

# Math-ilo Tu!

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# 1 Introduction

In this report we'll analyze step by step what we have learned during the Human Computer Interaction course summarizing the entire process that led us to the development of our high-fidelity prototype, exploring the main concepts and the different choices we have made to realize its final implementation.

You can find all the details of the Assignments and the source code of our application on the GitHub repository.

<https://github.com/polito-hci-2022/The-Islanders>

## 2 Project name, value proposition, team members and group name

The name of our group is **The-Islanders** and is made up by 4 members:

- Forma Giuseppe, s317932
- Mazzari Mattia, s291132
- Patti Flavio, s301104
- Testa Mario, s292630

**Project name:** Math-ilo Tu!

**Value proposition:** Turning Math into Reality.

## 3 Problem/solution overview

Our target users are math teachers from elementary school, whose interviews showed how improving students' capability of problem solving (in terms of understanding and analyzing the requests of a problem) and making lessons more appealing/students more participative are the primary needs. To address them, we have developed *Math-ilo Tu!*, an AR application that allows teachers to represent math problems into the real world.

## 4 Needfinding

### 4.1 Description of the initial domain of interest within your theme, and why you choose it

We have decided to choose the theme 2: **AR/VR for education**.

The project idea focuses on supporting elementary school teachers teaching math, because we think that a correct learning process at an early age is fundamental for children's future. So, having AR tools that can support teaching, might help improve the explanation of concepts related to math.

## 4.2 First round of interviews

After an accurate analysis, our target users at this stage are math teachers, whose relevant characteristics for us are:

- Experience in terms of years teaching math
- Age of kids they have been teaching to, since this affects the way lessons are approached

We decided to interview 3 math teachers:

- One normal user: a woman aged 38, with 2 years of experience in teaching math
- One expert user: a woman aged 57, with more than 20 years of service, so we might think that she will be very useful for our analysis because she can bring a different and more precise point of view with respect to a normal user with just a few years of teaching
- One extreme user: a woman aged 54 years working as an after-school teacher



Figure 1: Interview with teacher Beatrice Murgia

We were able to recruit these professionals thanks to the mom of a member of our group, who is an elementary school teacher, so she knows a lot of people in the domain from schools across different locations.

For distance and time problems (we could only make interviews on weekends,

but school are closed on Saturdays and Sundays) we have decided to do the interviews via Google Meet. We split into two groups of two colleagues, one colleague oversaw the asking of questions and the second one was responsible for taking notes and keep track of the valuable aspects helpful to extract afterwards the relevant needs.

As a precaution we recorded the audio of the conversation, priorly asking the explicit consent of the people interviewed.

We started asking some personal questions like “*How long have you been teaching?*”, “*In which elementary classes have you been teaching throughout the years?*” to learn the experience of the individual. Then we went further asking some general starting questions:

Since the first round of interviews has been important to define our target user needs, here’s the complete list of questions with a summary of the answers provided to us for each one of them:

#### 1. Tell me about your typical lesson

The lessons are mostly prepared at home, when they decide which topic to bring to class the next day. The approach depends a lot on the age of the children: for the youngest, they tell a story, they start from reality and topics are explained in a playful way: “*When I had to explain the comparison between numbers, I started by taking two kids one next to each other, so they could understand the difference in heights, I always try to compare in mathematical terms but also in real, tangible, terms*”.

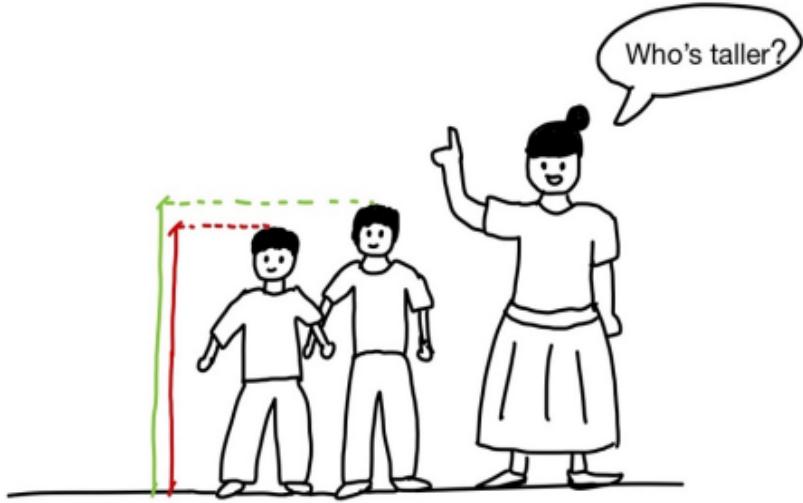


Figure 2: Example of comparison

For the oldest, the lessons get a bit more theoretical, teachers make them go to the blackboard, create a bit of competition and so on. At the end of each lesson, they usually do some exercises all together or assign homework to verify they have learnt the concepts explained. For the extreme user, however, the activity is quite different since it is mostly focused on doing the homework assigned by teachers in the morning, but also understanding kids' difficulties by both talking to them and to their parents, there's not a lot to prepare in advance.

**2. How useful is it for students to visualize the concepts that you try to explain in words?**

Visualizing the concept has been proven by all the participants to be very useful or even fundamental, they have noticed that it helps students learn better and concepts remain impressed in their minds.

**(a) And how do you usually do it?**

*"Mathematics starts with a direct comparison of the concept, like seeing an operation that can be drawn or explained through objects that the child can touch. I usually show multimedia exercises that textbooks now offer or videos taken from YouTube, but sometimes it's not enough. Anyway, the impact is easier for the children, they need to see and touch the concept. The concept must be dismantled to be more easily usable and this result is obtained only if the concept is "seen and touched", an abstract concept is generally difficult to understand."*

**3. What do you usually do to keep students' attention?**

Students get distracted pretty easily, especially younger ones who have no more than 40 minutes of attention. Some teachers involve students by calling them in turn to do an exercise on the blackboard, to make them feel protagonists: *"Everyone wants to be called and it becomes a group competition"*. Others start telling a funny story and the tone of the voice is important, stories need to be captivating, then they make the students work for another 10-15 minutes. The extreme user even allows more than a small break, afterschool is a mix between recreation to recover energy and study.



Figure 3: Source: iStockPhotos

**4. Try to remember the last time you struggled teaching a concept to students, how did you feel?**

It's really subjective, novice teachers tend to feel helpless, while more experienced ones don't, they know at the end of the day most of the students will understand the concept and it's better not to push too much those who struggle, since classmates can start denigrating or making fun of the latter for being slower.

**5. Tell me one thing students find easy and one thing that they find difficult (if any) when learning a new mathematical topic.**

Generally speaking, nothing is easy for kids: some may find a topic easier than others, but usually it's just a small group of students (not the majority) who have lots of difficulties and it's really hard to follow all of them in the same way and at the same time: "More teachers are needed so we can concentrate better on single students". In general, those kids struggle with logic, reading the text of a problem, extrapolating the most important data to plan a calculation strategy. Troubleshooting and problem-solving are the ones that bring the most problems, the mathematical procedure of adding, subtracting, etc. is mechanical and they usually have less problem with it. Kids usually don't ask a lot of questions, so difficulties are easily understood by looking at the exercises they do and the way they do them.

**(a) What specifically about math?**

*Based on my experience, children have difficulties in learning the concept of division, but again, I wouldn't focus on a single topic... It's mostly the calculation strategy, not the mechanical procedure, because that requires many steps and a bit of effort, while students think they are awarded for their speed instead of their ability to solve the problem with the help of logic.*



Figure 4: Source: iStockPhotos

(b) **What specifically about geometry?**

In geometry the most difficult thing for them is to identify shapes in physical objects, also the concept of perimeter and area are usually confused with each other. In this case it can be useful to make the problem as real as possible, for example associating the blackboard with the rectangle and so on...

**6. What is the current status of IT devices availability to support the lessons?**

During the last year, schools have been equipped with some tablets, which will be used as a support in class. Once the teachers will be trained, these mobile devices will be distributed in the classroom to the children and they will be able to work with these tools, but not all the teachers are ready. They have the tools, but they are not trained enough.

(a) **In this sense, how are teachers helped and updated in the use of a new technology?**

*"Last year we took a course organized by Apple, but it is still required to own some basic knowledge and time is never enough"*

**7. What else should we have asked about?**

An interesting trend between the answers to this question is the one related to what happens outside of the school hours. Children reach results because they are constantly followed at school, but then when some of them go back home, they don't have someone following or guiding them to do their homework in the right way. Therefore, they lose everything they have acquired the previous days. It also happens that some students exchange homework's solutions between them by phone or copy what others have written to hurry up and finish faster: *"It is not important the quantity of exercises but the quality with which they are carried out."*

### 4.3 Initial synthesis

From these initial interviews we were able to extrapolate some user needs that seem most relevant to us:

- (a) Teachers could need new ways to help **visualize** the mathematical concepts they are trying to explain to children, especially the more difficult ones. In fact, accosting an abstract problem with something that is real seems to help students understand the topic better and faster.
- (b) Teachers need to keep children's **attention for longer periods** of time as they get easily distracted. It seems that organizing group games or competitions can help to improve students' performances, participation and activeness.

- (c) Teachers need to follow their students' progress even outside school hours. Often when children return home, **they are not followed properly by their parents** on doing homework and this is the crucial moment when they really fix in their mind the concepts learned previously at school.
- (d) Teachers probably need a way to improve students' capability of **problem solving** in order to avoid fast responses (in most of the cases fast responses involve wrong answers), kids need to focus and create a logical solution to solve problems.

After a review with course assistants we realized that starting from the original needs, we could follow two different roads:

- Focus on the teacher's needs **to follow and keep track of the progress of the children also outside the school context**, but it required stepping away from school hours and some hard times for finding good interviewees.
- Focus on the teacher's needs **to improve kids' problem-solving abilities and attention** in class, which seemed to be the best option in terms of information already acquired and ease to collect interviews.

We chose to pursue the second road and we have narrowed down our needs to the second and the fourth only, since the first one would have been analyzed anyway in a AR/VR context.

For the full set of questions and answers, follow this link:

<https://github.com/polito-hci-2022/The-Islanders/tree/main/A1/Interviews>

#### 4.4 Second round of interviews

For the second round we decided to interview 2 more people:

- One immediate user: a woman aged 45, with 8 years of experience in teaching math
- One contextual inquiry with an immediate user (a woman aged 36, with around 5 years of experience teaching math) at "Sclopis" Elementary School of Via del Carmine, Turin.

Since we wanted to get deeper in the analysis of the more focused domain, we asked our interviewees questions and examples about the structure of the tests and exercises given to students, about the logic they want kids to have, painful steps and more. Our goal was to gather as many information as possible in this step, to define more precise user needs.

The questions asked to the teachers in this case were:

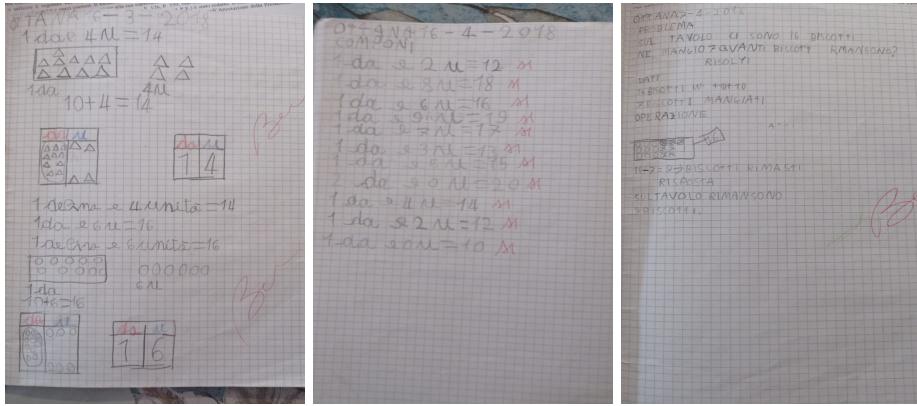
- (a) **What is the common structure of a test?**
- (b) **How long does a test take on average?**
- (c) **What kind of logical problems do you assign to students during tests? Can you provide us just 1 or 2 significant ones?**
- (d) **What is the goal you want them to achieve with your test?**
- (e) **How do you currently support the student during the reading of a problem?**
- (f) **How does a student approach the solving part? In particular the most challenging steps to execute, if any.**
- (g) **When you correct a test, what are the things to which you give more importance and what are the less important ones?**

Since this second round of interviews only served as a way to refine our user needs, the following list will explain the main and most useful notes that we were able to extract:

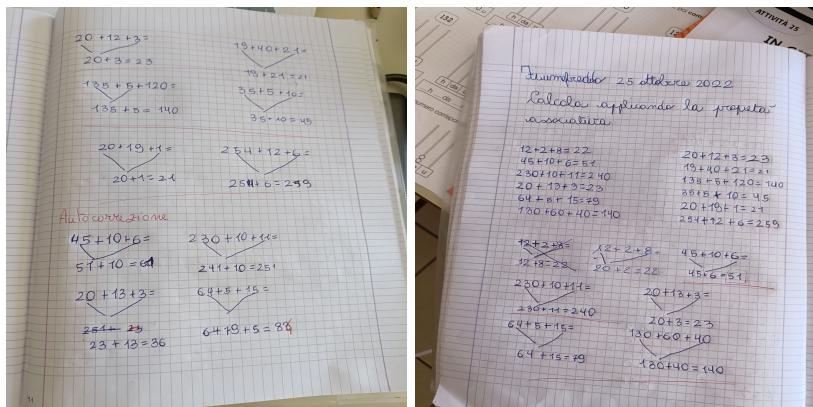
- Tests are usually based open-ended questions, to avoid students rushing to solutions and there is no fixed time limit, especially for younger kids.
- Problems include calculation of area, perimeter, comparisons and basic operations related to real life scenarios: fruit market, marbles, food, transports, animals, etc.
- Usually kids that spend more time outdoor have better understanding and logical capabilities than those who mainly focus on books, but it's hard to live the same experiences in the school context and there are no books about logic at this early stage.
- Teachers goal is to make kids understand how to solve a problem, its text, synthesize data correctly, which operations are needed and remember logical mistakes made in the past.
- Mistakes in calculations don't really weight a lot if the methodology and thinking is correct.
- Currently, a common strategy is to make kids write the procedure, but they get tired of writing and don't really enjoy the activity.

