המכללה
האקדמית להנדסה
בראודה
בכרמיאל

Math Learning Quest

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GITHUB:
https://github.com/shirel-G/AR-Learning-Quest.git

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Abstract

Mathematics education presents significant challenges for many students, particularly due to its abstract nature and the lack of engaging, hands-on learning experiences. Augmented Reality (AR) has emerged as a promising tool to bridge this gap by transforming mathematical concepts into interactive and immersive experiences. This paper presents Math Learning Quest, an AR-based educational game designed to enhance students' understanding of fundamental math operations through gamification and real-world interactions. In our approach, students scan a physical surface (such as a table or a piece of paper), where virtual buildings appear as interactive learning hubs. Each building represents a different mathematical operation, and students navigate through the game by solving problems and using gesture-based controls to operate elevators between floors. The game provides real-time feedback, reinforcing problem-solving skills and deepening conceptual understanding through a dynamic learning environment.
We explore the technical challenges of integrating AR into math education, including gesture recognition, stable virtual object placement, and real-time response optimization. Additionally, we evaluate the pedagogical benefits of AR-based learning, such as increased student motivation, improved conceptual retention, and enhanced engagement through immersive, interactive exercises.
Our findings suggest that AR, when combined with gamification, has the potential to revolutionize traditional math instruction by providing an experiential and interactive learning approach. The paper discusses key technological advancements, design considerations, and future opportunities for expanding AR-based educational tools, ultimately aiming to bridge the gap between theoretical knowledge and practical application in mathematics education.

Introduction

Mathematics education has long been recognized as a critical foundation for academic and career success. However, many students perceive math as abstract and challenging, often leading to disengagement and anxiety [5] . Recent advancements in educational technology have opened new avenues to address these challenges, with Augmented Reality (AR) emerging as a promising tool to revolutionize math learning [1] .

AR technology integrates virtual elements into the real world, enabling interactive and immersive learning experiences. Unlike traditional teaching methods, AR provides students with dynamic visualizations, allowing them to explore mathematical concepts in a hands-on manner [2] . Studies have shown that AR enhances students' engagement and motivation, reduces cognitive load, and improves conceptual understanding by bridging the gap between abstract theories and practical applications [4] .

In middle school education, AR applications have been particularly effective in teaching geometry, algebra, and probability. For instance, AR has been utilized to help students visualize geometric shapes, experiment with probability scenarios, and analyze data patterns in real-time [3] . Research highlights that AR not only supports deeper learning strategies but also fosters critical thinking and problem-solving skills [6] .

A case study involving junior high school students demonstrated significant improvements in learning outcomes when AR was integrated into probability and statistics lessons. Students reported higher self-efficacy, deeper conceptual understanding, and increased motivation to learn math [3] . These findings reinforce the potential of AR as an effective pedagogical tool that complements traditional methods and promotes active learning [1] .

This paper aims to integrate Augmented Reality (AR) into a game-based learning environment, where students interact with virtual mathematical structures overlaid onto real-world surfaces. By scanning a physical surface (such as a table or a sheet of paper), students can visualize buildings representing mathematical concepts, engage with virtual elevators through hand gestures, and receive real-time interactive feedback.

The following sections will discuss the theoretical framework, methodology, and results of implementing AR games for mathematics learning, along with practical recommendations for educators.

In this work, we explore the development of an augmented reality (AR) educational game designed to enhance mathematical learning. In **Chapter 2**, we present a literature review covering classroom learning in schools, the role of augmented reality in education—particularly in math—and gamification principles, including its mechanisms, challenges, and opportunities. **Chapter 3** details the engineering process, beginning with key insights from interviews, followed by requirements gathering, evaluation of alternatives, and the application of design thinking methodologies. This chapter also examines different AR approaches, concluding with a discussion on the final product, including its system architecture and content. In **Chapter 4**, we outline the expected achievements, key goals, evaluation criteria, and the anticipated impact of our solution. **Chapter 5** provides system diagrams, including a use case analysis, while **Chapter 6** presents the graphical user interface (GUI) prototype of the "Math Adventure Game." In **Chapter 7**, we define our evaluation and verification plan, including data analytics methodologies. Finally, **Chapter 8** includes references that support our research and development process.

2. Background and Related Work

2.1 Classroom in School

Classrooms in schools have traditionally served as structured environments designed to facilitate knowledge transfer and skill development. They are spaces where teachers utilize various instructional methods, including lectures, group activities, and problem-solving exercises, to engage students in learning [5]. However, these conventional methods often struggle to address the diverse learning needs of students, particularly in subjects like mathematics that require abstract thinking and conceptual understanding [1].

Research highlights that classroom settings can benefit greatly from integrating technology to enhance student engagement and comprehension [2]. Incorporating tools such as multimedia presentations and interactive simulations has shown promise in improving learning outcomes and motivation [4]. Yet, even with these advancements, many students continue to face challenges in grasping complex mathematical concepts, emphasizing the need for more innovative approaches [6].

What is STEM? STEM is an acronym that stands for Science, Technology, Engineering, and Mathematics. It represents an interdisciplinary approach to education that emphasizes hands-on learning, critical thinking, and problem-solving skills. STEM programs aim to prepare students for real-world challenges by particularly in geometry [1]. highlighted how AR reduces cognitive load and facilitates conceptual understanding in STEM education, allowing students to engage more deeply with the material [2].integrating these subjects into cohesive learning models. By combining theoretical knowledge with practical applications, STEM education encourages innovation and fosters a deeper understanding of complex concepts.

AR applications have been shown to significantly enhance students' problem-solving strategies and boost their confidence in mathematics learning environments [6]. These tools allow students to visualize complex geometric structures, simulate mathematical processes, and interact with scientific models in real time, creating tangible connections between abstract theories and practical applications.

For instance, AR modules focusing on probability empower students to conduct hands-on experiments with random events, fostering deeper comprehension of theoretical principles through interactive simulations [6]. Such experiences not only strengthen conceptual understanding but also improve retention and engagement by transforming passive learning into active exploration [3].

Existing solutions:

	Online	Free	AR	Visoualiztaion	Gamification
Khan academy	V	V	X	V	X
Axis learning	V	X	X	V	X
Axis communications	X	X	X	V	X

Table 1 - compering existing solutions

2.2 Augmented Reality

Augmented Reality (AR) enhances the real world by overlaying digital elements such as images, sounds, and interactive content in real-time. The term was first introduced in the 1990s by Boeing researcher Thomas Caudell, but its foundations date back to earlier experiments like the **Sensorama Simulator** and the **Sword of Damocles**.[14] AR is implemented through different methods, including marker-based, markerless, projection-based, and overlay AR. It is widely used in education, healthcare, manufacturing, and entertainment, offering immersive and interactive experiences. While AR continues to evolve, challenges such as hardware limitations and computational demands remain. However, its growing applications are expected to transform industries by improving training, decision-making, and user engagement.[15]

2.2.1 Augmented Reality in Math

The application of AR in education has gained significant attention in recent years due to its ability to enhance learning outcomes. demonstrated that AR can make abstract mathematical concepts more tangible by providing interactive visualizations.

Mathematics often poses challenges for students due to its abstract nature, requiring them to visualize concepts and manipulate symbols mentally. Augmented Reality (AR) addresses these difficulties by providing interactive, visual, and tangible representations of mathematical ideas [1].

AR applications in math education enable students to explore complex concepts such as geometric transformations, algebraic equations, and statistical distributions through hands-on activities [2]. For example, 3D visualizations allow learners to rotate and resize geometric shapes, fostering spatial reasoning skills and a deeper understanding of geometry [3].

In algebra, AR tools assist students in visualizing equations and graphing functions dynamically, enabling them to see the effects of parameter changes in real time [4]. Similarly, in statistics, AR simulations allow learners to experiment with probability models, observe patterns, and analyze data interactively [5].

Research has shown that integrating AR in math classrooms improves problem-solving abilities, enhances engagement, and reduces math anxiety [6]. By providing immediate feedback and encouraging exploration, AR tools create an active learning environment that supports conceptual understanding and retention [1].

In addition to providing immersive visualizations, our project utilizes AR to create a tangible learning experience. Students scan their real-world environment, and the system projects virtual buildings that serve as interactive learning hubs. Unlike traditional AR applications that focus solely on visualization, our game incorporates direct interaction, where students control elevators with gestures and receive real-time feedback on their problem-solving progress.

Overall, AR has proven to be an effective tool for making math education more accessible and engaging. Its applications extend beyond basic arithmetic and geometry to include advanced topics such as algebra, probability, statistics, and calculus [3]. Future developments aim to refine these technologies further, enabling deeper exploration of abstract mathematical concepts, such as functions, vectors, and 3D modeling, through interactive and immersive experiences [3].

2.3 Gamification

Gamification refers to the use of game design elements in non-game contexts to encourage participation and improve outcomes[8]. It integrates mechanics such as rewards, challenges, feedback, and leaderboards to motivate users and sustain engagement. Gamification has been widely adopted in education due to its ability to create immersive and interactive learning environments that enhance motivation and learning outcomes.

[5] explored the integration of gamification within AR-based learning platforms, demonstrating its effectiveness in maintaining students' interest and encouraging active participation. Gamified AR tools, such as interactive puzzles and competitive tasks, have been shown to improve learning outcomes by making mathematics more enjoyable and accessible.

[3] further emphasized that gamification fosters intrinsic motivation, helping students develop a positive attitude toward learning. By incorporating elements like progress tracking, leaderboards, and adaptive challenges, gamified AR platforms align educational goals with engaging experiences. This synergy has proven particularly effective in mathematics, where gamification reduces anxiety and builds confidence.

2.3.1 Mechanisms of Gamification

The key mechanisms of gamification include:

- **Points and Rewards:** Provide immediate positive reinforcement for completing tasks.
- **Leaderboards:** Foster competition and encourage continuous improvement.
- **Challenges:** Incorporate tasks that require problem-solving and critical thinking to engage students actively.
- **Levels:** Gradually increase task difficulty to support a structured learning progression, allowing students to build confidence and mastery step-by-step.
- **Feedback Loops:** Offer real-time feedback to guide performance and learning.
- **Badges:** Reward students with visual tokens for completing tasks or reaching milestones, providing a sense of accomplishment.
- **Achievements:** Highlight significant progress and mastery of concepts to motivate continued engagement and effort.

