



Team TechSmith
Teacher's Virtual Toolbelt
Michigan State University
Project Plan
Spring 2017

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2. Executive Summary

The Microsoft HoloLens is a new augmented reality computing platform. While wearing the device, the user's real-world view can be augmented with holograms. HoloLens applications allow for viewing, manipulating, and interacting with these holograms. Classical mechanics requires an understanding of multiple forces on objects and systems. This can be overwhelming for students to visualize mentally or on paper. This project aims to use the HoloLens as a teaching tool to help visualize difficult class concepts like classical mechanics.

A web application will allow the teacher to create lessons that include textual reference material and quizzes. These lessons may then be selected by the teacher and initiated inside of the HoloLens application. Multiple choice quizzes can be created by the teacher during their lesson planning. Students will be able to take quizzes on the web application during the lesson when triggered by the teacher through the HoloLens application. The results of the quiz may be viewed by the teacher on the web application at a later time.

The HoloLens application will give teachers access to default holograms in the form of basic shapes such as spheres, cubes, and arrows. This will give them the tools to present holograms based on what specific lesson is being taught. Also available to the teacher is the predefined reference material that they have created during the lesson planning which can be displayed inside the HoloLens.

Since the holograms are only visible while wearing the device, the teacher's mixed reality view will be streamed to the website to provide the students with an immersive view of the holograms as the teacher sees it. This will allow the students of the class to watch exactly what the teacher sees.

The goal of this project is to explore how the HoloLens platform can assist teachers in reducing the large learning curve presented by complex fields of study, such as classical mechanics, by demonstrating class concepts through augmented reality and hologram manipulation.

3. Functional Specifications

The Teacher's Virtual Toolbelt requires a website where the teacher may create lesson plans, and where students can view a stream of the HoloLens application as well as ask questions and take quizzes. The HoloLens application allows the teacher to use predefined holograms to aid in class concept visualization. Teaching with 3D holograms has the benefit of helping students visually understand difficult concepts and simulate forces through technology that has just recently become available.

3.1 Web Application

The website uses user-based authentication through Microsoft accounts to provide access to the application. Roles will be assigned to support different views and functionality for students and teachers. The student users will use the website to view a live stream of the lesson as it looks from the teacher's perspective through the HoloLens. The students have the ability to ask questions through the website, to which the teacher will be able to view and respond to accordingly. The students will also use the website to answer quiz questions when triggered by the teacher during the lesson.

Teachers will use the website to plan lessons, which include textual reference material and quiz questions to be triggered from the HoloLens during the lesson. The quiz results can be accessed on the web application after the quiz has been administered. Teachers will also be able to manage which students have access to their lessons with unique enrollment keys that they will distribute themselves.

3.2 HoloLens Application

The HoloLens application is used by the teacher. It contains base holograms such as arrows and simple shapes, as well as a live message board to view student questions. These holograms are available to the teacher for every lesson, regardless of what they planned as additional resources through the website. Also available to the teacher are the various predefined textual reference material that will open as 2D hologram billboards. All holograms can be added through the application's menu and removed using voice commands. They can also be moved and resized with natural hand gestures and voice commands.

The quiz questions created on the web application can be triggered through the HoloLens application menu. This opens the quiz to students and allows them to answer the questions from the website. The results of this quiz can later be viewed by the teacher on the web application. Student questions, submitted from the web application can be viewed inside the HoloLens and verbally answered by the teacher. These questions will appear automatically when submitted by a student.

4. Design Specifications

4.1 Web Application User Interface and Use Cases

The Teacher's Virtual Toolbelt web application will be accessible by both students and teachers. This application will differ in functionality for each type of user, enabling students to view live streamed lessons and interact with the teacher by submitting questions, and teachers to easily create and edit lesson plans and review lesson quiz results.

4.1.1 Login and Home Pages

The login page will be the initial page viewed by the user when attempting to access the web application, and both students and teachers will see the same view. This page will feature a simple user interface with a login button. Selecting the Microsoft login button will redirect the user to a Microsoft account login page, where they may log into the web application using their personal account. After successfully logging in with a valid Microsoft account, the user will be redirected back to the web application's Home page. If the user is new to the website, they will be prompted to register their email as either a student or teacher account. Once a teacher has registered a Teacher's Virtual Toolbelt account, they must also register an individual PIN number to easily access their account through their HoloLens device. Until the teacher specifies this PIN number, a button will appear on their home page asking them to do so. This PIN number may be updated at anytime through the teacher's course page.



Figure 4.1.1: Teacher's Virtual Toolbelt Home Page

4.1.2 Course Page

Upon logging in with a valid Microsoft account, the user will be redirected to the site's Home page. The user can navigate to their individual course page by selecting the "Course Page" button on the home page, or the course page icon in the top right corner of the site. This course page will contain a list of existing lesson plans as supplied by the course's teacher. If the user is a teacher, this list may be edited. The teacher will have the ability to create new course classrooms with lessons, delete existing lessons, open quiz results, or select to review and edit existing lessons from this page. The teacher can also access the individual stream key for each lesson on this page, start the live stream of the lesson, and refresh the stream key when needed.

