HACETTEPE UNIVERSITY
COMPUTER ENGINEERING DEPARTMENT

UNDERGRADUATE PROJECT FINAL REPORT

Project Name	Report Date
AR Lab	17/01/2020

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Project Coordinator	Report Approval
Asst. Prof. Dr. Burkay GENÇ Date: 17/01/2020	☐ Yes ☐ No If no, rational of rejection: _____

Project Video Youtube Link
https://www.youtube.com/watch?v=xSHAvruGWXA&t=14s

A. TECHNICAL RESULTS

ABSTRACT

In high school, experiments in physics and chemistry at the laboratory have been a little bit complex. Even if you are studying in the public schools almost you never make an experiment. This has several reasons like experimental equipment are expensive and schools can't buy a new one if something is broken, or single-use items also expensive so the school can't buy it either. Based on this we developed a mobile application that students can make an experiment in the laboratory as she/he wants. Moreover, students can make the experiment at home to learn topics better. All need is a phone and our application. We used the ARKit plugin which is developed by Apple. We used this plugin mostly for detecting the surface. Also, we are developing this project in Unity. We are making scenes for every experiment and keeping user data for level mode. Users can continue where is left. In level mode users only can move to the next level if complete current level. We also have an achievement page for user achievement.

Keywords: Augmented Reality, Education, Game, Chemistry, Physics

I. INTRODUCTION

The main goal of this project is to create a functional AR Application that can perform laboratory experiments. At the end of this semester, 2 of these experiments which are Acid & Base and Binding Atoms will be done. In the application, the main functionalities had been created. These functions contain the selection of the laboratory experiment. After the selection of the laboratory experiment, the scene of the experiment opens in the mobile application. The scene contains a menu that contains the laboratory equipment that is needed in the experiment. From this menu, the user can select the items that he/she will use in the experiment. These functions are ready for the first experiment, Acid-Base. After we finalized the experiment, the mobile application will have the gamification part, we will add username, user avatar, scoreboard, achievements, challenges. For users to have gamification information and to store this information, we will use Unity's packages.

Our main purpose in design is to make it simple. Because our target user group is mostly elementary and high school students. After our research on ideal design, we found some suggestions that are by professional mobile application developers. The most important one was to have the least number of buttons that have high functionalities. So we used this principle in our application design.

We finished the first semester of our project and I am happy to say that we accomplished every milestone we have set at the beginning of our projects for this semester. As I said before, our goal was to finish the design of the application and two of our five experiments. "Acid-Base" and "Molecules" experiments are ready for users to use. After the submission of the Progress Report, we mostly worked separately. Because we decided that, after the learning process it is more efficient for us to work separately and accomplish different milestones.

This report contains information about the developments that we made in the project in detail and the final state of our mobile application. We are going to explain which technologies that we used and the purposes of those decisions. As we said in the previous reports that we submitted our main purpose was to make our application as realistic as possible. But after some point, we decided to add some unrealistic effects to our project and we are going to explain the reasons for these decisions.

II. BACKGROUND

This is project is based on Augmented Reality which is a hot topic in today's technology. Augmented Reality provides the opportunity for interactive experiences of the real world that is enhanced with virtual objects, sounds, haptics, etc. through a technological device. Since augmented reality applications combine the real world with virtual things, the first step is understanding the environment beforehand to enhance it. Data collected by sensors on technological devices are processed with software applications to create a better understanding of the environment. Afterward, virtual things that are created in computers are inserted into the real world to become observable and interactable through devices. The most common devices for Augmented Reality are mobile phones and augmented reality glasses. We aim to make this project usable with minimum expenses henceforth we're developing it for mobile phones which are nowadays achievable for almost any family in our country.

