EXPLORING USER EXPERIENCE AND PERCEPTIONS OF A LOCATION-BASED AUGMENTED REALITY GAME: THE CASE OF METU DISCOVER

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

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Location-based games use real-world location as a fundamental element of gameplay, potentially influencing players' relationships with their surroundings. This thesis aims to understand user experience and perceptions of a location-based augmented reality game. To do that, a location-based augmented reality game named METU Discover is developed, which is focused on exploration of the flora in the Middle East Technical University campus ecosystem.

As a part of the development process, a usability test was conducted with seven participants and based on their feedback usability improvements were implemented to the game. In the main study, eight participants played the game and participated in an interview on usability of the game, the game's effects on plant awareness and participant's sense of belonging to the university.

Based on the analysis of the interview data, the impact of the developed game on the players is described in detail, along with the steps followed in its design and development which includes insights for the design of location-based augmented reality games, based on the results obtained from usability test. The data analysis revealed that the game encouraged players to explore their environment more and increased their awareness of the biodiversity of the campus flora.

Keywords: Location-Based Games, Augmented Reality, Usability, Plant Blindness, Sense of Belonging

ÖZ

BİR KONUM TABANLI ARTIRILMIŞ GERÇEKLİK OYUNUNUN KULLANICI DENEYİMİ VE ALGILARININ ARAŞTIRILMASI: METU DISCOVER ÖRNEĞİ

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Konum tabanlı oyunlar, çevreyi oyunun temel bir unsuru olarak kullandıklarından oyuncuların çevreleriyle olan ilişkilerini etkileyebilme potansiyeline sahiptir. Bu tez, konum tabanlı bir artırılmış gerçeklik oyununun kullanıcı deneyimini ve algılarını anlamayı amaçlamaktadır. Bunu yapmak için, Orta Doğu Teknik Üniversitesi kampüs ekosistemindeki bitki örtüsünü keşfetmeye odaklanan METU Discover adlı konum tabanlı bir artırılmış gerçeklik oyunu geliştirilmiştir.

Geliştirme sürecinin bir parçası olarak, yedi katılımcı ile bir kullanılabilirlik testi gerçekleştirilmiş ve geri bildirimlerine dayanarak oyunda kullanılabilirlik iyileştirmeleri yapılmıştır. Ana çalışmada, sekiz katılımcı oyunu oynamış ve oyunun kullanılabilirliği, oyunun bitki farkındalığı üzerindeki etkileri ve katılımcıların üniversiteye aidiyet duygusu üzerine bir mülakata katılmıştır.

Görüşme verilerinin analizine dayanarak, geliştirilen oyunun oyuncular üzerindeki etkisi, tasarım ile geliştirilmesinde izlenen adımlar ve kullanılabilir testinden elde edilen sonuçlara dayanarak konum tabanlı artırılmış gerçeklik oyunlarının tasarımı için içgörüler ayrıntılı olarak açıklanmıştır. Veri analizi, oyunun oyuncuları çevrelerini daha fazla keşfetmeye teşvik ettiğini ve oyuncuların kampüs florasının biyolojik çeşitliliğine dair farkındalıklarını artırdığını ortaya koymuştur.

Anahtar Sözcükler: Konum Tabanlı Oyunlar, Artırılmış Gerçeklik, Kullanılabilirlik, Bitki Körlüğü, Aidiyet Duygusu

To My Family

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LIST OF ABBREVIATIONS

AR	Augmented Reality
EKOSAM	Ecosystem Implementation and Research Center – Ekosistem Uygulama ve Araştırma Merkezi
DKM	Nature Conservation Centre – Doğa Koruma Merkezi
LBG	Location-based Games
PoI	Point of Interest
PGO	Pokémon Go
OSM	OpenStreetMap
VPS	Visual Positioning System
WGS1984	World Geodetic System – 1984

CHAPTER 1

INTRODUCTION

1.1. Purpose and Significance of the Study

The aim of this thesis is to develop a location-based augmented reality game focusing on flora in a specific environment and explore user's thoughts about such a game. For this purpose, a location-based augmented reality game, METU Discover, focuses on the flora (trees, plants, etc.) within the ecosystem of the METU campus is developed. The steps taken for designing and developing this game are explicitly explained and the players' thoughts about the game's different aspects are investigated.

Many studies mentioned that location-based games increase the players' knowledge about their physical environment. Based on the results from a questionnaire filled by 133 long-term players of a location-based game called Ingress, Söbke et al. (2017) found that gaining knowledge about the local environment is the second most preferred outcome of the game. Chess (2014) mentioned that Ingress "becomes a means of teaching players about their own regional spaces". In a study on 375 Pokémon GO players by Colley et al. (2017), almost 60% of the participants mentioned they had visited at least one new place.

There are studies that shows sense of belonging can be increased with the location-based games (Lawler-Sagarin et al., 2023; Vella et al., 2019). Lawler-Sagarin et al. (2023) also suggests the potential application of such games on university campuses to foster community engagement. Plant blindness, or the lack of plant awareness, is stemming from people's lack of understanding or underestimation of the importance of the plants (Wandersee & Schussler, 2001). Plant awareness can be increased with increased knowledge about the plants (Pany et al., 2022; Wandersee & Schussler, 1999). Pedrera et al. (2023) explained that plant blindness is linked to the comprehension of biodiversity.

Therefore, I think that a similar approach can be applied to METU campus, make METU students visit new places, and increase their plant awareness and sense of belonging to the campus. Apart from the location-based features, augmented reality mode has also been added to the game to enhance player immersion and social features are added to the game to increase social interactions between players.

The significance of this study is the usage of a location-based AR game with social aspects (leaderboard, teams etc.) focusing on the flora of campus. Also, findings from this study can help the design of location-based games aiming for improvement in user's plant

awareness and sense of belonging. Furthermore, the study adds to the body of knowledge on the relationship between location-based games and player behavior.

The research questions of the study are as follows:

- RQ1: What are the user's thoughts about METU Discover in terms of user experience?
- RQ2: What are the user's thoughts about METU Discover in terms of sense of belonging?
- RQ3: What are the user's thoughts about METU Discover in terms of plant awareness?

1.2. Definition of Terms

Location-based Augmented Reality Games: Location-based augmented reality games are the games that utilize augmented reality with location features (Laato, Inaba, et al., 2021).

Augmented Reality: Augmented reality defined as "a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information" by Klopfer & Squire (2008, p. 205).

Sense of Belonging: Sense of belonging defined as "the experience of personal involvement in a system or environment so that persons feel themselves to be an integral part of that system or environment" by Hagerty et al. (1992, p. 173).

Plant Awareness: Plant awareness is a phenomenon that describes individuals' awareness of plants and their significance, encompassing four key aspects: visual perception of plants, categorizing plants as living organisms, knowledge about the plants, and attitudes towards the plants (Pany et al., 2022).

Plant Blindness: Plant Blindness is the lack of plant awareness (Pany et al., 2022).

1.3. Outline of Chapters

The thesis consists of five chapters. Each chapter's content is summarized below:

- Chapter 1 – Introduction: This chapter provides a general introduction to the thesis, outlining its aim and research questions.

- Chapter 2 - Literature Review: A comprehensive review of current literature on location-based games is presented in this chapter. It covers essential elements in their designs, such as maps and points of interest, explores their applications in learning, and discusses their social aspects. Additionally, the chapter delves into the concepts of the sense of belonging, plant blindness, and the METU campus ecosystem.