Student users will only be able to select existing lessons on this page, which will direct them to the unique lesson page where the live stream may be viewed. The scheduled live stream date will be listed next to the lesson name until the lesson has started. Once the lesson has started streaming, "Live Now!" will appear next to the lesson name.

Student users will have the ability to enroll themselves in courses when provided a unique enrollment key. When a teacher creates a class on the web application, they will specify a course key that they would like to distribute to students. The student may navigate to their course page, enter this unique key, and select "Submit" to add the class to the student's course list. This will allow the user to access live lessons and materials for the course.

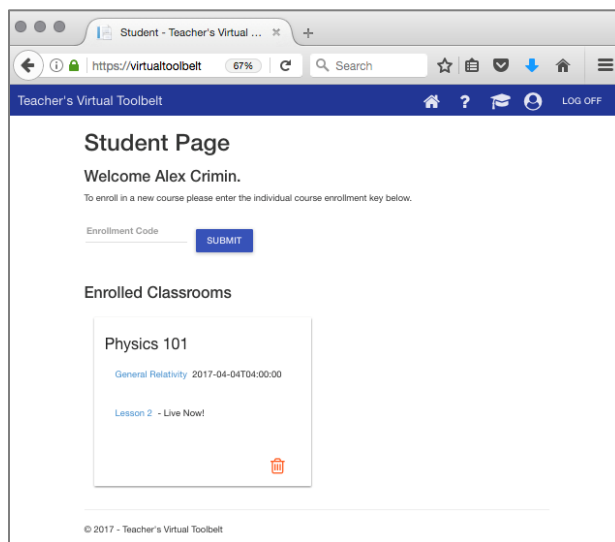


Figure 4.1.2: Student Course Page

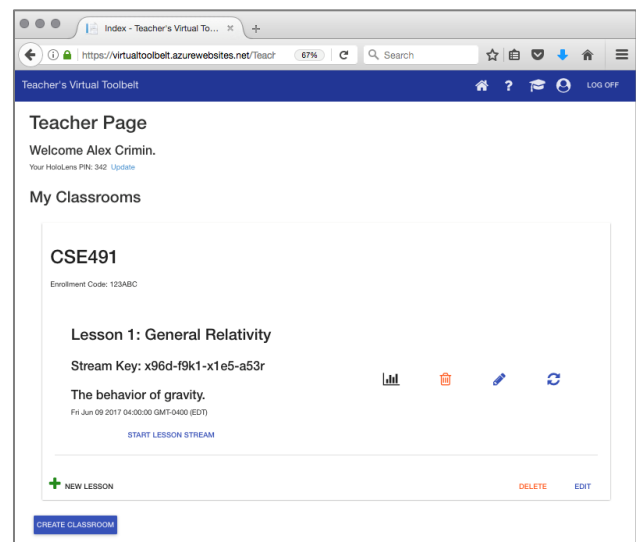


Figure 4.1.2: Teacher Course Page

4.1.3 New Lesson Page

If a teacher chooses to add a new lesson to their course by selecting “New Lesson” on their course page, a new lesson form will appear below the course name for the teacher to add a new lesson, name the lesson, add a description, and designate a specific time for students to view the live-stream of the lesson. Once the teacher selects submit, a dialog box will appear asking them if they would like to add reference material to the lesson now. The teacher may select yes, and will be redirected to the lesson editing page, or select no to stay on the course page. The teacher may add reference material to the lesson later by selecting the edit button next to the lesson on the course page. The teacher can add quizzes with a specified duration and textual reference material to a lesson at any time.

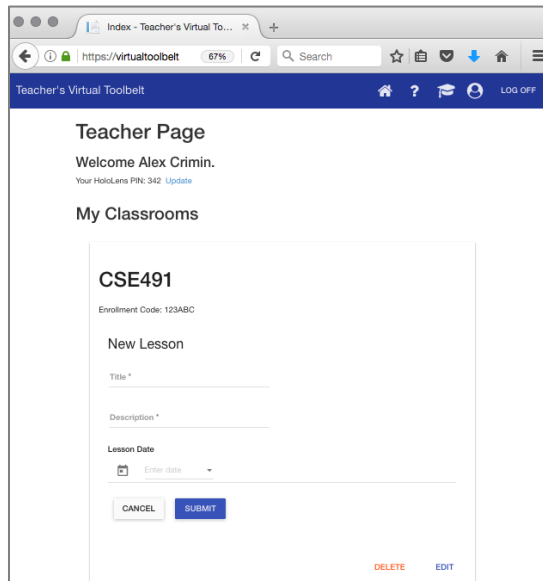
A screenshot of a web browser showing the 'Teacher Page' of the 'Teacher's Virtual Toolbelt'. The page is titled 'Teacher Page' and welcomes 'Alex Crimin.' with a 'Your HoloLens PIN: 342' and an 'Update' link. Under the 'My Classrooms' section, a card for 'CSE491' is shown with an 'Enrollment Code: 123ABC'. Below this card is a 'New Lesson' form. The form has fields for 'Title *', 'Description *', and 'Lesson Date' (with a calendar icon and a dropdown arrow). At the bottom of the form are 'CANCEL' and 'SUBMIT' buttons. To the right of the form are 'DELETE' and 'EDIT' links.

