reaching the high-fidelity prototype.

It also made us aware of how the process of learning could be complex. Indeed, detecting ways to make it simpler was the goal. Thanks to techniques such as gamification and technologies like AR, catching the attention of the user, which is one of the main targets while teaching, attempted to successfully complete the final goal.

The project transpired the effort to listen and understand the target users, design and prototype how to develop a good interactive system and finally evaluate it to identify problems before the actual implementation.

9.2 Group Feedback

The work throughout the course was balanced, split between all members of the team equally, where everyone did their part without issues, and everyone did all kinds of types of work.

The only time where work was divided based on experience of the members was in the last assignment where, despite the beginning in which the code writing was equally distributed among all the team members, at the mid-stage of the completion the team split in two parts. Bruno and Carlos focused on writing the final report while Alessio finalized the last missing features, such as achievements and AR initialization, and fixed various bugs while Sante created the 3D models, animations, and interactions.

The positive aspects of this group work were that, during the semester, we didn't experience any intense discussion and we didn't have any issues working together, as everyone was understanding and willing to peacefully discuss disagreements and problems to solve them quickly and appropriately. However, at times we had some communication problems because of misunderstandings of the tasks we assigned each other which caused some work to be duplicated and some personal time to be wasted.

In conclusion, our team is immensely proud of the collaborative effort invested in this project, and we are delighted with the outcome achieved. This experience has been a valuable learning journey, offering insights and lessons that have enriched our understanding and skills, encouraging both personal and collective growth.