These mechanisms leverage psychological principles, such as reinforcement and achievement motivation, to sustain user interest and promote deeper learning [8]. By combining these elements, gamification creates an environment where students feel motivated to learn while being actively engaged in the material.

Mechanism	Description	AR Implementation Example
Points & Rewards	Reinforce behavior with points or collectibles earned for completing tasks.	Virtual coins or stars appearing after solving a math problem.
Leaderboards	Rank students based on performance to encourage competition and improvement.	AR displays rankings on virtual boards updated in real-time.
Challenges	Provide tasks that require problem-solving and critical thinking.	Interactive AR puzzles requiring students to manipulate virtual objects.
Levels	Increase task difficulty gradually to build skills and confidence.	Unlock new AR environments or tools as levels are completed.
Feedback Loops	Offer immediate responses to guide and correct performance.	AR highlights errors visually or animates solutions for correct answers.
Badges	Recognize achievements with virtual tokens displayed in AR.	Award 3D badges that students can collect and view through AR apps.
Achievements	Motivate long-term engagement by celebrating milestones.	Unlock virtual trophies or animations for reaching learning goals.

Table 2 - gamification elements in the game

2.4 Challenges and Opportunities

While AR and gamification offer numerous benefits, their successful implementation in educational contexts requires overcoming several challenges. Despite its potential, integrating Augmented Reality (AR) into educational settings presents several challenges. **Technological barriers** remain a primary concern, as many schools lack the necessary infrastructure, including high-quality devices and stable internet connections, to support effective AR deployment [4]. Additionally, **teacher training** is crucial for successful implementation. Educators require proper guidance and professional development to integrate AR tools effectively into their teaching practices; without adequate training, the potential benefits of AR may go underutilized [6]. Another significant challenge is **cognitive overload**, particularly for students who are unfamiliar with AR technologies. The initial learning curve can be overwhelming, highlighting the importance of designing **intuitive and user-friendly interfaces** to ensure accessibility and ease of use [2]. In addition to these general AR challenges, our specific implementation introduces **unique technological and pedagogical challenges:**

- **Ensuring Accurate Hand Gesture Recognition:** Since our game allows students to control in-game elevators through hand gestures, the system must reliably detect and translate movements without lag. Implementing a **robust hand-tracking algorithm** and optimizing real-time response times are critical for maintaining a seamless user experience.
- **Stable Virtual Object Placement:** The AR system must ensure that virtual buildings remain **anchored to real-world surfaces** without unintended movement or distortion. This requires advanced **surface detection and tracking algorithms**, as well as the ability to adapt to different lighting conditions and environmental factors.
- **Minimizing Cognitive Load in Multi-Sensory Interactions:** Our AR system overlays interactive math elements onto real-world environments, which demands **simultaneous attention** to both digital and physical elements. To avoid overwhelming students, the UI must prioritize clarity, **visual hierarchy**, and **incremental complexity** in interactions.
- **Latency in Real-Time Feedback:** For an immersive learning experience, it is crucial that the AR system provides **immediate and responsive feedback** when students solve problems and interact with virtual objects. This requires **efficient data processing and optimized rendering techniques** to maintain real-time interactivity.

Despite these challenges, the growing accessibility of AR technology and its proven effectiveness in enhancing learning outcomes present a significant opportunity to revolutionize mathematics education. With targeted investments in **infrastructure and teacher training**, AR can become a **cornerstone of modern education**, bridging the gap between theoretical knowledge and practical understanding.Moreover, our approach—**combining AR with gamification and interactive problem-solving**—positions this technology as a **transformative tool** for engaging students in mathematics. By allowing students to interact with **spatially anchored mathematical objects**, use **gesture-based controls**, and receive **real-time feedback**, our system fosters a **deep, hands-on learning experience** that is both **engaging and pedagogically sound**.

3. Engineering Process

3.1Process Overview

The development process for this project began with identifying the need to improve mathematics education for young students through augmented reality (AR) technology. This stage involved conducting a comprehensive literature review and gathering insights from teachers and students to better understand existing challenges and requirements.
In the initial phase, we defined both functional and non-functional requirements, focusing on interactivity, accessibility, and user-friendliness. These requirements served as the foundation for the design and development of the platform.

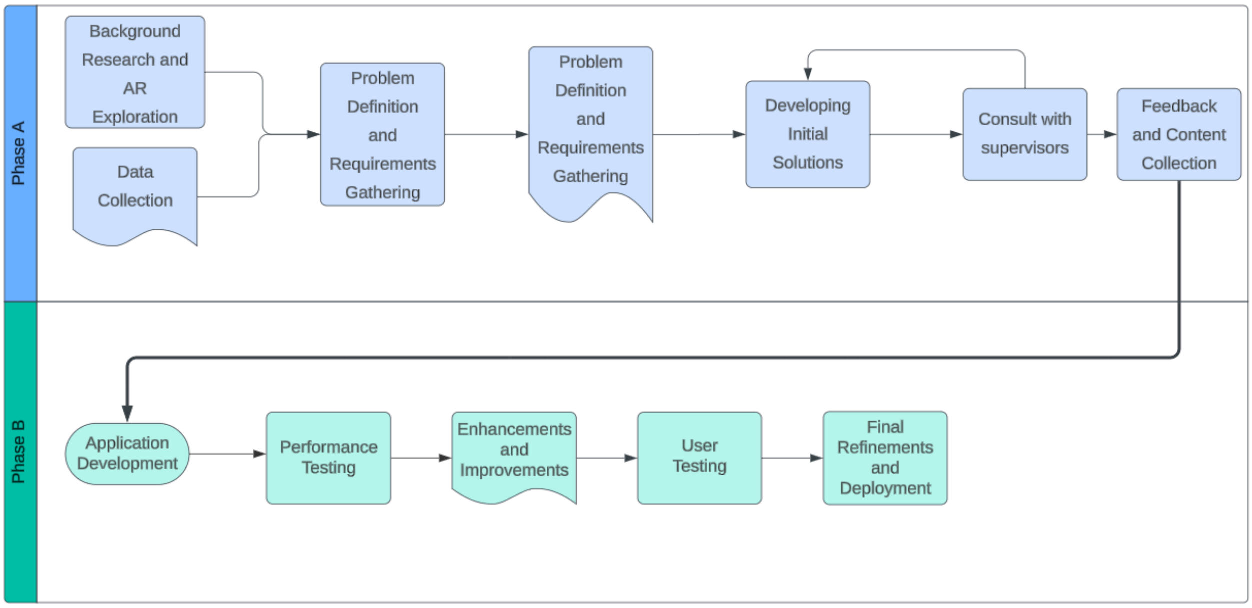

Figure 1- image displays work process flow

3.1.1 Interviews main conclusions:

. Through interviews with key stakeholders like Tchia and Mali, a math teacherd with a lot of experience, we identified major challenges:

in the first interview with Tchia the conclusions were:

- **Engagement:** Students find math boring and disconnected. Tchia noted, “They need to see math in action to connect with it.”

- **Retention:** Teachers highlighted difficulties in helping students retain concepts beyond the classroom.
- **Practical Application:** Students often struggle to see the relevance of math. Tchia explained, “Showing real-world uses of math can transform their perspective.”

in the second interview with Mali the conclusions were:

- **Gamification is essential**—students need motivation to practice outside the classroom.
- **AR should cater to different learning styles**, making math **visual and interactive**.
- **Linear functions and slopes** may be a **better fit for AR visualization** than the number line.
- **Collaboration boosts engagement**—group-based AR challenges could enhance learning outcomes.

  These insights will help refine our **game mechanics, topic selection, and user engagement strategies**. Mali also expressed interest in **testing the game with her students**, which could provide valuable feedback during development.

Our AR solution aims to make math interactive, improve retention, and connect theory to real-life applications.

3.2 Requirements Gathering Process

The requirements gathering process for this project employed a multi-dimensional approach to ensure the development of an effective and engaging augmented reality (AR) platform for teaching mathematics. The process began with a thorough literature review to align system requirements with cognitive learning principles, emphasizing visualization, interaction, and motivation enhancement.

Observations and interviews were conducted with educators, school administrators, and students to better understand the challenges of teaching mathematics in traditional classrooms and the opportunities for integrating AR technology. Additionally, discussions with developers and AR specialists provided insights into the constraints and possibilities of the Unity platform, which was selected as the development framework.

Educators emphasized the importance of a simple, intuitive interface that promotes interactivity and engagement. Students highlighted the need for gamified experiences to maintain interest and foster motivation. Feedback from stakeholders emphasized accessibility, ensuring that the platform accommodates diverse learning needs, including students with disabilities.

A collaborative brainstorming session with teachers and technology experts further refined the requirements, ensuring the platform supports modern teaching methods while remaining easy to use and scalable.

Functional Requirements

1. **Marker Recognition and Interaction:**
   The system will support scanning and identification of physical markers or objects using the device's camera, enabling seamless interaction with augmented content.
2. **Content Overlay:**
   The platform will dynamically overlay interactive 3D models, animations, and mathematical visualizations to simplify abstract concepts and promote understanding.
3. **Gamification Features:**
   Gamified elements such as tasks, challenges, levels, badges, and leaderboards will be integrated to enhance engagement, motivation, and learning outcomes.
4. **Real-Time Problem-Solving Activities:**
   The system will enable interactive mathematical exercises, including simulations and tasks designed for real-time exploration of concepts like number lines and arithmetic operations.
5. **Feedback and Progress Tracking:**
   The platform will include mechanisms for data collection and analysis to provide real-time feedback, track user performance, and monitor progress for improvement.
6. **Adaptive Learning Paths:**
   Teachers and students will be able to customize exercises and activities to align with individual learning goals, allowing flexible and adaptive pathways.
7. **Environment Scanning:** The system must detect a physical surface and place virtual buildings accordingly.
8. **Gesture-Based Interaction:** The application should allow students to trigger elevator movements using hand gestures.
9. **Real-Time Feedback:** The system should visually and interactively respond to student input, showing the movement of the elevator upon solving math problems.
10. **Collaboration Tools:**
    The system will support collaborative activities, enabling students to work in groups, share solutions, and discuss mathematical strategies through AR-based tools.
11. **Multimedia Integration:**
    The platform will incorporate audio, video, and text annotations to support diverse learning styles and enhance comprehension.
12. **Offline Functionality:**
    Key features, including marker recognition and task completion, will

operate offline to ensure uninterrupted access even without internet connectivity.