ARKit is one of the most popular platforms for augmented reality development for mobile phones. It possesses software tools that help us to do operations such as interacting with virtual objects, surface detection, object tracing, detection of different kinds of objects and many other environment related operations in order to achieve better environment recognition. For our project, we used ARKit scripts that help us to detect flat horizontal surfaces that are later on will be used to create virtual objects and some scripts to interact with these objects to do the experiments. We chose to use scripts from ARKit 2.0 Plugin for Unity.

Unity is a cross-platform game engine that is used to create 2D, 3D, Virtual Reality and Augmented Reality games and simulations. It was the platform where we spend most of our time while developing this project. As mentioned above, augmented reality is enhancing the real world by virtual things. ARKit is the tool we used for understanding the real world. Unity fulfilled our other expectations to create an augmented reality environment by enabling us to design virtual objects, their relationship with each other and the real-world environment.

III. RELATED WORK

There are several projects which aim to solve our specified problem. A few best examples of these projects are;

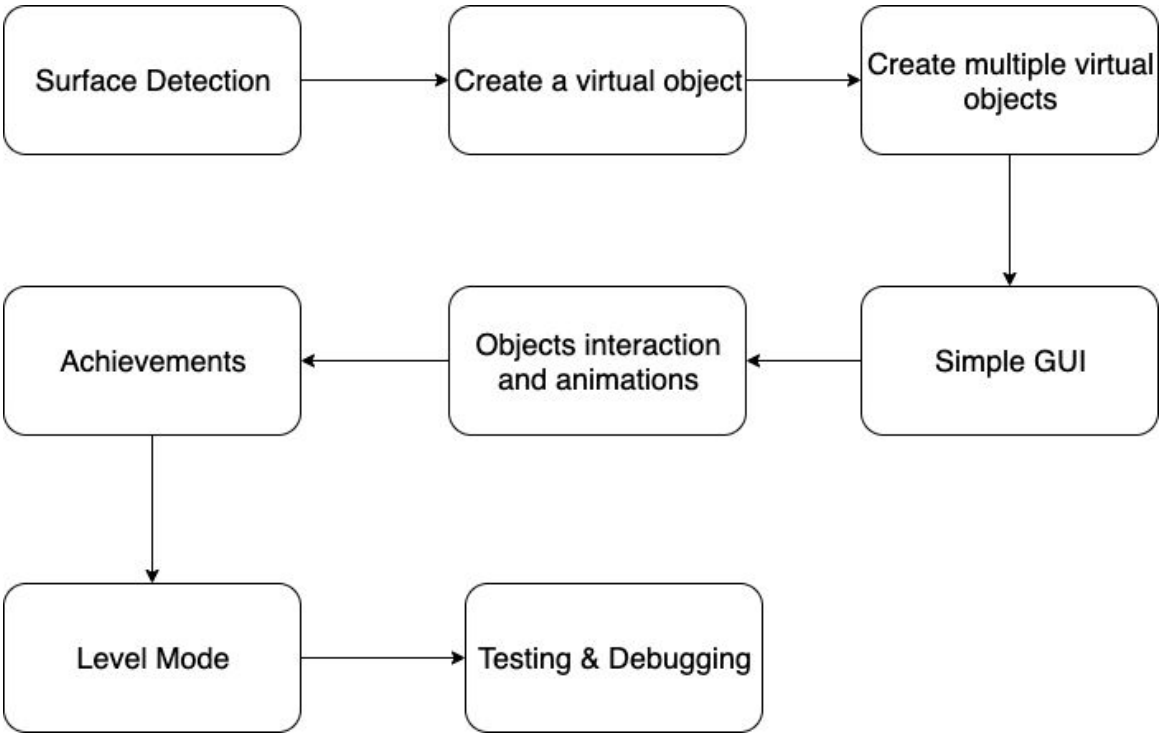
AR Chemistry: Its approach is based on physical objects. Camera recognizes cards which have symbols for some elements and creates virtual 3D models of those objects above the cards. When cards of elements that would bond touch, virtual models of elements bond and creates a molecule. After a few seconds, the atomic modeling disappears and a new virtual physical model is created above the cards which shows what that molecule would look like in the real world.