Figure 4.1.3: New Lesson Page

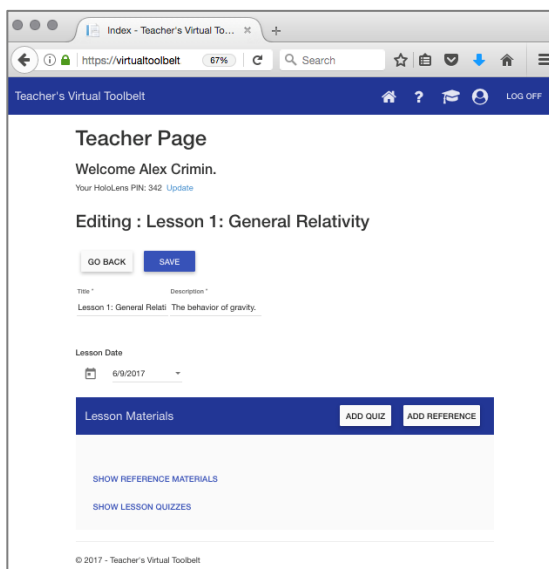
A screenshot of the 'Lesson Editing' page in the 'Teacher's Virtual Toolbelt'. The page is titled 'Teacher Page' and welcomes 'Alex Crimin.' with a 'Your HoloLens PIN: 342' and an 'Update' link. Under the 'My Classrooms' section, a card for 'CSE491' is shown with an 'Enrollment Code: 123ABC'. Below this card is a 'New Lesson' form. The form has fields for 'Title *', 'Description *', and 'Lesson Date' (with a calendar icon and a dropdown arrow). At the bottom of the form are 'GO BACK' and 'SAVE' buttons. Below the form is a 'Lesson Materials' section with 'ADD QUIZ' and 'ADD REFERENCE' buttons. Below this section are 'SHOW REFERENCE MATERIALS' and 'SHOW LESSON QUIZZES' links. At the bottom of the page is a copyright notice: '© 2017 - Teacher's Virtual Toolbelt'.

Figure 4.1.3: Lesson Editing Page

4.1.4 Lesson View Page

If a student selects an existing lesson, and the teacher has not begun the lesson through the HoloLens application, a message will appear to notify the student that the lesson has not yet begun. If the lesson has already begun when the student selects it from the list, a live stream of the teacher's HoloLens view will appear on the page. A chat box will also be accessible on this page for students to submit feedback and questions to the teacher. Students may submit questions anonymously if they would like. These questions will appear in the teacher's view through the HoloLens Application. The student can also view the same reference material that the teacher is displaying in the HoloLens on the student view page. If a URL is provided by the teacher when creating the reference material, the student may select the hyperlinked URL to be directed to websites containing more information about lesson topics.