13. **Teacher Dashboard and Analytics:**
    A dedicated dashboard will allow educators to monitor student progress, generate reports, and assess performance trends for better instructional planning.
14. **Support for Multiple Devices:**
    The system will be compatible with tablets, smartphones, and AR glasses, offering flexibility in deployment and use.
15. **Export and Sharing Features:**
    Users will be able to export reports and share results via email or cloud storage, promoting collaboration between students and educators.
16. **Interactive Tutorials and Guides:**
    Built-in tutorials and guided instructions will help students and teachers quickly familiarize themselves with the platform's features.

Non-Functional Requirements:

1. **Performance:** The platform will ensure a response time of up to 1.5 seconds for object recognition, content rendering, and user interactions to maintain smooth and immersive experiences.
2. **Reliability:** Error-handling mechanisms will provide informative messages and recovery options to prevent disruptions during use.
3. **Usability:** The interface will be intuitive, with clear instructions, tooltips, and multilingual support (Hebrew, English, and Arabic) for accessibility and ease of navigation.
4. **Compatibility:** The platform will be designed using modular principles, supporting easy scalability and integration with external systems and version control tools (e.g., Git).
5. **Maintenance:** The system will include well-documented code, technical manuals, and user guides to simplify debugging, updates, and feature enhancements.
6. **Resource Efficiency:** Optimizing memory and CPU usage minimizes energy consumption, contributing to extended battery life for mobile devices. By reducing background processes, lowering CPU wake-ups, and optimizing data retrieval, the application can operate more efficiently, consuming less power. we will use tools like *Battery Historian* (Android) or *Energy Usage* in Xcode Instruments (iOS) to monitor the app's power consumption before and after optimization . External power meters can also measure real-time energy usage during app execution.
7. **Security:** User data will be stored securely in a password-protected database with AES-256 encryption, ensuring data confidentiality. Additionally, all data transmitted between the client and server will be encrypted using TLS 1.3, preventing unauthorized interception. These encryption protocols ensure compliance with data protection regulations and enhance overall security.

8. **Accessibility:** The platform will include features for disabled users, such as adjustable fonts, high-contrast themes, keyboard navigation, and auditory support for visual content.
9. **Data Integrity:** Mechanisms for data validation, error logging, and input verification will ensure accuracy and reliability during data processing.
10. **Scalability:** The system will support expansion to accommodate new features and larger datasets without performance degradation.
11. **Cross-Platform Support:** The platform will be compatible with iOS, Android, and web-based platforms, ensuring accessibility on different devices and operating systems.
12. **Logging and Monitoring:** The system will include activity logs and error tracking tools for administrators to monitor performance and troubleshoot issues effectively.
13. **Compliance with Standards:** The design and implementation will follow IEEE 1633, which provides best practices for software reliability. For usability, we will comply with ISO 9241-11, ensuring the game is easy to use and user-friendly. Additionally, ISO/IEC 27001 will be followed to protect user data and maintain security. These standards help improve the game's reliability, usability, and data protection.

This process ensures that the AR platform meets both pedagogical and technical requirements, creating a scalable and impactful solution for mathematics education.

3.3 Evaluate Alternatives

3.3.1 Design Thinking

Design Thinking is a user-centered, iterative approach for solving complex problems by focusing on user needs, redefining challenges, and developing creative solutions (Brown, 2009). It is widely used in education and software development to promote innovation and ensure the final product meets user requirements. The process includes five key phases—**empathize**, **define**, **ideate**, **prototype**, and **test**—allowing teams to gather insights, generate ideas, create prototypes, and refine solutions based on user feedback.

In developing the "Teaching Math with AR" project, we applied Design Thinking to address the challenges of teaching abstract mathematical concepts.

Empathize Phase

We began by empathizing with students and teachers, identifying their challenges and needs through interviews and observations. **Personas** were developed to represent typical users of the system. For instance:

- **Student Persona:**
    - Name: Dolev, 12 years old
    - Goals: Improve understanding of math concepts, enjoy interactive learning experiences
    - Frustrations: Finds traditional math lessons abstract and hard to visualize
- **Teacher Persona:**
    - Name: Tchia, math teacher with 15 years of experience
    - Goals: Use innovative tools to make math concepts more engaging for students
    - Frustrations: Limited access to interactive teaching resources

To deepen our understanding, we created a **Empathy Map** focusing on these personas:

Student :

- **What they say:** want math to feel more like a game.
- **What they think:** Students worry about failing.
- **What they feel:** Students feel intimidated by abstract math concepts.
- **What they do:** Students disengage when lessons are static.

Teacher :

- **What they say:** It's hard to keep students engaged.Some students just don't get it, no matter how much I explain.
- **What they think:** I need better tools to make math exciting.
- **What they feel:** Frustration when students struggle or disengage.
- **What they do:** Try different teaching methods but struggle to make math interactive.

Define Phase

From the empathy phase, we defined the core challenge as: **"How might we use AR to make abstract math concepts tangible and engaging for students while providing teachers with effective teaching tools?"**

Ideate Phase

We brainstormed various solutions, applying divergent thinking to generate ideas and convergent thinking to refine them. Key ideas included:

- Gamified lessons with progress tracking.
- Interactive 3D simulations to visualize math operations.
- Collaborative activities to encourage group problem-solving.

Prototype Phase

A prototype was developed, incorporating math games, progress tracking, and interactive 3D simulations. This prototype aimed to address the needs identified in the empathy and define phases.

Test Phase

The prototype was tested with students and teachers through surveys, focus groups, and analytics. Feedback was gathered to evaluate usability, engagement, and educational impact. Insights from this stage informed iterative improvements to the solution.

This comprehensive application of Design Thinking ensured the solution was practical, engaging, and aligned with user needs.

3.3.2 Indirect AR and Direct AR in aducation

In **educational AR applications**, **direct AR** integrates digital content seamlessly into the real-world environment, allowing users to interact with virtual objects in their physical surroundings through **smart glasses or mobile AR**.[16] This creates a highly immersive learning experience, such as visualizing a number line on a desk. **Indirect AR**, on the other hand, confines digital elements within a screen-based view, where students interact with 3D models or animations without real-world alignment. While **direct AR** enhances engagement through immersion, it requires specialized hardware, making **indirect AR** a more accessible and scalable option for mobile learning. Choosing between them depends on **user experience goals, technological feasibility, and hardware availability**.

In this stage, we apply **design thinking** to explore different concepts, followed by **convergent thinking** to refine and select the best alternatives. Below are three primary alternatives for the "Teaching math with AR" project.

Alternative 1: Structured Learning Path

- **Platform:** Android\IOS mobile or tablet application
- **Gameplay Approach:** Guided progression through mathematical operations
- **Main Scenes:**
    - **Building 1:** Learning addition through augmented reality (AR-assisted explanations)
    - **Building 2:** Exploring subtraction with interactive AR exercises
    - **Building 3:** Understanding multiplication through step-by-step AR visualization

Alternative 2: Immersive AR Exploration

- **Platform:** Android\IOS mobile or tablet application
- **Gameplay Approach:** Fully immersive AR environment for real-world interaction
- **Main Scenes:**
    - **Building 1:** Addition problems visualized in real-world environments
    - **Building 2:** Subtraction operations integrated with physical objects
    - **Building 3:** Division concepts explained through interactive 3D models

Alternative 3: Gamified Math Challenges

- **Platform:** Android\IOS mobile or tablet application
- **Gameplay Approach:** Challenge-based learning with real-time problem-solving
- **Main Scenes:**
    - **Building 1:** A multi-operation interactive challenge using direct AR
    - **Building 2:** Unlockable AR-based math puzzles that encourage exploration
    - **Building 3:** Competitive mini-games where players solve math problems to advance

	Alternative 1	**Alternative 2**	**Alternative 3**
Technology	Indirect AR	Direct AR	Direct AR
Educational value	High (reinforces fundamental math concepts)	High (apply math in real world AR scenarios)	Medium (focuses on engagement through games)
Development complexity	Low (simpler AR with basic overlays)	High (requires real-time AR interactions)	Medium (AR combined with complex game logic)
Interactivity	Low (step-by-step guided exercises)	Medium (students manipulate AR elements)	High (students solve challenges in real-time)
Gamification	Minimal (traditional learning with AR aid)	Medium (learning through AR-enhanced tasks)	High (competitive puzzles, unlocking

			rewards)
Target Audience	Middle school students (ages 12-15)	Middle school students, teachers, and parents	Middle school students who enjoy challenges
Fun Factor	Low (structured learning)	Medium (interactive,hands on learning)	High (game-based, problem solving approach)

Table 3 – Solution Alternatives Evaluation

3.4 Product

3.4.1 Solution

For the **"AR math learning"** project, **Alternative 3** was chosen because it offers **high interactivity, strong gamification elements, and an immersive learning experience**, making it ideal for **middle school students (ages 12-15)**. By utilizing **direct AR technology**, the game encourages hands-on engagement, allowing students to interact with mathematical concepts in a **dynamic, challenge-based environment**. The combination of **AR-driven puzzles, competitive problem-solving, and progressive challenges** creates an enjoyable yet educational experience. This approach ensures that students remain engaged while reinforcing essential math skills through interactive and game-like learning.

3.4.2 System Architecture and Technologies

System Architecture:
The architecture follows a layered approach with three main layers: **Presentation Layer**, **Application Layer**, and **Database Layer**.

- The **Presentation Layer** in **Unity** updates the UI with **AR learning content**, including **gamified visualizations, tutorial videos, interactive text, and audio feedback**. Built with **Unity's UI system and AR Foundation**, this layer interacts directly with the **Application Layer** to present **real-time data, user progress, and adaptive AR elements**.