VRLab Academy: It's one of the most advanced AR/VR projects that simulate a laboratory environment. It creates this simulation in a virtual reality environment. Every object required for the experiment has interacted with virtual hands that user controls. This project has a large scale of experiments from different topics such as biology, chemistry and many different topics from physics. It uses virtual reality glasses as hardware. Its aim is to create a fully equipped laboratory environment with the expense of a virtual reality headset.

Simulating Educational Physical Experiments in Augmented Reality: It is one of the oldest projects on this topic which was developed in 2008. It focuses on mechanics education rather than different topics from physics and science. It provides a variety of tools for analyzes related to mechanics. Its setup uses two different hardware, one wireless pen, and one head-mounted display. Head-mounted display is used to combining real worlds with the virtual one visually while the wireless pen is used for interactions with real objects.

IV. METHOD

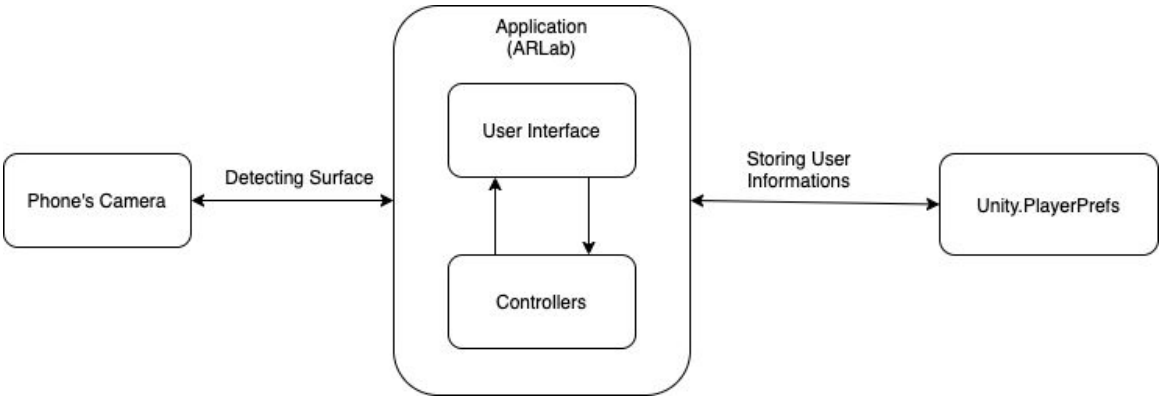
We used agile development method in this project. In every step we added functionalities to before step. Below diagram shows most general step of our project.



1. **Surface Detection:** We used ARKit plugin for this step. ARKit is developed by Apple and continue developing. We used this because this plugin is very efficient and common in the Augmented Reality world. Also, the company behind it is a continuous company and it seems like they will be kept developing.
2. **Create a virtual object:** For the virtual part of our project, we used Unity which can work with ARKit and this is pretty choosable for us.
3. **Create multiple virtual objects:** This was a little bit challenging for us because we are new on Unity and trying to figure out how Unity works but in the end we done this.
4. **Simple GUI:** This is a very important step for us because we build an application and for usage user interfaces more important than the functionalities. We used free assets for this step.
5. **Objects interaction and animations:** In this step, we used Unity built-in function which is OnCollisionEnter(). If the object has a rigid body and collider components, they can collide and with this function's help, we can detect a collision and manipulate objects to create animations.
6. **Achievements:** This step for gamification for our project. Our app does not have score type more likely moving in achievements because user make an experiment and for result users only accomplish or failure we can't score them at least for now.
7. **Level Mode:** We make levels for every sub-experiment. If the user completed a level, the user can move to the next level.
8. **Testing & Debugging:** This is the very last step of us. While we test it we don't find many bugs but we tried to our friends and their feedback golden for us. We fixed their issues.