- Chapter 3 – Method: This chapter provides a detailed explanation of the thesis's research design, methods for data collection and analysis, and the development stage of METU Discover, including the usability test conducted as part of the development.

- Chapter 4 – Results: This chapter includes the results from the interviews conducted with the participants.

- Chapter 5 – Discussion and Conclusion: This chapter includes discussion of the research questions based on the results of the study, limitations in the study and potential improvements for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1.Brief Introduction to Location-Based Games

Location-based games fall within the broader category known as pervasive games. Montola (2005) characterizes pervasive games as those that extend the traditional magic circle of play across social, spatial, and temporal dimensions. Specifically, location-based games represent a subset of mobile pervasive games, with location serving as the primary game mechanic. These games encompass all the expansions described by Montola (2005) allowing for gameplay at any time, in diverse locations, and facilitating social interaction. According to Avouris et al. (2013), in location-bases games, gameplay occurs on three different space: physical space, digital space and narrative (game space). Also Laato, Hyrynsalmi, et al. (2020) mentioned that location-based games can also be considered as exergames (games that motivate player to exercise) due to their positive effect on player's mild physical exercise.

The first category of location-based games is primarily designed for entertainment. These games utilize location as a fundamental game mechanic, aiming to captivate users and generate revenue for their companies. The typical core game loop involves players using the map to identify points of interest. Subsequently, players physically navigate to these locations to engage in various interactions, such as adding items to their inventory, participating in battles, or acquiring information. Notable examples of such entertainment-focused location-based games include Ingress (Niantic, 2013), Pokémon GO (Niantic, 2016), Draconius GO (Elyland, 2017), Jurassic World Alive (Ludia Games, 2018), Walking Dead: Our World (Next Games, 2018) and Harry Potter: Wizards Unite (Niantic, 2019).

Since its launch in June 2016, Pokémon GO has maintained its status as the most popular location-based game. While Pokémon GO wasn't the first location-based game—Niantic, the developer, had previously released Ingress three years prior—its release marked a turning point, transforming location-based gaming into a cultural phenomenon that attracted players from diverse backgrounds. In 2016, the game had an impressive 232 million active players (*Pokémon Go Revenue and Usage Statistics (2023)*, n.d.). The key factor contributing to Pokémon GO's widespread popularity is its association with the globally recognized Pokémon franchise. A study involving 2612 Pokémon GO players revealed that a significant motivation for starting the game is a prior connection with the Pokémon franchise (Alha et al., 2019). Furthermore, research by Laato et al. (2021)

indicates that nostalgia plays a crucial role in enhancing players' ability to immerse themselves in the game's fictional world, therefore increasing the overall meaningfulness of the gaming experience. Leveraging the popularity of established franchises to build a broad player base has become a common strategy among game developers, as seen in examples like Jurassic World Alive (Ludia Games, 2018) and Harry Potter: Wizards Unite (Niantic, 2019). Figure 1 shows a map view of the Jurassic World Alive. In addition to entertainment these location-based augmented reality games also affect players behaviors and attitudes. Such as increase of their spatial orientation skills (Carbonell Carrera et al., 2018), increase of the mild physical exercise (Laato, Hyrynsalmi, et al., 2020), enhancement of sense of belonging (Vella et al., 2019), increase in psychological well-being (Laato et al., 2022).



Figure 1: Screenshots from Jurassic World Alive

2.2. Location-Based Serious Games

Commercial popular location-based games can teach people new subjects or create a change in their behavior, but they are not developed with these intentions; therefore, they are not considered serious games. However, the insights gained from the experience and varied applications of elements in location-based games for entertainment, coupled with research findings, lay the foundation for designing and enhancing location-based serious games. Zyda (2005) defines serious games as cognitive competitions executed on a computer, employing entertainment to achieve objectives related to serious issues such as government or corporate training, education, health, public policy, and strategic communication.

Laato et al. (2021) demonstrate that location-based games can inject engaging content into otherwise mundane and familiar environments, making them valuable tools for teaching various subjects. The applications of location-based games in education span from formal teaching topics in classrooms to topics beyond the official curriculum, catering to students ranging from 5th grade to university level (Ribeiro et al., 2021). These educational games cover diverse subjects, including history (Laato, Rauti, et al., 2020) ecology (Kamarainen et al., 2018), and local city information (Avouris et al., 2013; Huizenga et al., 2009). Another educational application involves using location-based games to teach about nature. Moreover, Kamarainen et al. (2018) note that augmented reality games enable students to learn outside of the classroom and allow them to connect better with engaging the environment more directly.

In addition to educational purposes, some location-based games are developed specifically for various research topics. Naghadeh (2022) created the location-based game METU GO to assess the usability of location-based games. Schade et al. (2023) developed the location-based game MapUncover to explore how gamification elements in such games impact users' exploration behavior.

2.3. Augmented Reality Games

Augmented reality (AR) is a technology that enables users to engage with a real environment while introducing an additional layer of information. Klopfer & Squire (2008, p. 205) defines augmented reality as “a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information.”. This typically occurs when users interact with a trigger object or location within the application. Application superimposes digital data such as visuals, texts, or videos onto the real world. In essence, AR adds another layer of information to reality without disabling the connection with the real world.

Cheng & Tsai (2013) define two main types of AR namely, image-based AR and location-based AR. Image-based augmented reality experience is triggered by a match with an image of an object. This may be as simple as reading a QR code from a card or using a head-mounted display like Microsoft HoloLens and looking at a faulty electronic device and getting a hologram manual on how to fix that. On the other hand, in location based-based applications, metadata is connected to a real location represented by a point of interest (PoI) and the user needs to physically go there to activate the augmented reality layer. Even though there are differences between both types of augmented reality, both allow the addition of augmented digital data (visuals, texts etc.) to the physical environment through screens.

Augmented reality can be used to support the engagement and learning of the students. An example might be Kamarainen et al. (2018)’s augmented reality application called EcoMOBILE which focuses on teaching about the ecology and environment to undergraduate students. It consists of many modules such as Atom Tracker in which

students follow the oxygen atoms' journey in the environment and learn the O_2 / CO_2 cycle of the environment. Another example is Akçayır et al. (2016)'s application of image-based AR technology to increase laboratory skills of the university students.

Not all location-based games incorporate augmented reality, but it is a common feature in games such as Pokémon Go and Jurassic World Alive. When players approach a point of interest in the game, they have the option to engage with the PoI using augmented reality. However, in these games, AR feature is optional, and users can still earn the same rewards without utilizing AR. Location-based games that exclude augmented reality limit interactions to points of interest on the map screen, eliminating the use of the camera. In a location-based game study based on the METU campus, Naghadeh (2022) reported user feedback suggesting the addition of augmented reality features to the game.

There are different augmented reality applications, both image-based and location-based types, focusing on the different aspects of the university campuses (Andri et al., 2018). One example, CAViAR, is using image-based AR and inertial navigation for indoor navigation in university campus (Delail et al., 2012). Another example, Campus Event App by (T. Chao et al., 2014) focusing showing the events on the campus. Yu et al. (2015) developed an AR application which allows users to gain information about the ecology of the campus. Giraldo et al. (2016) developed a virtual application that use augmented reality for the University of Quindio. Garay-Cortes & Uribe-Quevedo (2016) developed a location-based augmented reality game to increase fresh year student's familiarity with the landmarks in the campus. Ozcan et al. (2017) developed an AR application which detects buildings in the campus and provide information about them. Jindal et al. (2023) developed an application, TWUEXPLORAR, to help users to find necessary facilities in the campus. Lu et al. (2021) developed a campus navigation application that use ARCore for both indoor and outdoor locations.