Futhermore, from the contextual inquiry we were able also to obtain photos of exercises carried out by students and corrected by their teachers.

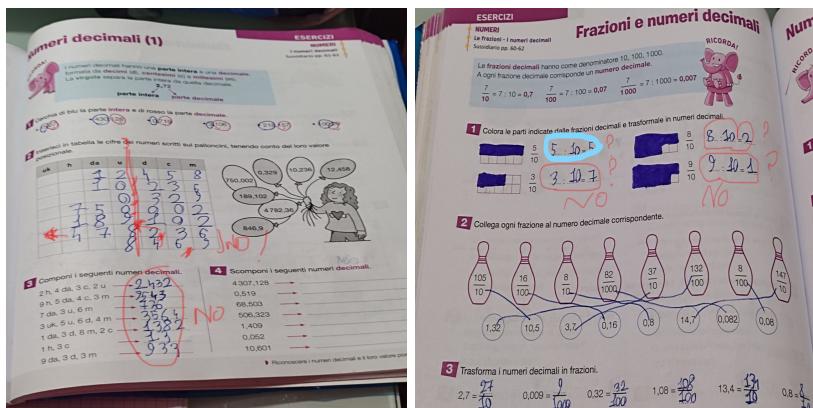
• First grade exercises:



• Third grade exercises:



• Fourth grade exercises:



For the full set of interview notes, follow this link:  
<https://github.com/polito-hci-2022/The-Islanders/tree/main/A2/Interviews>

## 4.5 Synthesis

After a **brainstorming** on Miro:

[https://miro.com/app/board/uXjVPLP09pA=/?utm\\_source=notification&utm\\_medium=email&utm\\_campaign=daily-updates&utm\\_content=go-to-board](https://miro.com/app/board/uXjVPLP09pA=/?utm_source=notification&utm_medium=email&utm_campaign=daily-updates&utm_content=go-to-board)

we have extracted the main user needs from the first and second interviews:

- **Deep user need (1):** *Teachers need to keep children more active and participative during the lesson because they often make the same mistakes.*

This was derived by the following answers:

**What do you usually do to keep students' attention?** Students get distracted pretty easily, especially younger ones who have no more than 40 minutes of attention. Some teachers involve students by calling them in turn to do an exercise on the blackboard, to make them feel protagonists.

**How does a student approach the solving part? In particular the most challenging steps to execute, if any.**

The most complex and common steps are: understanding the text (as they don't want to read), synthesizing the data, understanding which operation to do rather than another [...] and remembering the mistakes made previously!

- **Deep user need (2):** *Teachers need a way to improve students' capability of problem solving in order to avoid fast responses.*

This was derived by the following answers:

**Tell me one thing students find easy and one thing that they find difficult (if any) when learning a new mathematical topic.**

Generally speaking, nothing is easy for kids: some may find a topic easier than others, but usually it's just a small group of students (not the majority) who have lots of difficulties and it's really hard to follow all of them in the same way [...] In general, those kids struggle with logic, reading the text of a problem, extrapolating the most important data to plan a calculation strategy.

**How do you currently support the student during the reading of a problem?**

“[...] Usually kids that spend more time outdoor have better understanding and logical capabilities than those who mainly focus on books, but it's hard to live the same experiences in the school context.”

**What specifically about math?**

“[...] students think they are awarded for their speed instead of their ability to solve the problem with the help of logic.”

- **Deep user need (3):** *To explain a new problem to their students, teachers need to simplify the comprehension, and at the same time make it more appealing and easy to digest than it is now.*

This was derived by the following answers:

**How do you currently support the student during the reading of a problem?**

The teacher usually asks students to describe how to solve the problem in words, writing it in the notebook [...], but they get tired of writing and don't really enjoy the activity. [...] Those who focus a lot on books usually do worse than those who stay less on books and spend more time outdoor, in the sense that those who approach reality and real problems often have better logical skills.

**Tell me about your typical lesson.**

The approach depends a lot on the age of the children: for the youngest, they tell a story, they start from reality and topics are explained in a playful way [...] I always try to compare in mathematical terms but also in real, tangible, terms”.

## 4.6 Solution

For each need, we set a 5-minute timer and had each team member individually come up with as many ideas as possible during that period, keeping in mind there were no wrong answers and focusing on "What to do", instead of "How to do it". Then, we looked together at all the ideas.

- (a) *Teachers need to keep children more active and participative during the lesson, because they often make the same mistakes.*
  - i. Make kids play interactive games in class
  - ii. Tell funny stories about math to incentivize listening and questioning from students

- iii. Give small rewards (not necessarily connected to the school domain) as positive reinforcement.
  - iv. Draw students' attention
  - v. Let kids self evaluating themselves about what they wrote in an exercise
- (b) *Teachers need a way to improve students' capability of problem solving in order to avoid fast responses.*
  - i. Divide students in heterogeneous groups in order to help each other
  - ii. Give to kids a prefixed amount of time to think to possible solutions, before actually replying
  - iii. Allow teachers to create more engaging and better explaining scenarios to represent the problem and the logic behind
  - iv. Let the student explain by words what's going on in the problem and the approach they would use
  - v. Make them try to solve a problem in many different ways in order to develop different points of view of the same thing
- (c) *To explain a new problem to their students, teachers need to simplify the comprehension, and at the same time make it more appealing and easy to digest than it is now.*
  - i. Make the problem more appealing, according to children's taste
  - ii. Do more lessons outdoor
  - iii. Approach the explanations of a new topic with real-life examples
  - iv. Allow students to bring personal toys in class for the lesson explanation
  - v. Have dedicated hours for clarifications and doubts

**Best solution:** *Allow teachers to create more engaging and better explaining scenarios to represent the problem and the logic behind.*

The idea is that teachers can represent math problems with virtual life-like scenarios, that can be personalized according to children's preferences. We chose this solution by post-it voting, each member got three votes to mark three ideas and we ended up with a solution that should cover all the deep needs founded, since creating virtual life-like scenarios in class can make the connection with real life problems easier, simplifying comprehension and unlocking logical reasoning, while customization can make kids more active since they feel part of the experience.

## 5 Tasks and Storyboard

### 5.1 Tasks

- **Simple task:** Choose the most suitable way to represent and analyze a math problem.

*It's a simple task because the text analysis of the problem it's a common routine of the teacher, it can be done directly in class or prepared in advance at home and then explained at school.*

- **Moderate task:** Personalize the problem according to children's preferences for a more engaging analysis.

*It's a moderate task because attracting students' attention isn't always needed, sometimes they straight enjoy the topic, sometimes they don't.*

- **Complex task:** Show different step-by-step solutions of the math problem to facilitate students' comprehension

*It's a complex task because it's infrequent, from our interview results we know that just a small number of students really struggle to solve a problem once it has been correctly analyzed. Showing alternative solutions step-by-step might clarify children's doubts and unlock the full logical comprehension of the problem.*

### 5.2 Storyboard



Figure 5: Storyboard

We chose this storyboard because it perfectly represents the simple and moderate tasks found:

- **fig.1-3:** At home, the teacher prepares the problem to present the next day at school and can create a virtual scenario on Math-ilo tu! starting from the environment that better explains the problem's context.
- **fig.4-5,8:** During the lesson, the teacher gets students involved by letting them personalize different objects composing a scenario and proceeds explaining the problem.
- **fig.6-7:** The storyboard does not represent well how to solve the complex task, but the idea is that one or more students might still struggle understanding, so eventually the teacher can guide them with a step-by-step solution or make variations according to children's questions.

## 6 Low-fidelity Prototype

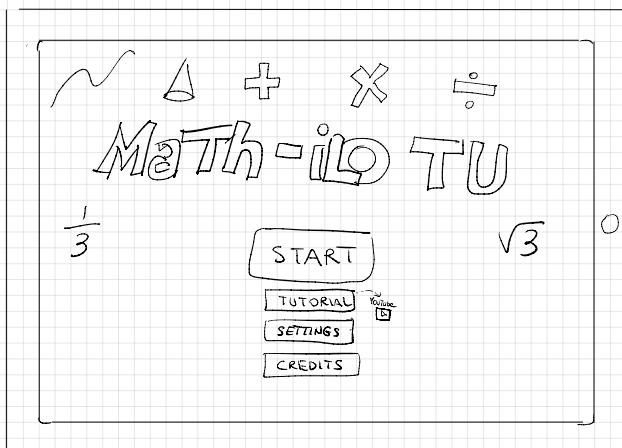
To realize the goal of our solution exemplified in the storyboard we decided to use two modalities:

- **AR + Collaborative:** in the first modality teachers call the students to the desk to explain the problem with an AR scene populated in advance with objects. Children can be involved more by proposing variations to build stories that best fit their preferences. If some students still struggle, teachers can proceed with a step-by-step explanation to clarify children's doubts(i.e. adding, removing or replacing objects in the scene).
- **AR + Individual:** in the second modality, the teacher prepares a sequence of questions related to the problem. Then the students are asked to play individually a quiz. When they answer correctly, a certain number of objects related to that question is unlocked and can be used to populate the scene. In this case, the quiz questions are providing the input to the logical reasoning, not the teacher speaking.

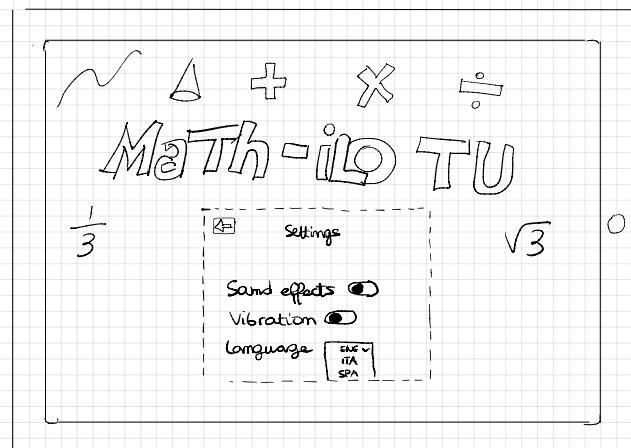
Since both of the modalities could need to visualize a certain number of objects, a big screen is required. So the chosen target devices are tablets.

### 6.1 Paper Prototype 1

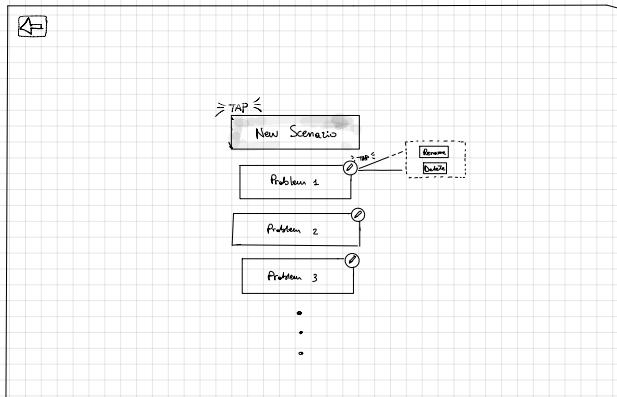
The following pages show the pdf of paper prototype 1.