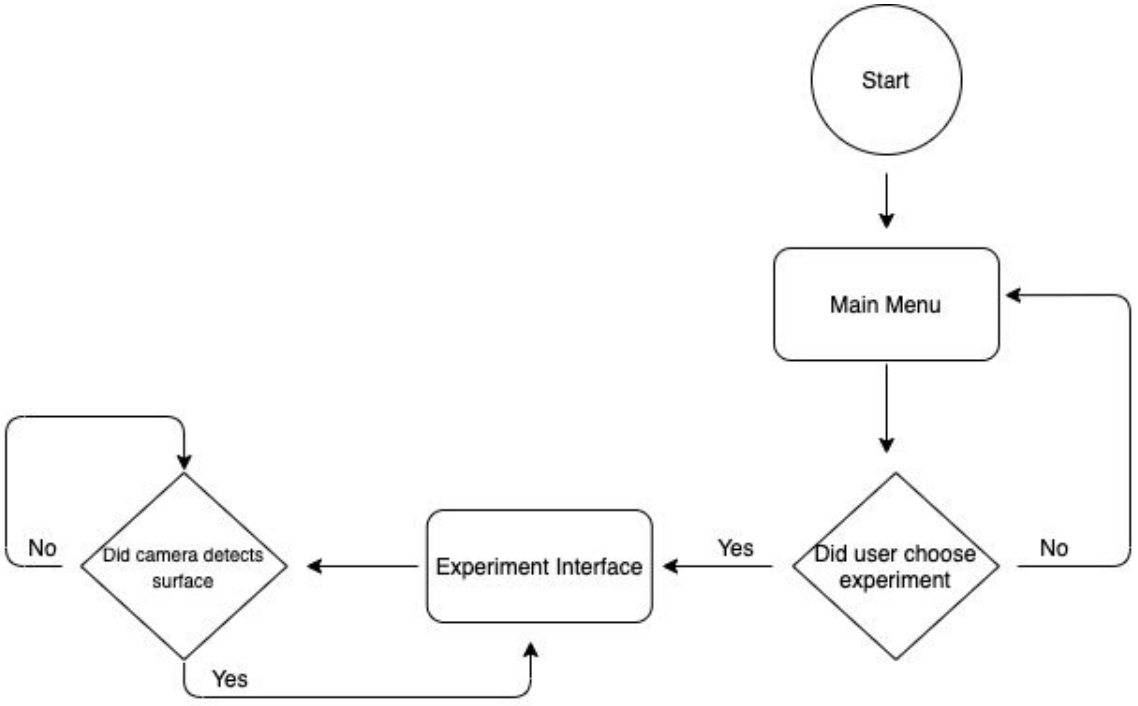
V. TECHNICAL DESIGN AND CONFIGURATION

Context diagram for the application is as follows:



As the user choosing an experiment, the phone's camera starts and try to find a surface. When finding it, it notifies the controller to create a plane prefab to notify user. After the user sees the plane, the user starts the experiment. With the help of the controller, the user can create virtual objects and make interactions with each other. When the user decides to leave the application, user progress would be saved in Unity.PlayerPrefs for later can continue which level user left. We developed our project in Unity and take a build from Unity and with Xcode we can install to phone.

Main Flowchart of the application:



VI. PROJECT IMPLEMENTATION

At the end of the first term of the academic year, our goal was to finish two experiments in our project. These experiments are “Acid-Base” and “Molecules”. Additional to these we needed to create the menus and achievement screens because even though there are only two experiments in the mobile application, other properties of the application should be complete. We have achieved these goals that we set at the beginning of the term.

As a beginning, we created a menu for our application. In this menu, we are asking the user to pick an experiment. After picking an experiment from the area that contains the experiments, the user can click the “Select Experiment” button to enter the experiment. There is a button on the menu that the user can go for the achievement screen.

When user clicks for the “Achievement”, there will be listed on the screen. This listing contains the achievements that the user can achieve by completing some assignments in the experiments. When a user accomplishes an achievement, the achievement will be visible in the user's screen as a sign for completed achievement.