2.4. Points of Interest

Points of interest (PoIs) refer to specific locations displayed on a digital or physical map, typically featuring notable elements such as buildings, parks, or game objects (Laato et al., 2019). In the context of location-based games, PoIs are spots on the map where players engage in various interactions, such as acquiring items or inspecting objects. These locations and players' interactions with them often form the core mechanics of location-based games. The locations of these points in location-based games are usually inspired by real-life locations, but there are also games with PoIs that are not based on real-life locations, such as Draconius GO.

Points of interest are integral to the appeal of location-based games, significantly shaping players' gaming experiences. Therefore, the creation of these points of interest is very important. Various games employ different methods to establish these points of interest, however Tregel et al. (2017) identify three main methods for creating points of interest:

- **(Semi) Random**: This method involves using an algorithm to automatically generate points of interest from the map database, yet it may result in points of interest that can pose security concerns for players.

- **Crowd-sourced (User Generated)**: In this method, points of interest are created by the user community in collaboration with specific criteria provided by the developers.

- **Manually Created by Content Creators**: In this method, points of interest are entirely placed by the developers.

Each game may use one or a combination of these methods to create points of interest, and each method comes with its own set of advantages and limitations. Laato et al. (2019) categorized the three mentioned methods as automatic content creation (semi-random) and manual content creation (crowd-sourcing, manually created by content creators). In their study, Laato et al. (2019) evaluated the quality of points of interest (PoIs) in five popular location-based games: Pokémon GO, Ingress, Jurassic World: Alive, The Walking Dead: Our World, and Draconius GO. Their evaluation criteria include the following categories: connection to real-world places, uniqueness and metadata, and placement.

Jurassic World: Alive, The Walking Dead: Our World, and Draconius GO are games that use semi-random automatically generated points of interest based on the map information from online map services. Map information from the map service is processed by an algorithm to choose PoI locations all over the world. Out of these three games, Jurassic World: Alive and The Walking Dead: Our World use Google Maps service and Draconius GO uses OpenStreetMap service. While these games achieve evenly distributed PoIs on a global scale, they often lack a meaningful connection to real-world locations, reducing the uniqueness of the points.

The strategic placement of PoIs is crucial, requiring consideration for player safety, and should follow any local regulations. Certain areas are designated as off-limits for such games, exemplified by the Tuol Sleng Genocide Museum in Cambodia, which banned location-based games within the museum premises due to disturbances caused by players (“Cambodia Bans Pokemon Go Game at Genocide Museum,” 2016). Games relying on automatically generated PoIs, such as Draconius GO, face notable challenges, with PoIs appearing in private properties, uncharted forests, military zones, and even high-traffic highways. Figure 2 provides a visual example of a PoI situated in the middle of a highway. On the contrary, The Walking Dead: Our World and Jurassic World: Alive which can be seen in Figure 1, utilizing Google Maps, exhibit a more refined distribution of PoIs, avoiding locations outside public roads, in contrast to Draconius GO, which utilizes OpenStreetMap.

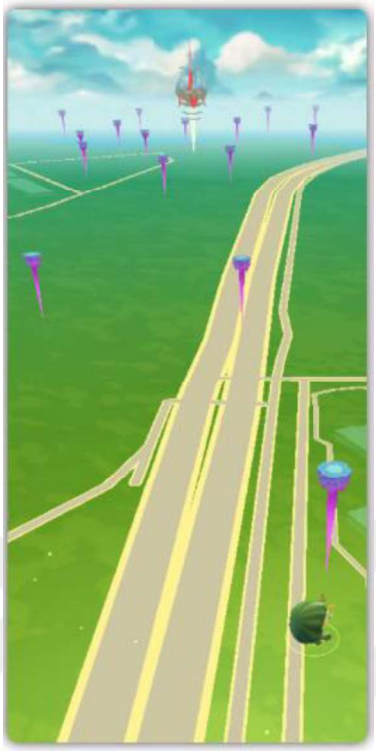


Figure 2: Screenshot from Draconius GO (Laato et al., 2019)

Pokémon GO and Ingress, both developed by Niantic, employ a distinctive approach for generating points of interest (PoIs) by combining two methods, namely, crowd-sources and manually created PoIs, known as the Portal Network. In contrast to the algorithmic generation utilized by other games, these Niantic games leverage peer-reviewed crowdsourcing, allowing players to actively contribute to the creation of PoIs within the game world. This player-driven process involves users nominating new PoIs by submitting their locations along with accompanying pictures, titles, and descriptions. The proposed PoIs undergo a peer-review process conducted by other players, and if they meet Niantic's criteria and pass the review, they are incorporated into the game environment. Niantic's guidelines exclude potential PoIs that lack safe pedestrian access, are situated in private residential areas, or may disrupt the operations of critical institutions such as hospitals, police stations, and fire stations. These safety measures fix the potential safety problems of the algorithmically placed points of interest of the other games. While this method establishes a more direct connection between PoIs and real-life locations, and, enhancing player immersion; it also introduces a bias towards more densely populated areas (Colley et al., 2017; Laato et al., 2019).

The findings from Laato et al. (2019) indicate that games incorporating manually created points of interest (PoIs) show superior quality across the above mentioned three methods within urban areas. However, they may fall short in terms of achieving the broad coverage provided by algorithmically generated PoIs. Colley et al. (2017) support this by revealing

that Pokémon Go's PoIs tend to favor urban environments, creating an inherent advantage for players residing in these areas. While the manual creation approach may contribute to the establishment of safer PoIs, issues persist, due to human nature. For instance, In Colley et al. (2017)'s study, 11% of participants reported instances where they put themselves at risk, such as crossing streets without proper caution while playing Pokémon Go. This suggests that, despite efforts to enhance safety, challenges still exist, underscoring the need for ongoing consideration of player safety in the design and implementation of location-based games.

2.5. Maps in Location-Based Games

The visual style and data source of a map holds critical importance in location-based games since the map serves as the primary interface for player interaction. Different maps are designed with varying aims and abstractions, two examples might be the wildlife map (Figure 3a) and the bus route map (Figure 3b) of the METU campus. While both maps portray the same location, each emphasizes distinct aspects of the area. To better understand and categorize map styles in location-based applications and games, we can explore these maps in two axes. The first axis distinguishes between mutable and immutable maps (Lammes & Wilmott, 2018). Mutable maps allow players to influence the map through their actions, whereas immutable maps present a static playground that focuses on providing information to players.

Figure 3a: METU Nature Map (*Gençlik ve Kent İçin Doğa*, n.d.)

Figure 3b: METU Campus Bus Route Map (*Kampüs Ringleri | Office of Transportation*, n.d.)