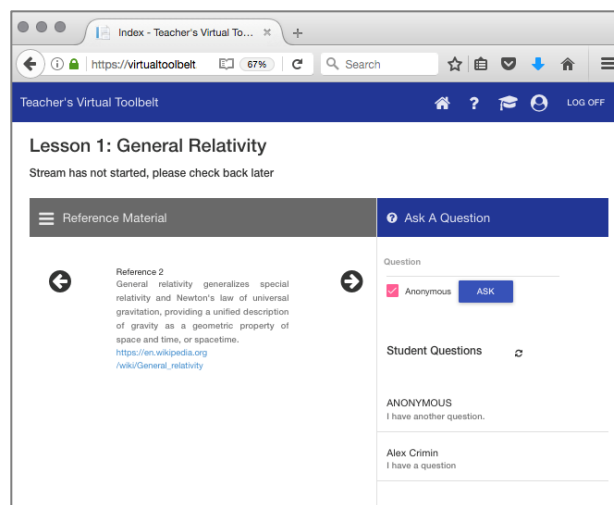


Figure 4.1.4: Lesson Unavailable to Student

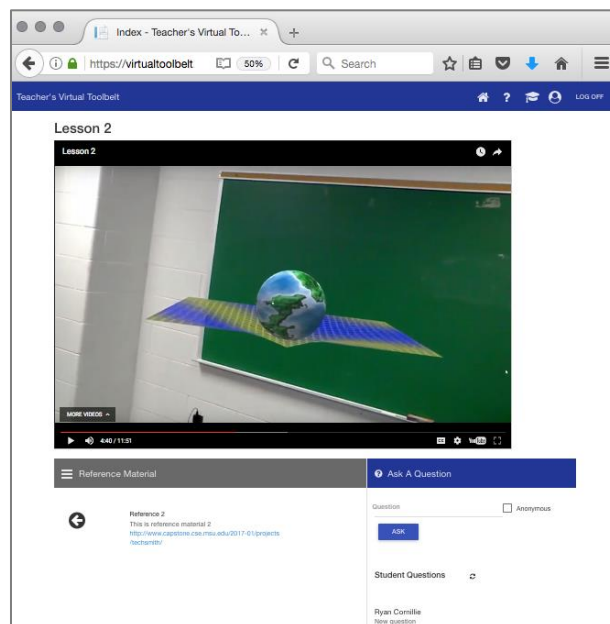


Figure 4.1.4: Live Stream of Lesson for Student

4.1.5 Quiz Score Page

If the teacher wishes to view the lesson quiz scores that were recorded after the quiz was administered to students, they can select the bar graph icon next to the lesson on the course page. This will redirect the teacher to the Quiz Score page. This page will contain bar graphs for every quiz question, specifying the number of answers recorded for each question option.

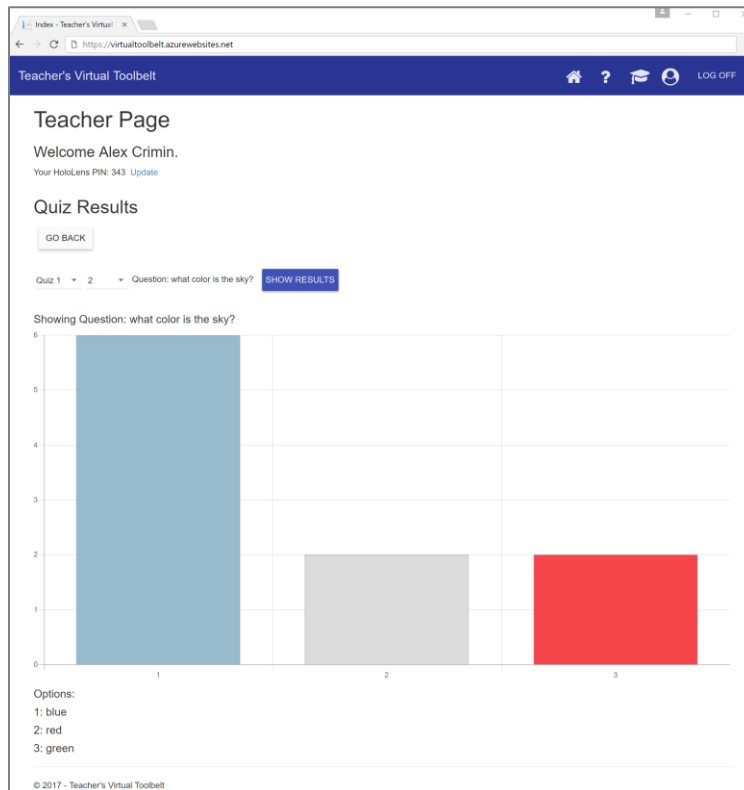


Figure 4.1.5: Quiz Results for the Lesson

4.2 HoloLens Application User Interface and Use Cases

The HoloLens application will be designed to be used exclusively by the teacher. Since these holograms are only visible inside the HoloLens device, it is essential that the mixed reality view of the holograms is streamed from the HoloLens to the web application in order to allow students to see the holograms as the teacher does.

The HoloLens application will allow the user to select and manipulate simple shapes and objects. For subjects such as classical mechanics, this can help to illustrate the forces on objects. Figure 4.2 below shows a possible hologram configuration, in which the user has selected a cube and two arrows to depict the force of gravity and the normal force. The same view inside the HoloLens will be visible to the students through a video stream to the web application.