When a user clicks for the “Select Experiment” button after picks the experiment that he/she wants to do, there will be two options that pop-ups to the user. The first one is “Level Mode”, the second one is the “Free World” button. “Level Mode” button is to select a level in the experiment. Levels are for users to complete given instructions about the experiment. “Free World” button is for users to try different operations that are not in the “Level Mode”.

For all experiments, the screen that opens after selecting “Free World” or “Level Mode” is the same. The camera of the mobile phone that the user will be open and all the screen will be a camera view of the mobile phone. There will be a button in the right button for selecting the object that the user wants to create and after selecting the object that the user wants to create, when he/she clicks on the screen the object will be spawned.

In Level Mode, when the user is doing the given assignment before the mobile applications do the operation after the collision between the objects, it asks the user for the possible outcome. We added this to test the user's knowledge about the subject and whether he/she learns from the mobile application.

When a user finishes the given assignment, the mobile application automatically goes to the next level and the instructions of the next level will open.

These are all the work we did this semester. We used the ARKit plugin for Unity. ARKit is for implementing projects in Unity for Augmented Reality. Detection of the surface, all the effects we did and assets that we use are possible by ARKit and Unity. Assets are the objects that we are using in our experiments. For example, the dispenser that we are using is an asset. Every asset has components that are specifying the properties of that asset. We designed every asset by using these components.

There are many ways in Unity that can be used for animations and effects. In these two experiments, we mainly wrote code for the animations that we want.

We used ARKit’s libraries for ground detection. We used ground detection for creating a surface that the user can make the experiments on.

Unity has many libraries that can be used for mobile application design. We used Unity’s libraries for designing the mobile application. All the buttons and the actions that happen after the press on the button are made in Unity.

For the gamification side of the mobile application, we used Unity’s libraries. Unity is providing developers a function that creates a database for the users and stores in a .json file. By this library, we are able to store the achievement information of the users.

VALIDATION AND RESULTS

In every step of the project, we carry on our work by controlling the outputs of our previous development. Because every development that we made was connected and after a point, it was getting hard for us to find the error that we made when we ran into an error. This method helps us a lot in the developing process. Because every development that we made was changing a lot in the assets and if we had a problem in the previous implementation we could easily guess that a new error is caused by the new implementations that we made.

As I said before we used ARKit's libraries for ground detection. ARKit requires at least the iPhone 6s model. But even in the iPhone 6s's camera is not enough for ARKit to make proper object detection. Therefore sometimes our application is having problems in low models of iPhone. But this problem is not because of us. This is a problem that happens in every ARKit project.

Before starting the implementations of every experiment, we planned the properties that the experiment needs to have and the assets that we are going to use. At the end of both of the experiments, we achieved every goal that we said and finished the implementations of the experiments.

CONTRIBUTION(S) TO INDUSTRY AND ECONOMY

The starting point of our project was about the economies of schools in Turkey. Most of the schools in Turkey have no extra money for laboratory tools. Therefore students in these schools are finishing middle school and high school without going to laboratories to overlearn the information that they have learned in science classes. But nowadays every child has a mobile phone. That's why we decided to develop a mobile application that contains science experiments.

This will help to economy because schools are going to be able to perform experiments with students without paying money for laboratory tools.

INNOVATIVE ASPECTS

As we stated in the "Contribution(s) to Industry and Economy" section our starting point was to give access to every student for laborite experiments. In education, even if schools have nice laboratories students are only able to access these areas in-class hours. But with our application students will have access to a laboratory even in their houses. They will have more time to practice the information that they learn in theory.

Our application has an achievement database. So teachers can give these experiments as homework to the students for them to study individually.

As a conclusion, our main purpose is to let students learn in particle exercises. Because every research about the education of applied sciences is saying that students at an early age are learning better by particle exercises.