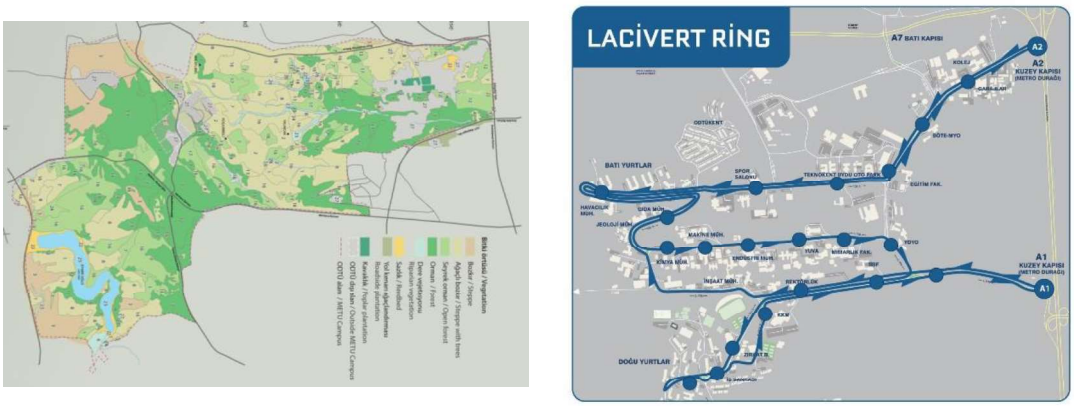


Figure 3: METU Nature and Bus Route Maps

The second axis involves the distinction between the usage of generic or stylized maps. Generic maps are similar to those found in standard geolocation apps such as Google Maps or Yandex Maps and are used in some location-based games like METU GO by Naghadeh

(2022). These maps present conventional cartographic details like street names, building locations, and area names.

Conversely, games featuring stylized maps introduce an abstraction of the regular map by omitting excessive textual information such as street and building names. Instead, these maps incorporate game-related information, emphasizing their role as a supportive element for gameplay rather than acting as a game board. Examples of stylized maps can be observed in games like Pokémon GO and Walking Dead: Our World, where maps primarily focus on providing information about the in-game world rather than conventional geographic details like street names and building names.

The accurate visualization of the player's surroundings is crucial in location-based games, as they are designed to be playable worldwide and they require a substantial map database. Companies can either establish their own data sources or utilize existing databases. Various potential sources and databases are available, including commercial services like Google Maps or Yandex Maps. While these services may require licensing agreements and payment for use in location-based games, they offer the advantage of providing more precise and up-to-date information on geolocation.

Alternatively, there is the option of using free platforms such as OpenStreetMap (OSM), an open-source, crowdsourced map service. OSM is freely accessible and allows users globally to contribute new information, similar to Wikipedia. In Turkey, the nonprofit organization "Yer Çizenler Herkes için Haritacılık Derneği" (*Yer Çizenler Herkes İçin Haritacılık Derneği*, n.d.) facilitates crowdsourced mapping efforts. However, OSM has some drawbacks, including the potential for outdated data and a scarcity of information in rural areas. Due to its crowdsourcing nature, more popular areas, such as tourist attractions and major city centers, tend to have richer details due to higher community contributions, potentially resulting in fewer points of interest in rural regions.

2.6. Social Aspect of Location-Based Games

Traditional video games typically fall into two categories: single player, where individuals engage in a non-shared digital space, or multiplayer, where players share the same digital space. Location-based games, as a subset of pervasive games, have a unique characteristic in that they encompass both digital and physical spaces simultaneously. Even if players do not interact within the digital realm, they all coexist in the same physical space. This dynamic increases the potential for face-to-face social interactions among players while playing the game. As a result, the social aspect becomes an inherent part of location-based games, whether it was intentionally emphasized by the game designers or not.

Amin et al. (2009) highlighted the close connection between location-based applications and social activities, emphasizing their role in supporting group activities such as making plans and searching for new ideas. Their research indicated that the majority of location-based searches within these applications take place when individuals are in the company

of others. This connection between location-based applications and social activities also extends to the connection of location-based games and social activities.

While most location-based games don't require players to interact with each other, allowing for solo gameplay, a significant number of players prefer engaging with these games in a social context. According to a study by Söbke et al. (2017), only 2% of Ingress players choose the solitary approach, emphasizing the importance of forming social groups within the game. In Colley et al. (2017)'s study on Pokémon GO, 70% of respondents reported that they never played alone, with only 12% consistently choosing solo play. Another study revealed that 90% of participants played Pokémon GO with friends and family (Vella et al., 2019). These findings collectively suggest that people predominantly enjoy location-based games in group settings. Additionally, Vella et al. (2019) noted that such group play enhances players' existing connections with friends and family. A significant aspect of the "play together" behavior is that, even in instances where games don't mandate cooperative play or offer additional points or rewards for doing so, players voluntarily choose to engage in collaborative gameplay.

In certain instances, games introduce an "event" game mechanic, compelling players to work together to attain specific rewards within a specified timeframe. For example, Pokémon GO have raid game mechanic which cause player to meet in a physical space and cause potential interaction with each other (Bhattacharya et al., 2019). A study by Laato, Islam, et al. (2020) illustrated that, during the COVID-19 pandemic, the fear of missing out motivated Pokémon Go players to actively socialize, highlighting the impact of social factors of the location-based games even during a global pandemic.

The study conducted by Vella et al. (2019) on Pokémon GO players revealed that the game not only strengthens bonds within existing social circles (friends and family) but also serves as an icebreaker, facilitating new conversations with strangers. More than 88% of participants in Lawler-Sagarin et al. (2023)'s research on Pokémon GO, reported meeting new people while playing the game. Laato et al. (2022) showed the association between the cooperative game mechanics in the LBGs and psychological well-being. Additionally, the social aspect of games has been shown to enhance the player's connection with the game itself. Laato et al. (2021) found that social factors, such as social self-efficacy and community identification, contribute to the overall meaningfulness of location-based augmented reality games.

2.7. Sense of Belonging

Hagerty et al. (1992) define the sense of belonging as "the experience of personal involvement in a system or environment so that persons feel themselves to be an integral part of that system or environment."(p. 173) This system encompasses organizations and relationships, while the environment includes both natural and cultural surroundings. Consequently, an individual can experience a sense of belonging in various contexts, such as a friend circle, school, hobby club, neighborhood, or university campus.

In a study on Pokémon Go players, it was found that players' sense of belonging to their local circle and environment increased as a result of playing the game (Vella et al., 2019). Participants mentioned that they began to perceive their local environments from a different perspective, like tourists, visiting places they had never explored before. Therefore, location-based games can be used to enhance these feelings of belonging. Oleksy & Wnuk (2017)'s study on Pokémon GO shows that place attachment due to playing the game is related to satisfaction players gained from the play and social interactions during the game, not related to playtime or the distance covered by the players during the game.

Lawler-Sagarin et al. (2023)'s study on Pokémon Go aligns with the idea that location-based games can enhance players' sense of belonging to their communities, emphasizing a positive correlation between higher engagement in the game and a heightened sense of belonging. This suggests the potential application of such games on university campuses to foster community engagement. Strayhorn (2018) defines the sense of belonging in the subject of colleges as follows:

> *"Students' perceived social support on campus, a feeling or sensation of connectedness, and the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the campus community or others on campus such as faculty, staff, and peers." (p. 4)*

The sense of belonging among college students is intricately linked to various factors, as evidenced by existing research. Gopalan et al. (2022) and Pedler et al. (2022) highlight the association between students' mental health and retention, respectively, with their sense of belonging. Freeman et al. (2007)'s study on freshmen emphasizes the correlation between a student's sense of belonging to the university and their perception of social acceptance. Gopalan & Brady (2020)'s research further underscores that a 4-year college student's sense of belonging is tied to the utilization of campus services, persistence, and mental health. Meehan & Howells (2018) stress the critical importance of the sense of belonging for new students' perception of academic staff, highlighting the positive impact of virtual communities on this sense. Pedler et al. (2022) delve into the association between the sense of belonging and academic motivation and enjoyment, thereby influencing student retention. Stubblebine et al. (2024)'s study reveals a positive connection between extraversion and agreeableness personalities and the sense of belonging to college. This collective body of research emphasizes the multifaceted nature of the sense of belonging in a college setting and its profound impact on students' well-being and academic success.