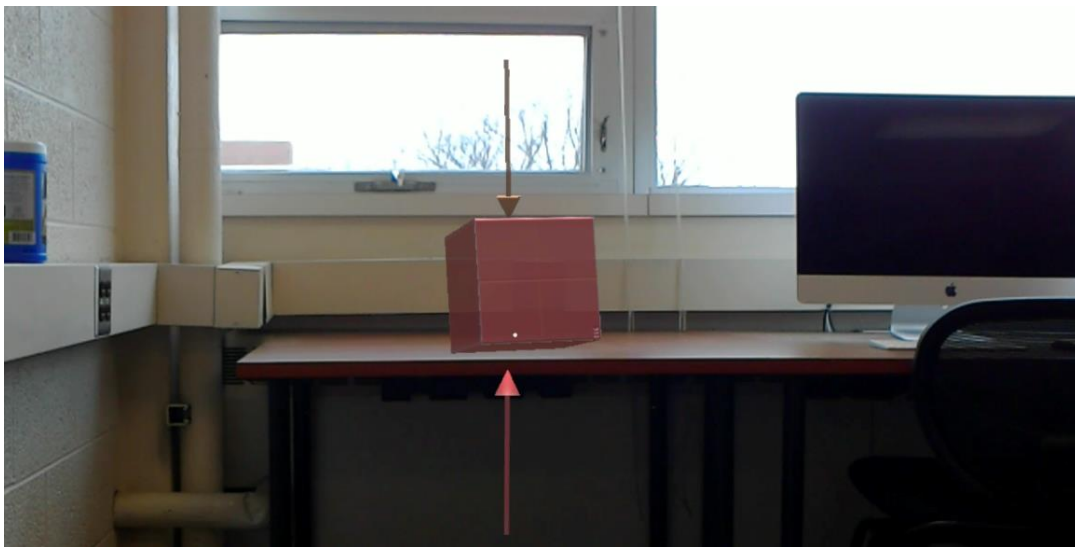


Figure 4.2 Sample View of a Hologram Inside the HoloLens

4.2.1 HoloLens Teacher Authentication

To identify the teacher using the HoloLens, they will first be presented with a PIN entry screen. This is a small numeric PIN number that is created by the teacher when they register an account on the web application. “Air-tap” gestures can be used to select each number. Figure 4.2.1 below shows this interface.

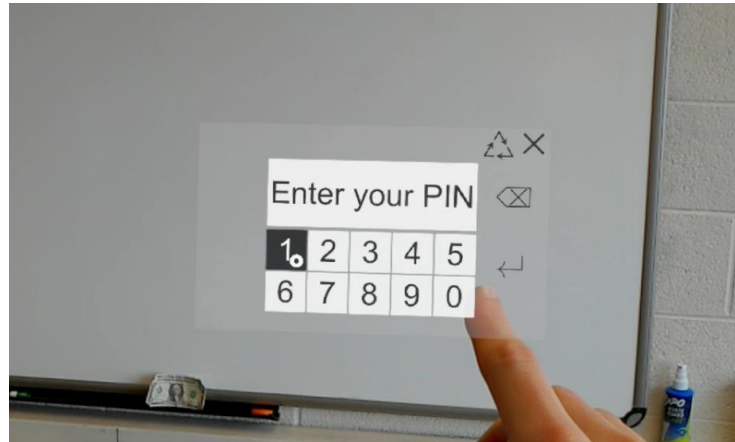


Figure 4.2.1 HoloLens Teacher Authentication

4.2.2 Selecting a Classroom and Lesson

Once authenticated with a PIN number, the teacher will be able to select a classroom from their created classrooms and then an existing lesson from a list of lessons that have been planned on the web application. This can be done using a press and release gesture. Once a lesson has been selected, they will be presented with a menu that allows them to generate holograms from a set that includes 3D shapes, text, and arrows. A start lesson button in the HoloLens will open the stream for students using the web application to view the lesson. Figure 4.2.2 shows a 2D hologram with a list of classrooms that the teacher can select with an air-tap gesture.