- The **Application Layer** processes game logic through modules such as the **Math Game Module**, **Feedback Module**, and **Analytics Module**. These modules provide dynamic interactions, real-time feedback, and progress tracking.
- The **Database Layer** manages user data, game progress, and AR content. It uses **local storage** and **caching** to enable offline functionality and ensures quick access to datasets like math content and interactive activities.

Technologies Used:

- **Unity Game Engine**: For creating 3D models, animations, and interactive environments. Enables gesture-based interactions for controlling elevators.
- **Vuforia SDK**: Provides AR tracking and object recognition capabilities, including model training for math objects like numbers and operators. Used to recognize and map physical surfaces where buildings are projected.
- **Real-Time Physics Engine**: Simulates elevator movement in response to user input.
- **Backend Database**: Examples include **Firebase** or **SQLite** for storing progress, preferences, and puzzle solutions.
- **Unity Analytics**: Tracks user interactions, progress, and engagement metrics to tailor learning experiences.

AR Process:
The AR system works as follows:

1. **3D Models Creation**: Mathematical objects (e.g., numbers, operators) are modeled in Unity.
2. **Tracking and Recognition**: Vuforia SDK identifies physical objects and overlays AR math problems and interactive elements.
3. **Interactive Gameplay**: Players interact with AR elements, such as solving math problems or manipulating number lines, which dynamically update based on user input.
4. **Feedback and Analytics**: Unity Analytics tracks user progress, providing insights into engagement and areas needing improvement.

3.4.3 Application Content

To create an effective and immersive system, the following components will be implemented:

Audio:

- **Narration**: Guides users through game instructions, offers hints, and explains math concepts.

- **Game Characters**: Virtual math mentors or teachers provide interactive feedback and progress updates.

Scenes:

- Each level includes narrated instructions (e.g., “Solve the puzzle to unlock the next building”) to enhance user engagement.

Models:

- **Math Operations Models**: Interactive 3D models for numbers, operators (addition, subtraction), and puzzle pieces.
- **Characters**: Virtual teachers or guides modeled in 3D to assist users during gameplay.
- **Environments**: Vibrant and dynamic environments, representing buildings or spaces where math operations occur, designed to appeal to children.

Gamified Visualizations:

- Visual elements such as progress bars, badges, and rewards to reinforce user engagement.

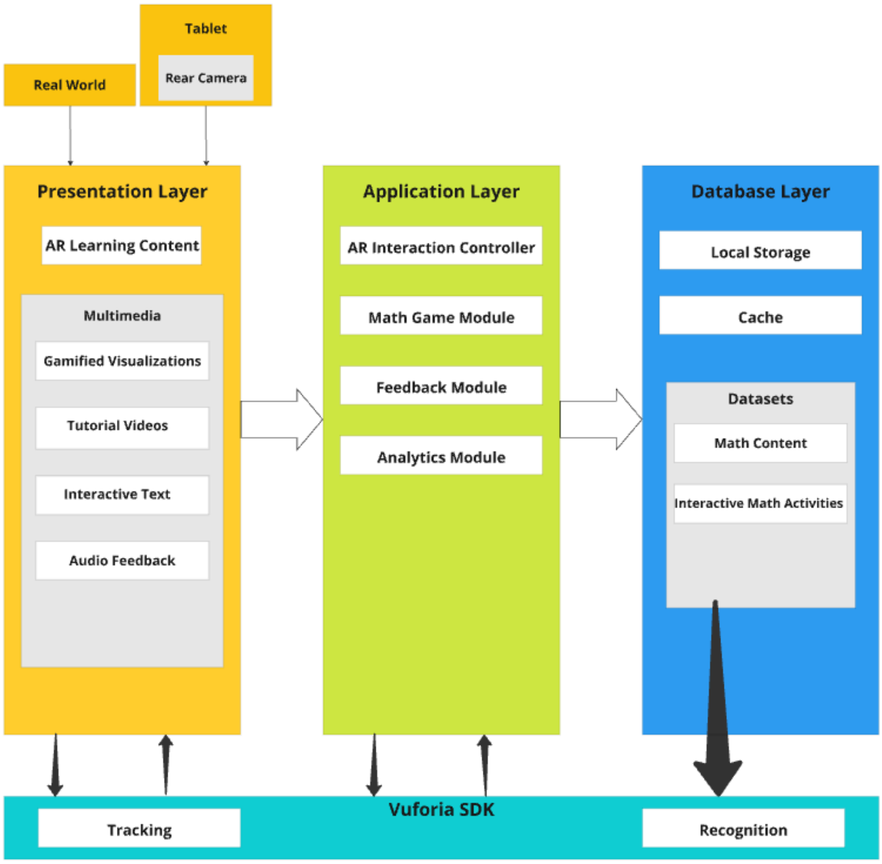

Figure 2 – The application architecture

4. Expected Achievements

This project aims to develop an AR-based platform that enhances mathematics learning by transforming abstract concepts into tangible, interactive experiences. Through gamified elements and visualizations, the platform will promote active participation, improve comprehension, and encourage a positive attitude toward mathematics. It will also support critical thinking, problem-solving skills, and boost students' confidence. Designed for accessibility, the platform will be compatible with affordable devices to ensure seamless adoption in classrooms.

4.1 Key Goals

- **Simplify abstract mathematical concepts** such as number lines and operations through **interactive AR models** for a more engaging and intuitive learning experience.

- **Integrate gamification mechanisms** like **points, badges, and challenges** to sustain motivation and encourage active participation.
- **Enhance critical thinking and problem-solving skills** by promoting **exploration and experimentation** with mathematical operations.
- **Ensure a user-friendly design** that makes the platform **accessible and adaptable** for different educational levels and classroom environments.
- **Support scalability** to accommodate **various learning needs**, allowing educators to customize content based on students' progress.

4.2 Evaluation Criteria

1. **Knowledge Improvement**
    - Conduct **pre- and post-tests** to measure conceptual understanding.
    - Expect an **increase of X points** (based on interview data) in students' math scores after using the platform for a set period.
2. **Engagement and Motivation**
    - Track **average time spent on the platform** per session.
    - Measure **task completion rates**, aiming for at least **Y% of students** completing all assigned activities.
    - Use **gamification analytics** (e.g., points earned, badges unlocked) to assess engagement levels.
3. **Usability and User Experience**
    - Conduct **student and teacher surveys** using a **Likert scale (1-5)** to measure ease of use, clarity of instructions, and overall satisfaction.
    - Aim for at least **Z% of users rating the platform as "easy to use" (4 or 5 out of 5).**
4. **Skill Development**
    - Analyze **error rates in problem-solving tasks** to track improvement.
    - Measure the **time taken to complete exercises**, expecting a **decrease in average response time** after multiple sessions.
5. **Classroom Integration**
    - Conduct **observations and interviews** with teachers to assess how smoothly the platform integrates into lessons.
    - Aim for at least **X% of teachers** reporting that the platform is **easy to incorporate** into their teaching practices.
6. **Long-Term Knowledge Retention**
    - Perform **follow-up tests** after one month to determine how much information students retain.
    - Expect at least **Y% retention of key concepts**, based on post-test vs. follow-up test results.

4.3 Expected Impact

- **Enhance Mathematical Understanding**: Improve students' ability to solve arithmetic and geometric problems using **AR-based visualizations**. Target a **10-15% increase** in test scores based on pre- and post-assessments.
- **Increase Student Engagement**: Ensure that at least **80% of students complete** assigned activities, with a minimum of **70% of students using the platform for at least 30 minutes per session**.
- **Boost Motivation Through Gamification**: Track **achievement progression** (badges, points, and challenge completions), aiming for **75% of students unlocking at least three levels** within the first month.
- **Improve Confidence in Math Skills**: Through student surveys, aim for at least **85% of students reporting increased confidence** in problem-solving after using the platform for four weeks.
- **Ensure Usability and Accessibility**: Based on **teacher feedback and usability testing**, aim for **90% of educators rating the platform as easy to integrate** into lessons.
- **Measure Long-Term Knowledge Retention**: Follow-up tests after one month should indicate at least **70% retention** of newly learned concepts.

5. Diagrams

5.1 Use Case

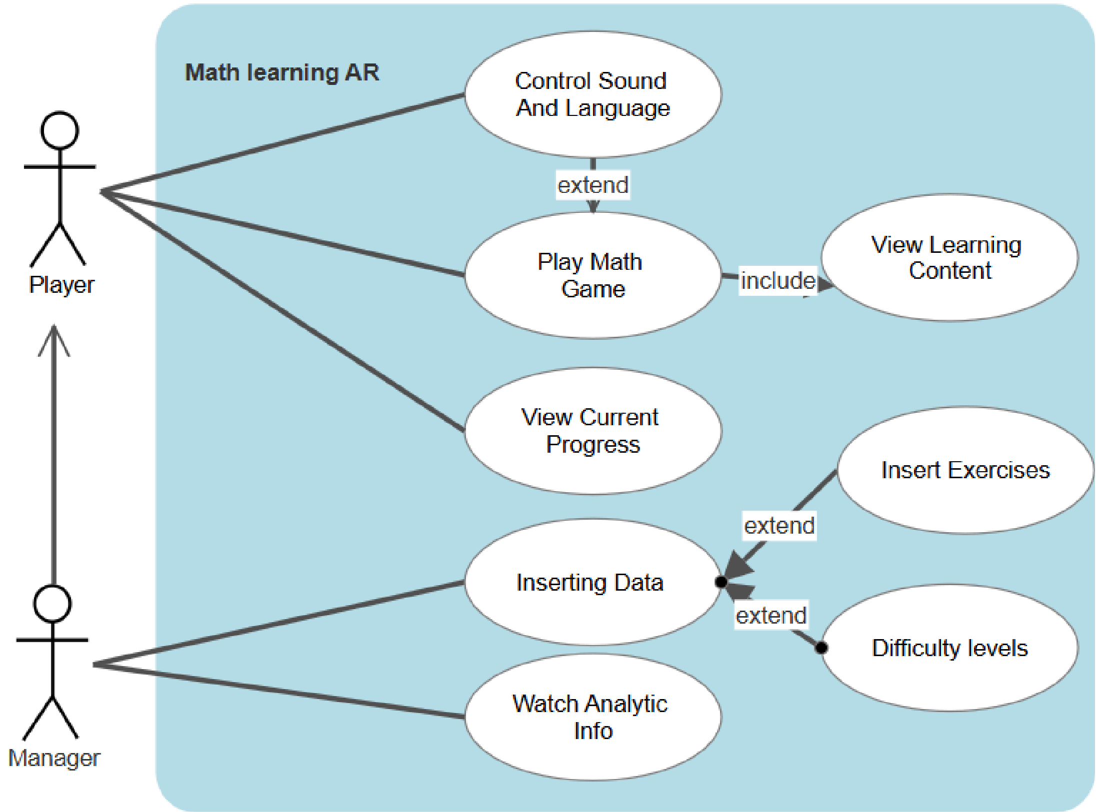

Figure 3 – The application use-case

Use case	Control Sound and Language
Description	Allows the player to adjust the sound and language settings of the application.
Actors	Player
Triggers	"Settings" icon clicked
Successful Scenario	1. The system opens the settings view. 2. The player adjusts the sound or language settings. 3. The system saves the updated settings. 4. The player exits the settings view.
Alternative Scenario	The player cancels the changes and exits the settings view without saving.