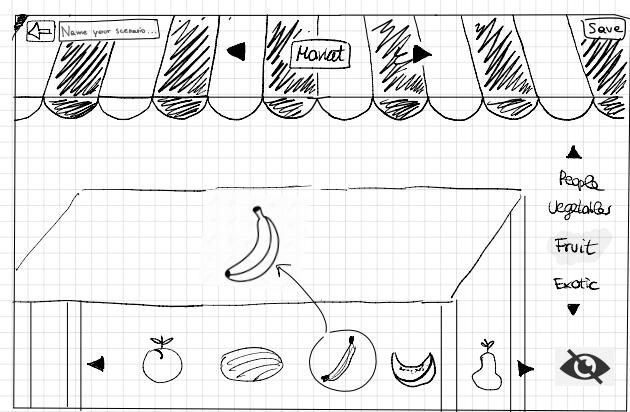
Homepage



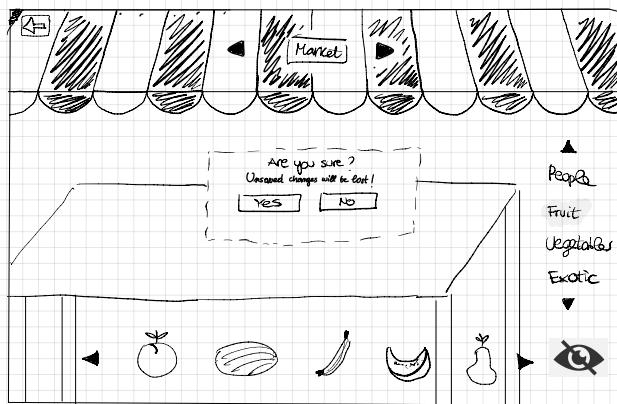
Settings



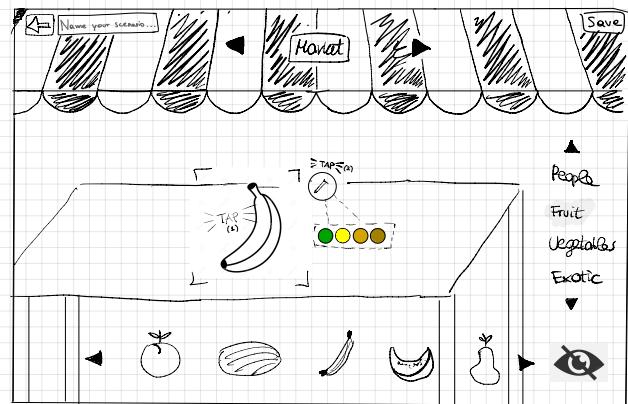
Create a new scenario  
or open a saved one



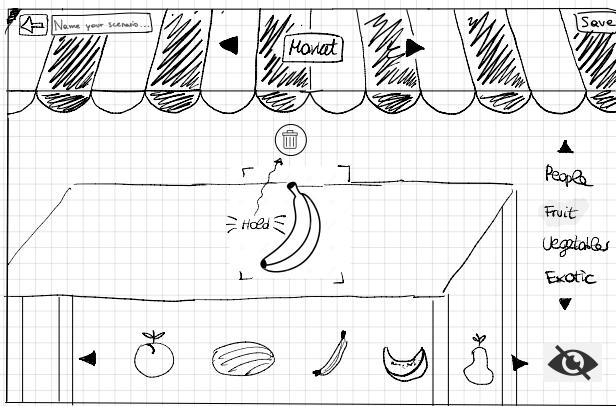
Add objects to the scenario  
(Banana from Market)



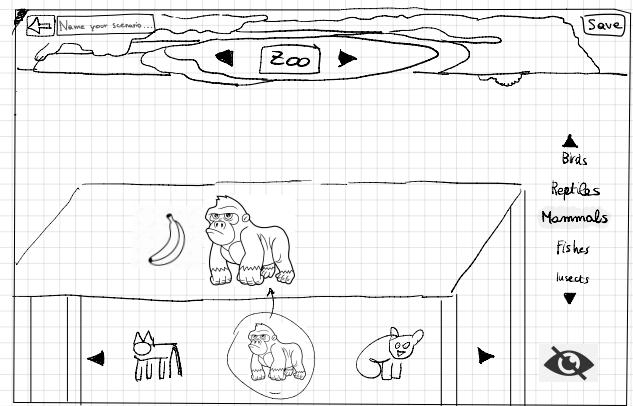
Exit popup when  
tapping back button



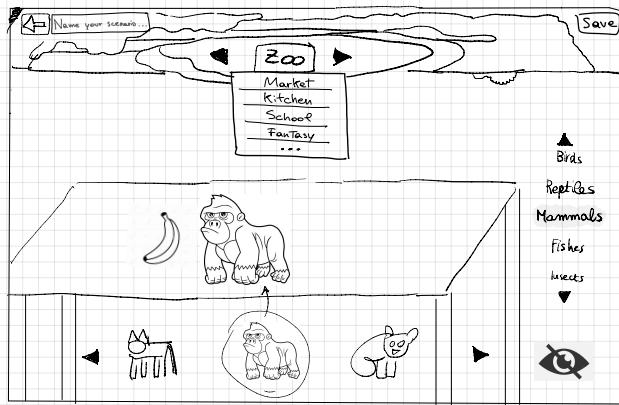
Editing objects  
(change color)



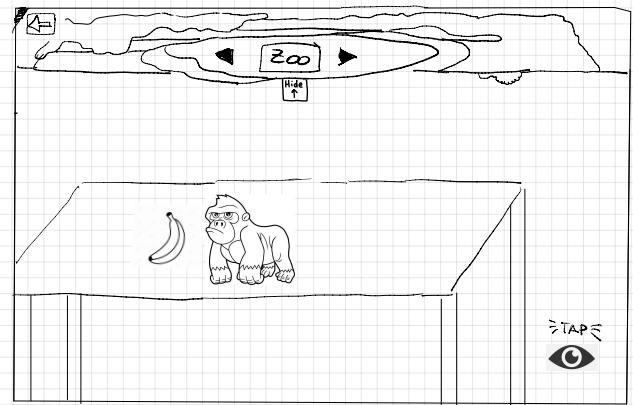
**Editing objects  
(delete)**



**Adding object  
(Monkey from safari)**

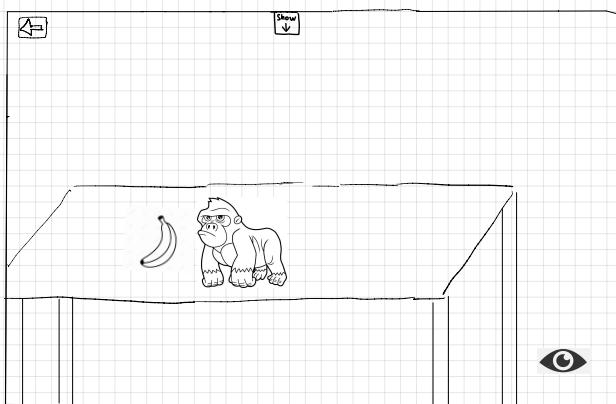


**Change environment**



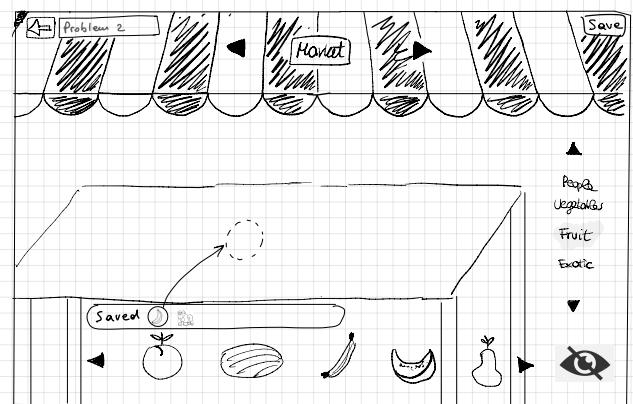
**Preview Mode (with Tob Bar)**

9



**Preview Mode (Tob Bar hidden)**

10



**Populate saved scenario with  
saved objects**

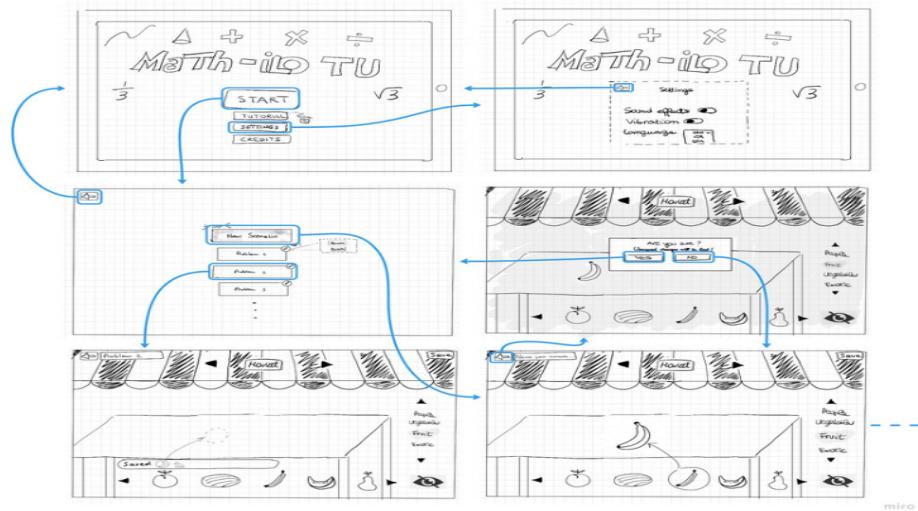
11

## 6.2 High-Level Flow Diagram

Click on the link to see the full high-quality version on miro.  
<https://miro.com/app/board/uXjVPDF048M=/>

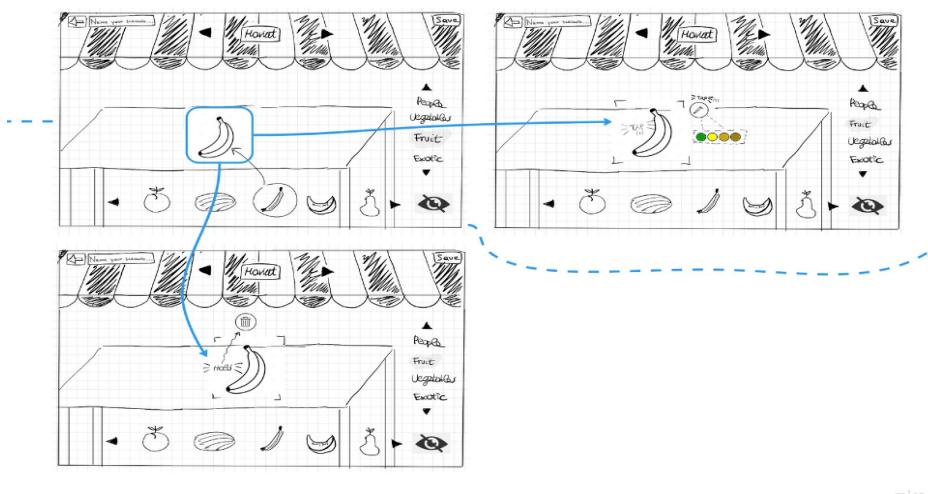
- **Part 1: Interaction with screens**

Move between screens, create a new scenario or open a saved one.  
 By exiting, the user knows unsaved changes will be lost.



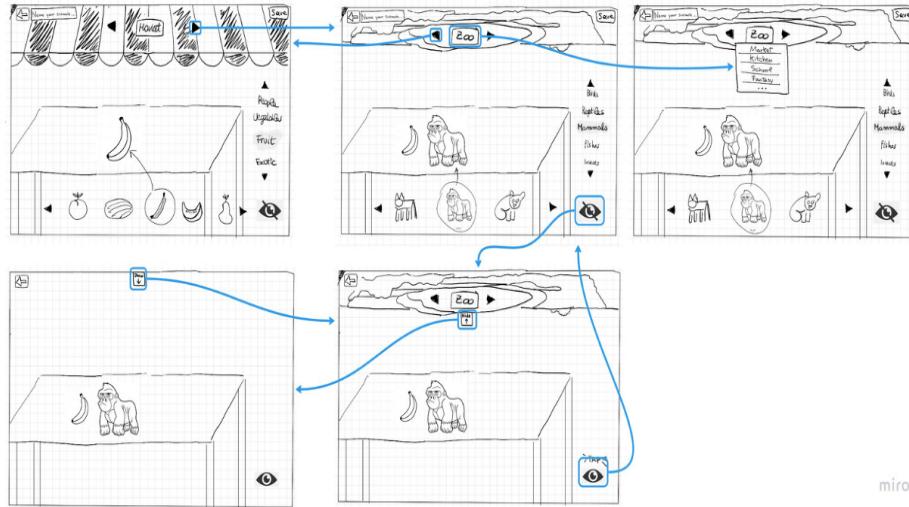
- **Part 2: Interaction with AR objects**

Tap objects to edit, hold and drag to delete.



- **Part 3: Interaction with scenario**

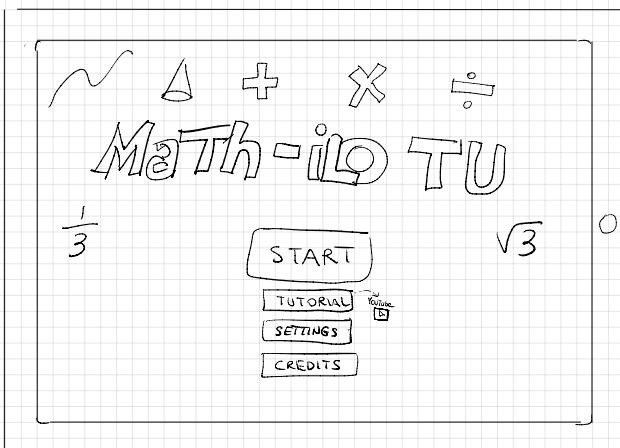
Changing Environment by clicking or swiping allows adding elements from different domains. Hiding UI elements according to user preferences.



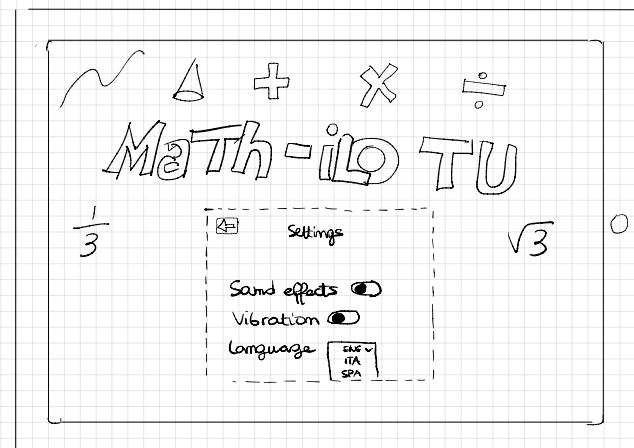
Prototype 1 perfectly connects to the storyboard, as it satisfies all the figures presented. It allows representing a problem, personalize the objects to the teacher's or kid's preferences and, with the ease of using similar interaction, to represent step-by-step solutions.