Martinez & Munsch (2019) suggests different methods to increase sense of belonging such as encouraging students to participates in clubs in university and orientation program continue through the time. Freeman et al. (2007) mentioned that increasing encouragement of the student participation is associated with the high degree of sense of belonging. Vella et al. (2019) mentioned that exploration and discovery can provide the foundation for the developing sense of belonging to a place. Given that location-based

games inherently involve these features, a connection between playing LBGs and cultivating a sense of belonging can be expected. The contribution of location-based games to exploration behavior is explained in the following section.

2.7.1 Exploration in Location-Based Games

Exploration, defined as the active process of discovering and navigating the environment, is a crucial aspect of how individuals engage with and establish connections to the world around them. In contemporary society, the primary tools for such exploration have shifted, with mobile phones emerging as crucial devices for urban discovery (Viswanathan et al., 2022). This ongoing process of exploration significantly contributes to an individual's spatial knowledge, fostering familiarity with new places and routes. Importantly, the act of exploration has been linked to positive impacts on a person's sense of belonging and overall well-being, encompassing both psychological and biological aspects (Schade et al., 2023).

Understanding and promoting exploration behavior among individuals presents a unique challenge, particularly in the context of regular location apps that typically prioritize efficiency by recommending the shortest or fastest route. This utilitarian approach contrasts with how people naturally choose routes, as individuals often consider additional criteria such as aesthetic appeal or novelty when navigating (Golledge, 1995). Consequently, conventional applications tend to offer users similar routes from Point A to Point B, limiting opportunities for meaningful exploration of the surrounding area. Moreover, studies such as Ruginski et al. (2019) have demonstrated that frequent use of GPS applications can contribute to a reduction in spatial knowledge skills, including both perspective-taking and mental rotation abilities. On the other hand, Carbonell Carrera et al. (2018) shows that playing Pokémon Go increase the spatial orientation skills of the players.

In a study conducted by Schade et al. (2023), researchers introduced a GPS map application named MapUncover. This application incorporated fog-of-war mechanics inspired by strategy video games, where a part of the map is initially unavailable and opens up as the player takes specific actions. This gamification element, coupled with leaderboards, served to motivate users to actively explore their environment, fostering a more engaging and exploratory approach to navigation. In a separate study by Vella et al. (2019) on Pokémon Go players, participants experiencing social anxiety reported that the game served as a motivation for them to go outdoors more frequently.

Exploration not only changes people's relationship with the environment but is also influenced by the nature of that relationship. People can be categorized based on their accommodation status in a place as tourists, new locals, and locals, and each category exhibits distinct exploration behavior when engaging with points of interest in the city (Viswanathan et al., 2022). Local residents tend to frequent familiar places and follow established routes within the city and even though they are looking for new places, they also explore areas close to these already known locations (Amin et al., 2009). In contrast,

tourists seek novel experiences, often venturing into unfamiliar territories to discover unique attractions.

Exploration in a city often involves discovering new points of interest. According to Viswanathan et al. (2022), there are three situations in which people seek information about new points of interest:

1) On the Spot: In this category, individuals are looking for a place they can easily access without spending much time choosing the "perfect" spot. An example could be a hungry person searching for a quick place to eat without seeking a fine dining experience.

2) Moments of Boredom: This category includes people who are bored and have more time to explore and discover new places through location-based applications. They may dedicate extra time to finding the perfect restaurant for a date or a unique experience.

3) Refining Plans: Individuals in this situation fall between the above two categories. They seek personalization and contextualization of results, but it's not their primary focus, indicating a balance between spontaneous and intentional planning.

Newcomers, or new locals, are individuals who have recently moved to a different place, city, or country. Establishing a "sense of familiarity" in this new environment is a challenging task for newcomers, requiring them to connect with the place through the exploration of points of interest. Barkhuus & Wohn (2019) conducted interviews with newcomers to New York City and identified three exploration modes:

1) Wandering: In this mode, individuals explore without a specific aim in mind. They are open to random encounters and the discovery of new places such as bars, parks, and cafes while wandering. Among the three exploration modes, this one involves the least use of location-based applications.

2) Walking: This mode describes people walking with a general purpose but without specific, predetermined details. They might be searching for a nearby bakery to buy bread or a cafe to relax, but they do not have a particular bakery or cafe in mind. Location-based applications are often used in this exploration type.

3) Heading For: In this mode, individuals have a specific purpose in mind and head toward a particular place to fulfill that purpose. For example, they may go to a restaurant where they have a reservation. Location-based applications are frequently used by newcomers in this exploration mode.

Different studies use location-based games to improve the exploration behavior of the users (Zhang & Nakajima, 2020). In Vella et al. (2019)'s study on Pokémon GO (PGO) participants, it was noted that users felt like tourists and explored new places in their towns, leading to a shift from their regular, local behavior to a more tourist-like

exploration behavior. On Colley et al. (2017)'s study on Pokémon Go, almost 60% of the participants mentioned they had visited at least one new place. Another study on Pokémon Go by Lawler-Sagarin et al. (2023), shows that 78.2% of the participants visited new places during the game.

Exploration is also one of the reasons for the players decision to continue the location-based games. In their study, Alha et al. (2019) conducted an online survey involving 2612 Pokémon GO players to investigate the factors influencing players' decisions to start, continue, or quit the game. The researchers identified three main themes for players continuing to play, namely Progression (personal goals, joy of discovery, collecting), Situation habit (commitment), and Positivity (exploration, exercise, relaxation).

2.8. METU Campus Ecosystem and Related Organizations

The METU Ankara campus, covering an area of 45 km2, encompasses diverse ecosystems, including forests, steppes, and freshwater environments. METU campus's steppe ecosystem is one of the few Central Anatolian steppe ecosystems with minimum intervention (grazing, pesticides, etc.). Due to this minimal influence, it contains some of the rare examples of herbaceous plant species. The natural steppe cover in the METU campus is home to around 700 plant species, making up one-third of the total plant species (2100 plant species) within Ankara's borders.

METU forest is predominantly populated by black pines, with scotch pines and Taurus cedars being other prevalent tree species. Additionally, tree-like steppe vegetation, including hawthorn, wild pear, almond, and mahaleb, can be found in the campus area, which was planted during the afforestation activities in the past decades.

In addition to the rich plant life, the METU ecosystem is home to a variety of animals. Birds are the most extensively studied organisms within the METU fauna, with observations revealing more than 210 bird species, accounting for about half of Turkey's avian fauna. Moreover, recent years have seen the identification of over 100 butterfly species in METU (*About | ECOSYSTEM IMPLEMENTATION AND RESEARCH CENTER*, n.d.).

Due to these reach features the METU ecosystem has become a focus of nature-centered organizations. METU Green Campus Society (ODTÜ YKT) was established in 2017 to actively contribute to the balanced social, economic, and ecological development of the METU campus. It engages in activities related to green campus components like water, energy, climate change, natural environment, waste and recycling, materials, and transportation. One of these activities is a campus walking tour that focuses on teaching participants about the different types of trees on campus ("Yeşil Kampüs Topluluğu - Biz Kimiz," n.d.).

The Nature Conservation Centre (DKM) is a foundation created in 2004 by a group of ecologists and nature conservationists. The purpose of DKM is defined as to gather a

centrally organized pool of expertise and technical capacity to conserve biodiversity in Turkey and the surrounding region. It also collaborates with EKOSAM to organize events within the METU campus (*Doğa Koruma Merkezi*, n.d.).