Table 4 - Control Sound and Language

Use case	Play Math Game
Description	Allows the player to engage with interactive math challenges in AR.
Actors	Player
Triggers	Game start button clicked
Successful Scenario	1. The system loads the math game. 2. The player interacts with the game challenges. 3. The system records the player's progress and scores. 4. The player completes the game session.
Alternative Scenario	The player exits the game before completion, and progress is not saved.

Table 5 - Play Math Game

Use case	View Learning Content
Description	Provides access to educational content related to the math challenges.
Actors	Player
Triggers	Game session starts
Successful Scenario	1. The system loads the relevant learning content. 2. The player reviews the content as part of the game. 3. The player exits the content view when ready to continue the game.
Alternative Scenario	-

Table 6 - View Learning Content

Use case	View Current Progress
Description	Allows the player to see their progress, scores, and completed challenges.

Actors	Player
Triggers	"Progress" icon clicked
Successful Scenario	1. The system displays the progress dashboard. 2. The player reviews their current progress and scores. 3. The player closes the dashboard.
Alternative Scenario	-

Table 7 - View Learning Content

Use case	Watch Analytic Info
Description	Allows the manager to monitor overall player analytics and performance.
Actors	Manager
Triggers	Admin dashboard accessed
Successful Scenario	1. The system opens the admin dashboard. 2. The manager views player activity and analytics. 3. The manager filters data for specific metrics. 4. The manager exits the dashboard.
Alternative Scenario	The manager encounters errors loading analytics or data.

Table 8 - Watch Analytic Info

Use case	Inserting Data
Description	Allows the manager to insert new exercises and configure difficulty levels for the math challenges.
Actors	Manager
Triggers	"Insert Data" button clicked
Successful Scenario	1. The system displays the data insertion interface. 2. The manager selects the type of data to insert (e.g., exercises or difficulty levels). 3. The manager inputs or uploads the data. 4. The system validates and saves the data. 5. The manager receives confirmation and exits the interface.

Alternative Scenario	The manager cancels the operation or encounters an error, and no data is saved.

Table 9 - Inserting Data

Use case	Insert Exercises
Description	Allows the manager to add custom exercises to the platform.
Actors	Manager
Triggers	"Insert Exercises" option selected within data insertion.
Successful Scenario	1. The system loads the exercise creation form. 2. The manager inputs the exercise details, including questions and answers. 3. The system validates the data and saves the exercises. 4. The manager confirms and exits the form.
Alternative Scenario	The manager cancels the process, and the exercises are not saved.

Table 10 - Insert Exercises

Use case	Insert Difficulty Levels
Description	Allows the manager to configure difficulty levels for math challenges.
Actors	Manager
Triggers	"Difficulty Levels" option selected within data insertion.
Successful Scenario	1. The system displays the difficulty level settings. 2. The manager defines or adjusts levels and criteria. 3. The system saves the updated settings. 4. The manager exits the interface.
Alternative Scenario	The manager cancels the process, and changes are not saved.

Table 11 - Insert Difficulty Levels

6. GUI Prototype

6.1 Math Adventure Game

1. Game Entry & Setup

- The player opens the game and sees the **main menu**.
- Options:
  - **"New Game"** → Starts a fresh game.
  - **"Continue"** → Loads previous progress.
- If starting a new game:
  - The player enters a **nickname**.
  - A short **introduction video/tutorial** explains how to interact with AR elements.
  - The player scans a flat surface to **position the AR game environment (math buildings)**.

2. Stage Selection & Mission Briefing

- The player selects a **math building**, each representing a different math operation.
- The **first stage (Addition Building)** is unlocked by default.
- A **mission briefing screen** appears:
  - Displays the **goal** (e.g., "Solve 5 addition problems to unlock the next building").
  - Provides an **AR demonstration** of how to interact with objects.

3. Solving Math Problems (Core Gameplay Loop)

- The player enters the building and interacts with AR objects representing numbers.
- The game presents **math challenges** in a **real-world setting**, such as:
  - Dragging **virtual numbers** into place to complete equations.
  - Using **hand gestures** or tapping to select answers.
  - Moving an **elevator between floors** to find the correct sum or difference.
- After submitting an answer:
  - **Correct answer** → A positive animation plays, points are awarded.
  - **Incorrect answer** → A hint appears, and the player can retry.

4. Feedback & Progression

- After completing all questions in a stage:
  - The player sees a **summary screen** with:
    - Score
    - Time taken
    - Number of correct attempts

    - Based on performance, players **earn stars or badges**.
    - Unlock the **next building** (e.g., **Subtraction Building**).

5. Game Completion & Final Reward

- After completing all buildings (Addition, Subtraction, Multiplication, Division), the player unlocks a **final challenge**.
- Upon completion, they receive a **final reward**, such as a **custom avatar upgrade** or **special animation**.
- A **leaderboard or achievement board** shows top-performing players.