### 6.3 Paper Prototype 2

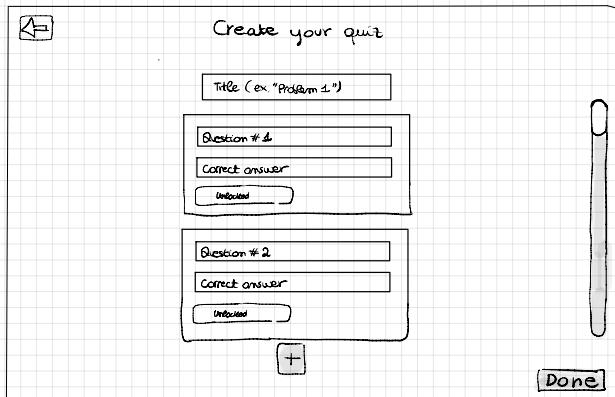
The following pages show the pdf of paper prototype 2



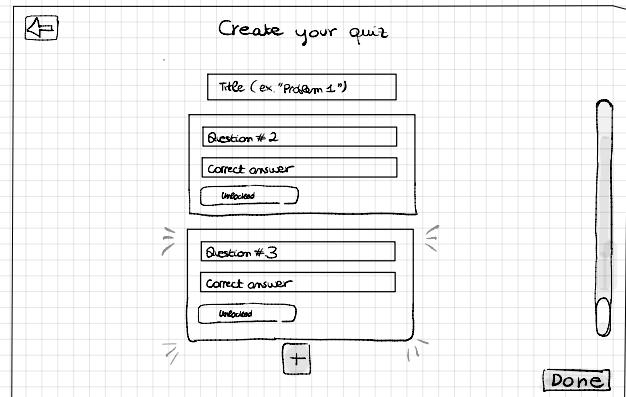
Homepage



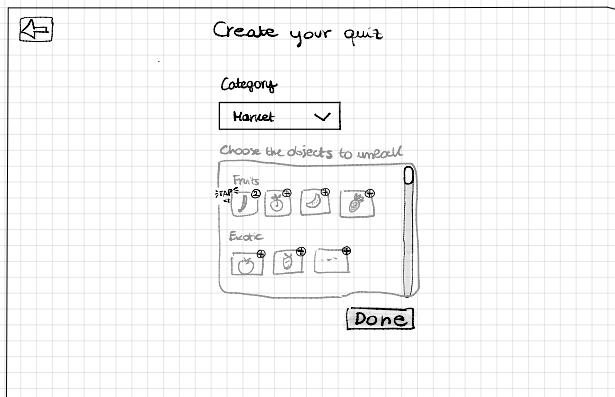
Settings



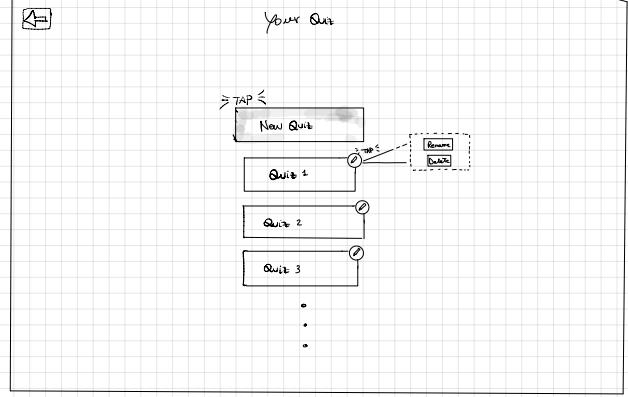
Set up a new quiz



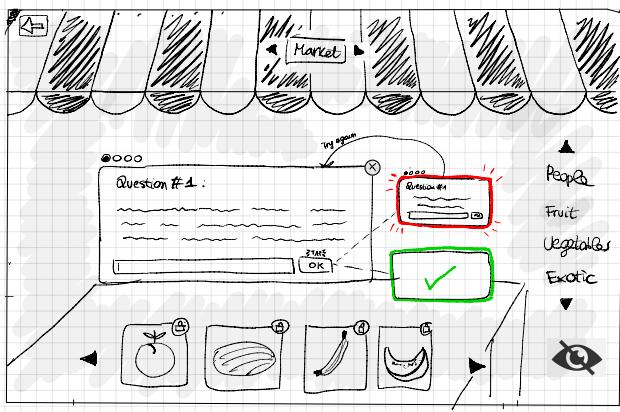
New question added



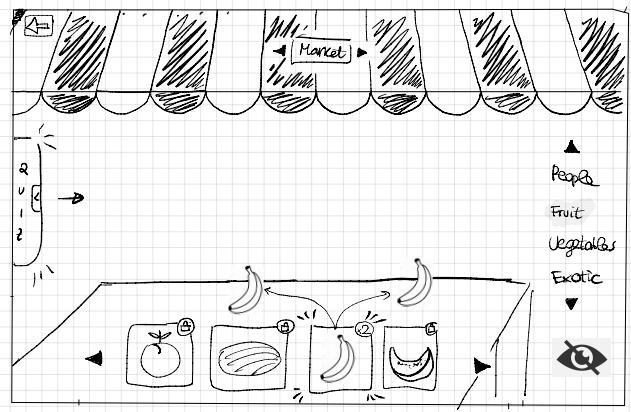
Select objects to unlock when the question is answered correctly



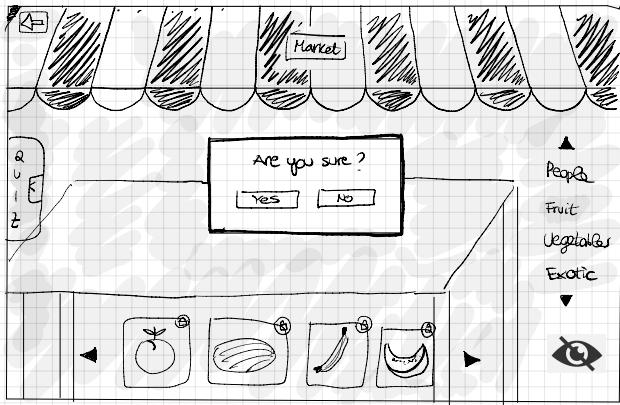
Create a new quiz or open a saved one



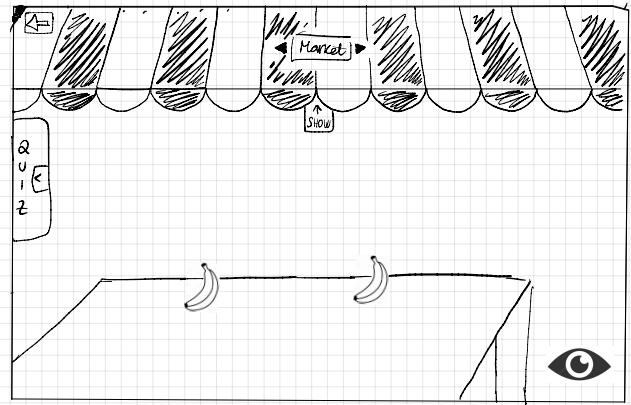
In the scene, if question is wrong, retry.



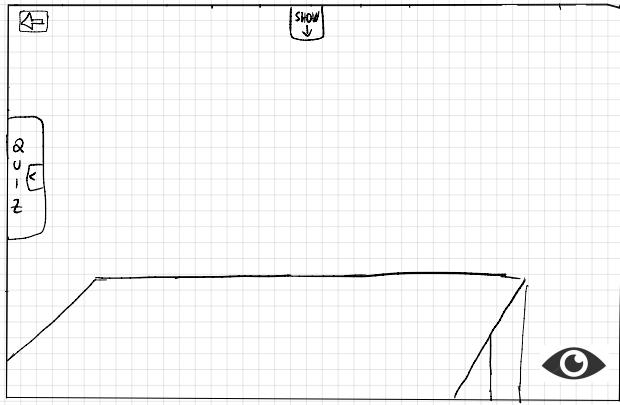
If the question is right unlock objects



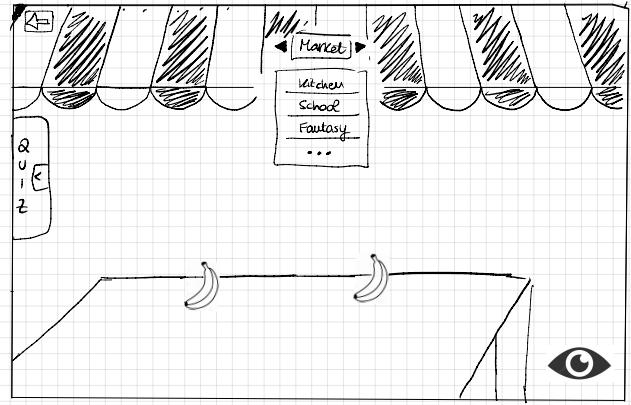
Exit popup



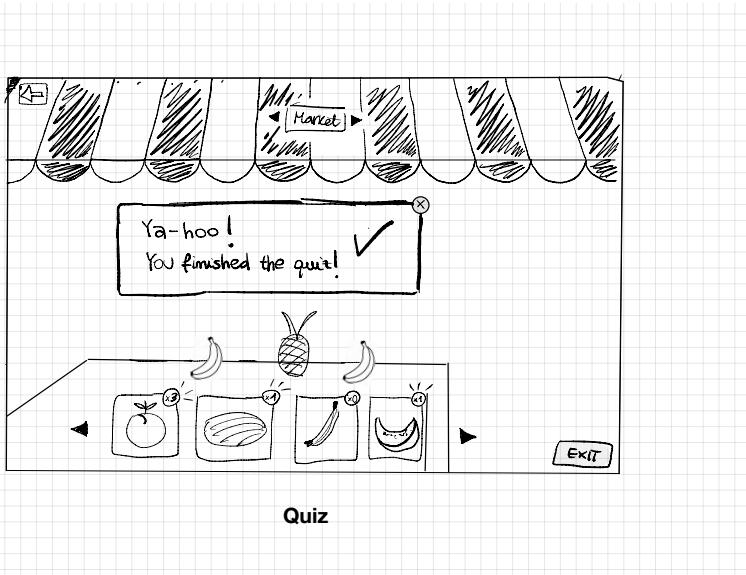
Preview Mode



Preview Mode (Top Bar Hidden)



Change environment



Quiz

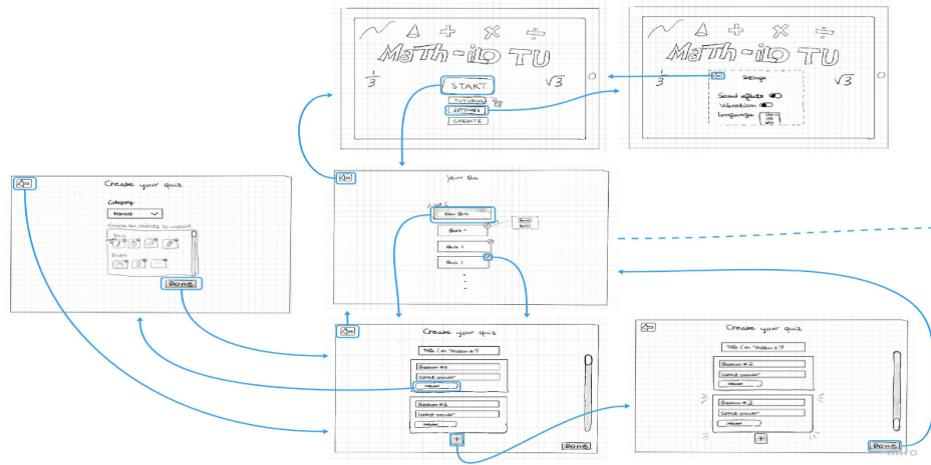
## 6.4 High-Level Flow Diagram

Click on the link to see the full high-quality version on miro.

[https://miro.com/app/board/uXjVPDUy49k=/?share\\_link\\_id=562727687200](https://miro.com/app/board/uXjVPDUy49k=/?share_link_id=562727687200)

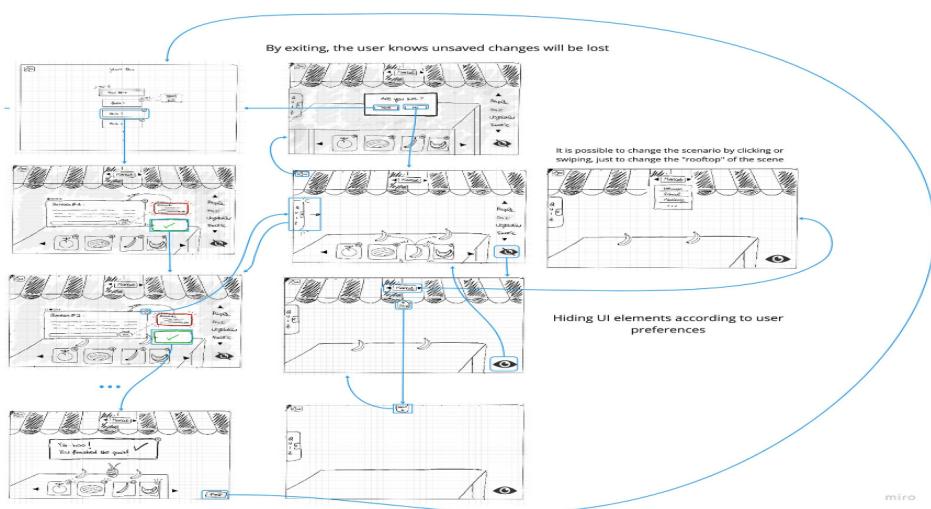
- **Part 1: Interaction with screens**

Move between screens, create a new quiz, open a saved one, add a new question to a certain quiz and choose the object to unlock.



- **Part 2: Interaction with quiz and scenario**

Answer to the question of the selected quiz in order to unlock objects. When all the objects are unlocked, the user can create the scenario inherent to the problem.



Prototype 2 doesn't follow all the storyboard figures to perfection as Prototype 1 does. It still allows representing a problem in a virtual scenario, but lacks of fast personalization capabilities. However, adding an interaction to personalize the objects on the go, would surely adapt it better to the second row of the storyboard.

