Software Engineering Department
Braude College of Engineering

Final Project in Information Systems Engineering - Phase I

# Augmented reality in Industry 4.0

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# ABSTRACT

The Industrial Internet of Things (IIoT) represents the next phase of industry innovation. The idea enables connectivity between sensors, devices, machines and systems through an internet network. IIoT technology enables the collection, exchange and analysis of data so leveraging IIoT can lead to improvements in productivity, efficiency and overall industry performance.
The Institute for Advanced Manufacturing in Karmiel is a joint venture of the Israeli Ministry of Economy and the Academic College of Engineering Braude which focuses on promoting a prosperous and innovative manufacturing industry through advanced technologies that conform to the principles of Industry 4.0 and is based on the IIoT. The institute hosts daily tours for regional students to stimulate interest in modern industrial technologies and manufacturing careers. However, engaging youth and fostering curiosity and enthusiasm during these tours is a challenge. It is difficult for instructors to capture the attention of students and sweep them away with the complex technological ideas. To address this problem, our project offers an innovative solution - a user-friendly application that increases interactivity during tours using augmented reality technology. This integration of the virtual layer in the physical environment of the youth will result in the enrichment of the visitor's experience and the improvement of the tour experience, this application aims to promote industrial awareness among youth for potential career paths in manufacturing.

# 1.INTRODUCTION

One of the main methods of exposing youth to technology and innovation is through study tours in research institutes such as the Institute for Advanced Manufacturing. However, a significant challenge lies for the teaching and training personnel who try to capture the attention of the youth and arouse their interest.

Today, augmented reality (AR) technology is used in educational tours to enhance the learning experience [19]. Studies have proven that AR can be an effective tool for improving the understanding of complex concepts, increasing motivation and fostering interest among visitors in technological issues [10].

The institute hosts educational tours and presents the various stages and innovative technologies in development and production in the industry. The tour is based on understanding the importance of connecting all environmental devices to the Internet and creating a connected network [24]. While today's youth are familiar with mobile devices, computers and video games from a young age, understanding the basics of network connectivity and new Industry 4.0 technologies remains a significant hurdle.

The solution we offer to increase motivation is an application that incorporates augmented reality (AR) technology, to stimulate curiosity, inspiration, and excitement among teenagers on Industry 4.0 issues. The unique application will allow visitors to explore and manipulate virtual representations of the institute's industrial technologies and will incorporate game elements.

The institute is expected to benefit from the application by an increase in the number of young people visiting while they gain a better understanding of industrial technologies and a push to engage in these professions and integrate into the industrial workforce.

# 2.BACKGROUND AND RELATED WORK

## 2.1. The fourth industrial revolution

The industrial revolution refers to a transformative period characterized by the emergence of new dynamic technologies, products and industries that revolutionized the entire economic structure, led a leap forward in development and accelerated cultural, social and even ecological changes.

The industrial revolution is an ongoing process with four primary waves. The first revolution (1784) was centered on the invention of the mechanical weaving loom, which led to the establishment of mechanized workshops powered by steam. The Second Revolution (1870) introduced the industrial conveyor belt and electric power, allowing factories to produce at higher rates. The third revolution (1969) brought programmable controllers, electronics, communications and computers, enabling automated production. The ongoing industrial revolution transformed production through mechanization, electrification and automation, leading to significant advances in productivity and efficiency [7].

Industry 4.0 denotes the fourth industrial revolution, which focused on the digitization and automation of production through smart technologies such as machine learning, big data, and the Industrial Internet of Things (IIoT) [12]. This revolution is driving the emergence of smart factories with connected machines that share real-time data across the supply chain [13]. The combination of advanced technologies, including augmented reality (AR) and cloud computing, optimizes processes by minimizing costs, maximizing product quality and increasing flexibility in response to rapid market changes [16].The application of Industry 4.0 poses challenges, mainly ensuring a safe interaction between humans and robots, a task that requires the industry to produce new intuitive interfaces for this purpose [8]. Other hurdles include enabling affordable technological connectivity and developing agile data-driven policies to respond to evolving conditions through big data analytics [14]. AR is proposed as a solution, increasing spatial awareness in complex factory environments through visual data [8].

In conclusion, Industry 4.0 represents the latest industrial revolution, applying decision-making from real-time data and intelligent automation to production. Although it offers productivity benefits, it also presents many challenges that require innovative technological solutions and operational strategies.

## 2.2. Augmented reality

Augmented reality (AR) is an emerging technology that superimposes virtual information, such as text, images, 3D models, and multimedia, onto the real environment through computer simulation, serving as a bridge between the digital and physical worlds. This technology enables users to experience and interact with their surroundings in novel and revolutionary ways [5].

AR garnered significant attention from users with the development of the so-called Google Glass in 2013. These glasses represent a Head-Mounted Display (HMD) device in the form of eyewear, allowing users to view applications and web pages in an augmented reality environment [19] Microsoft also attempted to implement its version of 3D glasses using AR technology, resulting in the creation of the "HoloLens", a Head-Mounted Augmented Reality Display (HMARD) device designed to be worn on the head. Another AR application exploited by the well-known Nintendo Switch home console is represented by the game "Mario Kart Home Circuit". This new game takes full advantage of AR technology [2].

However, AR systems are not limited to specific wearable devices but are also implemented on smartphones through improved algorithms. Notably, in 2016, a game application called "Pokemon Go" was launched by Niantic and Nintendo, which experienced a surge in downloads within just one week.

The continuous advancements in augmented reality technology across various platforms and devices demonstrate its growing significance and potential for revolutionizing human-computer interactions in diverse contexts.

### 2.2.1. Augmented reality in the industry

The emerging augmented reality (AR) technology facilitates the integration between humans and their technological environment. Moreover, it contributes to the optimization of employee training, enhances the availability of real-time information for employees, and ensures the improvement of safety conditions in industrial environments.

One of the most crucial aspects of AR is the interaction between users and the devices, which can be wearable or non-wearable. However, the interface must be intuitive and straightforward to promote effective user engagement [16].

There are many devices available for AR uses for example:

- Head mounted device (HMD) - a display device that is placed on the head or as part of a helmet and displays images of the real virtual environment over the user's perception of the world.
- Handheld devices - small computing devices with a display that the user can hold in his hands. It uses video systems to upload visual metrics and uses sensors such as digital compasses and GPS units.
- Other display devices - desktop computer monitors, etc.

The application of augmented reality in the industry are in first place with 35% smart glasses, in second place with 27% tablet, then with 16% screen, projector with 15% and finally. A smart phone with 7% [9].

### 2.2.2. The effect of augmented reality on the learning experience

Currently, the use of technology to improve teaching and learning experiences in the classroom is promoted. One of these technologies is AR, which allows layering of virtual information on a real scene to increase the user's perception of reality.

In the educational context, it has been proven that augmented reality offers a number of advantages such as increased involvement in learning and increased understanding when it comes to spatial skills [10].

Most of the research projects examined the framework of the cognitive theory of multimedia learning and the cognitive load theory (CTML) [4].

The CTML theory is based on 3 basic assumptions about how humans learn from words and images: The theory assumes that humans have different channels for visual, auditory, and verbal information. In addition, it assumes that each channel has a limited capacity to process information and that learning is an active process of filtering, selecting and organizing information [3][17].

### 2.2.3. The effect of augmented reality on learning in a science center

Augmented reality (AR) technology has demonstrated promising effects on learning in informal science education settings, such as science centers and museums, by enhancing learning through multiple visualizations and digital information. This approach leverages the advantages offered by theories such as the cognitive theory of multimedia learning, allowing learners to interact through various channels and engaging visitors through a combination of physical objects and virtual enhancements [11].

Another example is a study by [19], where the researchers compared learning outcomes between an AR-enhanced exhibit on geology concepts and a non-AR exhibit. The AR group, using handheld devices to view 3D visualizations, showed better knowledge gains on geology tests, and qualitative data indicated that AR increased engagement and collaborative learning.

The advantage of AR for students lies in the production of dynamic environments where motivation and interaction are the main features [10]. From an additional article, it emerged that within the study framework, the implementation of augmented reality in an educational context was successful for children of different ages and at different school levels, positively impacting children's satisfaction and confidence. Notably, the effect of AR was to increase the speed of learning and understanding.

However, from the tests conducted, the challenge discovered in the field is that, although understanding was good, the improvement in knowledge retention is minimal. Thought must be invested in creating an augmented reality experience that leads to meaningful learning, and adapting to AR can be complicated for some students [18].

## 2.3. Motivation and gamification

The term motivation describes why a person does something. It is the driving force behind human actions that is the process that initiates, guides and sustains goal-directed behaviors [6].

There are several motivation theories, the most important of which is the self-determination theory (SDT).

### 2.3.1. Self-determination theory (SDT)

Self-determination theory is a theory of motivation and personality that concerns people's innate tendencies and innate psychological needs. It concerns the motivation behind people's choices in the absence of external influences and distractions. The theory compares internal and external motivations with a growing understanding of the dominant role played by internal motivation in individual behavior, which relates to performing an action for personal satisfaction versus performing an action to achieve an external goal (extrinsic motivation).

The theory proposes three main internal needs involved in self-determination: the universal and innate need for autonomy, competence, and connectedness.

In this study, we would like to test our ability to influence the motivation of the youth to take an active part during a tour of an advanced manufacturing institute and learn about the emerging field of Industry 4.0 through the use of an augmented reality application.

In our application we will base on the theory of self-determination in that the youth will use the application with little prior training (autonomy).

They will work in small groups so that each group will receive a tablet for independent work (connection) and they will be asked to deal with more challenging tasks than they know from normal classroom learning through the use of an augmented reality application and the application of creative and critical thinking (competency). We expect that learning through the application and the curiosity to experience elements of augmented reality may increase the motivation of the youth for active participation and even a growing interest in the industry and its range of capabilities [15].