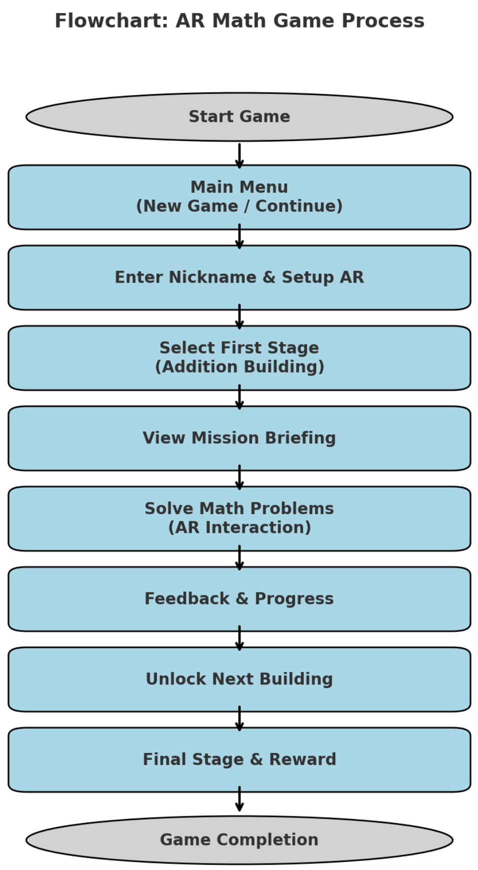

Figure 4 – The application flowchart

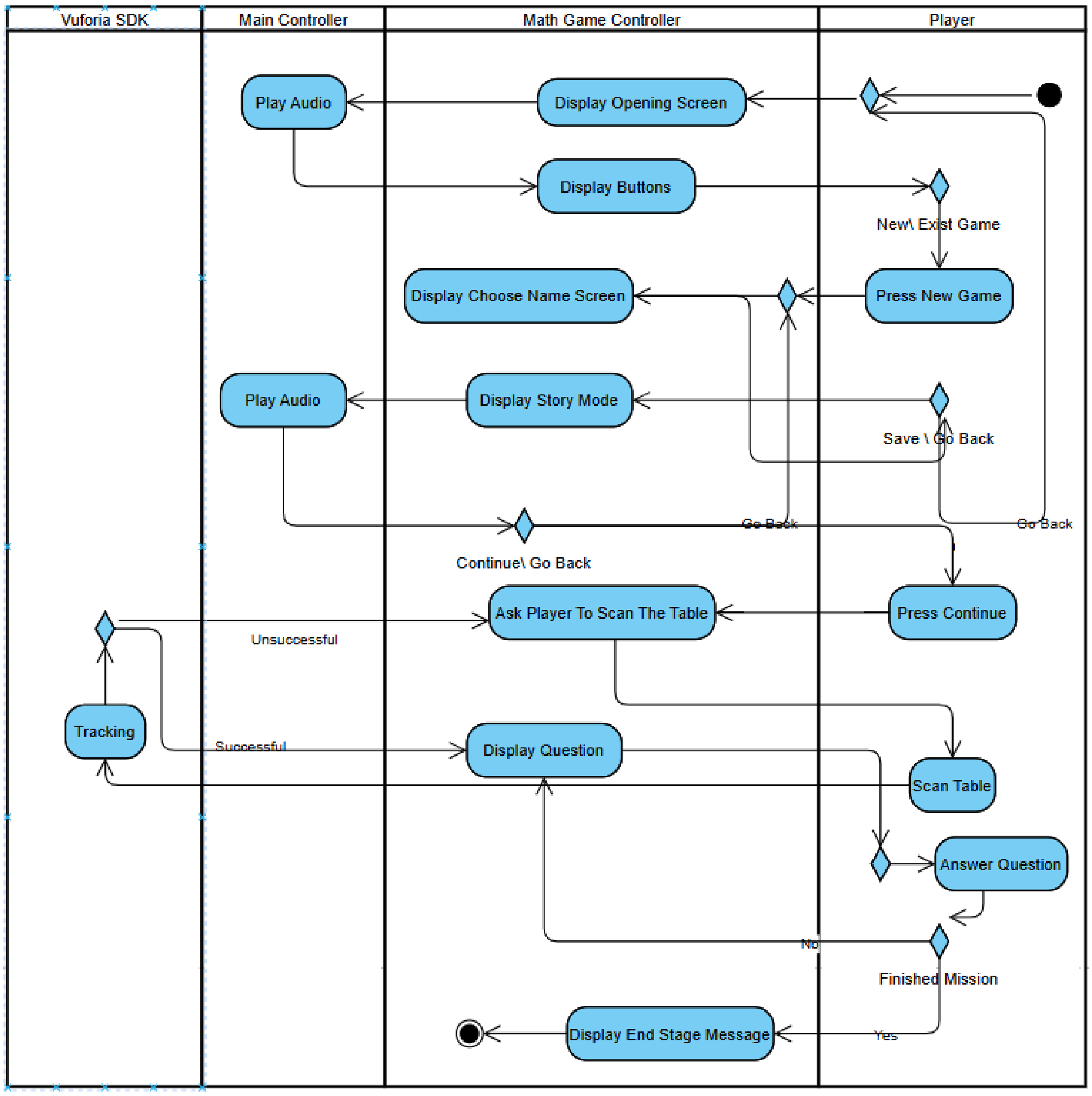

Figure 5 – The application activity diagram

As they progress, the challenges grow more complex, encouraging logical thinking and improving problem-solving skills. The game provides immediate feedback for incorrect answers, helping players learn from their mistakes. At the end of each level, players receive a summary of their performance, including their score and any rewards earned, such as stars or achievements. Each stage builds on the previous one, ensuring a gradual learning curve that keeps the players motivated and engaged.