## 6.5 Selection Rationale

### 6.5.1 Pros of Paper Prototype 1

- UI is minimal, intuitive and **simple to understand**
- It allows to make variations to the scenarios and **customize the objects** on-the-go (according to teacher's or kids' preferences)
- Teachers can keep using traditional tools(paper,online,etc...) to find math problems, only then they can use the app to **represent and analyze** them
- Teachers can **prepare scenarios in advance** (e.g. at home) to be ready to use in class
- It **covers adequately all the three tasks presented**

### 6.5.2 Cons of Paper Prototype 1

- There is no possibility to keep track of previous steps (**no undo/redo buttons**)
- The list of available objects is limited and there is **no way to request new items** (e.g. for future updates)

### 6.5.3 Pros of Paper Prototype 2

- Quiz are common activity for kids so they could possibly **feel more comfortable** than seeing straight AR
- Scenarios automatically build themselves after a correct answer, this could possibly **stimulate problem solving** abilities of kids
- It covers adequately first and second task

### 6.5.4 Cons of Paper Prototype 2

- A bit more complexity is added: **teachers must prepare the quiz** beforehand (writing the questions, choosing the locked objects and their category, showing alternative logical steps to reach a solution requires creating another quiz or a lot of steps to edit the one in use)

- Third task is not totally covered: it **doesn't allow to make variations** to the scenarios and customize the objects on-the-go (according to teacher or kids preferences), which we believe it is more effective than a predefined quiz to help kids finding the best solution to a problem

#### 6.5.5 Final choice

At the end we decided to follow the path of **Paper Prototype 1** because it seems to be the most effective and straightforward way to represent a problem, unlock students' logical capabilities and speed up their learning process.

This way, students are under the continuous observation of the teacher who can analyze their answers, make variations to the scenarios and lead the whole class to the best solution to the proposed problem.

## 7 Medium-fidelity Prototype

### 7.1 Some considerations and improvements

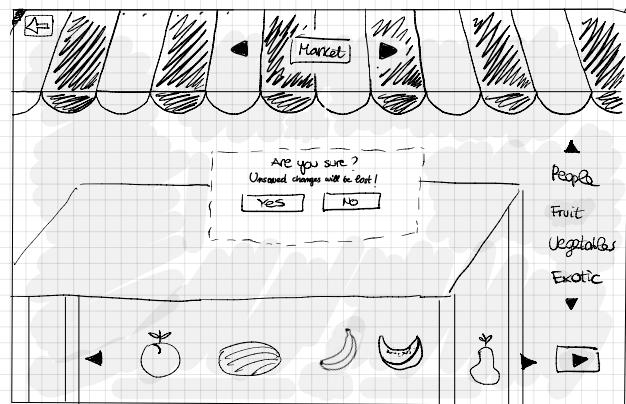
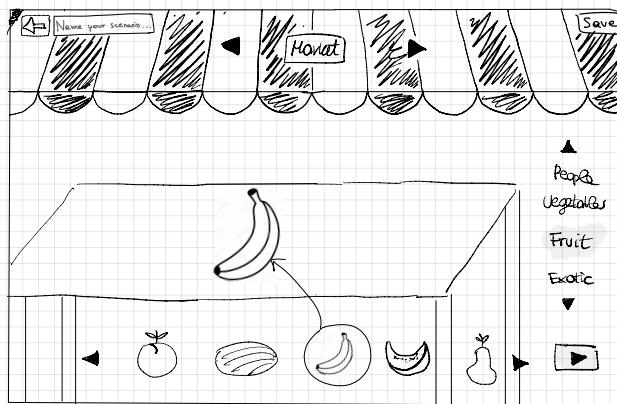
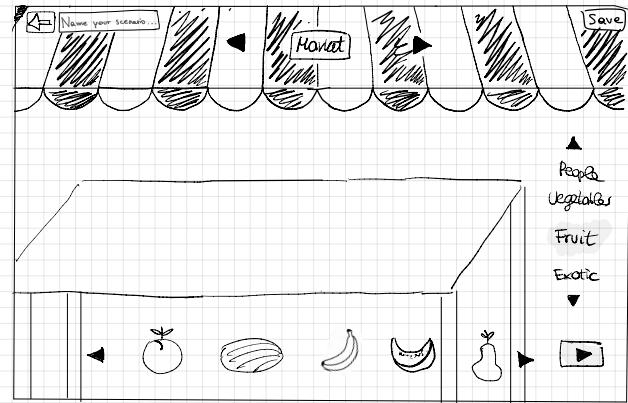
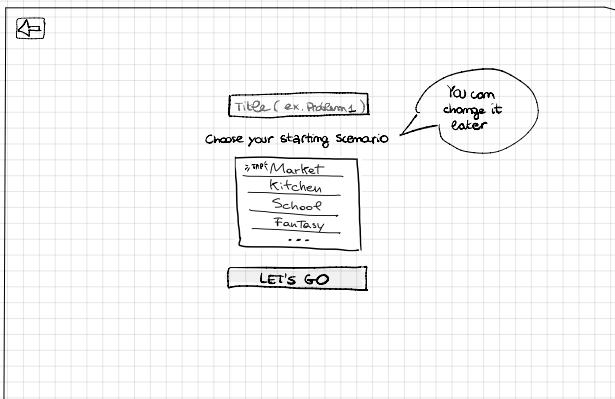
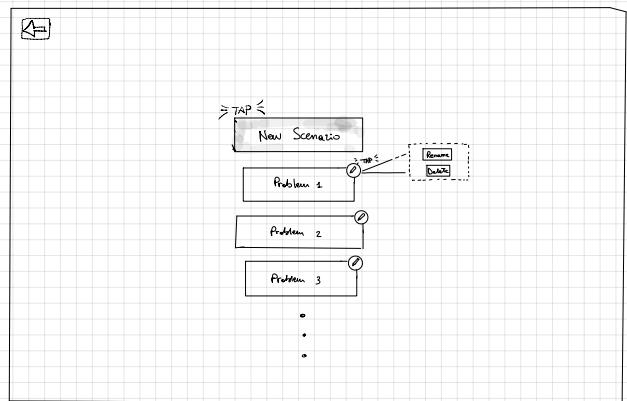
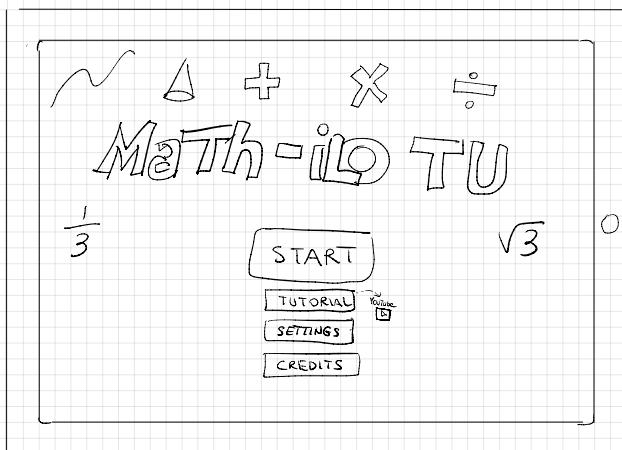
During a review with Professor L. De Russis we discussed about the implementation of the "eye" button to hide/show the UI used to edit the scenario. In particular, he pointed out that first time users may not immediately understand the meaning of that button and how it can be used. Rather, he advised us to separate the "editing" part, from the "playing" part in which the scenario was previewed. So at the end, we all agreed to split the two moments and have:

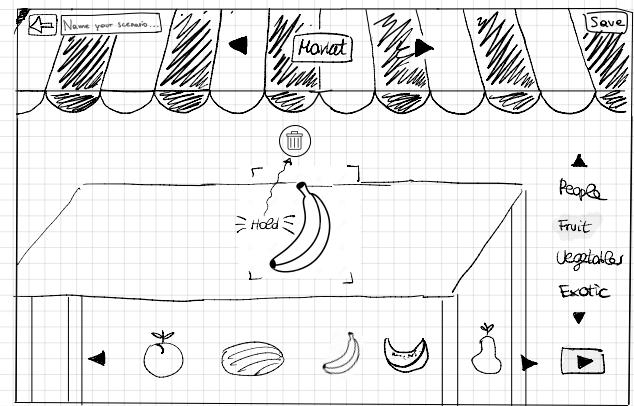
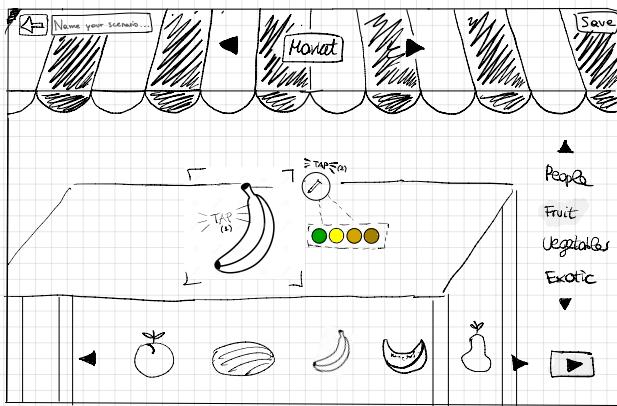
- an Edit mode, where the scenario could be easily edited by the teacher
- a Preview mode, where the scenario could be shown to kids without any distraction
- the "eye" button was also replaced with a "Play" button to access the Preview mode and a "Pencil" button to access the Edit Mode

Another useful advice was to give teachers the possibility to select which initial environment to start with.

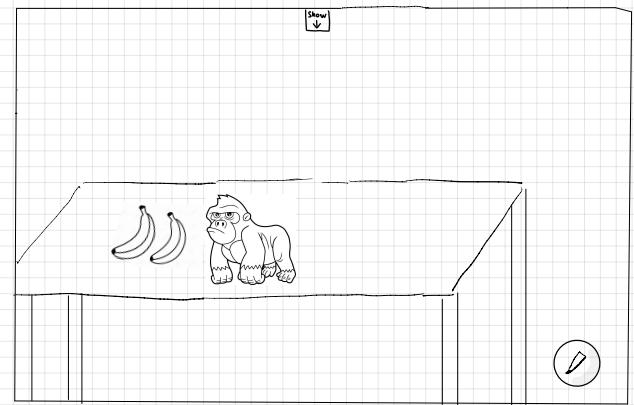
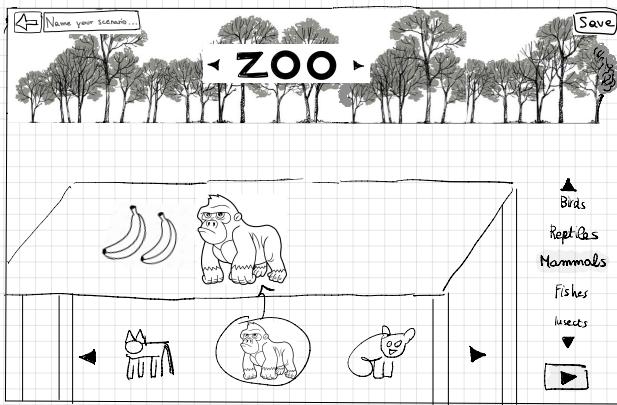
### 7.2 Revised Paper Prototype

We implemented those significant changes, and the following pages show the PDF of the Revised Paper Prototype.

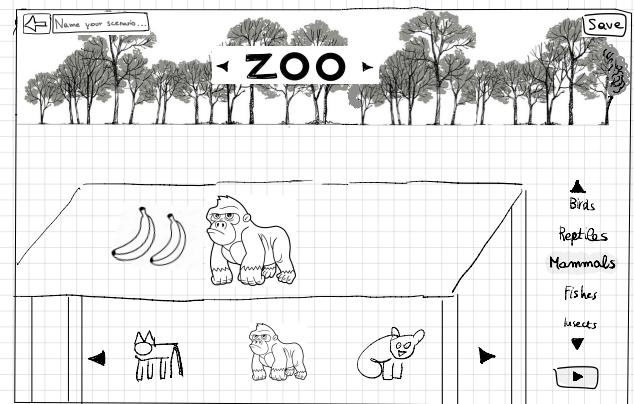
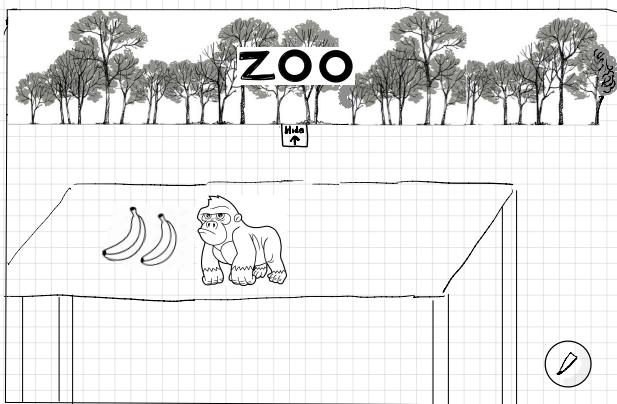




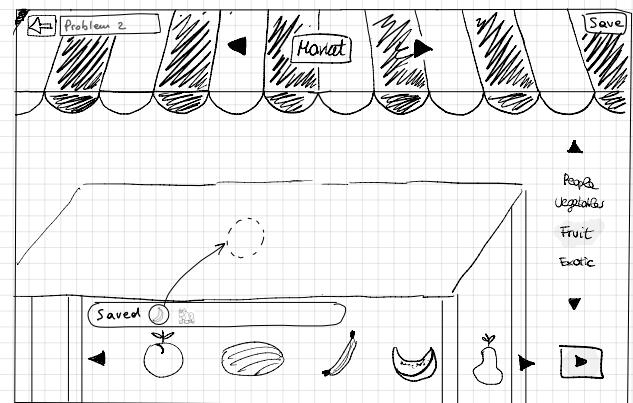
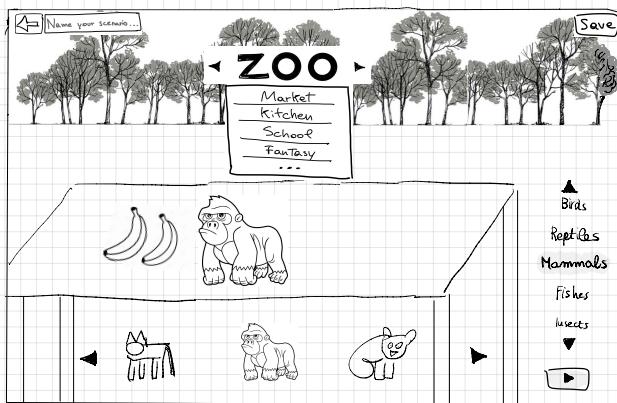
6



8



8



### 7.3 Medium-Fidelity Prototype

The Medium-Fidelity prototype has been implemented on Figma:

<https://www.figma.com/proto/96fGYfc8XauxmLnk9NS33J/math-ilo-tu?node-id=2%3A2&starting-point-node-id=2%3A2>

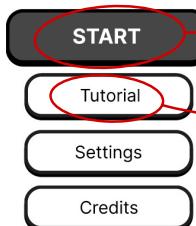
All the team members covered different parts of the implementation at different times, so there was no defined splitting of roles and everyone gave roughly the same contribution.