### 2.3.2. Gamification

Gamification is a strategy that integrates entertaining and immersive gaming elements into nongame contexts to enhance engagement and motivate certain behaviors. Gamification uses game design and mechanics, such as badges, leaderboards, points and rewards, to encourage active participation and make task enjoyable [25].

In an academic article that explores the intersection of motivation and gamification, the research focused on how gamification techniques can effectively enhance user motivation. Despite the fact that our research primarily focuses on the pedagogical approach to teaching intricate subjects within the industrial sector, we made the deliberate decision to integrate gamification components into our study. The rationale behind this choice lies in our aspiration to augment user motivation and foster increased engagement and participation among the participants [14].

# 3. ENGINEERING PROCESS

## 3.1. Work process

The research process commenced with the identification of the problem statement, which was facilitated through discussions with the institute's representative and our supervisor. To gather comprehensive insights, we conducted an interview with Uri Ben Hanan, head of the Institute for Advanced Manufacturing, and undertook two observational tours of the institute. During these tours, we engaged in discussions with the institute's instructors and a representative from the Beit Hakerem Cluster, who provided valuable information regarding the needs and preferences of the regional youth, our target audience [26].

In the initial stages of the research, we delved into the field of augmented reality by reviewing relevant literature and acquainting ourselves with the Unity platform. This allowed us to gain an understanding of the current state of research and enabled us to establish innovative research objectives.

During the observational tours, we generated ideas and made informed decisions regarding the optimal implementation of the application to effectively achieve our goal of captivating and inspiring youth about the evolving landscape of industry. The interview with Uri Ben Hanan provided us with a clear direction, emphasizing the primary aspiration of the application, as he stated, "We aim to light the spark for a child to become an engineer."

In the final phase, we initiated the design process for the user interface, focusing on its visual appeal and usability. Additionally, we commenced the collection of educational content to be integrated into the application.

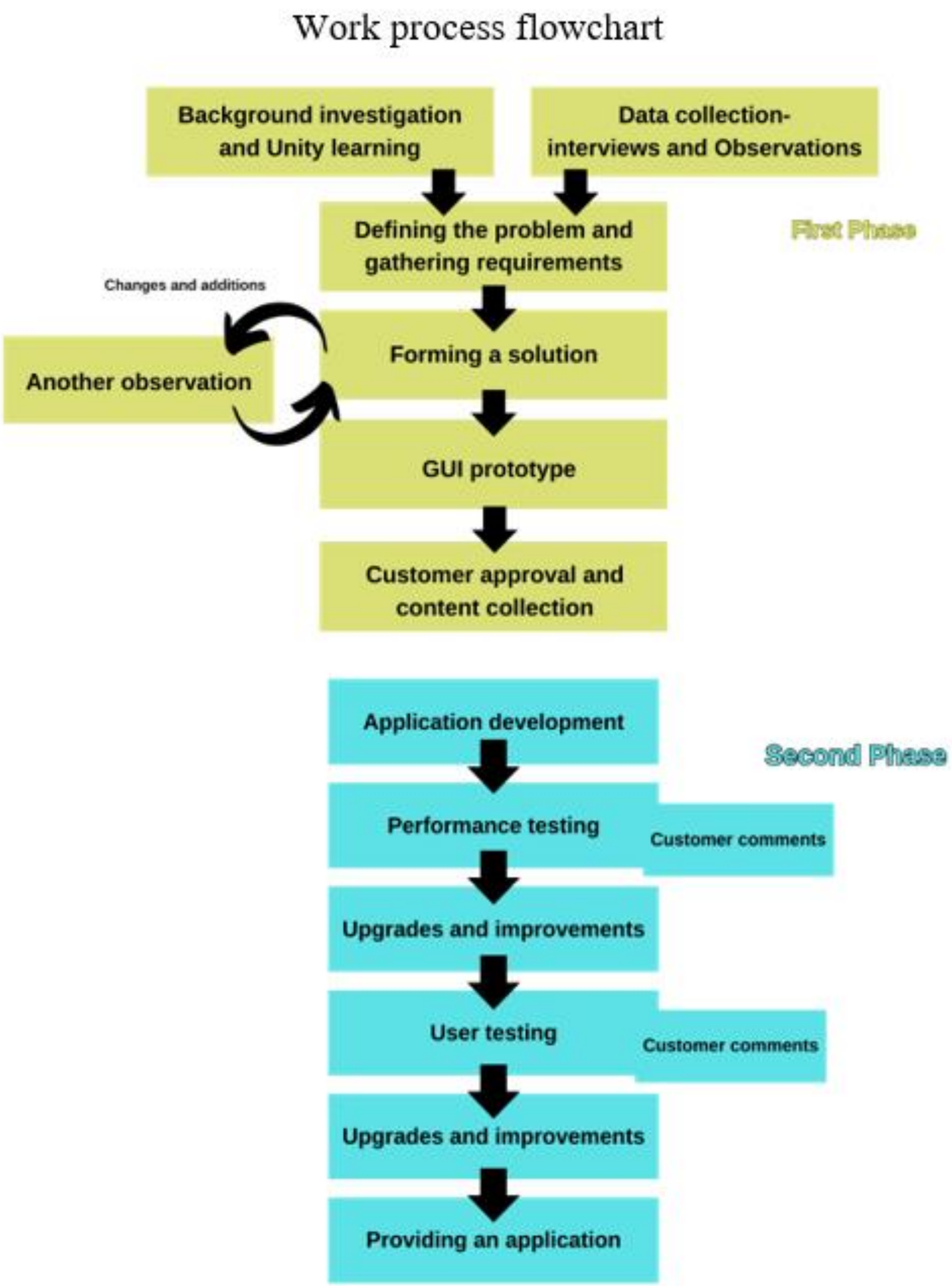


**Figure 1-** image displays work process flow

## 3.2. Requirements Gathering Process

The requirements elicitation process was conducted through a multi-faceted approach. Initially, a comprehensive literature review was undertaken to identify system requirements aligned with cognitive theory principles, ensuring the preservation of visual and verbal channels and the facilitation of user engagement.
Subsequently, observational tours and interviews were conducted with stakeholders from the Institute for Advanced Manufacturing and representatives of the target audience from Eshkol Beit HaKerem. Concurrently, collaborative efforts were made with students enrolled in an augmented reality course at the college to gather additional requirements, particularly pertaining to the constraints associated with the Unity platform.
The interview with Uri Ben Hanan, emphasized the criticality of interface simplicity and convenience, as well as the importance of promoting cooperation and interactivity. Otniel Ronen, Chief Marketing Officer at Advanced Manufacturing Institute, underscored the significance of interface accessibility for all user groups and the advantages of integrating virtual elements within the physical environment.
Finally, a brainstorming session was conducted with an institute representative to ensure the development of a comprehensive set of system requirements.

### Functional requirements:

**1.** The system will allow scanning and identification of physical objects in the environment using the device's camera.
**2.** The system will allow displaying an overlay of relevant information and explanations on familiar objects.
**3.** The system will contain a convenient and friendly intuitive interface to encourage the involvement of the participants.
**4.** The system will allow the user to perform actions in the interface and be active.
**5.** The system will allow the user to display abrasive elements.
**6.** The system will allow the collection of user feedback to improve the user experience and track user interactions, progress, and engagement.

### Non-functional requirements:

**1. Performance:** The system should provide a limited response time of up to 3 seconds for object recognition, information retrieval and gameplay to keep the user engaged.
**2. Reliability:** The system should be stable and reliable by handling errors and presenting informative error messages to users when necessary.
**3. Usability:** The interface should be intuitive and easy to include clear operating instructions and use familiar colors for basic operations. In addition, the interface will include the option of using 3 languages (Hebrew, English and Arabic).

**4. Compatibility:** The system shall have a modular design adhering to best practices for easy maintenance, with well-documented code and comprehensive user, technical, and API documentation. Version control (Git) for change tracking, release management, and collaboration.

**5. Maintenance:** The system will be easy to update through documentation according to standards that promote consistency. They cover annotation conventions, documentation generators, naming conventions, code design, design documentation and version management procedures.

**6. Performance efficiency:** the system should optimize the utilization of resources such as processor and memory through management algorithms, to minimize energy consumption and extend the battery life of the tablet device.

**7. Security**: The system will keep the users' information in the password-protected database.

**8. Documentation**: The system documentation will be comprehensive, well organized and accessible to ensure that new developers can understand the system and facilitate ease of use, maintenance and future improvements.

**9. Accessibility:** The system will also be accessible to disabled users. It will contain readable and understandable textual content, font sizes and color contrast. In addition, visual information will always be accompanied by an auditory option.

**10. Data integrity**: the system will ensure accuracy in scanning models, it will be able to deal with errors and maintain optimal performance.

## 3.3. The system architecture

The architecture consists of a structure of layers, the Presentation layer, the logic layer, and the Data layer. The display layer includes the GUI user interface, and everything related to user input and output.

The logic layer includes all the models and enables the management of the entire system. This layer is the heart of the system, it receives the instruction through the display layer, processes them and executes through the data layer.

And the data layer includes the databases including the device's local databases.