METU EKOSAM (Ecological Research and Planning Center) is a center focused on conserving biodiversity in Turkey's rich ecosystems, with a primary emphasis on the METU campus. Its main objective is to develop monitoring, conservation, and training activities related to these ecosystems. One of the methods is establishing the "Citizen Science Initiative" to share knowledge about steppe, forest, and lake ecosystems with citizens of all ages and strengthen the connection of METU with society. The center also prioritizes engaging young individuals, encouraging them to connect with METU's natural richness, make observations, and develop learning skills related to scientific processes (*About | ECOSYSTEM IMPLEMENTATION AND RESEARCH CENTER*, n.d.)

TürSay (BioBlitz) is a biological diversity detection activity that aims to identify as many species as possible in a specific area within a short period and contribute to the documentation of biodiversity through the collaborative efforts of participants. Involving expert natural scientists, volunteer nature guides, and the participation of citizens, the event takes an instant snapshot of the biological diversity in a region. BioBlitz can occur in any type of geography (urban, rural, or suburban) and in areas of any size, ranging from a small garden to an entire city.

During the event, applications like iNaturalist are used to capture photos of observed organisms, which are later identified by experts. Following expert species identification, the photos of observed organisms, along with location information, become part of the Global Biodiversity Information Facility database, accessible to everyone.

In addition to collecting data on a region's biodiversity, one of the main goals of the event is to engage the local community's interest in nature and nature conservation issues, encouraging citizen science interaction. These events allow local residents to interact with the biological diversity of their living areas, enabling them to contribute as amateur scientists to scientific and conservation efforts. In this aspect, BioBlitz events are an example of a comprehensive citizen science initiative (DKM, 2023).

In METU, the TürSay organization took place for the first time in 2018, and its fifth version, TürSay 2023, was held in May 2023. The event is organized collaboratively by DKM, METU EKOSAM, and METU EKOSAM Student Society. Findings from this event are publicly shared on the iNaturalist website and application (*TürSay 2023 - ODTÜ Yerleşkesi, Ankara*, n.d.).

2.9. Plant Blindness & Awareness

Wandersee & Schussler (1999) introduced the term "plant blindness" to characterize the phenomenon wherein individuals fail to notice the plants in their environment and are unable to recognize the importance of plants. Since its inception, the term has gained

popularity, and alternative phrases have been suggested. Parsley (2020) proposes the use of "plant awareness disparity" instead of plant blindness to address ableism associated with the latter term. More recently, Pany et al. (2022) emphasized the term "plant awareness," delineating it across four aspects: visual perception of plants, categorization of plants as living organisms, knowledge about plants, and attitudes toward plants (See Figure 4). They defined plant blindness as the lack of plant awareness.

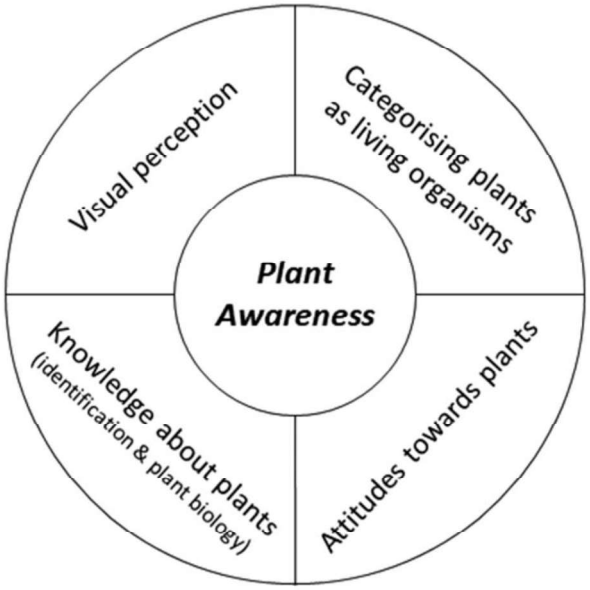


Figure 4: Aspects of Plant Awareness (Pany et al., 2022)

Wandersee & Schussler (1999) explained one of the potential reasons for plant blindness as people having less knowledge about plants than animals. Building on this, Wandersee & Schussler (2001) hypothesized that a well-planned education about plants could be the best way to solve plant blindness in the long term. Additionally, Pany et al. (2022) pointed out that increased knowledge about the diversity of plants might cause people to understand the important roles of plants in the environment and increase positive attitudes towards them, moving beyond the classic idea that plants are appreciated solely for their beauty.

There are studies aimed at measuring plant blindness in individuals and within the education system. Ahi et al. (2018) conducted a study analyzing plant blindness in Turkish textbooks used in basic education, revealing no significant difference in emphasis between plants and animals in the textbooks. Marcos-Walias et al. (2023) studied 259 students in the Spanish education system and found that plant blindness exists among students at all education levels. Krosnick et al. (2018) implemented an intervention using pet plants, assigning each student the task of growing an unknown plant throughout the semester, and observed a decrease in plant blindness among university students. Pany et al. (2022) developed two scales, namely, "plants as living organisms" and "knowledge about plants," to measure plant awareness.

Plant blindness, or the lack of plant awareness, is associated with various environmental issues, particularly stemming from people's lack of understanding or underestimation of the importance of plants (Wandersee & Schussler, 2001). Pedrera et al. (2023) conducted a study on secondary students and based on the results, explained that plant blindness has multiple aspects and is linked to the comprehension of biodiversity. Marcos-Walias et al. (2023) highlighted that at least three United Nations Sustainable Development Goals focus on biodiversity. Due to the connection between biodiversity and plant blindness, the lack of plant awareness may pose a risk to achieving Sustainable Development Goals (Amprazis & Papadopoulou, 2020).

2.10. Summary

Studies covered in this chapter show that sense of belonging can be increased with the location-based games (Lawler-Sagarin et al., 2023; Vella et al., 2019) and plant awareness can be increased with increased knowledge about the plants (Pany et al., 2022; Wandersee & Schussler, 1999) .

I was curious whether a location-based game focusing on the plants in the Middle East Technical University Ankara Campus could affect student’s plant awareness, exploration behavior in the campus, while contributing to their sense of belonging to the campus and help them socialize.

CHAPTER 3

METHOD

3.1. Design of the Study

The purpose of this study is to explore the user experience and perceptions of a location-based augmented reality game (METU Discover) focusing on the flora on the people. For this purpose, following research questions are investigated in the study:

- RQ1: What are the user's thoughts about METU Discover in terms of user experience?
- RQ2: What are the user's thoughts about METU Discover in terms of sense of belonging?
- RQ3: What are the user's thoughts about METU Discover in terms of plant awareness?

To answer these questions, the study is designed as qualitative research utilizing semi-structured interviews. Figure 5 outlines the overall structure for the design of the study. First, an initial version of the METU Discover is developed, and usability test is conducted as a part of the iterative development to improve the usability of the game. METU Discover is improved based on the feedback from the usability test, then the main study is conducted.

In the game, players entered their names and chose one of the two teams (East or West Dormitories) during the first launch. The main game loop involves players checking the locations of points of interest (plants) on the map screen and they are expected to approach these locations using the map. When players get closer to a point of interest, they interact with the PoI, read information about it and add it to their collection. This interaction earned one point for the player, updating the player's status on the leaderboard.

Data collection in both usability test and main study took place after gameplay, via interviews which were conducted with seven and eight participants for each study, respectively. After data collection, data is coded openly to come up with emerging themes by utilizing MAXQDA software. More detailed descriptions are given in the following sections.