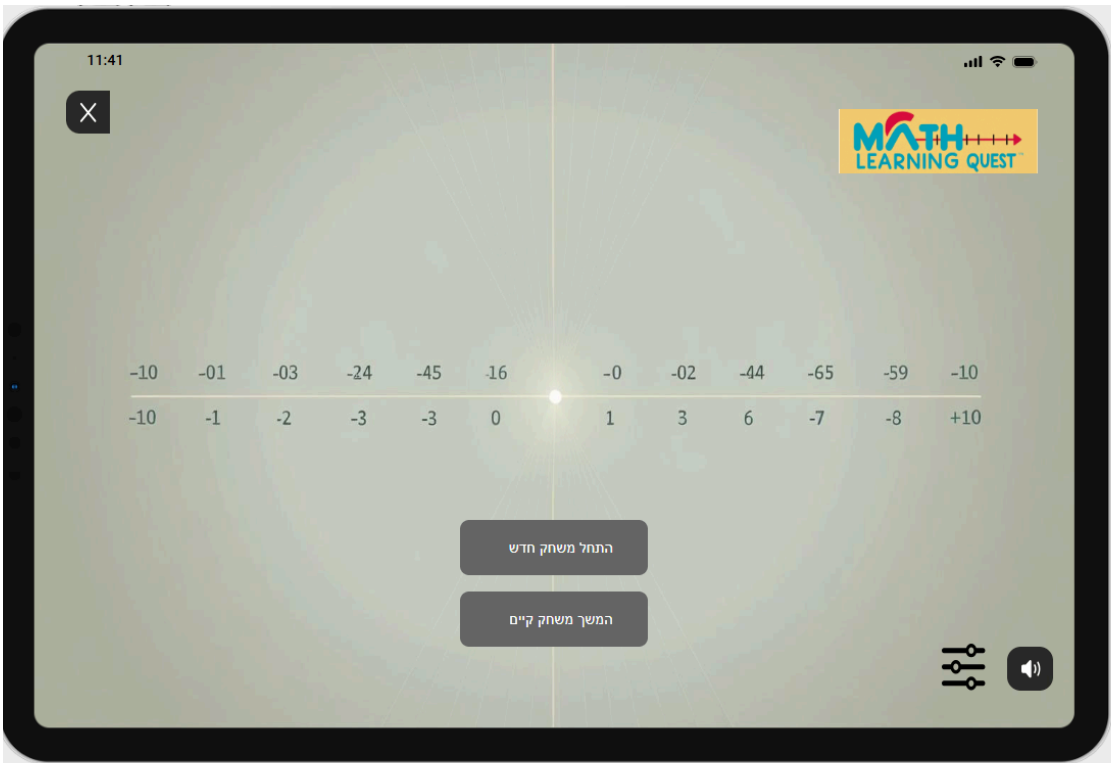

Figure 6– The first screen of the application

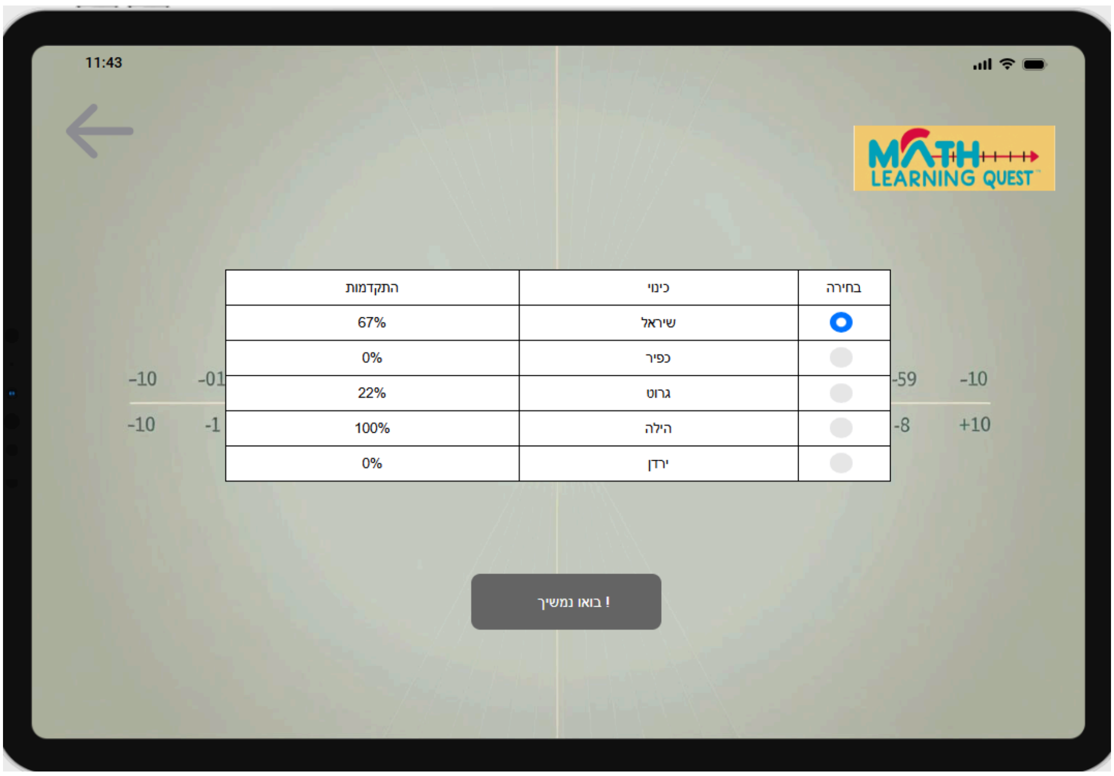

Figure 7– user can choose his game and see progress

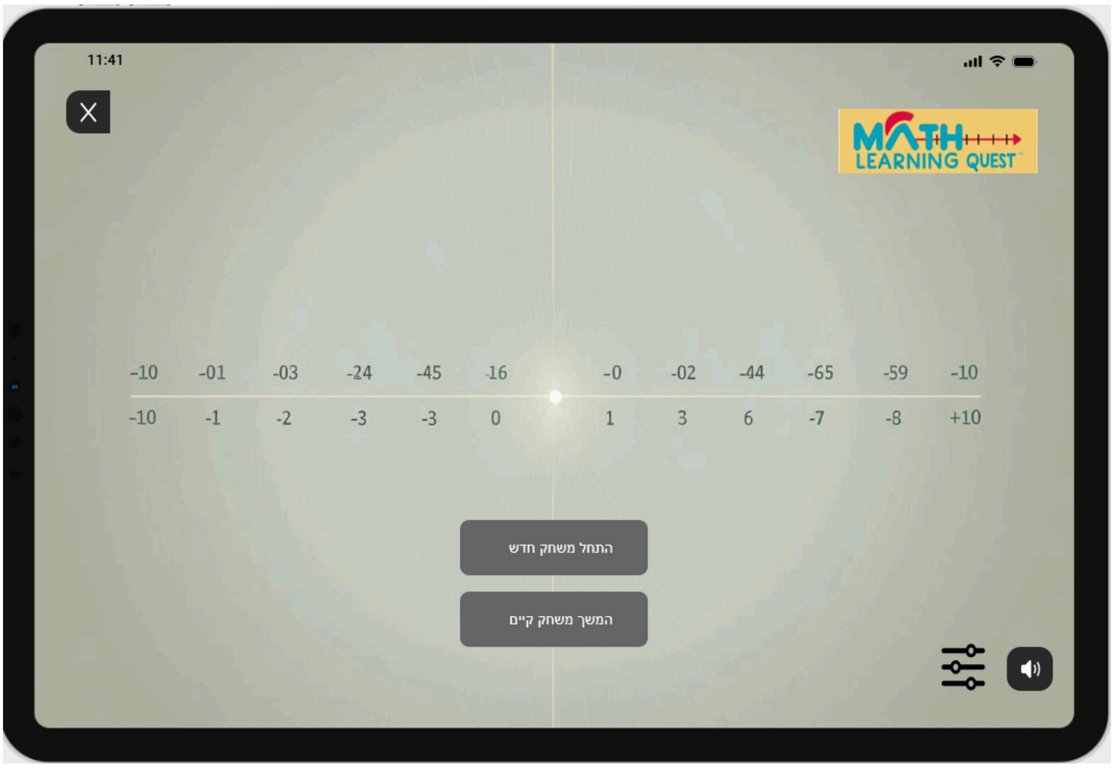

Figure 8– start a new game or continue one

Figure 9– choose a nickname

Figure 10– the directions screen where the game's story is played

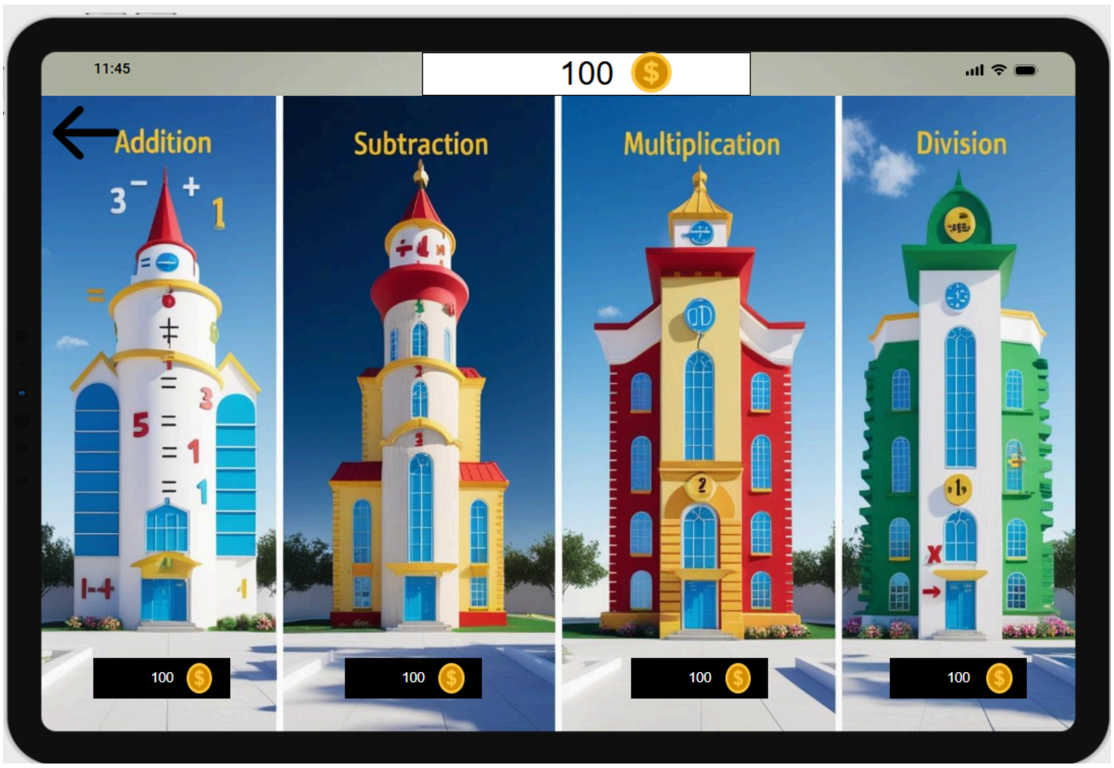

Figure 11– The game screen where you can choose math operator to start

Figure 12– The user need to choose if he want to study or practice

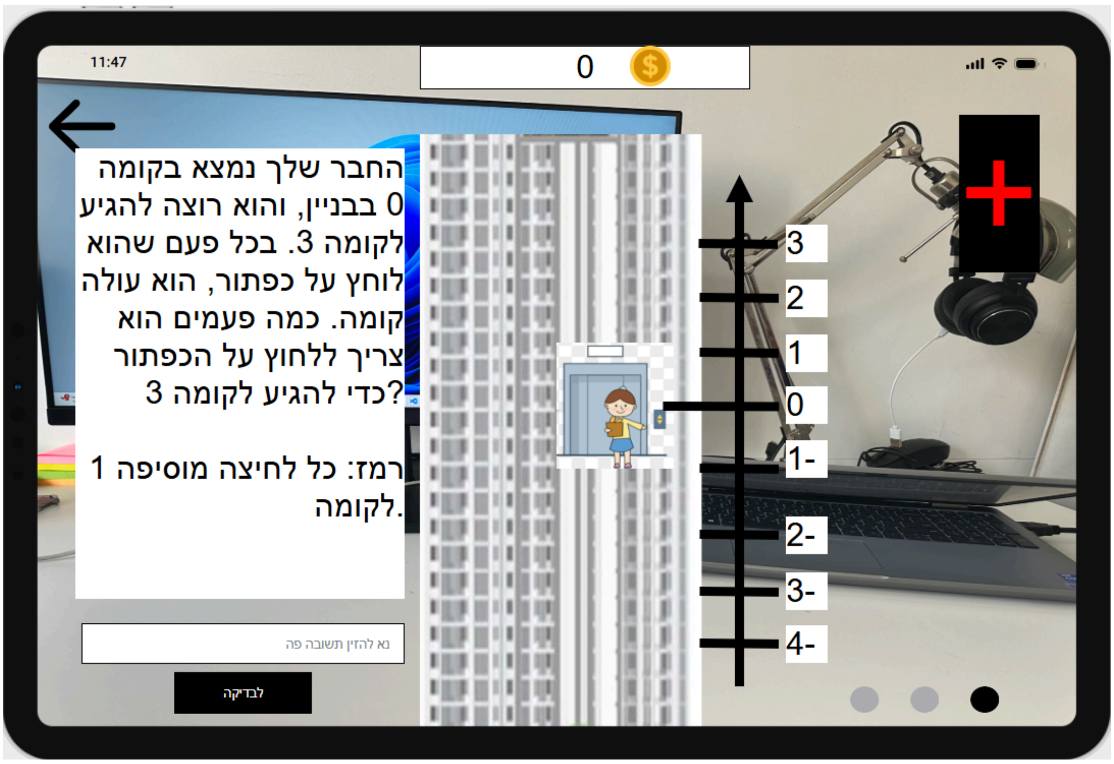

Figure 13– a game question

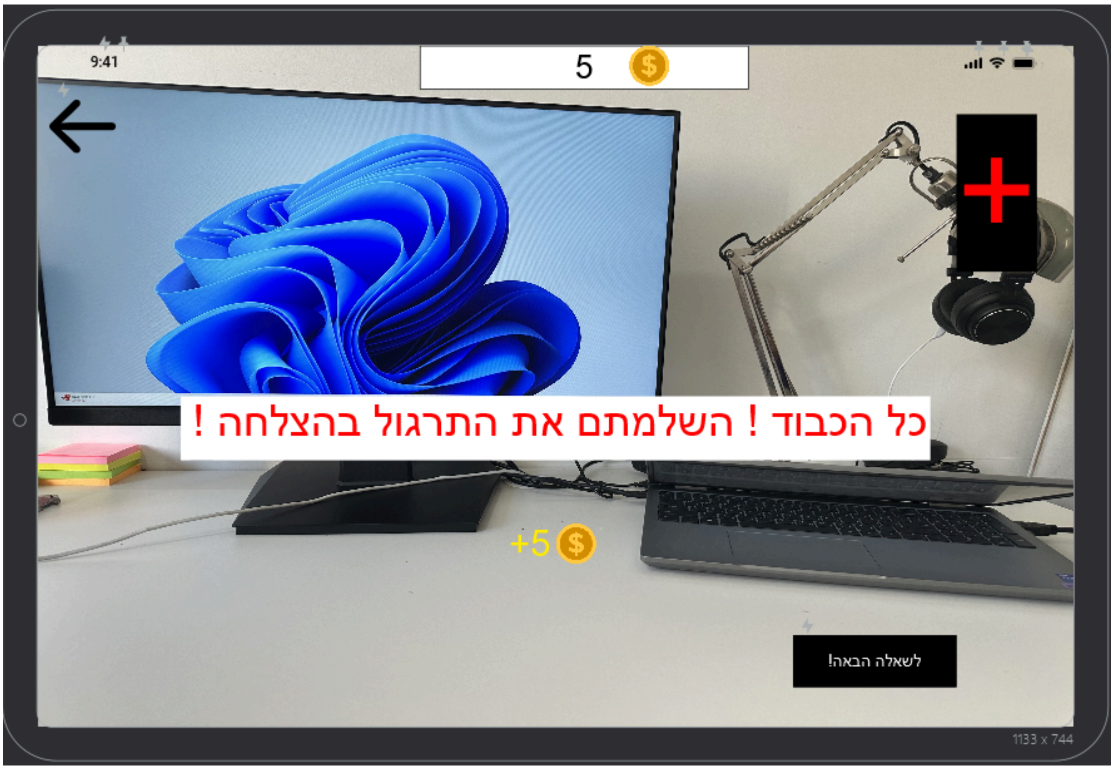

Figure 14– The user get automatic feedback after answering

7. Evaluation / Verification Plan

To validate the success and usability of our augmented reality (AR) application for teaching mathematics, we have developed a detailed **Evaluation/Verification Plan** (see Table 2). This plan outlines the goals, assessment methods, and benchmarks needed to measure the app's effectiveness in engaging students and improving math learning outcomes.

Category	Objective	Metrics
1. Student Interaction	Measure student engagement and usage of AR features.	**Average session duration** should exceed **5 minutes**.
		Track the **number of interactions** students perform during usage.
2. Learning Effectiveness	Assess improvement in understanding mathematical concepts.	**Pre- and post-assessment results** should show a **20% or more improvement**. The students in the experiment will get exams.
		Teacher feedback on content relevance and effectiveness in improving learning.
		Analyze **response times** to questions as indicators of comprehension.
3. User Experience	Evaluate usability and user satisfaction with the system.	Collect **student feedback surveys** focusing on ease of use and engagement.
		Achieve a **System Usability Scale (SUS)** rating of **85 or higher**.
		Track **navigation errors** to identify usability issues.
4. System Performance	Ensure the system runs smoothly and reliably.	**Response time** for AR interactions should not exceed **50ms**.
		Maintain **99.5% uptime** during testing periods by Implement

		real-time uptime monitoring using tools.
		Average session duration without crashes should exceed **30 minutes**.
5. AR Environment Detection	Ensure stable and accurate surface recognition	**Success rate of accurate surface detection (should be 90% or higher) by Using Unity's AR Foundation & ARKit/ARCore to log detection times, accuracy, and failure reasons.**
	Validate reliable detection of hand gestures	**Recognition accuracy should exceed 85%**

Table 12 – Evaluation Metrics

Prototype Testing and Feedback

We will release an initial prototype of the AR app to students and educators, allowing us to collect feedback on usability, engagement, and educational impact. These evaluations will include:

- **Pre- and post-assessments** to measure knowledge retention and improvement.
- Surveys to gather user opinions on the app's design, functionality, and overall experience.