In order to better explain how and why it covers the three tasks and to clarify its usage for our reviewers (or for those wishing to test our Figma prototype) we proposed a **practical example of a use case** (reported in the [README](#) of Assignment 4) with some steps to follow to be able to have a taste of all the functionalities without facing unwanted behaviors, as well as a list of limitations.

The following pages show some of the most significant screens of our Medium-Fidelity Prototype, each one of them with a short comment.

# MATH-ilo TU!

Homepage, it has 4 buttons with different styling to give different importance to them



By clicking start, you go to the scenario selection screen

Tutorial

Tutorial with steps for beginner users

Settings

Credits



Hi there, I am here to guide you through the main functionalities of Math-ilo Tu! Let's start customizing your scenario. First, select a banana!

Tutorial for beginner users



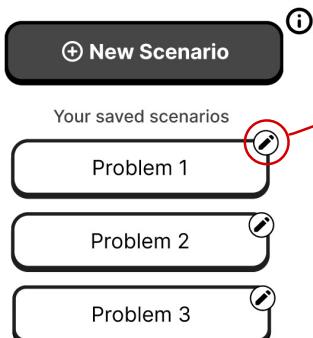
Merchants

Fruit

Vegetables



Scenario selection, here you can decide to set up a new scenario or open a saved one.



⊕ New Scenario

Your saved scenarios

Problem 1

Problem 2

Problem 3

By clicking on this edit icon, you can rename or delete each scenario.

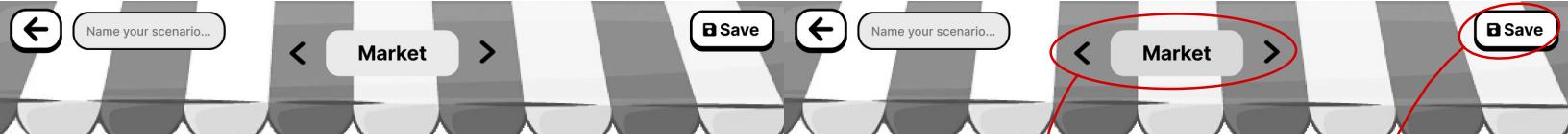
New scenario set up, here you add a name and select the initial environment to start with



Name your scenario...



Let's go!



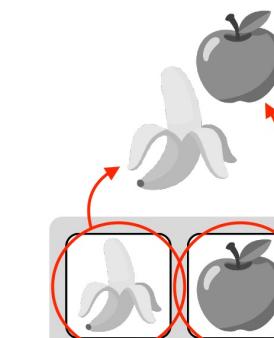
↑  
Merchants

Edit mode, this is what the user sees at the beginning: an empty scenario



Fruit

Vegetables  
▼



By swiping this label, you can change environment and discover more objects to add

A save button, saves the new scenario

↑  
Merchants

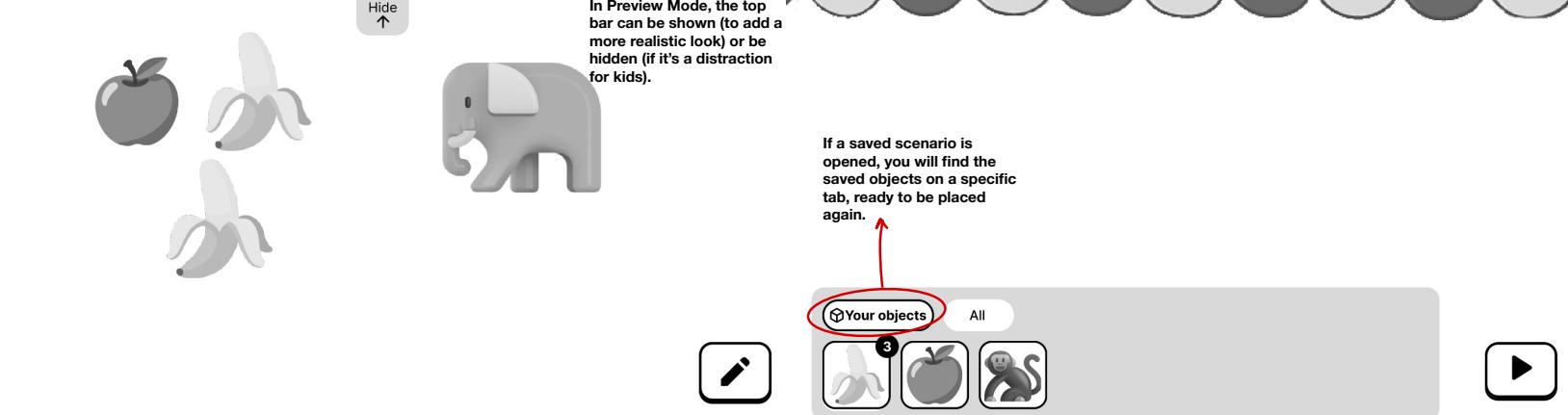
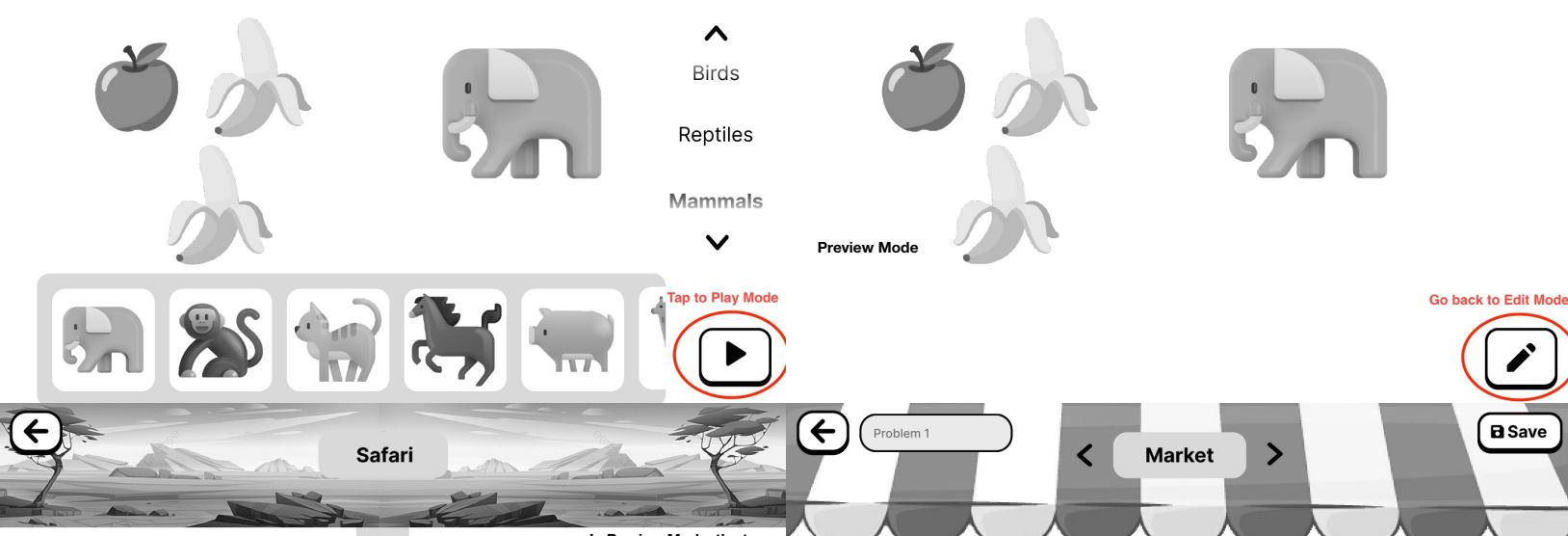
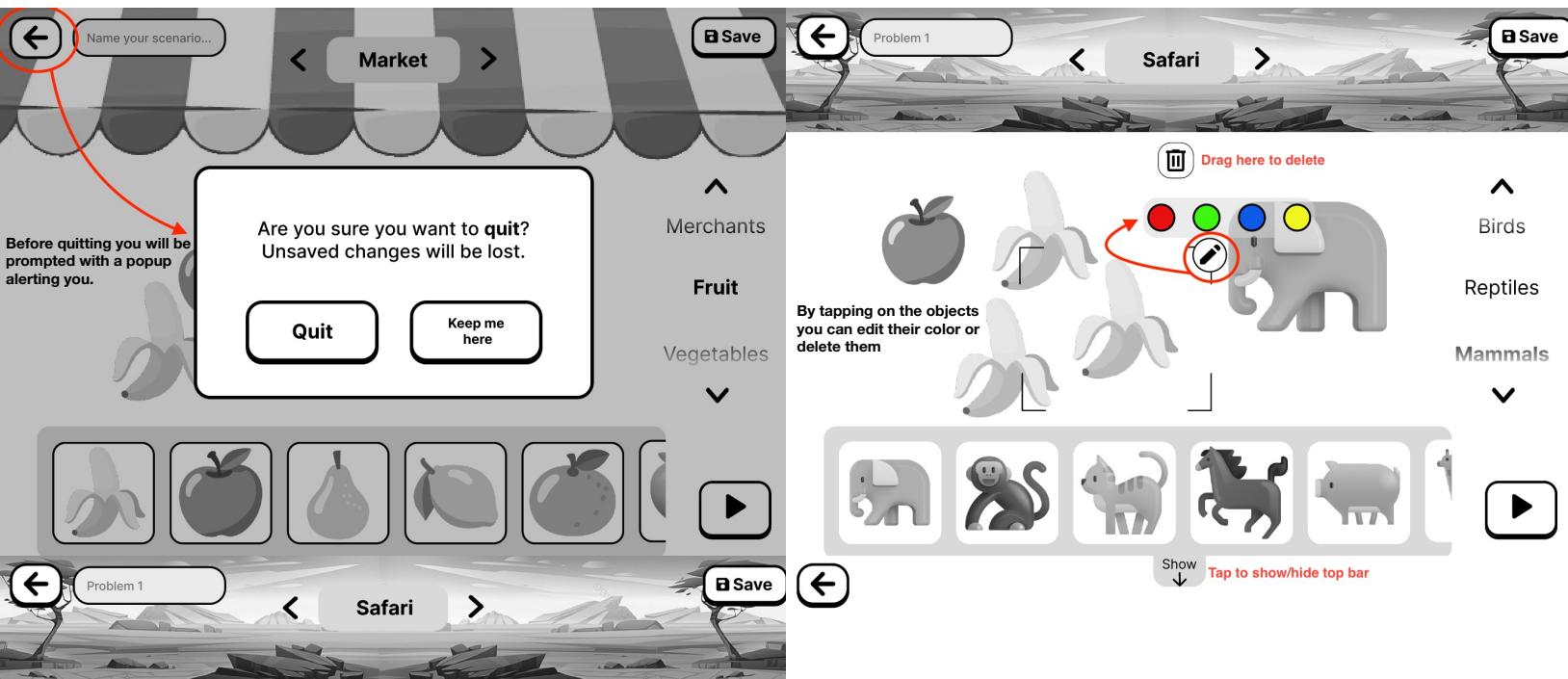


You can add objects by clicking on their cards at the bottom

Fruit

Vegetables  
▼







Merchants

### Fruit

#### Vegetables



Then, you can switch to  
"All" if you need to add  
more objects



All



## 8 Heuristic Evaluation

### 8.1 Receiver Heuristic Evaluation

[https://docs.google.com/document/d/1S\\_jt36M7WS29IfJWsCqd0ydBDG\\_ADPgr/edit](https://docs.google.com/document/d/1S_jt36M7WS29IfJWsCqd0ydBDG_ADPgr/edit)

### 8.2 Discuss of severity level 3 or 4 heuristic violations that the evaluators found

#### 1. H3: User Control and Freedom

Where: Adding objects to scene

What: It is not possible to go back on item addition. For example, if two bananas are added, it is not possible to go back to one.