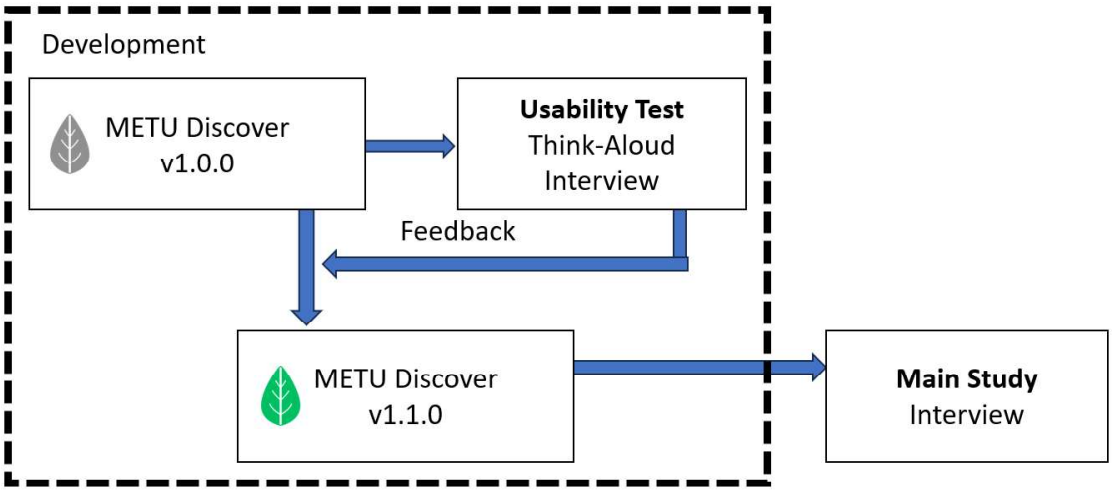


Figure 5: Research Design Diagram

3.2. Participants

Two groups of participants, for usability test and main study, voluntarily participated in the study. The approval of the METU Human Subjects Ethics Committee and the Informed Consent Form for both studies, are provided in APPENDIX A, APPENDIX B, and APPENDIX C, respectively. Participation in the study was voluntary and participants' informed consent was taken.

3.2.1 Usability Test Participants

The usability test aims to identify and fix any usability problems in the game. Thus, students who take the CEIT360 Introduction to Visual Design / Basic Elements of Visual Design course which focuses on usability were aimed as the potential participants. An e-mail including a brief description of and invitation to study was sent to students attending this course.

A total of seven participants took part in the test, two male (29%) and five female (71%). Participants' ages were between 21 and 23 years (M = 22.4, SD = 0.73). Only two participants stated that they play video games regularly. Three participants have prior location-based game experience from playing Pokémon Go. Table 1 shows the demographics of the participants who contributed to the usability test.

Table 1: Demographics of the Participants Contributed to the Usability Study

Participant ID	Gender	Age	Prior LBG Experience	Game Preference	Active Player
PP1	Female	23	-	Mobile Hyper Casual	Yes
PP2	Male	23	-	FPS, MMORPG	-
PP3	Male	22	-	Strategy	Yes
PP4	Female	23	Pokémon Go	-	-
PP5	Female	23	-	-	-
PP6	Female	22	Pokémon Go	-	-
PP7	Female	21	Pokémon Go	-	-

3.2.2 Main Study Participants

For the main study, participants were not required to be experts on usability. Therefore, study announced on public METU student boards. Eight participants volunteered to join the study, one female (13%) and seven male (%87). Six participants were active METU students (75%), and two participants were METU graduates (25%). Participants' ages were between 19 and 32 years (M = 23.88, SD = 4.11).

Five participants defined themselves as active game players. Four participants have prior location-based game experience, three participants played Pokémon Go, and following games played by different participants: Harry Potter: Wizards Unity, Campus Hunt and Ingress. Moreover, participants have been on the METU campus from two years to ten years as for game completion (M = 5.25, SD = 2.95). Table 2 shows the demographics of the participants.

Table 2: Demographics of the Participants Contributed to the Main Study

ID	Gender	Age	Education Level	Years spend in METU campus	Prior LBG Experience	Weekly Average Gameplay (hour)
P1	Male	21	1st Year Bachelor	3	-	10
P2	Male	23	1st Year Bachelor	4	Pokémon Go	10-20
P3	Male	19	1st Year Bachelor	2	-	30
P4	Male	29	PhD. Student	10	-	3-4
P5	Male	32	MS. Graduate	10	Pokémon Go, Harry Potter: Wizards Unite	-
P6	Male	23	4th Year Bachelor	6	Campus Hunt	0.5
P7	Male	23	Bachelor Graduate	4	Ingress, Pokémon Go	8
P8	Female	21	3rd Year Bachelor	3	-	-

3.3. Data Collection

For both usability test and main study of the study, data collection took place via interviews which were conducted with the participants after the gameplay. Participants also filled out a demographics form, including information about their age, gender, education level, and gaming experience (See APPENDIX D for demographics form). Then, they participated in a semi-structured interview regarding their gaming experiences (See APPENDIX E for interview questions). The interviews were conducted in Turkish, the main language of both the participants and the interviewer. Consequently, quotes from the participants have been translated into English for reporting purpose. Interview sessions are recorded and later transcribed for analysis.

3.2.3 Usability Test Data Collection

In the usability test, participants installed the developed game on their Android smartphones and played it with the assistance of the researcher. Since this was a usability test and for the sake of easy completion the developed game contained eight PoIs. During the gameplay, participants were asked to think-aloud and encouraged to verbally express their observations about the game, while their statements were noted down by the researcher. After the game session completed, participants took part in interviews that focused on general usability of the game and gameplay. The total duration of the interviews was 46 min, duration was varied from 3 to 15 minutes (M = 6.57, SD = 4.14), see Table 3 for the details. Based on the feedback from participants in the usability test, improvements were made in the game, including features, interface, gameplay etc.

Table 3: Interview Durations of the Participants Contributed to Usability Test

Participant ID	Duration of Interviews (min)
PP1	3
PP2	8
PP3	5
PP4	3
PP5	15
PP6	9
PP7	3
Total	46

3.2.4 Main Study Data Collection

As for the main study, players engaged in the game on the METU campus without the researcher's assistance. They had the freedom to play as much as they wanted before the interview. Following the gameplay session, players are invited to an interview about their experience (See APPENDIX E for interview questions). Interview questions are chosen in a way that to explore research questions of the study. The total duration of the interviews was 83 minutes (M = 10.38, SD = 2.45). Only one participant collected all (30) the plants in the game (M = 9.00, SD = 8.65). Their gameplay and interview information are shown in the Table 4.

Table 4: Interview and Gameplay Durations of the Participants Contributed to the Main Study

Participant ID	Duration of Interviews (min)	Number of Gameplay Session	Total Gameplay Time (min)
P1	8	5	30
P2	6	10	10
P3	11	2	150
P4	14	2	20
P5	9	1	30
P6	11	2	35
P7	11	2	20
P8	13	1	30
Total	83		

3.4. Data Analysis

The data analysis procedures were the same for both usability test and main study which utilize thematic analysis. After data collection was completed, I transcribed the interviews, read all the transcriptions twice to be familiarized with the data. Then, I uploaded the transcriptions to MAXQDA, and tried to identify and tag themes emerging from the data by using open coding. Consequently, quotes from the participants have been translated into English for reporting purposes.