While user feedback is critical, we will also employ **evaluation heuristics** specific to AR applications, ensuring the app is comfortable to use, respects privacy, and performs well across diverse hardware setups. Drawing from industry guidelines, such as Nielsen's usability principles (1990) and adaptations for AR in education, we will examine the app's interface, accessibility, and interactivity.

Data Analytics

To gain deeper insights into user behavior, we will implement **analytics tracking** through Unity's built-in analytics tools. This will allow us to monitor:

- **Progress metrics**: Levels completed, points earned, and challenges solved.
- **Engagement trends**: Average time spent in each session and interaction patterns.
- **Performance indicators**: Frequency of errors, app crashes, or slowdowns.

By combining quantitative data from analytics with qualitative feedback from users and experts, our evaluation process will provide a comprehensive understanding of the app's performance and areas for improvement. This iterative approach ensures the AR platform effectively supports math learning and delivers a meaningful educational experience.

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ביצוע ראיון עם תחייה מורה למתמטיקה בחטיבת הביניים:

מראיינים: כפיר ושיראל
מרואיינת: תחייה

כפיר: שלום תחייה, תודה שהסכמת להתראיין. נתחיל בכמה מילים עלייך – מה הרקע שלך כמורה למתמטיקה?

תחייה: שלום. אני מורה למתמטיקה כבר 15 שנה. אני מלמדת בעיקר בחטיבת ביניים ותיכון, בנוסף אני גם אחראית על הכנת תוכניות לימוד מותאמות אישית לתלמידים מתקשים.

כפיר: נתחיל בשאלה שמעסיקה אותנו מאוד היום – איך את מתמודדת עם הקושי של תלמידים להתרכז בשיעורים?

תחייה: האמת שזה מאתגר. אני רואה שתלמידים מתקשים מאוד לשמור על קשב וריכוז, במיוחד בשיעורים עיוניים כמו מתמטיקה. העולם שלהם מוצף במסכים, עדכונים ורעש וזה בהחלט משפיע עליהם. לפעמים, גם כשהם פיזית בכיתה, הראש שלהם במקום אחר.

שיראל: ומה את עושה כדי לנסות לשפר את הריכוז של התלמידים?

תחייה: אני משתדלת לשלב פעילויות שמשנות את הקצב של השיעור. למשל, מעבר בין עבודה קבוצתית לעבודה אישית, שילוב של חידות מתמטיות או משחקים קצרים המחייבים את כולם להיות מעורבים. לפעמים אני גם נותנת לתלמידים כלים להשתמש בטכנולוגיה, כמו לפתור תרגילים באפליקציות מתמטיות. זה יוצר אצלם תחושת רענון ומחבר אותם לנושא בצורה שהם יותר רגילים אליה.

כפיר: זה נשמע כמו גישה מאוד מעניינת. תגידי, שמעת פעם על המושג "מציאות רבודה"?

תחייה: האמת שלא. מה זה בדיוק?

שיראל: מציאות רבודה זו טכנולוגיה שמוסיפה אלמנטים דיגיטליים לעולם האמיתי דרך מכשירים כמו טלפונים או משקפי AR. למשל, אם את מכוונת את המצלמה של הטלפון לספר לימוד, הטכנולוגיה יכולה "להציג" מודל תלת-ממדי של גרף או צורה גיאומטרית מעל הדף, כאילו הוא באמת שם.

תחייה: אה, מעניין מאוד. זה בעצם משלב בין המציאות לדברים וירטואליים בצורה ויזואלית?

כפיר: בדיוק, זה מאפשר לתלמידים לראות דברים שקשה לדמיין במציאות – כמו גרפים, צורות או אפילו תהליכים מורכבים – כאילו הם קורים ממש מול העיניים.

שיראל: איך לדעתך טכנולוגיה כזו יכולה לעזור בשיעורי מתמטיקה?

תחייה: אני חושבת שזה יכול להיות כלי שיתרום להם. כשאני מלמדת גיאומטריה במרחב, תמיד יש תלמידים שמתקשים לדמיין איך צורות מתנהגות בשלושה ממדים. אם הם יוכלו לראות את הצורות האלו מול העיניים, אולי אפילו להסתובב סביבן ולבחון אותן מכל זווית, זה יכול לשנות לגמרי את ההבנה שלהם.

כפיר: ומה לגבי תלמידים שמתקשים במיוחד?

תחייה: אני חושבת שזה יכול לעזור להם בצורה יוצאת דופן. יש תלמידים שהמוח שלהם עובד בצורה יותר ויזואלית, וזו דרך מושלמת לגשת אליהם. אם הם יוכלו לראות איך משוואה משנה גרף בצורה מוחשית, זה עשוי להיות הרבה יותר ברור להם מאשר הסברים מופשטים או ציורים על הלוח.

שיראל: ואיפה את רואה את האתגרים בטכנולוגיה כזו?

תחייה: קודם כל, זה נשמע כמו משהו שדורש הרבה תקציב, מה שלא זמין בכל בית ספר. בנוסף, המורים יצטרכו לעבור הכשרה כדי לדעת איך להשתמש בכלים האלה בצורה אפקטיבית. בגילי למשל לא יהיה פשוט ללמוד איך משתמשים בכלים האלו.

כפיר:כן אני מבין, ובכל מקרה אם היה לך את הכלי הזה בכיתה, איך היית משתמשת בו?

תחייה: הייתי משתמשת בו כדי להמחיש נושאים מורכבים יותר, כמו גרפים, וקטורים, או אפילו הסתברות, דרך הדמיות חיות. אולי אפילו הייתי יוצרת איתו פעילויות אינטראקטיביות, שבהן התלמידים צריכים "לשחק" עם האלמנטים הוירטואליים כדי לפתור בעיה.

שיראל: תודה רבה לך תחייה! היה מרתק לשמוע את דעתך ולחשוב יחד איתך על האפשרויות.

תחייה: תודה לכם, היה מעניין מאוד. אני תמיד שמחה לשמוע על דרכים חדשות להפוך את הלמידה למשמעותית יותר.

ראיון מספר 2 עם מלי -מורה למתמטיקה בחטיבת הביניים

שיראל: נעים מאוד מלי, אשמח לשאול אותך כמה שאלות מקדימות בתחום ההוראה שלך.

מלי: בשמחה!

שיראל: מה הם האתגרים המרכזיים שאת רואה בהוראה ספציפית במתמטיקה.

מלי: אני חושבת שהאתגר המרכזי הוא להגיע לכל תלמיד בצורה שבעצם הוא הכי יבין אותה.

לדוגמא יש תלמיד שיבין נושא בפעם הראשונה ויש תלמיד שהוא שמיעתי ויש כל מני סוגים של ילדים. בקטע השמיעתי למשל, צריך להראות דברים במתמטיקה, צריך להדגים ולהשוות ולעשות הרבה דברים כדי שהתלמידים יבינו כי זה לא בא להם באופן טבעי וישר ולפעמים הם גם לא מבינים למה בכלל צריך ללמוד נושא מסוים .

שיראל: אוקי הבנתי. האם יש שיטות שאת משתמשת בהן על מנת להפוך את המתמטיקה ליותר מובנה ומעניינת?

מלי: הרבה, למדתי הוראה מתקנת אז לקחתי ממה שלמדתי הרבה דברים מועילים אז אני מיישמת את זה על התלמידים שלי. למשל במשוואות יש לי מיצג שאני נותנת לתלמידים שני בתים וכל פעם שמישהו עובר הוא צריך לשלם אז הוא הופך את הסימן שלו ויש לי כל מני שיטות. אני מסבירה כמו שהייתי רוצה שיסבירו לי. בנוסף, אני מאוד מאמינה בעבודה בקבוצות כי השיח המתמטי מאוד עוזר. אני גם משלבת הרבה דיגיטל באמצעות המודל שיש לתלמידים. אני גם משתמשת בתוכנת desmos.

שיראל: אני רוצה לשתף שאני מורה פרטית למתמטיקה ואני מרגישה הרבה הזדהות עם כל מה שציינת. יש הרבה נושאים שקשה לתלמידים לתפוש.

מלי: נכון מאוד, קשה להם מאוד גם הנושא של לתרגל, הם לא מתרגלים בבית כי זה בלי ציון, הם צריכים מוטיבציה.

שיראל: אני מסכימה איתך ולכן חשבנו על לפתח משחק שיהיה במציאות רבודה ויעזור לתלמידים.

מלי:וואו זה יהיה מעולה

שיראל: אנחנו בחרנו להתמקד בנושא שהרגשתי שמאוד קשה לתלמידים שלי להבין שזה ציר המספרים. הרגשתי שלתלמידים מאוד קשה להבין למה מספר שלילי כפול מספר שלילי הוא חיובי ובכללי את הנושא.

מלי: אני חושבת שגם הנושא של פונקציה קוית הוא רעיון לא רע שאפשר לממש אותו, הנושא של שיפוע מאוד קשה לתלמידים ואני חושבת שניתן להסביר וזה יהיה טוב למציאות רבודה. אם אני מטפס או יורד זה יותר קל או קשה, אני תמיד מדגימה את זה כשאתה עולה כל 4 קומות אז אתה עולה יותר מהר. ובאמצעות משחק במציאות רבודה הם יבינו יותר טוב, זאת דעתי.

שיראל: אז את חושבת שבאופן כללי היית מחליפה את הנושא של ציר המספרים ועוברת לפונקציה קווית?

מלי: אני אגיד לך למה , אני חושבת שציר המספרי הוא נקודתי ושמציאות רבודה פחות מתאימה לנושא זה.

שיראל: אוקיי אני מבינה ומקבלת את זה ובהחלט נתייעץ על כך ונחשוב על זה. תודה רבה על כל העזרה שלך.

מלי: בשמחה ואני מאחלת לכם בהצלחה. את מוזמנת לנסות את המשחק שלכם על התלמידים שלי.

שיראל: תודה רבה! נהיה בקשר ובהחלט נתייעץ איתך.