The details of the layers appear in figure 2:

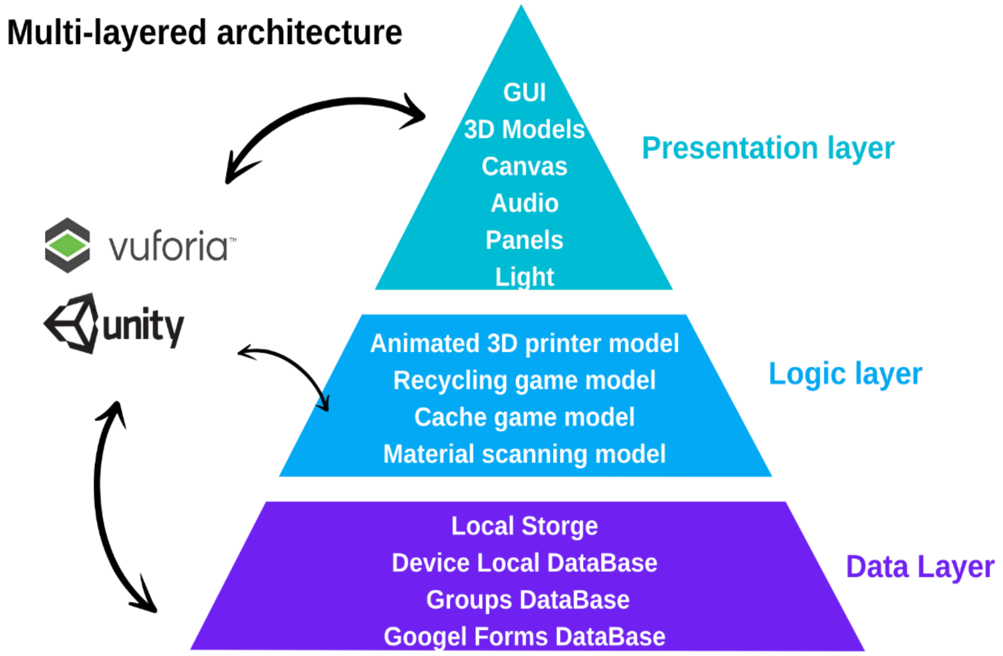


**Figure 2-** image displays multi-layered system architecture

## 3.4. The technological process

- Set up Unity development environment with AR components and plugins such as Vuforia and Model Target.
- Create a new project and configure build settings for ARCore platform.
- Implement scanning and object detection using Vuforia and Model Target.
- Overlay virtual elements on scanned models using AR.
- Provide additional information through text, audio, and images.
- Integrate gamification mechanics and game logic using C# scripts.
- Design intuitive user interface with buttons, panels, and input elements.
- Perform comprehensive testing to identify and resolve bugs and usability issues.

**The technological process flowchart**

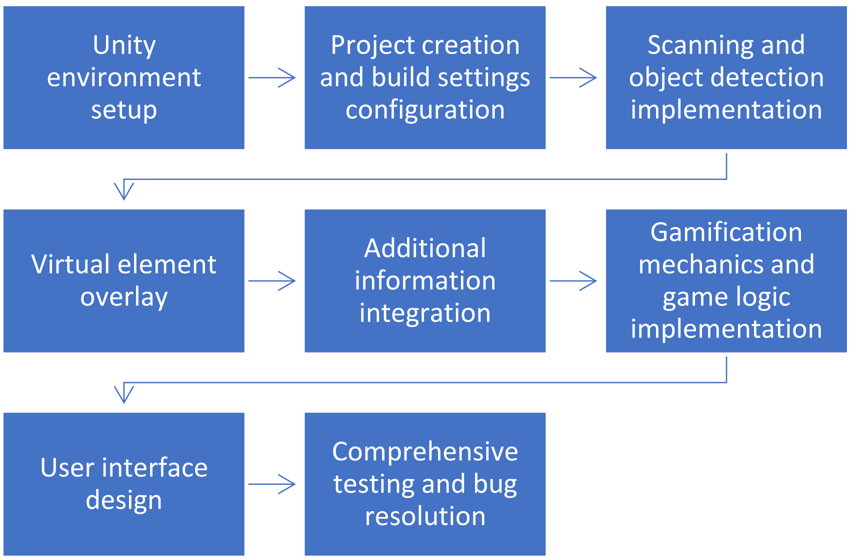


**Figure 3-** image displays the technological process flowchart

# 3.5. Technologies

## 3.5.1. Technological enabler – Unity platform

**Unity** is the world's leading platform for creating and playing real-time 3D (RT3D) content. Creators, from game developers to artists, architects, car designers, filmmakers, and others, use Unity to bring their imaginations to life [20]. Specifically, the Unity platform provides a comprehensive set of software solutions for creating real-time interactive 2D and 3D content for mobile phones, tablets, computers, consoles, and virtual and augmented reality devices.

In the fourth quarter of 2021, Unity averaged 3.9 billion monthly active end users who consumed content created or interacted with its solutions. The apps developed by these creators were downloaded an average of five billion times a month in 2021[20].

Unity gives users the ability to create games and experiences in both 2D and 3D, and the engine offers a primary C# scripting API.

The Unity editor is supported on Windows, macOS, and the Linux platform, while the engine itself currently supports building games for more than 19 different platforms, including mobile, desktop, console, and virtual reality.

Creators can develop and sell user-generated assets to other game makers through the Unity Asset Store. This includes 3D and 2D assets and environments for developers to buy and sell. Unity Asset Store was launched in 2010. By 2018, there were about 40 million downloads through the digital store.

Unity's engine powers some of the world's highest-grossing mobile games, such as Pokémon Go and Activision's Call of Duty Mobile.

## 3.5.2. Technological enabler – Vuforia engine

Vuforia is a comprehensive augmented reality (AR) software development kit (SDK) widely used in the industry known for its advanced capabilities. Vuforia enables developers to easily create AR applications using computer vision technology that enables the detection and tracking of planar images and 3D objects in real time.

This image registration capability allows developers to position and orient virtual objects, such as 3D models and other media, relative to real-world objects when viewed through a mobile device's camera. The virtual object then tracks the position and orientation of the image in real time so that the viewer's perspective on the object corresponds with the perspective on the target. Thus, the virtual object appears to be part of the real-world scene [28].

Vuforia provides Application Programming Interfaces (API) in C++, Java, Objective-C++, and the .NET languages through an extension to the Unity game engine [27].

# 3.6. The tools we will use

**Vuforia:** an AR platform that provides tools for creating augmented reality experiences and offers features such as image recognition and object tracking. In addition, we will use ModelTarget tool for scanning the models in 360 degrees [23].

**Unity:** is a game engine used to develop AR applications and using it as the development environment is useful for building the project.

**Visual studio:** software for editing and running codes for writing scripts in c#.

**Unity Asset Store:** a market where you can find a variety of assets, 3D models, textures, animations, and plugins that we will use to improve the visual quality of the application.

**ARCore:** A mobile AR platform to enable AR features on supported devices.

Git system: version control with which we can manage changes in the project files, share with the team member and track revisions over time.

**Digital camera:** We will need a digital camera to take pictures of objects or to scan physical objects for which we have created models.

## 3.7. The Challenges

**Integrating augmented reality into the project:** working in the Unity development software requires expertise, in addition, the development will support Google's core AR platform, which will require work adapted to it.

**Object scanning and recognition:** object recognition and scanning capabilities using the Vuforia AR platform and the use of a target model for 360 degrees scanning.

**Performance optimization:** in order for the performance to be smooth and the software to run in a reasonable time, optimization techniques should be used to prevent blockages and efficient processing.

**User interface design:** integrating virtual reality seamlessly without blocking the user's field of vision and causing him confusion.

**Virtual reality stability:** ensuring stability in different lighting conditions and environments using the cloud anchors of the AR core.

**The implementation of the games in the application:** requires expertise in game development and the integration of fascinating educational content.

## 3.8. Client Interaction During the Development Process

The Agile methodology was adopted for this project to efficiently deliver a functional product to the client. Agile project management emphasizes an iterative process, where work is conducted in short cycles called iterations or sprints. At the end of each iteration, a working product increment is presented to the client for immediate feedback.

This approach creates a dynamic and adaptable work environment, enabling the team to effectively address changes. Given the limited project timeline, it is crucial to deliver a valuable application to the client. Therefore, the preference is to work in brief intervals, facilitating regular collaboration with the client and incorporating their input throughout the development process. Insights from each iteration are applied to the next, ensuring alignment with the client's requirements. This iterative approach minimizes discrepancies between the client's specifications and the final product, reducing the cost of error rectification through early issue detection and resolution. Actively involving the client in the development process diminishes the likelihood of misalignment between their requirements and the actual implementation. This collaborative approach streamlines development, reduces costs, and results in a product that closely aligns with the client's vision [1].

## 3.9. Algorithms and Functions

Algorithms and possible functions we will use:

1. **Location update function** - track the location of the product on the screen.
2. **Collision check function** - for the purpose of detecting the insertion of a product into the basket.
3. **Image and object recognition** - image/object recognition in space using the device's camera and Vuforia SDK.
4. **Augmented reality** - dressing a three-dimensional model in the user's space virtually.
5. **Sound playing function** - depending on the successful execution of an action.
6. **Unity libraries**

## 3.10. Implementation of SDT principles in the application

| SDT principles in the application | |
|---|---|
| **Autonomy** | Users without prior preparation will perform intuitive operations in the application such as dragging elements and the challenge of scanning models in the environment using the tablet camera, on their own. |
| **Relatedness** | The visitors feel connected through the cooperation required in the tasks and the common goal of each group to be the winner. |
| **Competence** | The users use judgment and critical thinking in the task, in order to succeed in the tasks in the application and solve the puzzles. |

**Table 1 -** SDT principles if the application

# 4. DIAGRAMS

## 4.1. Main Scenarios

The system comprises several primary scenarios, each designed to enhance the user experience and facilitate learning:

1. **Framework Story:** The first scenario serves as the overarching narrative that accompanies the application. It revolves around two brothers who aspire to own bicycles and request them as birthday presents from their father. The brothers interactively purchase the bicycles by dragging products into a virtual basket within the application. The story progresses with one of the brothers falling off his bike and damaging his helmet. The narrative concludes with the suggestion of printing a new helmet using a 3D printer.
2. **Cache Search Game:** The second scenario involves a search for hidden elements scattered throughout the institute's space. Each discovered element contains informative text about 3D printing technologies. Users engage in solving puzzles that guide them to locate these elements, promoting exploration and knowledge acquisition.
3. **3D Printer Operation:** The third scenario focuses on familiarizing users with the operation of a 3D printer. It introduces three essential buttons: material selection, model selection, and activation. Users are prompted to scan the printer using their device, and through augmented reality, virtual buttons are overlaid in the user's space. By interacting with these virtual buttons, users can observe the printer's functionality and gain an understanding of its operation.
4. **Printing Materials:** In the fourth scenario, users are encouraged to scan as many 3D models as possible at the designated station. Upon successful scanning, users can identify the models and access detailed information about each material through virtual displays within their augmented reality space.
5. **Recycling Materials:** The fifth scenario aims to educate users about the environmental impact of waste. The system presents a series of buttons, each corresponding to a specific type of waste. When a button is pressed, information about the ecological consequences of that particular waste is displayed. This scenario involves scanning a photograph and overlaying a virtual model using augmented reality technology.
6. **Recycling Game:** The sixth scenario takes the form of an interactive game where users are required to sort materials into appropriate recycling baskets. The game incorporates auditory feedback to indicate successful actions, enhancing user engagement and reinforcing the importance of proper waste management.