Why: User is not able to go back one step, needs to start from scratch

Severity: 3

#### Our opinion on it:

*We agree on the fact that the prototype lacks of functionalities like undo/redo (as it was expressed on another violation with a lower severity). But the violation above (impossibility to go back one step and need to start from scratch) is related to a simple limitations of the prototype. To be more specific, we knew that not every window provided all the possible interactions, so the README had some steps to follow, to avoid facing these kind of limitations (otherwise the number of windows in Figma would have been too big to handle). They didn't ask for any clarification, so they simply assumed it was an intended behavior.*

*We still decided to implement undo/redo functionality in the high-fidelity prototype, as suggested on another violation.*

#### 2. H4 Consistency and Standards

Where: Scenario Choosing

What: The deletion of any scenario always results in the deletion of scenario 1

Why: The wrong scenario is deleted.. Deleting scenario 2 or 3 effectively removes scenario 1.

Severity: 3

#### Our opinion on it:

*This is not the behavior meant for the real application, of course. We thought it was okay to present the delete interaction only for one component from the list, and for the rest of them it was simply assumed to work the same way. It was just a way to make the prototype a bit lighter and they could, again, ask us for clarification.*

#### 3. H3 User Control and Freedom

Where: Tutorial

What: Selecting items in some orders can cause items already chosen to disappear

Why: An unintended action happens

Severity: 4

**Our opinion on it:**

*This is not the behavior meant for the real application, of course. We probably missed to check that button, but we don't see the reason of pointing out a simple mistake made in Figma as a violation of severity 4. It doesn't help us making a better high-fidelity prototype, it simply points out that we forgot to check a button connection in Figma...*

**4. H3 User control freedom**

What: Create scenario interface

Why: If I add a monkey, then I can't remove it. If I was wrong to add it I would like to remove it. You don't specify how to do it

Severity: 3

**Our opinion on it:**

*Same response made for the first violation. Not every window provided all the possible interactions, the Figma was counting already 80+ windows.*

**5. H3 User Control and Freedom**

Where: In tutorial

What: it is possible to click on some elements such as the apple which interrupt the tutorial.

Why: It makes no sense to make elements clickable if they are harmful to the functioning of the tutorial

Severity: 3

**Our opinion on it:**

*It was clearly (and again) a wrong connection made in Figma.*

At the end, we did not find the violations marked with severity 3 and 4 very useful. They were pointing out some mistakes in button connections (which can happen if we look at the high number of windows present in our Figma prototype), rather than focusing on real violations. However, we have found some of the lower severity violations to be much more important to us:

- Violation 2: current active scenario label resembles a textual input, which led us to changing its style
- Violation 14: undo actions on the Tutorial, which led us to implement undo/redo functionalities both on Tutorial and Edit Mode
- Violation 11: no error prevention when deleting a saved scenario, which led us to implement a modal asking the user to confirm his action

- Violation 17: tutorial lacking some functionalities, which led us to add more information about the main interactions available

## 9 High-fidelity Prototype

### 9.1 Description of the tool, framework and libraries used for the application

**GitHub Repository** containing the full code of the prototype:

<https://github.com/polito-hci-2022/Math-ilo-tu->

The development process has been executed on two iPads (6th and 7th gen), both on iOS 15. So the prototype is intended to work properly only on iPad with iOS version > 11.0 and chip > A7.

The high fidelity prototype of Math-ilo Tu! was built using **React Native** (0.65.1), a React-based framework for cross-platform development.

**ViroReact** (2.23.0) library was used as base for the AR implementations, it runs javascript code natively across all AR (ARKit for iOS and ARCore for Android) platforms.

Other libraries used are:

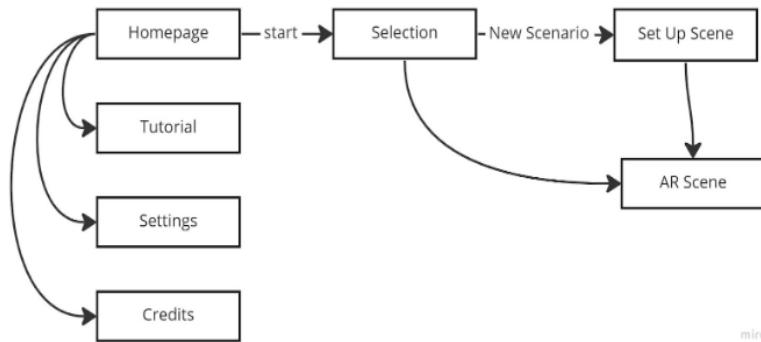
- **React Redux** (8.0.5): together with Redux-Persist, to implement a local persistent storage without the need of a database.
- **React Navigation** (v6): to implement routing and navigation functionalities.
- **React Native Picker** (2.4.8): to implement a selection wheel.
- **React Fast Image** (8.6.3): to implement faster rendering for static images.
- **React Native Toast Message** (2.1.5): to implement a customizable alert message on the Homepage.

Other software used are:

- **Blender** (3.3.1): used for 3D modeling and final export with textures.
- **Adobe Substance 3D Painter** (8.2.0): fundamental for the creation of all the textures and skins of the 3D models.
- **Adobe After Effects** (23.0.0): for the realization of individual graphic elements inserted in the textures and for the backgrounds at the top of the environments.

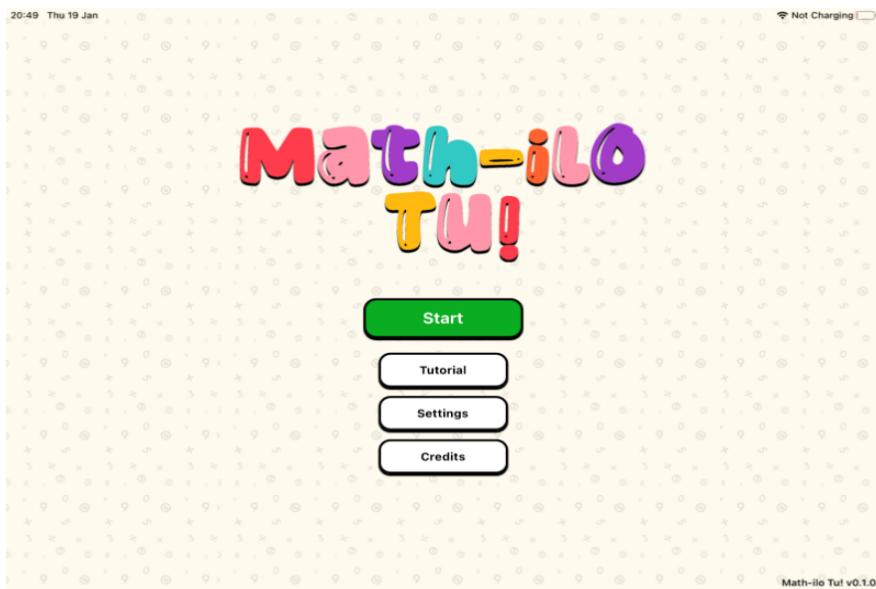
## 9.2 Overall architecture of the application and description of the most significant screens.

The structure is the following (only most significant components and containers are provided):



miro

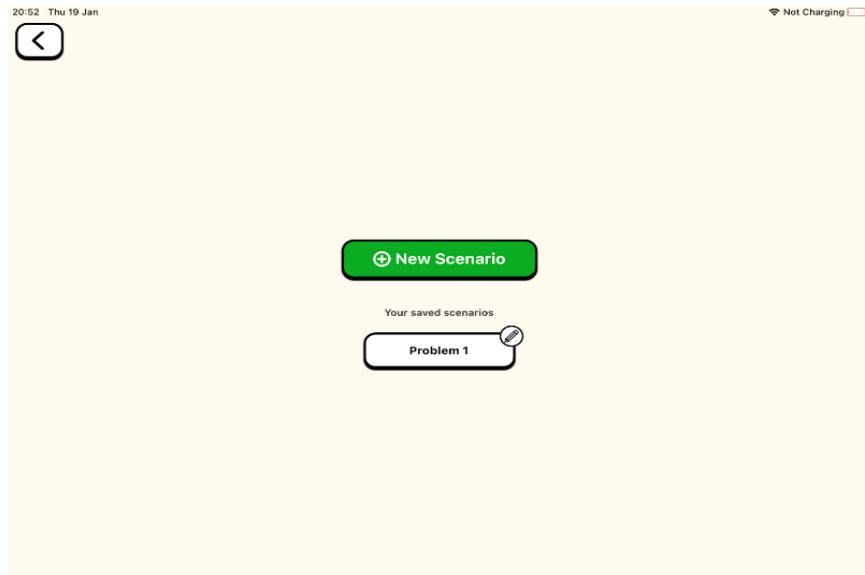
- **Homepage:** the main screen, which contains an animated background, the logo and 4 buttons: Start, Tutorial, Settings and Credits.



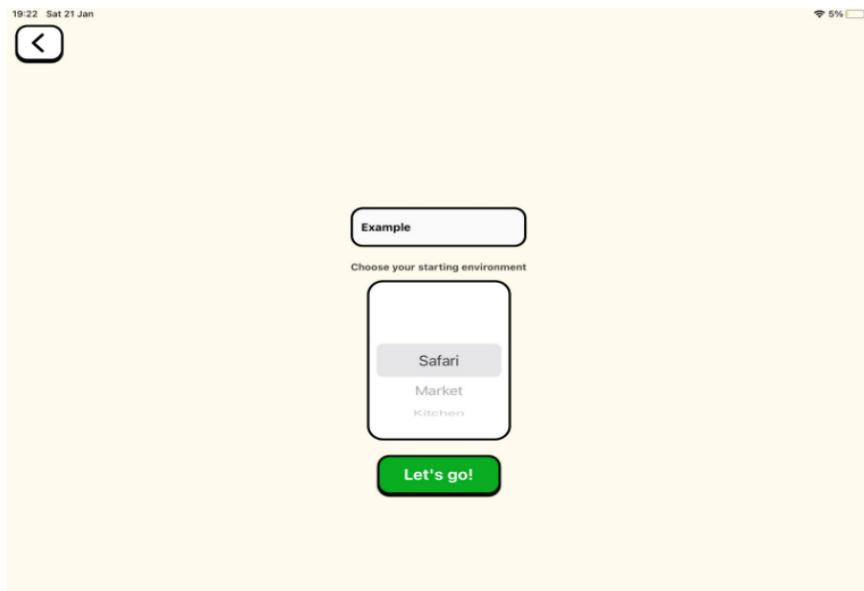
- **Tutorial:** an AR scene with the presence of an avatar that helps the users get confident with the application, guiding them through some easy steps.



- **Selection:** a screen with an entry button to create a new scenario and also shows the saved ones (if any).



- **Set Up Scene:** a screen that allows to set up a new scenario by choosing its name and the starting virtual environment among the ones available.

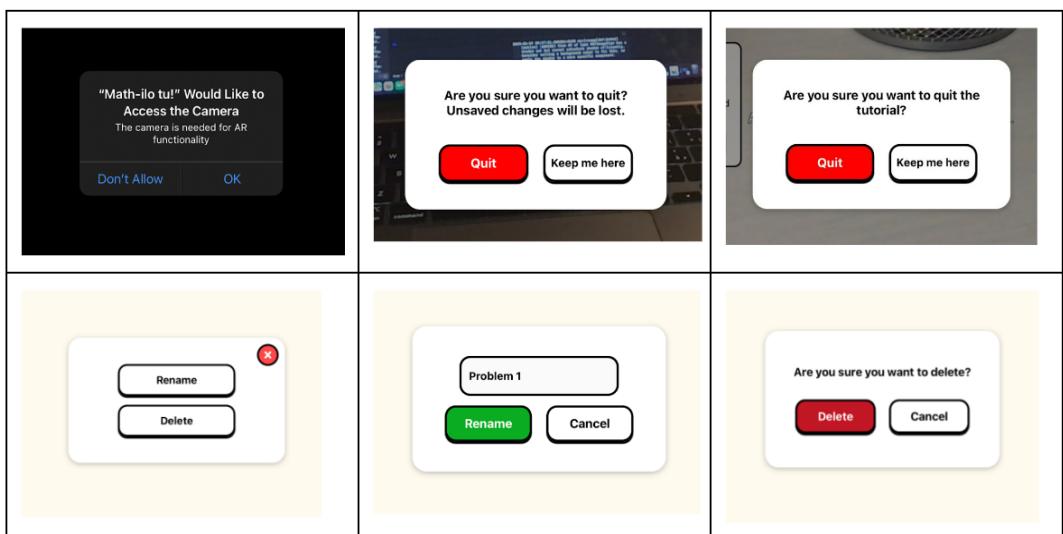


- **AR Scene:** where “we turn Math into Reality”. It is the screen where it’s possible to use the camera to find a flat surface and then edit the scene by adding 3D objects, personalize them, change the environment, etc.





Others:



### **Hard Coded parts:**

- Only the list of objects available has been hard coded into a file called: **objects.js**.
- The list of saved scenarios is initially defined as an empty array in a persistent Redux storage, this allowed us to avoid implementing a database with the relative API, while still preserving data persistency for testing purposes.

### **Limitations:**

- Since ViroReact had some known bugs and issues open, we couldn't implement the task of personalizing the objects as previously shown in the low-fidelity and medium-fidelity prototype. Specifically, the onClick function on AR objects didn't work properly, so we opted for an "Edit Object" tab with the list of all the objects added to the scene, selectable independently.
- For the same reasons, no pinch to zoom to scale objects is available.
- When the objects are placed into the scene, they are all put at the center position relative to where the plane has been located.
- When changing from the "Dragging" object interaction to the "Rotate" one, the user needs to lift the finger from the screen, otherwise the gesture isn't correctly executed.
- Objects do not respond to the laws of physics such as gravity, forces applied by the users with their fingers, and so on.
- Settings don't actually work, they only show possible functionalities such as Mute on/off, Vibration on/off and languages option.
- Only the English language is available at the moment.