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B. PROJECT RESULTS

I. CHANGES TO PROJECT PLAN

We adhered to the project plan we had previously determined.

II. PROJECT MILESTONES AND OBJECTIVES

Milestone #	Primary Objective	Due Date	Project Deliverable (if any)	Milestone Achieved?
1	Surface detection and placing virtual objects to that surface by using ARKit	31.10.2019		Yes
2	Optimizing measurements of virtual objects correspondingly to environ- ment	7.11.2019	An uprunning mobile application that detects surface and places a virtual object	Yes
3	A prototype of the experiment will be created and hit testing will be done.	14.11.2019	The places of the objects in experi- ments will be finalized	Yes
4	3D models that are needed for the experiment will be produced and pur- chased	28.11.2019		Yes
5	Needed animations will be produced and added to the prototype.	5.12.2019	3D models of the experiment materi- als will be in the decided places and the animations will perform between objects.	Yes
6	Frontend of the mobile applications will be done.	12.12.2019	Graphical user interfaces of the mo- bile application will be done.	Yes
7	The interaction at AR between the virtual objects will be done. The scene for the second experiment will be designed.	26.12.2019	Planned experiments will be per- formed in AR. The main scene of second experiment will be done.	Yes

8	User profiles and other gamification tools will be added to the application	02.01.2020	In the graphical user interface, gamification tools will be available for users	Yes
9	Testing & Debugging	09.01.2020	Our mobile application will be used and tested by various amounts of people and by the feedback we will develop our AR Project	Yes
10	Light estimation: Making virtual objects look more realistic by adjusting lighting correspondingly to environ- ment	16.01.2020	More realistic experiments will be available for use	Yes

III. PROJECT PRACTICES AND MEASURES

Task #	Task Description	Responsibility	Start Date	Finish Date	Success Criteria	Task Succeeded?
1	An AR application that can detect the ground and add vis- ual object will be created.	All members	24.11.2019	7.11.2019	Detecting flat sur- face perfectly	Yes
2	A prototype AR environment that enables to interact with virtual objects by mobile screen touches will be created.	All members	7.11.2019	14.11.2019	Able to hold and drag a virtual object	Yes
3	A prototype of our laboratory environment which has 3D models of experimental materi- als combined with visual effects will be developed	Kaan Mersin	14.11.2019	05.12.2019	Animations and virtual objects will be connected adequate	Yes
4	A user friendly GUI will be created.	Hüseyincan Kaynak	05.12.2019	12.12.2019	Routing of pages working correctly	Yes

5	Virtual objects interacting with each other	Ahmet Tarık Kaya	12.12.2019	26.12.201 9	Objects interact with a small error margin	Yes
6	Gamification will be developed and added to the application.	Hüseyincan Kaynak	26.12.2019	02.01.202 0	All these properties works,	Yes
7	Test & Debugging	Kaan Mersin	02.01.2020	09.01.202 0	Every 4 out of 5 people who uses likes	Yes
8	Light estimation of objects	Ahmet Tarık Kaya	09.01.2020	16.01.202 0	realistic as possible	Yes

Team Member	**Task # Under Responsibility**	**Description of the Work Done**
Ahmet Tarık Kaya	3	Tarık's job was mostly with the existence of the objects in the virtual environment. At first, he researched how to place an object on the detected surface and after that, he worked to control and change positions of objects via screen touches using scripts. Virtual objects in our augmented reality environment have different behaviors when they interact. Tarık's main occupation in the second half of the semester was about behaviors that are related to movement. Other than that, Tarık was working on light estimation using ARKit's tools which gives virtual objects more real to life visualization by lighting virtual objects based on the lighting of the real world.
Hüseyincan Kaynak	3	Hüseyincan mainly focused on detection on the ground plane to do that researched ARKit surface detection tools, plugin, scripts, etc. After that design a user-friendly GUI. Consider, harmonious colors and background images. Design some buttons, search for free GUI assets that we can use. We want to users keep constantly playing and this can achieve with gamification. To do that Huseyincan added level mode in our every experiment. User tries to pass levels to get more levels. Also, he added achievements menu. If the user has done some levels we gave them achievement and she/he can see it on the achievement page. Also, at the end of the level, we ask a pop-up question to the user if the user can answer correctly then move to the next level.
Kaan Mersin	3	During this period, he was responsible for finding the right assets and animations for the Acid&Base experiment. Adding the animations to a specific object after or while the collision was his job. While we were developing our project, we are always testing our code and the predicted outputs. Because in Unity, we are using a lot of different properties and combining them with each other. So we were moving forward very carefully to prevent any possible error. Kaan asked our friends and colleague to test our experiments. They helped us to find bugs and possible errors in the project and we solved those miswritten codes.