By implementing these scenarios, the system aims to create an immersive and intellectually stimulating tour experience for visitors to the institute. It is anticipated that the integration of augmented reality technology will pique visitors' curiosity, enhance their attentiveness, and facilitate a deeper understanding of the presented concepts.

## 4.2. Use Case

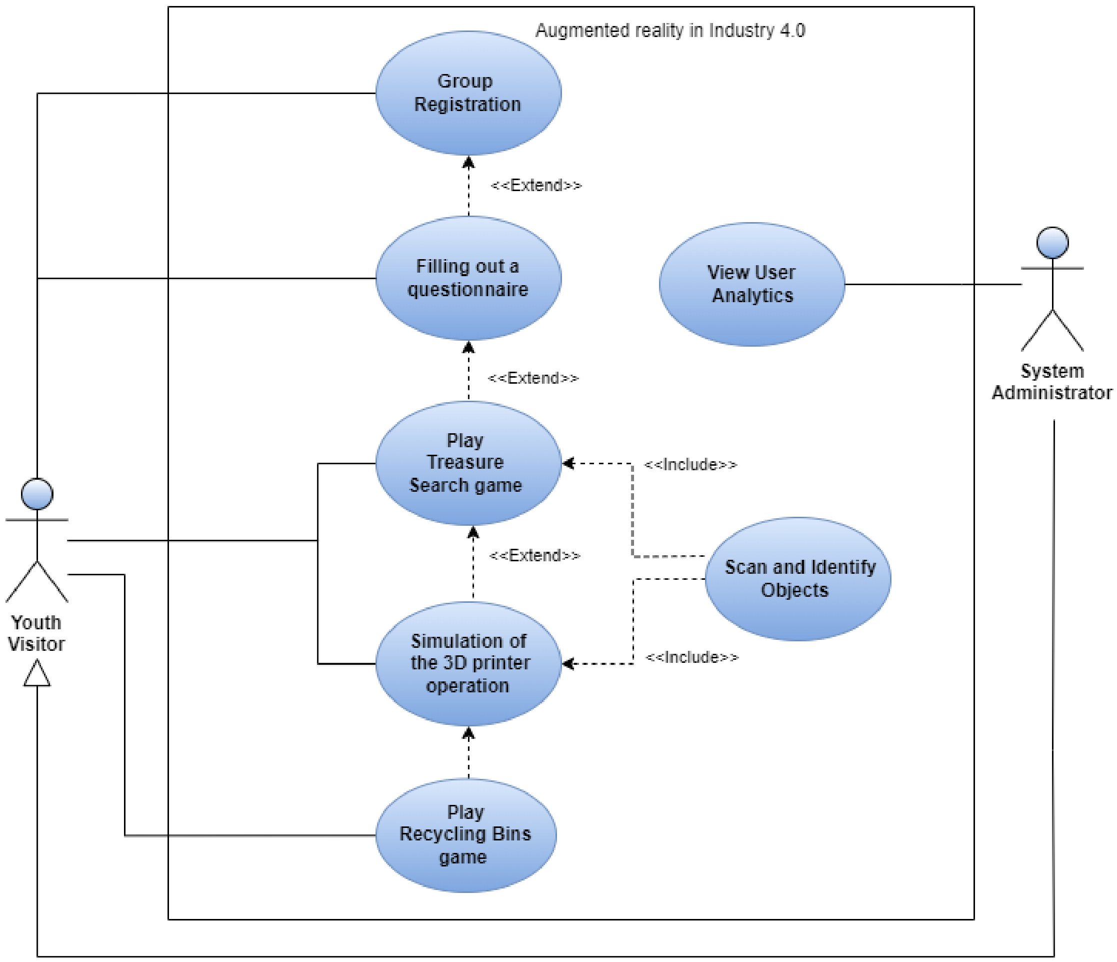


**Figure 4 -** image displays the Use Case

| | |
|---|---|
| **Use case** | Group Registration |
| **Description** | The user fills in the names of the group members for registration |
| **Actors** | Youth Visitor |
| **Triggers** | Clicking the 'Save' button |
| **Initial Conditions** | The user is on the registration screen |
| **Successful Scenario** | **The names are saved successfully.**<br>1. Registration screen: The user navigates to the registration screen, where they are prompted to input the names of group members.<br>2. Inputting group member names: The user enters the names of the group members into the designated fields.<br>3. Clicking 'Save' button: After entering the data, the user clicks the 'Save' button to proceed.<br>4. Input validation: The system validates the input provided by the user.<br>5. Success message: If the input is valid, the system displays a success message confirming that the group has been registered. |
| **Alternative Scenario** | If the user encounters difficulty entering the names due to technical issues:<br>1. The app displays a message suggesting troubleshooting steps, such as restarting the app or checking for updates.<br>2. Alternatively, the app provides a contact option for technical support to assist the user in resolving the issue. |

**Table 1 -** Group Registration

| | |
|---|---|
| **Use case** | Filling out a questionnaire |
| **Description** | The user fills out a questionnaire through a link or QR scan |
| **Actors** | Youth Visitor |
| **Triggers** | Clicking on the questionnaire link or scanning QR. |
| **Initial Conditions** | The user has completed the registration process. |
| **Successful Scenario** | **The questionnaire has been successfully completed and saved.**<br>1. Accessing questionnaire: The user utilizes a link or a QR code to access the questionnaire.<br>2. Clicking the link or scanning the QR code: The user clicks the link or scans the QR code, which directs them to the questionnaire.<br>3. Completing the questionnaire: The user successfully completes the questionnaire, ensuring all questions are answered accurately.<br>4. System acknowledgment: After completing the questionnaire, the system acknowledges the user's completion.<br>5. Smooth transition: The system smoothly directs the user to the next scene |
| **Alternative Scenario** | If the user encounters difficulty accessing the questionnaire due to connectivity issues:<br>1. The app provides alternative access options, such as entering a unique code or accessing the questionnaire offline.<br>2. Alternatively, the app displays a message suggesting troubleshooting steps, such as checking internet connection or trying again later. |

**Table 2 -** Filling out a questionnaire

| | |
|---|---|
| **Use case** | Play Treasure Search game |
| **Description** | The user reads a story and selects elements from the story to continue the activity. |
| **Actors** | Youth Visitor |
| **Triggers** | The user clicks on elements in the story |
| **Initial Conditions** | The previous questionnaire was completed successfully |
| **Successful Scenario** | **The system recognizes the selected elements and continues to the next scene.**<br>1. The user is immersed in a narrative experience that includes interactive elements to select.<br>2. Progressing through the story: As the story unfolds, the user is instructed to click on specific elements within the narrative.<br>3. User interaction: The user clicks on the instructed elements as the story progresses. |
| **Alternative Scenario** | If the system fails to recognize the user's choice due to technical issues or an incorrect click:<br>1. The app displays an error message informing the user about the recognition issue.<br>2. The app suggests potential solutions, such as refreshing the page, checking for updates, or ensuring proper internet connectivity. |

**Table 3 -** Play Treasure Search game

| | |
|---|---|
| **Use case** | Simulation of the 3D printer operation |
| **Description** | The user learns about how a 3D printer works. |
| **Actors** | Youth Visitor |
| **Triggers** | The user presses a button to continue after reading the explanation. |
| **Initial Conditions** | The user has completed the story scene. |
| **Successful Scenario** | **The system displays an explanation about the printer and leads to the next scene.**<br>1. Detailed explanations about 3D printing: The user receives clear and comprehensive information about how a 3D printer operates.<br>2. AR simulation: The user interacts with an AR simulation of the printer, enabling a visual understanding of the process.<br>3. Correct processing: Each action taken by the user is correctly processed by the app, ensuring accurate demonstration of the 3D printing operation. |
| **Alternative Scenario** | If the app encounters technical difficulties or is unable to provide the explanation:<br>1. The app displays a message acknowledging the issue and apologizing for the inconvenience.<br>2. Alternatively, the app prompts the user to try again later, indicating that the issue will be resolved in future updates. |

**Table 4** - Simulation of the 3D printer operation

| | |
|---|---|
| **Use case** | Scan and Identify Objects |
| **Description** | The user scans the printer and selects a model and material for printing. |
| **Actors** | Youth Visitor |
| **Triggers** | The user presses selection and activation buttons. |
| **Initial Conditions** | The user is informed of the information about the printer. |
| **Successful Scenario** | **Scan and identify the objects successfully.**<br>Applying knowledge from previous scene: The user applies the knowledge gained from the previous scene by learning the 3D printer through the app.<br>1. Scanning a model: The user successfully scans a model for the 3D printer using the app's interface.<br>2. Choosing the right material: The user accurately chooses the appropriate material for the selected model.<br>3. Virtual representation: The app displays a virtual representation of the printing process. |
| **Alternative Scenario** | If the app encounters technical issues or the explanation fails to load:<br>1. The app displays a notification informing the user about the difficulty in accessing the explanation.<br>2. It offers alternative options, such as providing a textual explanation within the app or redirecting the user to a troubleshooting guide.<br>3. Alternatively, the app suggests trying again later or checking for updates to resolve the issue. |