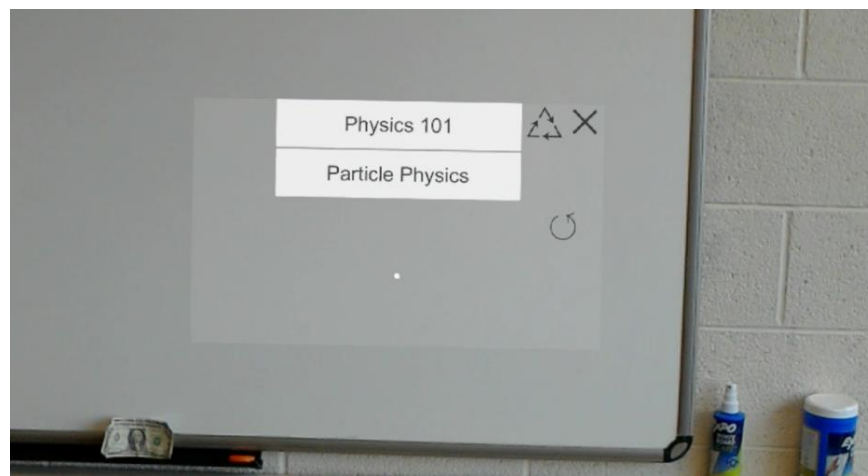


Figure 4.2.2 HoloLens Classroom Selection

4.2.3 Hologram Manipulation

The teacher will see a set of holograms that they are able to interact with. These holograms can be rotated, resized, and moved using hand gestures and voice commands. Holograms can be moved around in the 3D environment by looking at a hologram and then performing the press and hold finger gesture. While holding this gesture, the hologram will move as the user's hand does. Upon release of this gesture, the hologram will be placed in the new location. Rotation will also use the press and hold gesture. To distinguish between moving and rotating, the voice command "start rotate" will transition the application into rotation mode. When looking at a hologram, this voice command will allow the press and hold gesture to now rotate the hologram in the direction of the hand's movement. Following the "stop rotate" voice command, the application will return to using this gesture for hologram movement. Resizing will be performed through voice commands. When looking at a hologram, the user will be able to say "make smaller" or "make bigger" to control the size of the holograms. Figure 4.2.3 shows a configuration of holograms that can be used to illustrate gravity. The holograms help to show how massive objects warp space. The holograms can be manipulated in real time to show the moon orbiting around the earth in the indentation in space created by the earth.

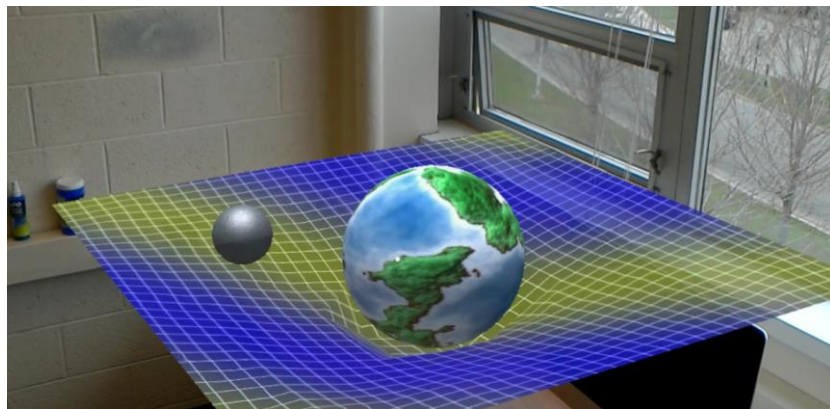


Figure 4.2.3 Holograms Manipulated to Illustrate Gravity

4.2.4 Reference Material

Reference material can be selected from the HoloLens application menu. Reference material text, specified during lesson plan creation on the website, will be rendered as text and implemented as a billboard in the HoloLens application that will always face the user. Reference material can be hidden and shown as needed. Figure 4.2.4 shows a sample view of reference material about planetary motion that is displayed alongside holograms of the earth and moon. The 2D hologram of text will rotate to remain readable as the user moves and rotates their head.



Figure 4.2.4 HoloLens Reference Material

4.2.5 Quizzes and Student Questions

The HoloLens application menu will have a list of the quizzes that the teacher has created for the current lesson. Upon selecting one of these quizzes with the tap and release gesture, the quiz will automatically open on the web application. The quiz button in the HoloLens will flash red while the quiz runs for the specified duration and then highlight green to show that the quiz has completed. At this time the students will no longer be able to answer the quiz questions on the web application.

Students are able to submit questions for the teacher to see during the lesson. A 2D hologram with a list of the submitted questions will automatically appear in the bottom right corner of the HoloLens when a new question is submitted. The teacher will also be able to toggle the visibility of this live chat box from the HoloLens application menu.

5. Technical Specifications

5.1 System Architecture

The main components of the system will be:

1. Single Page Application written with HTML, CSS, and JavaScript
2. ASP.NET Web API
3. C# HoloLens Application
4. Low latency live stream to YouTube through OBS/Microsoft MRVC Viewer Application
5. SQL Database hosted on the Microsoft Azure Cloud