## **10 Usability testing**

### **10.1 Preparation and run**

As suggested on the Assignment 6 PDF, we ran four usability tests of our applications and gathered four participants from our target population:

- **Tester 1:** Rita Maria Maugeri, 54 years old, 20+ years of teaching experience. She has taught math in the past.
- **Tester 2:** Donata Galeardi, 60 years old, 26+ years of teaching. She has taught Math in the past.
- **Tester 3:** Ilenia Bocchi, 24 years old, at her first year working as a math teacher.

- **Tester 4:** Olga Basile, 25 years old, 1+ years of teaching in math.



Figure 6: Testers

The first and third tests were run with Mario Testa as the facilitator and the rest of the team members as observers.

The second and fourth tests were run with Mattia Mazzari as the facilitator and the rest of the team members as observers.

Sadly, we didn't have the opportunity to do our tests at school. So all the evaluations have been conducted at teachers' homes.

Our 3 initial tasks were, shortly:

- Create a representation of a math problem

- Personalize its elements
- Display a step-by-step solution for it

(for the full description, see section 5.1)

We didn't refine them, but since each of the three tasks covered more than one component at a time, we decided to expand them into smaller actions, so the participant could better follow a [scripted context](#) (in the means of a story) carefully crafted by us and, at the same time, by isolating the actions, we could have a better understanding of how the single components design choices affected usability:

- Task 1 (create a representation of a math problem) has been split into T2, T3, T4.
- Task 2 (personalize its elements) has been split into T5, T6 (and T7).
- Task 3 (display a step-by-step solution of the problem) is executed as T8.
- To assess the utility of the tutorial, we propose T1.

| <b>Task</b> | <b>Text of the task</b>   | <b>Success criteria</b>   | <b>Methodology</b> |
|-------------|---|---|--------------------|
| <b>T1</b>   | Execute the Tutorial and follow its steps                                   | The screen shows the text “ <i>You’re done with the tutorial...</i> ”         | Thinking aloud     |
| <b>T2</b>   | Create a new scenario choosing a starting environment                       | The screen loaded the scenario and the camera is on                           | Thinking aloud     |
| <b>T3</b>   | Place objects from the catalogue to the scenario                            | The chosen objects are shown inside the scenario                              | Thinking aloud     |
| <b>T4</b>   | Save the scenario for later   | Save button shows “ <i>Saved</i> ” label for 2s                               | Thinking aloud     |
| <b>T5</b>   | Open a saved scenario and populate it with the saved objects                | The screen loaded the scenario and saved objects are shown on the bottom bar. | Thinking aloud     |
| <b>T6</b>   | Personalize objects in the scenario   | At least one object is deleted or has a different appearance.                 | Thinking aloud     |
| <b>T7</b>   | Preview your scenario   | Editing tabs are hidden.  | Thinking aloud     |
| <b>T8</b>   | Represent a step-by-step solution to the proposed math problem (see script) | Scenario is showing: 1 Zebra, 1 Giraffe, 1 banana, 1 apple.                   | Thinking aloud     |

### **Artifacts:**

- Consent forms: [https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/consent\\_forms.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/consent_forms.pdf)
- SUS post-questionaries: [https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/SUS\\_filledin.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/SUS_filledin.pdf)
- Usability testing protocol for tester 1 (same structure for all testers): <https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/1/usability%20test%201.docx>

## **10.2 Results**

### **10.2.1 Usability Test 1**

The first usability test was done with a 54yo teacher with 20+ years teaching experience, who had taught math in the past. She has basic experience with informatics and uses a laptop rather than a tablet.

We knew this wasn't the optimal target user due to her possible difficulties using a tablet, but the outcome was still surprisingly positive.

| <b>Task</b> | <b>Time</b> | <b>Num. of errors</b> |
|-------------|-------------|-----------------------|
| <b>T1</b>   | 3m:44s      | /                     |
| <b>T2</b>   | 1m:27s      | 2                     |
| <b>T3</b>   | 1m:10s      | 1                     |
| <b>T4</b>   | 8s          | 0                     |
| <b>T5</b>   | 2m:1s       | 1                     |
| <b>T6</b>   | 1m:21s      | 0                     |
| <b>T7</b>   | 7s          | 0                     |
| <b>T8</b>   | 1m:7s       | 0                     |

What we've learned:

1. The Tutorial can be a bit more explicative, especially on the first step, by saying what's achievable with this app (e.g., "Here you can represent a math problem by placing virtual objects into the real world")
2. The Catalogue could be separated from the environment. So the teacher can select the environment just to make the scenario look better, and in the catalogue all the objects are present, maybe with a filter to better discriminate if they belong to a different macro-category.
3. We can implement animations in the future (for examples Animal objects dragged onto Food objects will eat them, as suggested from the teacher).

#### Links:

- System Usability Scale 1:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/1/SUS\\_1.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/1/SUS_1.pdf)
- Consent form 1:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/1/consent\\_1.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/1/consent_1.pdf)
- Usability Testing 1:  
<https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/1/usability%20test%201.docx>

#### 10.2.2 Usability Test 2

The second usability test was done with a 60yo teacher with 26+ years teaching experience, who had taught math in the past. She has basic experience with informatics and uses a laptop rather than a tablet.

| Task | Time   | Num. of errors |
|------|--------|----------------|
| T1   | 4m:30s | 3              |
| T2   | 1m:20s | 0              |
| T3   | 1m:40s | 1              |
| T4   | 5s     | 0              |
| T5   | 2m:30s | 1              |
| T6   | 1m:40s | 1              |
| T7   | 40s    | 1              |
| T8   | 1m:7s  | 0              |

What we've learned:

1. Some elements in the UI of the scene are not intuitive or visible: it is not clear whether the user can add objects by dragging or pressing, maybe a “+” icon for each element in the bottom bar would help understand at first look what to do. Also in the right bar the arrows are not clickable, so this confuses the user which does not get that this area is scrollable with one finger. The button “Show/Hide Top Bar” is not always quite visible, as well as the trash icon to delete objects.
2. In the scenario, once the surface is localized and the user taps on the quad, there is no feedback about the fact that the user at this step can place the objects, when creating a new scenario.

#### Links:

- System Usability Scale 2:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/2/SUS\\_2.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/2/SUS_2.pdf)

- Consent form 2:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/2/consent\\_2.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/2/consent_2.pdf)
- Usability Testing 2:  
<https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/2/usability%20test%202.docx>

### 10.2.3 Usability Test 3

The thirds usability test was done with a 24yo teacher at his first year of teaching, she has been a math teacher since last September. She has good experience with informatics and uses a tablet on a daily basis.

If we compare it to the previous tests, we see a tremendous difference in the number of errors, time and also in the way she approached the different tasks. We believe that being used to a tablet and the informatics domain in general, helps a lot when learning/understanding a new app.

| Task      | Time   | Num. of errors |
|-----------|--------|----------------|
| <b>T1</b> | 3m:27s | 0              |
| <b>T2</b> | 34s    | 0              |
| <b>T3</b> | 1m:12s | 0              |
| <b>T4</b> | 12s    | 0              |
| <b>T5</b> | 52s    | 0              |
| <b>T6</b> | 49s    | 0              |
| <b>T7</b> | 8s     | 0              |
| <b>T8</b> | 1m:54s | 0              |

The third participant didn't find any problem at all when using the app, so we asked a few more question to assess the problems found by previous participants:

1. She agrees that the button to Hide/Show the top bar in the preview mode, isn't enough visible. But she finds the functionality useful if the screen is too overcrowded.
  2. She thinks that dividing the objects into categories for different environments is a simple concept and doesn't find it hard to understand at all. She proceeds saying that, in general, she doesn't really need to have all the objects in the catalogue, because she understood how to move in the app. But maybe someone else could find it easier to understand and it could definitely be a faster option.
- System Usability Scale 3:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/3/SUS\\_3.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/3/SUS_3.pdf)

- Consent form 3:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/3/consent\\_3.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/3/consent_3.pdf)
- Usability Testing 3:  
<https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/3/usability%20test%203.docx>

#### 10.2.4 Usability Test 4

The last usability test was done with a 25yo teacher with 1+ years teaching experience in math. She has basic experience with informatics and uses a laptop rather than a tablet, although she has familiarity with both of these devices. For this reason, overall the results are quite good:

| Task      | Time   | Num. of errors |
|-----------|--------|----------------|
| <b>T1</b> | 2m:31s | 2              |
| <b>T2</b> | 20s    | 0              |
| <b>T3</b> | 1m:42s | 0              |
| <b>T4</b> | 5s     | 0              |
| <b>T5</b> | 2m:11s | 1              |
| <b>T6</b> | 1m:43s | 1              |
| <b>T7</b> | 44s    | 1              |
| <b>T8</b> | 1m:7s  | 0              |

What we've learned:

1. The app was not responsive in finding a flat surface and the user did not understand how the quad was following her movements.
2. The preview button in the AR scene on the bottom right corner may not be so useful at the end, since the user wants to edit the objects at any time.

#### Links:

- System Usability Scale 4:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/4/SUS\\_4.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/4/SUS_4.pdf)
- Consent form 4:  
[https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/4/consent\\_4.pdf](https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/4/consent_4.pdf)
- Usability Testing 4:  
<https://github.com/polito-hci-2022/The-Islanders/blob/main/A6/Usability%20Tests/4/usability%20test%204.docx>

### 10.3 Overall problems in performing tasks

- **T1 (Execute the Tutorial and follow its steps):** there are no big problems to report, Tutorial was successfully performed by all the participants, some being slower or faster than others.
- **T2 (Create a new Scenario):** when creating a new scenario, the action of entering a name was tried to be skipped (some users didn't understand immediately it was mandatory) and some users tend to be very slow when typing on the virtual keyboard if they have no familiarity with tablets.
- **T3 (Place objects from the catalogue to the scenario):** one of our limitations is that objects are always placed at the centre of the screen, overlapping among each other. Without dragging the objects, the user is not able to distinguish them, especially when he places the same 3D models multiple times.
- **T4 (Save the scenario for later):** no problems to report.
- **T5 (Open a saved scenario and populate it with the saved objects):** same as T3, without any additional problem.
- **T6 (Personalize objects in the scenario):** some users found a bit unhandy to always have to go to the tab "Edit Objects" and select objects from the horizontal scrolling area to personalize them. This wasn't the interaction we designed on previous prototypes, but unfortunately, an issue of Viro React forced us to change it.
- **T7 (Preview your scenario):** tester 2 and tester 4 did not find the way to preview the scenario immediately
- **T8 (Represent a step by step solution to the proposed math problem):** at this points users were comfortable enough with all the interactions, so there are no problems to report.

### 10.4 Potential changes

1. The Tutorial can be a bit more explanatory, especially on the first step, by saying what's achievable with this app (e.g., Here you can represent a math problem by placing virtual objects into the real world"). **This emerged with tester 1.**
2. The Catalogue could be separated from the environment. So the teacher can select the environment just to make the scenario look better, and in the catalogue all the objects are present, maybe with a filter to better discriminate if they belong to a different macro-category. **This emerged with three out of four testers.**

3. The third tester pointed out that children could be confused if we add a piece of cake while being in the Safari environment. This is in contrast with the previous potential change. A possible idea is to have a setting that allows switching between the two behaviors. **This emerged with tester 3.**
4. We can implement animations in the future (for example Animal objects dragged onto Food objects will eat them). **This emerged with tester 1.**
5. The button "Hide/Show top bar" in Preview mode could be more visible in the UI. **This emerged with all the testers.**
6. After pressing on the quad in the scene, the app could visually give a feedback to the user with a "green tick" when he can place the objects, while at the moment the objects scrollbar unlocks and the quad disappears from the UI. Moreover, a "+" can be placed over the object cards to make the adding interaction more understandable. **This emerged with tester 2 and 4.**
7. Objects added to the scenario needs to placed where there is more space or users can be allowed to add objects by dragging them (instead of clicking on their cards) where they prefer. **This emerged with all the testers**

## 11 Conclusions

### 11.1 What we have learned in this course

- During the HCI course of this semester, we learned how to develop and design an application from scratch, starting from finding the needs of a target population.
- We became proficient in interviewing people correctly and extrapolating useful information from their answers to build the main tasks our application had to serve.
- We then learned how to build proper prototypes for 3 different fidelity levels (paper, design tool, real application), acquired skills in Figma and understood how to evaluate and finally test each of the prototypes previously mentioned.
- Regarding our lab theme, we understood the basics of Augmented Reality, the libraries available and the possibilities this technology has to offer.
- Regarding our own project, we acquired new skills by using React Native and Viro React for the first time (create a cross platform mobile app, load 3D objects, etc.), learned how to use XCode to build projects on iOS devices, practiced 3D objects modeling on Blender and Latex writing on Overleaf.

## 11.2 Group feedback

- **Giuseppe Forma:** realized all the 3D models on Blender, their textures and the images used as background on the top for each type of environment (Market, Safari and Kitchen). Indeed, he is enrolled in the Cinema Engineering master degree. He doesn't own the required devices to contribute independently to the coding development.
- **Flavio Patti:** massively contributed to the progressive realization of the report. Since he doesn't own any iOS devices, he participated in the coding development observing the changes in code in real-time on the devices of the other members of the group.
- **Mario Testa:** great on React, CSS and product design, contributed to the overall development of the application since he owns an iOS device and a MacBook to run XCode, and designed all the nice-looking screens and components.
- **Mattia Mazzari:** contributed to the overall development of the application, since he owns the iOS devices required to build and test the application on XCode. If it wasn't for him, Viro would have never run on our devices.

Overall, during the whole semester, each one of the members of this group actively participated and contributed to the labs, listening to the feedback of the teachers and applying progressively the suggested changes in all the processes of the realization of the application.