**Table 5** - Scan and Identify Objects

| | |
|---|---|
| **Use case** | Play Recycling Bins game |
| **Description** | The user participates in a game where he must sort waste into the correct recycling bins. |
| **Actors** | Youth Visitor |
| **Triggers** | The user starts the game by pressing a start button. |
| **Initial Conditions** | The system displays bins and items for recycling. |
| **Successful Scenario** | **The user sorts all the objects correctly.**<br>1. Engaging in recycling game: The user participates in a recycling game within the app.<br>2. Dragging and dropping items: The user drags virtual items and drops them into the correct recycling bins based on their material or type.<br>3. Correct placements: Each item is placed into the correct bin by the user.<br>4. Positive feedback: Upon successful placement of an item, the app responds with positive feedback, acknowledging the correct action taken by the user.<br>5. Success sounds: Additionally, the app plays success sounds to further reinforce the user's achievements and encourage continued participation in the game. |
| **Alternative Scenario** | 1. If the app encounters technical issues or fails to load the materials cycle game.<br>2. The app displays a notification apologizing for the inconvenience and explaining the issue. |

**Table 6** - Play Recycling Bins game

| | |
|---|---|
| **Use case** | View User Analytics |
| **Description** | The system administrator reviews the responses to the questionnaires that the young participants completed. |
| **Actors** | System Administrator |
| **Triggers** | The system administrator |
| **Initial Conditions** | The system administrator wants to view questionnaire responses and data. |
| **Successful Scenario** | **The questionnaire is filled out successfully and the user ends the application**<br>1. The System Administrator logs into the application<br>2. Selects the option to view questionnaire responses<br>3. The System Application displays the data from Google Forms<br>4. The System Administrator reviews and analyzes the data |
| **Alternative Scenario** | 1. If the Google Forms data is unavailable, display an error message. |