IV. PROJECT BUDGET

Item #	Description of Income	Date of Income	Planned Amount	Actual Amount	Amount Difference

Item #	Description of Expense	Date of Expense	Planned Amount	Actual Amount	Amount Difference

Overall Balance	Planned Amount	Actual Amount	Amount Difference
Income			
Expense			
Total			

V. PROJECT RISKS

Risk Item #	Description	Probability	Effect	Did It Happen?	How did you (or will you) handle its occurrence? (Plan-B)
1	To have a low light in the camera view	Medium	Medium	Yes	Notify user for experimenting in a more convenient environment
2	Ground being too indented	Low	Medium	Yes	Notify user for experimenting in a more convenient environment

VI. SELF EVALUATION

We found our team as successful. We have known each other and our past, we worked for 2 years with each other in student clubs. We experienced planning work and projects with each other. Maybe as individuals, we are not good but as a team, we eliminate our missings. During this semester we got a meeting every week thanks to our advisor. It helps that improve our project very much. We did all the milestones that we planned. At this point, we can't say that our app is great because this is a one year project we don't accomplish in our mind yet. We have done all functionalities but we don't proud our GUI. We mostly used free assets but at some point, we need to design some panels and we can't a harmony with used assets. But this semester we try to improve GUI, we try to improve our design skills.
Also with this project, we applied to Hacettepe Ön Kuluçka and we have been accepted. We are working there for 2-3 weeks and it helps us to look at our project with a different point of view. In there we think some innovations can be added to the project. We will implement it in the second semester.
https://www.hacettepeonkulucka.com/ this is a website for Hacettepe Ön Kuluçka you can see us there as AR Akademi. This website is still in progress.

VII. LESSONS LEARNED

This project improved us many ways but I believe the most important ones of those were our improvements as software developers and researchers. We had many kinds of different assignments and course projects in past years but this projects taught us something none of those courses taught before. We were developing a project on a topic that we are not taking a theoretical course simultaneously for the first time. Further to that, this topic we were developing our project on was a topic none of has had any previous information on. This helped us improve ourselves on researching and use info we obtained from that research for software development without taking directions for every single step from somebody else.

Another lesson we learned from this project was realizing how challenging it can be to develop new skills in a topic that you have no background in and no matter the difficulty, it is possible to achieve that with enough effort. If we went back in time, we would probably allocate more weeks for learning the basics of AR development when planning first semester and set easier milestones. At the beginning of the semester, we needed to spend too much extra hours that sometimes could become overwhelming due to our lack of background in AR and game development in order to match our milestones. Nevertheless we are not regretting our decisions even though sometimes it became overwhelming. At the end of the day we were able to accomplish our milestones successfully which means we pushed ourselves closer to our limits compared to a scenario with easier milestones. That resulted with more self improvement for every member of the team.

One last thing this project made us realize how important dividing tasks between team members was. At the beginning of the semester, we weren't doing an effective task dividing since all we were doing was learning the basics and every single one of us needed to learn those basics in order to do task division at the later parts of the project. After we made significant progress on learning the basics, we started to divide tasks and it strongly improved efficiency of our work as a team.