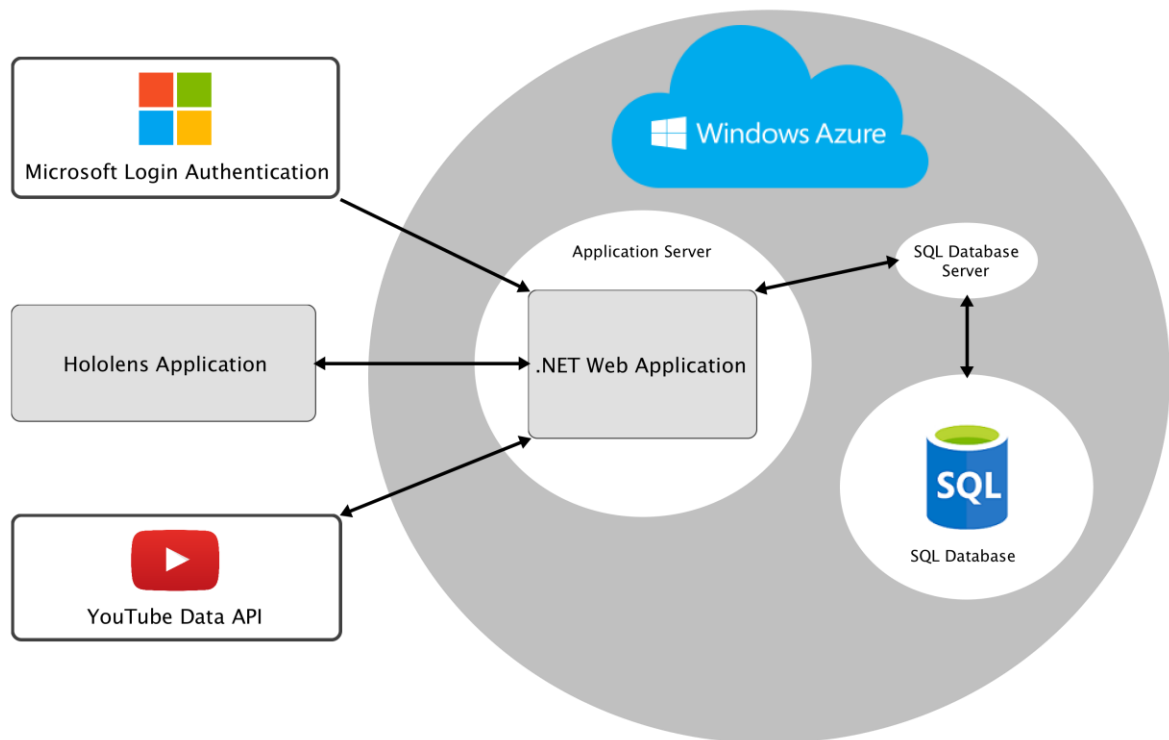


Figure 5.1 Teacher's Virtual Toolbelt System Architecture Diagram

5.2 Single Page Web Application

The single page web application will be one of the two main user interfaces for the Teacher's Virtual Toolbelt system. This application may be accessed by both students and teachers from any web browser. The application will be hosted on Microsoft Azure, which allows for easy manipulation of data flow through the system's SQL Database, which will also be hosted on the Azure cloud as well. The application will implement a web service layer using the ASP.NET Web API framework. These API endpoints will allow the application to send and receive lesson and course information to and from the remote SQL Database. This communication will be facilitated through simple HTTP GET, POST, PUT, and DELETE requests. These configured API endpoints will allow for the seamless data sharing between the web application and the HoloLens application.

The single page application architecture allows for streamlined interactions between the website and user. After the initial loading of the application, only portions of the website will need to be updated upon subsequent requests by the user, rather than reloading the entire page for every response. This fluidity supports a simple user interface that is easy to navigate by the user. The AngularJS JavaScript framework will be used to bind and manipulate data from the application models to be used in the website views. The data in the application views and models will work in tandem, synchronizing with each other automatically if changes are made.

The web application will function differently for each type of user, either a student or teacher. All users will need to login to the website with their existing Microsoft account. After entering their Microsoft credentials, their account will be authenticated and the user will be redirected back to the application's home page. The application will also be invoking role-based authorization to allow for only teachers to update and make changes to their course lessons, but still allow for students to view live streaming events. Teachers will have the ability to register courses on the website by filling out a simple enrollment form, which will save the course information to a table in the SQL Database. Teachers will also have the ability to add lesson plans to courses. These lessons may consist of quizzes with multiple choice questions and textual reference material for the lesson. All of this information will need to be stored in the SQL Database as well as repopulated by the website when lesson editing is required, and also to be accessed by the HoloLens application when the lesson plan is needed during the live lesson stream.

5.3 Live Streaming

Microsoft provides a Unity plugin to render the holograms on the HoloLens camera to create the view as would be seen while wearing the device. This low-latency stream is accessed through a UWP application also provided by Microsoft. The teacher connects to their HoloLens by entering its local IP address in this application, where the desktop view can then be streamed through Open Broadcaster Software to YouTube through the steam key provided when creating a lesson. The teacher starts the stream on the website that makes YouTube start recording the lesson. Each lesson and its corresponding view have the streaming URL for an embedded YouTube player to play the live stream for the students. When creating a new lesson or starting a stream, the teacher will be asked to authenticate with a Google account in order to communicate with their YouTube account. Once the teacher ends the lesson, the stream is stopped and saved on their YouTube channel for future use.

5.4 HoloLens Application

The HoloLens application will be created as a Unity application. Unity allows 2D and 3D objects to be placed in a 3D space and render them as holograms in the HoloLens application. The Unity project will be built into a Microsoft Windows Store application which can then be deployed and executed on the HoloLens device. Unity uses C# scripts that can be attached to hologram objects to update and manipulate objects as a result of different gestures and voice commands. These scripts will use RESTful API calls to get information from and update the Azure SQL Database. These changes in the database will then also be reflected on the web application.