**Table 7** - View User Analytics

## 4.3. Activity Diagram

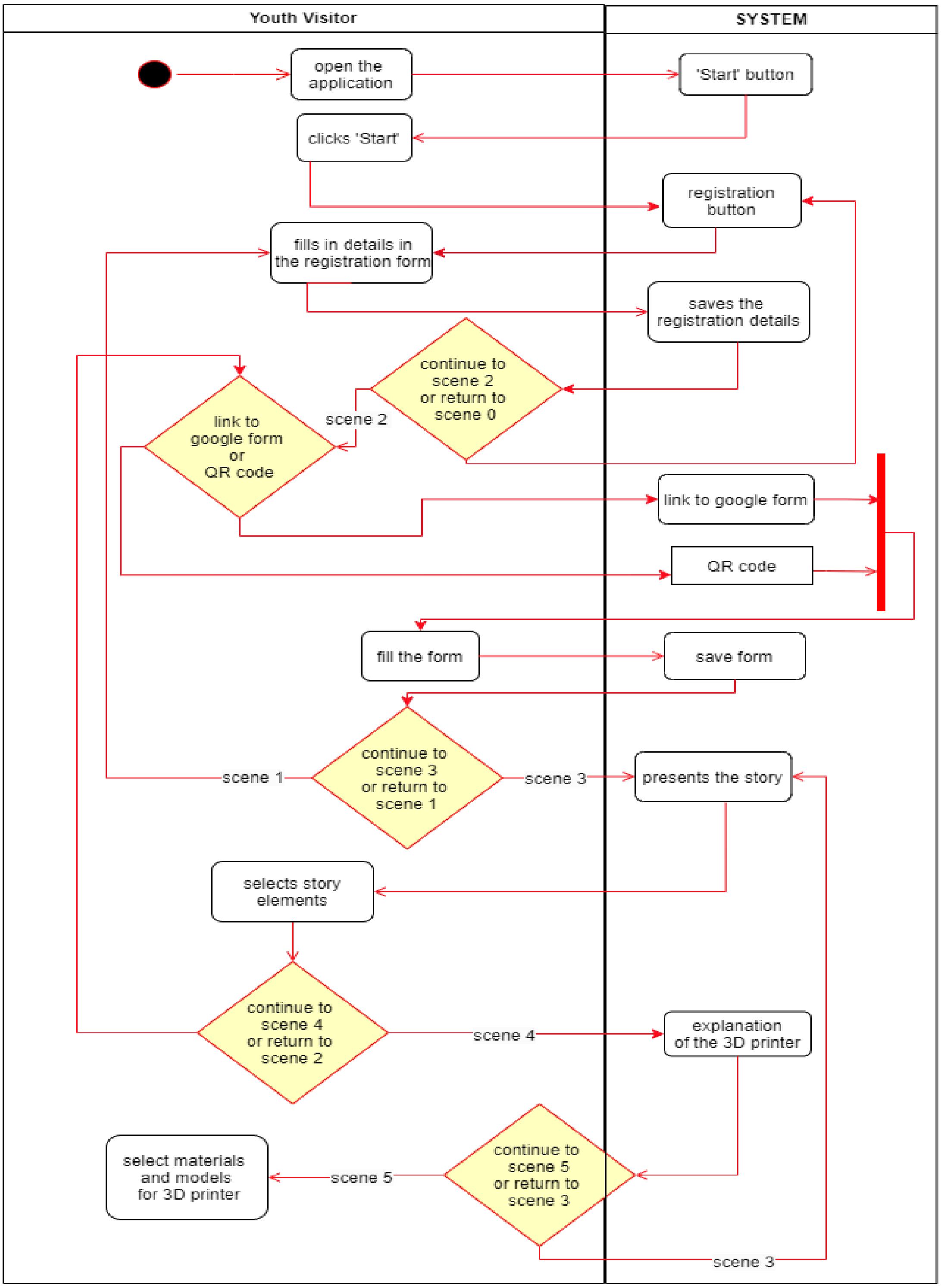


**Figure 5-** image displays the Activity Diagram first half

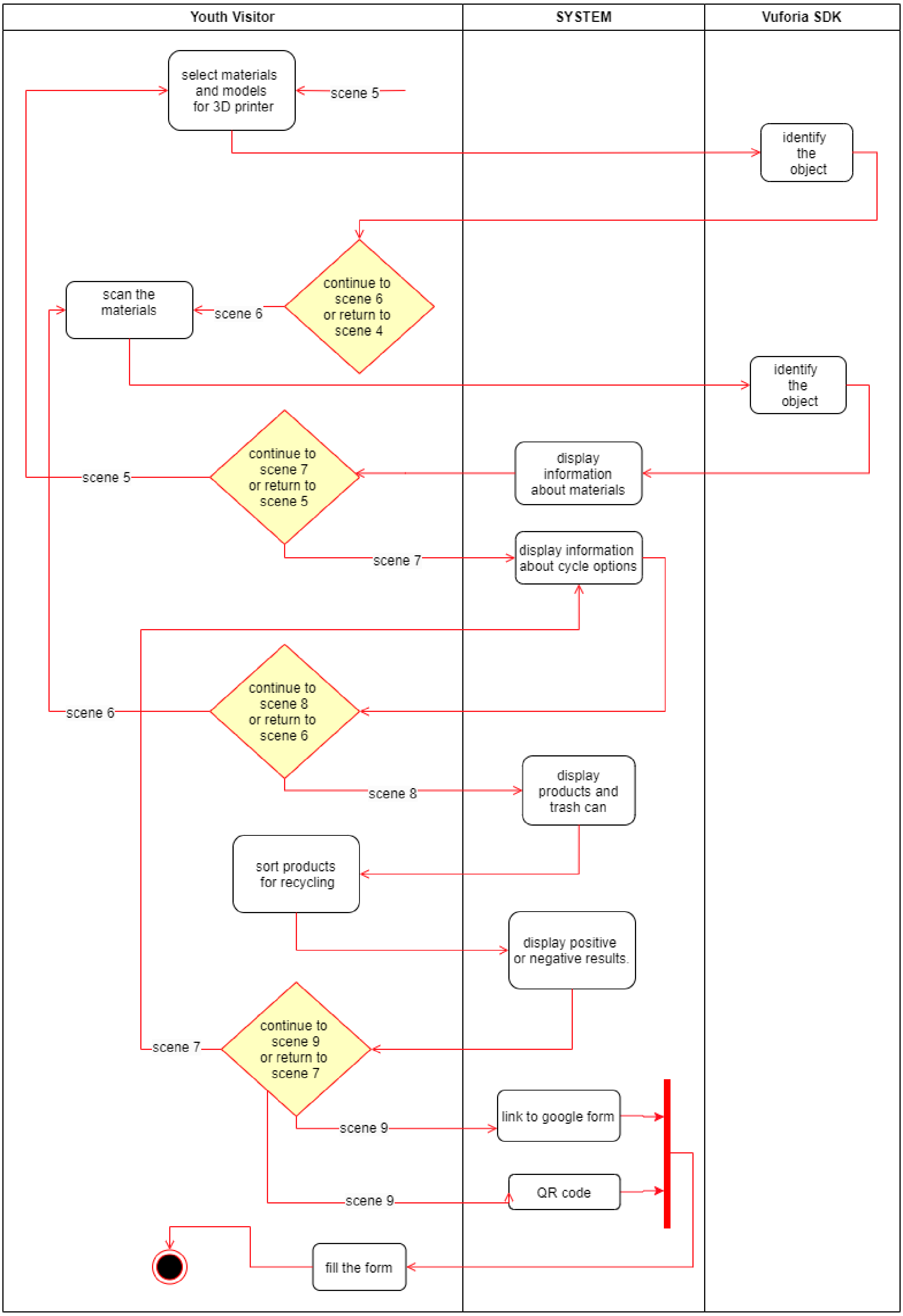


**Figure 6-** image displays the Activity Diagram second half

## 4.4. Class Diagram

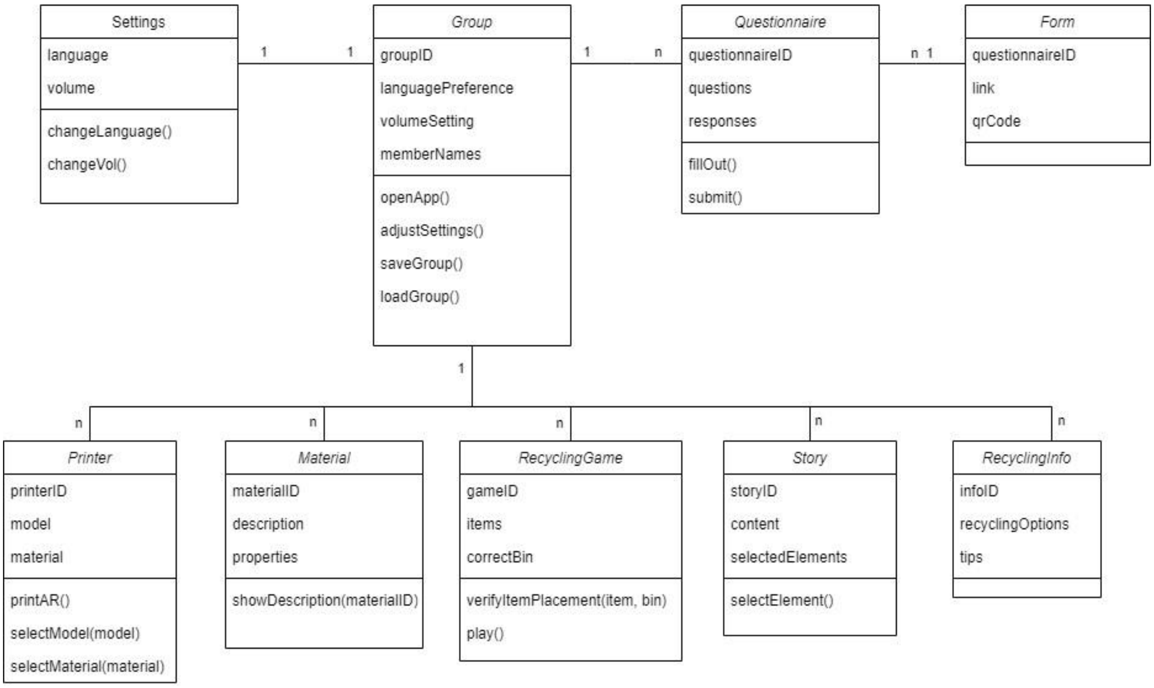


**Figure 7-** image displays the Class Diagram

# 5. GUI Prototype

## 5.1. Prototype

**Scene 0 - Opening:**

Includes an opening screen, a button to go to the next scene and a settings button.

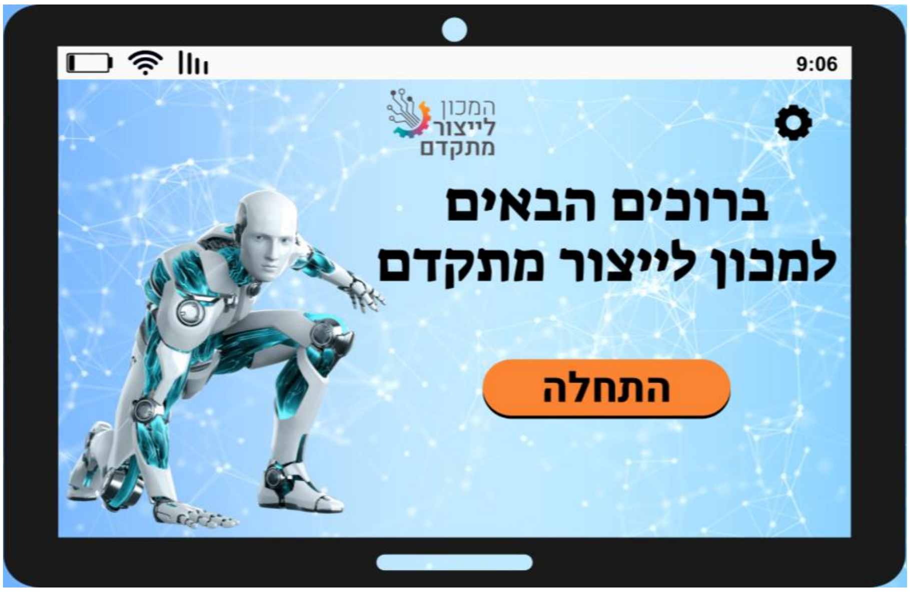


**Figure 8-** image displays the Opening screen

## Settings screen:

Includes the option to change settings -

1. language selection (Hebrew, Arabic or English)
2. Volume change

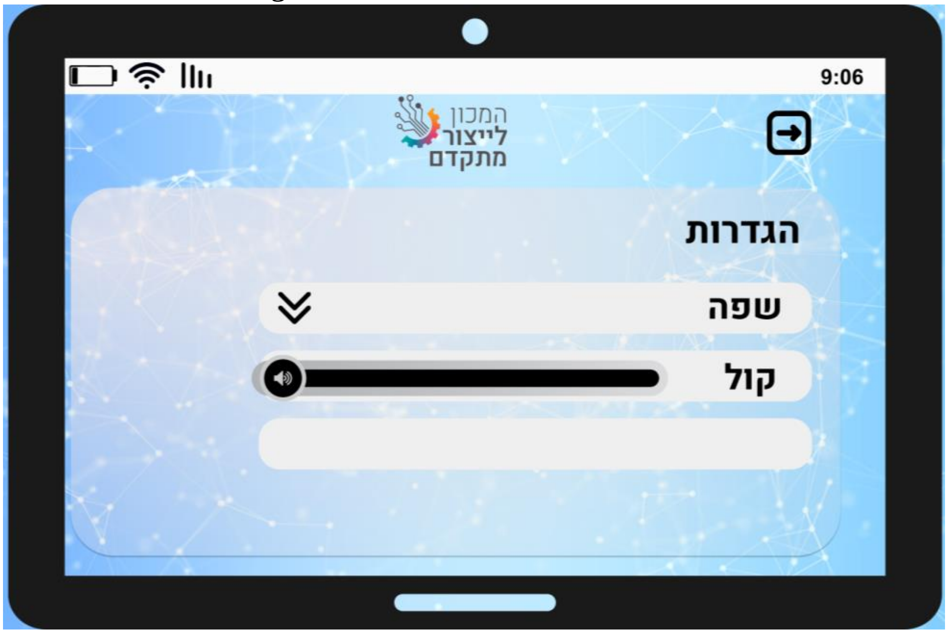


**Figure 9-** image displays the Settings screen

## Scene 1 - Registration:

Includes text box and player selection option.

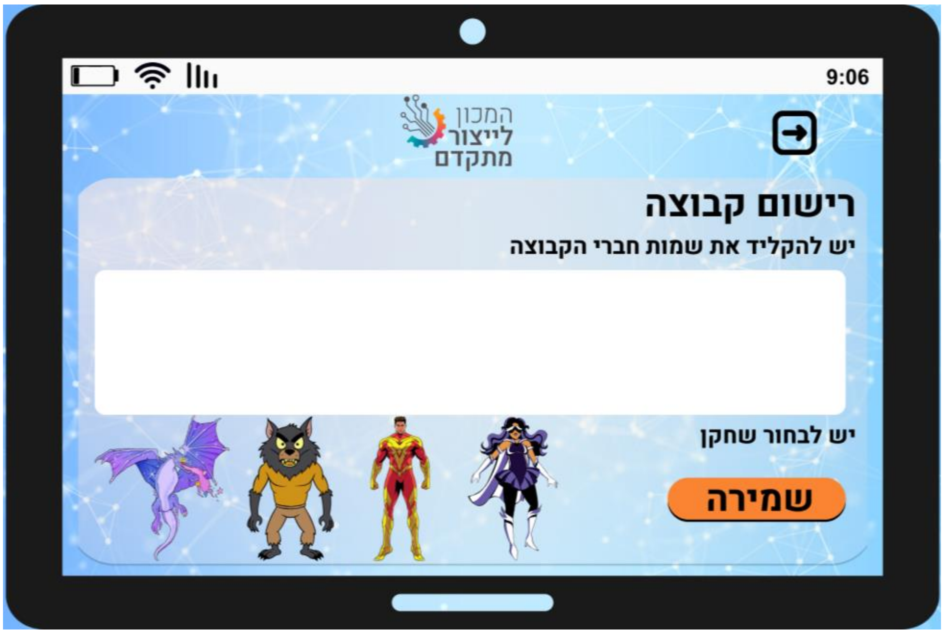


**Figure 10-** image displays the Registration screen

**<u>Pop up for successful registration screen:</u>**

Includes opening a continue button to the next scene.

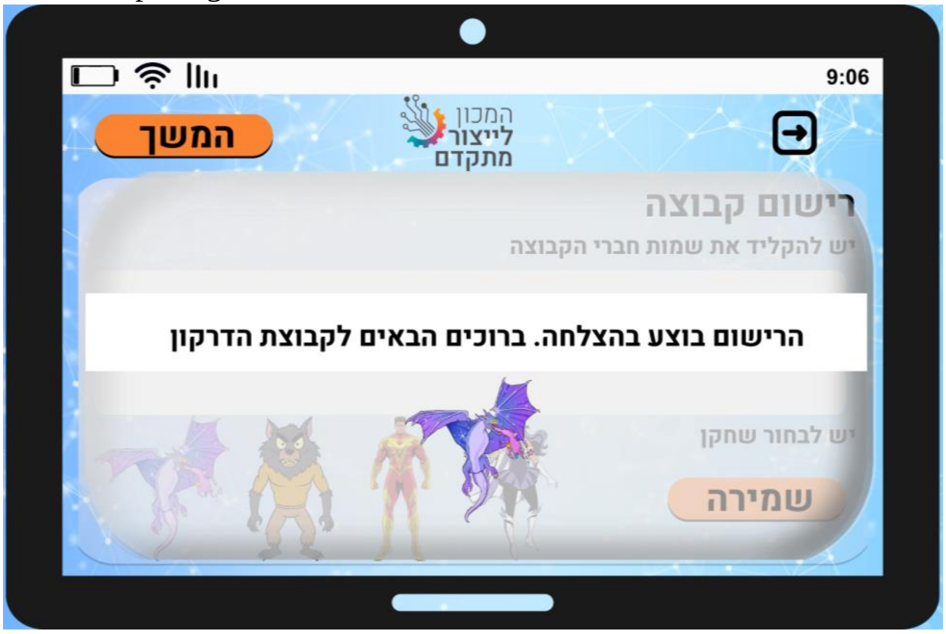


**Figure 11-** image displays Pop up for successful registration screen

**<u>Scene 2 - Opening Questionnaire:</u>**

Includes two options beyond the form - QR and link.
The questionnaire is designed to collect research data to examine the degree of understanding among visitors following the use of the application.

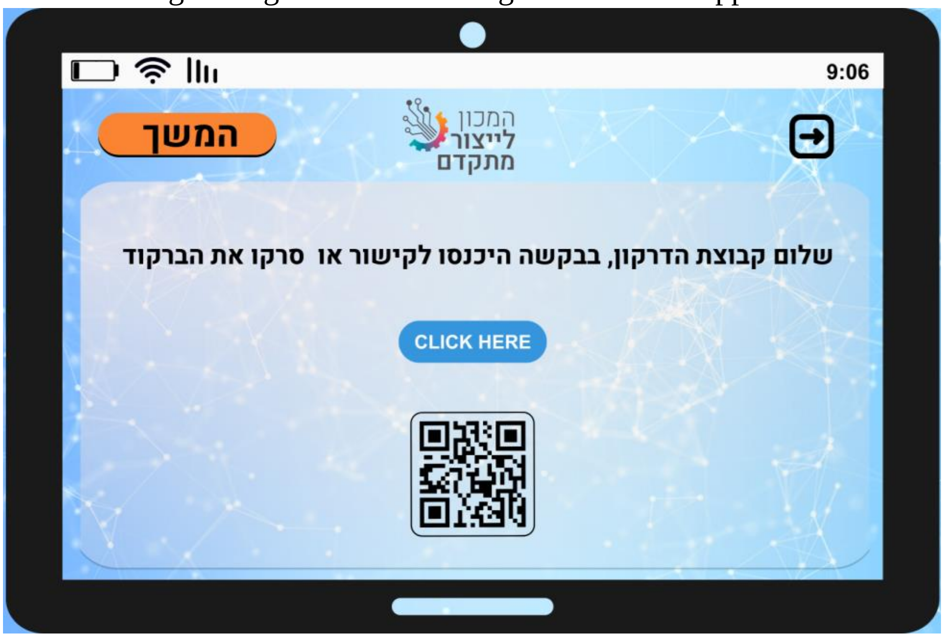


**Figure 12-** image displays the Questionnaire screen

**Scene 3 - Frame story:**

The story will be animated including interaction with the user:


**Figure 13-** image displays the Frame story screen

**Continue the frame story:**

Includes a game of dragging elements into a shopping basket. We expect the participants to drag the elements into the basket intuitively from their experience using similar applications and without any prior training (autonomy).

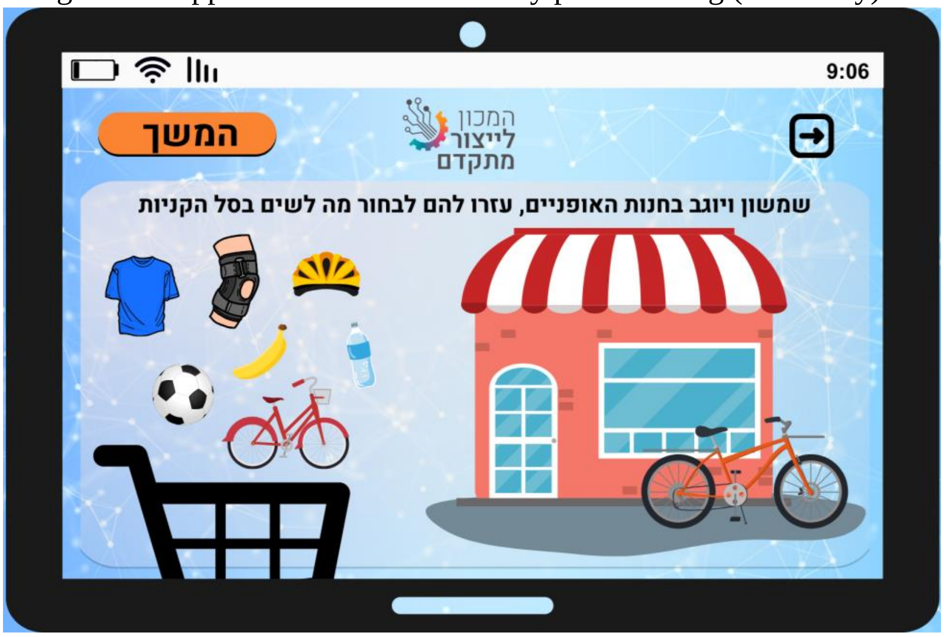


**Figure 14-** image displays the continuation of Frame story screen

## **Continue the frame story**:


**Figure 15-** image displays the continuation of Frame story screen


**Figure 16-** image displays the continuation of Frame story screen


**Figure 17-** image displays the continuation of Frame story screen

## Scene 4 - Explanation of a 3D printer:

The system shows the user a hint according to which the user will recognize the item and scan it. The users are required to be active and scan elements in the space according to the cognitive theory, this increases the active learning process.


**Figure 18-** image displays the 3D printer screen

## Screen when scanning an element:

The system will display an explanatory text related to 3D printing technology. In accordance with the cognitive theory, we present both visual information and verbal information.


**Figure 19-** image displays the 3D printer screen when scanning

**<u>End screen Play the cache:</u>**

Includes a button to go to the next scene


**Figure 20**- image displays Play the cache screen

**<u>Scene 5 - Printer operation:</u>**

Includes 3 buttons on the printer where each button opens a short explanation and a skip button to the next scene. After the explanations are finished, it will be possible to scan the physical printer and identify its model.


**Figure 21**- image displays the printer screen

## Printer scan screen and imaging:

It will be possible to press 3 buttons in augmented reality and simulate the activation of the printer.
Users will be required to face a new challenge of model scanning and virtual operation in augmented reality, staring at the competence principle of the SDT theory.


**Figure 22**- image displays the printer in AR

## Scene 6 - Printing materials:

The user will scan as many models as possible at the station.


**Figure 23**- image displays scanning materials screen

The following example includes opening an explanation screen about the material properties of the model.


**Figure 24**- image displays the continuation of scanning materials screen

**<u>Scene 7 - Material circulation:</u>**

Clicking on any of the three images will display facts on the subject. After opening the three images, the user will press the button to go to the next scene.


**Figure 25**- image displays the materials circulation screen

## Augmented reality simulation screen:

The user will find a picture and scan it and the system will put on the picture a mountain of waste to illustrate a dump and emphasize the importance of protecting the environment. In searching the image for scanning, the users are based on the autonomy principle of SDT so that they do not get any prior knowledge.


**Figure 26**- image displays the materials circulation in AR screen

## Tips screen for the beginner recycler:

Includes a button to go to the next scene.

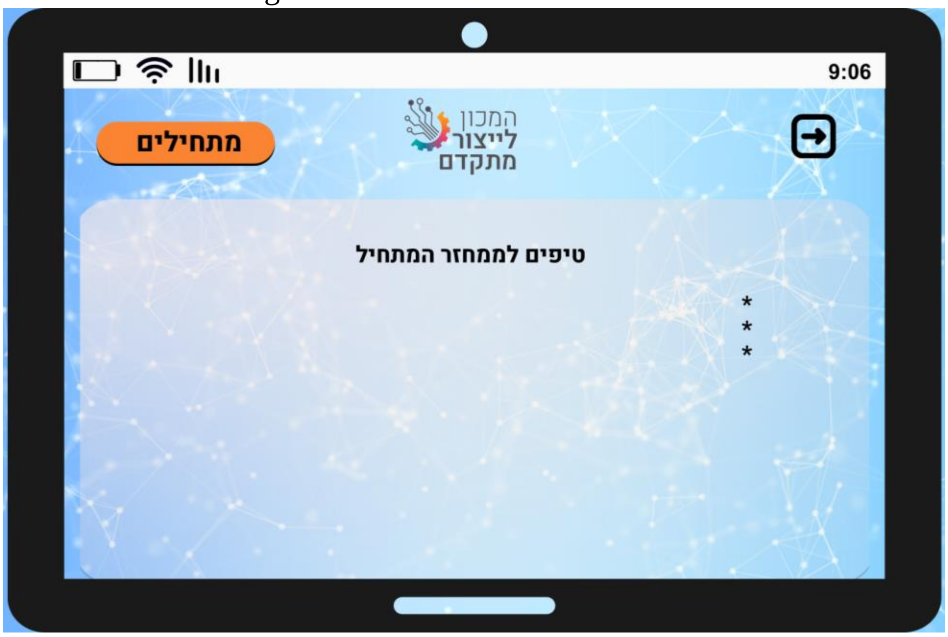


**Figure 27**- image displays the recycler tips screen

**Scene 8 - Materials cycle game:**

Including recycling bins and items that must be classified into the appropriate recycling bin by dragging. Applause sounds will be heard on each successful drag to the basket. Game elements are used in order to allow users to gather integrated information and increase interaction according to the principles of cognitive theory.