5.5 Software Technologies

- JavaScript, AngularJS
- C#
- HTML
- CSS
- Open Broadcaster Service
- Microsoft Mixed Remote View Compositor

5.6 Development Environments

- Visual Studio
- Unity

5.7 Test Plan

Git will be used for version control. New features will be created on new branches through GitHub. As these features are completed, pull requests will be created requesting to merge those features into the master branch. Pull requests will always include a summary of the changes and a plan for how to test the new features. Once reviewed and tested by the team, these changes will be merged into the master branch.

As working builds are developed we will perform user testing among both the development team and possibly other parties. Identified bugs will be tracked as issues on our GitHub repositories. Issues will be assigned to team members and can be closed when they have been resolved.

Figure 5.8 below shows the database schema for our application. Reference alludes to predefined reference material created by the teacher during lesson planning, this may need to expand depending on future techniques needed. Curiosities refer to questions asked by the students and are visible to the teacher during a lesson in the live chat window.



6. Risk Assessment

HoloLens Development

Difficulty: High

Priority: High

Description: No one on the team has experience developing HoloLens applications and only one team member has previously developed in the Unity environment. We are unaware of the capabilities and limitations of a HoloLens application.

Mitigation: Begin researching and use Microsoft's HoloLens Academy tutorials to learn the basic processes of HoloLens application development.

Mixed Reality Live Stream

Difficulty: High

Priority: High

Description: Since only the person wearing the HoloLens is able to see the holograms, being able to stream the teacher's view of the holograms to students is a key component of the system. There is minimal documentation about how to implement this feature and how to direct this stream to our own web application.

Mitigation: Immediately begin implementing a live streaming channel using the Microsoft Mixed Remote View Compositing Toolkit and Azure Live Streaming Media Services. We will also be considering all other alternatives, such as using Open Broadcaster Software as the streaming endpoint.

HoloLens and Web Service APIs

Difficulty: Medium

Priority: High

Description: We need to create a web service that is able to communicate with our HoloLens application. This is necessary for actions such as being able to start lessons and quizzes through HoloLens voice commands and have these actions reflected in the web application.

Mitigation: Research implementing API endpoints for the HoloLens within our ASP.Net web application.

Reference Material

Difficulty: Medium

Priority: High

Description: Teacher must be able to add reference material from a webpage when preparing a lesson on the web application. It appears that it is not possible to use the HoloLens Microsoft Edge browser inside of a Unity application.

Mitigation: Research possible solutions for rendering web reference material and the best ways to save the reference material data.

7. Timeline

Week 1: January 9 - January 15

- First meetings with team members
- On-site meeting with TechSmith clients
- Scheduled weekly team meetings
- Scheduled weekly conference calls with clients
- Begin HoloLens development tutorials
- Set up test ASP.Net web application

Week 2: January 16 - January 22

- Continue with HoloLens Tutorials
- Begin working with Mixed Remote View Compositor
- Complete and prepare for Status Report Presentation
- Draft majority of Project Plan document

Week 3: January 23 - January 29

- Prepare Project Plan slide deck
- Review and finalize Project Plan document
- Prepare and rehearse presentation
- Set up web application framework
- Complete HoloLens Academy tutorials

Week 4: January 30 - February 5

- Prototype HoloLens application (basic hologram manipulation)
- Add models to web application
- Create lesson support for web application
- Basic authentication, registration, and roles for web application

Week 5: February 6 - February 12

- Working MRVC stream to web application
- Create (and take) quiz support for web application
- HoloLens lesson selection GUI
- Start quiz and start lesson support from HoloLens
- **Team “Hackathon” February 11 - 12**

Week 6: February 13 - 19

- Edit Lessons in web application
- Edit quizzes in web application
- Software Improvements for Alpha presentation
- Prepare Alpha presentation and slides

Week 7: February 20 -26

- Alpha presentation (February 21)
- Lesson Planning: add reference material
- Lesson Planning: add text
- View quiz results on web application

Week 8: February 27 - March 5

- Render text reference material in HoloLens
- Students question (curiosity) support from web application

Week 9: March 6 - March 12

- Spring Break (March 6 - March 10)

Week 10: March 13 - March 19

- View student questions in HoloLens
- Improve GUI for selecting and manipulating holograms

Week 11: March 20 - March 26

- Web application styling
- Support for class low latency and online streams
- **Team “Hackathon” March 25 - 26**

Week 12: March 27 - April 2

- Continue web application styling
- Prepare and rehearse Beta Presentation
- Extensive testing and improvements before Beta

Week 13: April 3 - April 9

- Beta Presentation (April 4)

Week 14: April 10 - April 16

- Begin working on video
- More improvements and fixes

Week 15: April 17 - April 23

- Finish Project Video
- Final improvements and fixes

Week 16: April 24 - April 30

- Project Video (April 25)
- All deliverable due, Design Day set up (April 27)
- Design Day (April 28)