**Figure 28**- image displays the Materials cycle game screen

**A pop-up screen that displays a message to the user that the game is over:**

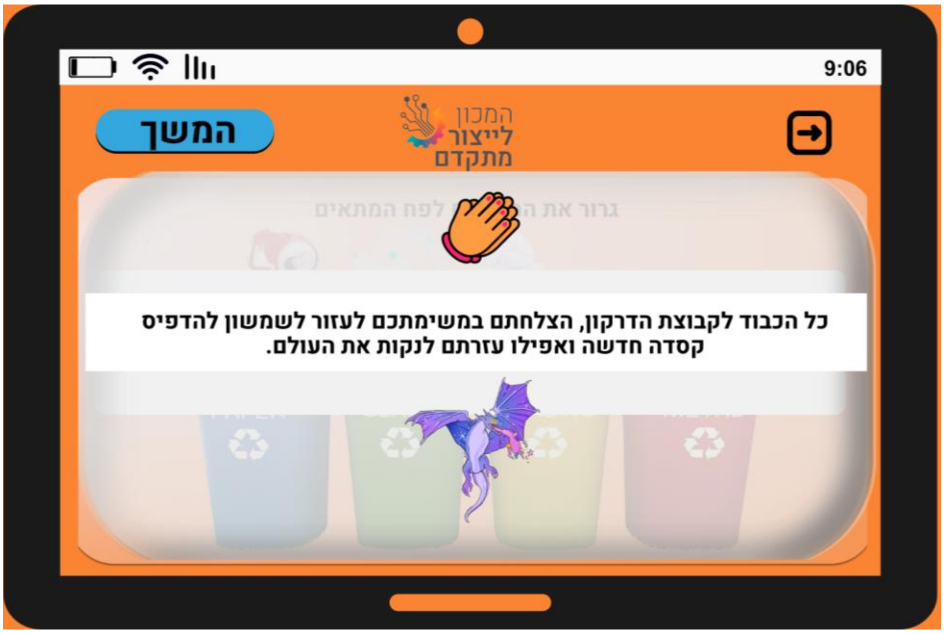


**Figure 29**- image displays pop up screen

**<u>Scene 9 - Final Questionnaire:</u>**

Includes a link button or QR to scan.

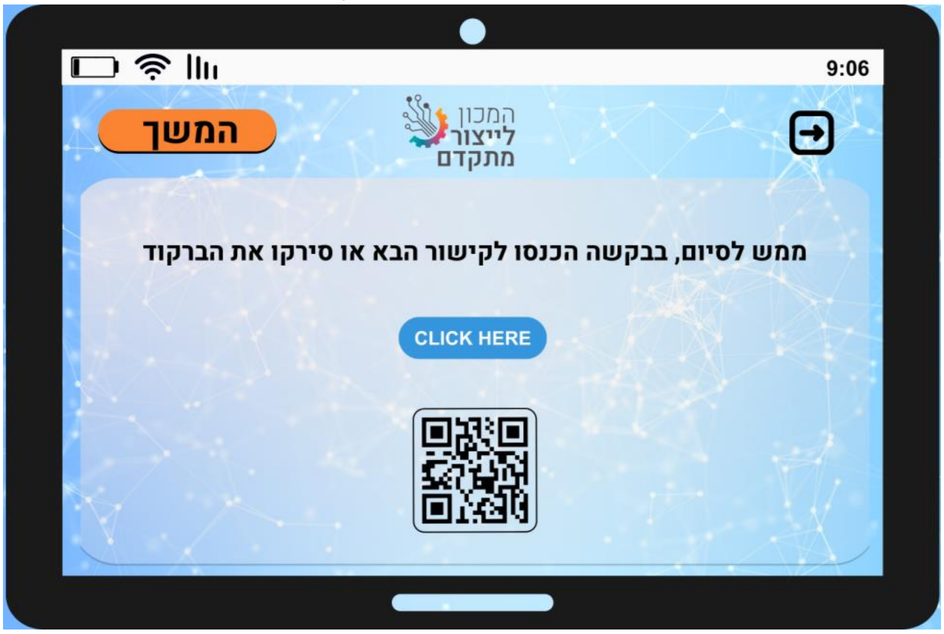


**Figure 30**- image displays the final questionnaire screen

**<u>The end screen includes a button back to the first home page:</u>**


**Figure 31**- image displays the end screen

# 6. EXPECTED ACHIEVEMENTS

During the project we aim to develop a dedicated application for visitor tours of the Advanced Manufacturing Institute.

- The application will focus on presenting technologies in Industry 4.0 where the main innovation of the software will be the integration of augmented reality (AR) as part of the software's capabilities and it will focus on a comprehensive study of 3D printing technologies, presenting possible uses, materials and printing methods.
- The soft application ware will enable the identification of elements in space and the addition of 3D models to the real environment so that visitors can explore and control virtual representations of the technologies in the institute at different angles and sizes and thus better understand how they work.
- The application will combine virtual games, challenging tasks and puzzles and it will also offer virtual rewards that will encourage involvement and active learning.

The application will allow adding additional information, it will combine text, sound, and visual images.
And above all, the software will be accessible, it will be available in different languages such as Hebrew and Arabic so that it will suit the variety of populations.

# 7. EVALUATION

To ensure the success of implementing our application for use by visitors in an advanced manufacturing facility, we will test the technical performance of the system and evaluate the nature of use by the users and the user experience.
Using the success indicators we can evaluate the effectiveness, the impact of the project and how well it meets the goals.
<u>The success indicators of the project:</u>
**User involvement:** through questionnaires we will examine the nature of the use of the application, user interactions and the average duration of use.
**User rating:** we will examine the user experience through questionnaires and satisfaction surveys. We will strive for 85% satisfied users
**Functionality and performance:** through tests we will examine the accuracy of scanning the objects and examine the absence of performance problems and crashes. We aim for 5% object recognition failures.
**Educational impact**: through trivia questions and questionnaires we will examine the improvement of the users' knowledge, the understanding of the concepts we have conveyed and the motivation of the participants to continue learning about the industry and the employment opportunities it offers. In addition, we will collect feedback from educators regarding the effectiveness of the educational components. We aim for an 80% improvement in understanding the material after using the application. and a 90% improvement compared to a control group on a tour without an app.
**Customer satisfaction:** feedback from the representatives of the Institute for Advanced Creation on compliance with the project requirements and schedules. We will examine the customer's satisfaction with the quality of the products and whether there is interest in future improvements and continued cooperation, using standard. We strive for 90% satisfaction from the stakeholders.
**Technical indicators:** We will examine the performance indicators of the application in terms of loading times, device compatibility and memory usage.
**Involvement of the stakeholders:** We will examine the level of involvement and cooperation of the stakeholders throughout the life cycle of the project [22].

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# 9. Appendix

## 9.1 Interviews

### 9.1.1. Interview with Uri Ben Hanan

**An interview with Uri on the subject of planning an interactive and educational tour for youth at the institute.**

**Interview date:** 3.4.24

**Interviewers:** Ido Saada and Bar Steiner

**Interviewee:** Uri Ben Hanan, head of the Institute for Advanced Manufacturing

**Background:**

Uri is a representative of the Institute for Advanced Manufacturing and also acts as a tour guide for visitors to the institute. The students usually arrive without prior knowledge of technology, so the tour is designed to introduce them to concepts related to 3D printing and additive manufacturing in a fascinating way.

**key points:**

**1. Learning approach:**

- Start by showing students something tangible and connect it to a concept (e.g. 3D printing)
- Let the students research and look for relevant examples/applications in the institute
- Provide hands-on activities or simulations for a more interactive experience

**2. Size and structure of the group:**

- Assuming that a class of 40 students is divided into two groups of 20 each
- Divide each group of 20 further into 4-5 smaller groups for focused activities
- Rotate groups through different stations/activities

**3. Flow of tours and activities:**

- Consider holding a 30-minute activity period, followed by knowledge sharing between groups
- Alternatively, conduct an hour-long tour, then gather for a collective debriefing session
- Use pre- and post-tour questions to assess level of knowledge and interest
- Combine different media (3D models, sound, text sections) for a multi-sensory experience
- Focus on building one comprehensive module before replicating to other stations

**4. Key concepts and messages:**

- Presentation of different materials for 3D printing (polymers, metals) and their properties
- Discussion of sustainability aspects (recycling, consumables)
- Explanation of additive manufacturing processes and unique product capabilities
- Emphasize career opportunities and exposure to the industry

### 5. Delivery and communication

- Preference for young instructors for better involvement
- Use simple language and style appropriate for the target age group
- Incorporate interactive elements such as augmented reality, avatars and gameplay
- Leverage existing resources (e.g., videos, presentations from partner companies)

### 6. Adaptability and containment:

- Provide content in several languages (Hebrew, Arabic, English) for accessibility
- Include parents or family members in the experience, if possible
- Respond to different learning styles (visual, auditory, kinesthetic)

### 7. Continuous improvement:

- Conduct pilot tests with a small group to gather feedback and refine the experience
- Collaborate with pedagogical experts to deliver content and deliver effective messages
- Iterate and improve the module based on observations and feedback

The interview highlights Uri's insights and recommendations for creating a fascinating and educational tour experience that exposes the students to the world of 3D printing and industrial production while cultivating interest in an industrial career.