For the usability test, data analysis revealed six main themes, which were Location Accuracy, Competition and Social Features, Sense of Accomplishment, Motivation, User Experience, and Favorite Features.

As for the main study, nine main themes emerged namely, Location Accuracy and Map, User Experience, Points of Interest, Augmented Reality, Environment, Motivation,

Exploration and Sense of Belonging to METU Campus, Competition and Social Features, and Improvement Suggestions.

3.5. Game Design and Development

To realize the main aim of the study and find answers to the pursued research questions, a location-based augmented reality game named METU Discover is developed. Unity (2022.3.8f1) game engine is used for the development of the game. The game is developed for the Android mobile operating system. Unity is a widely used platform for developing both academic and commercial location-based games, including popular titles like Pokémon GO, Ingress, and METU GO (Naghadeh, 2022). The detailed feature manual of Unity was helpful during the development stage. ARCore Geospatial API (v1.40.0) is used for the augmented reality features in the game. The initial version of the METU Discover was developed and tested with seven participants to improve the usability of the game before the main version. Improvements were made to the game based on the feedback from participants volunteered in the usability test. Figure 6 shows the map view of the METU Discover (v1.1.0).

In the game, players entered their names and chose one of the two teams (East or West Dormitories) during the first launch. The main game loop involves players checking the locations of points of interest (plants) on the map screen and they are expected to approach these locations using the map. Players can also use the augmented reality mode to see the points of interest and distinguish PoIs from the other plants in the environment. Upon approaching a PoI, a pop-up screen would appear for the interaction. When players interacted with the pop-up screen, an information screen about the plant at that location would open, and the plant would be added to the player's collection. This interaction earned one point for the player, updating the player’s status on the leaderboard. Additionally, the colors of the PoIs on the map changes based on which team had collected the same PoI the most.



Figure 6: Map View

4.5.1 *Points of Interest*

The selection of points of interest (PoIs) is crucial for the appeal and safety of a location-based game. It is essential to ensure that PoIs do not pose risks to players, especially by avoiding locations that are dangerous or forbidden to enter. Thus, all PoIs have been chosen with careful consideration to eliminate any risks for players. Additionally, the campus primarily comprises car-free walkable areas, making it inherently less risky to play a location-based game within the campus compared to playing a similar game in a city setting.

On the other hand, I was not an expert in the classification of plant types. I tried to utilize various data sources. The primary resource was the iNaturalist TürSay event data archive, an initiative organized by the Nature Conservation Centre (DKM) and METU Ecosystem Implementation and Research Center (EKOSAM). The iNaturalist TürSay event provides a collection of identified plants along with their locations and pictures, accessible on the website and application (*TürSay 2023 - ODTÜ Yerleşkesi, Ankara*, n.d.). Figure 7 shows the project page of the TürSay 2023. These identified plants serve as a foundational reference for potential points of interest. Additionally, the METU Green Campus Society conducted a campus walking tour in October 2023, specifically focusing on educating participants about different tree types on the campus. I actively participated in this event, enhancing my knowledge about various trees present in the campus environment and experience the activity.



Figure 7: Screenshot from iNaturalist Mobile Application - TürSay 2023 Project Page

To identify other plants that were not initially recognized, a species identification application (Seek by iNaturalist) is used. This mobile application utilizes image recognition technology to help users identify various plant species. Additionally, specialists in the field were consulted to assist in the identification of the plant species. Based on these, Points of Interest (PoIs) are chosen manually which falls under the "manually created by content creators" category for specification of PoIs, as defined by Tregel et al. (2017). The goal was to incorporate various types of trees at different locations, encouraging players to travel and explore various parts of the campus. In the usability test, eight PoIs were utilized to establish a more achievable target. For the main study, the total number of PoIs increased to 30, encompassing a total of 25 plant types. The locations of the chosen PoIs on the campus can be viewed in Figure 8.

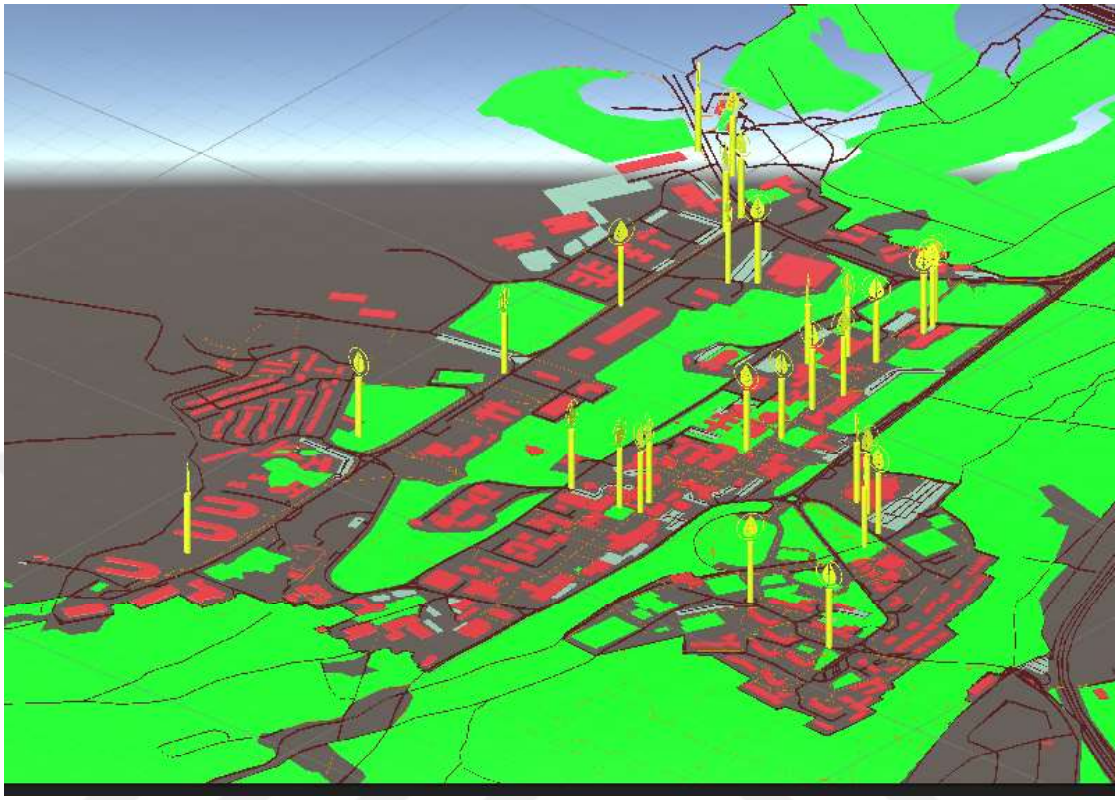


Figure 8: Plant Locations in Unity Editor View

For each plant, the following information is recorded:

- Name: The Name of the plant
- Location: The latitude and longitude coordinates of the plant are obtained using GPS trackers on the phone and satellite images in web services. Altitude data is not recorded.
- Description: A brief description of the species that was created from public databases such as Wikipedia and iNaturalist.

PoI information is stored in a JSON file on the Firebase server, accessible to each user client. Storing the data on a remote server ensures easy updates without requiring any changes on the client side.

When a player approaches a point of interest (PoI) location in the real world, a notification appears, enabling the player to add the plant to their collection and open the plant information screen. On this screen, players can read details about the plant and see others who have interacted with the same trees, encouraging social interaction. Figure 9 displays the plant information screen in the game.

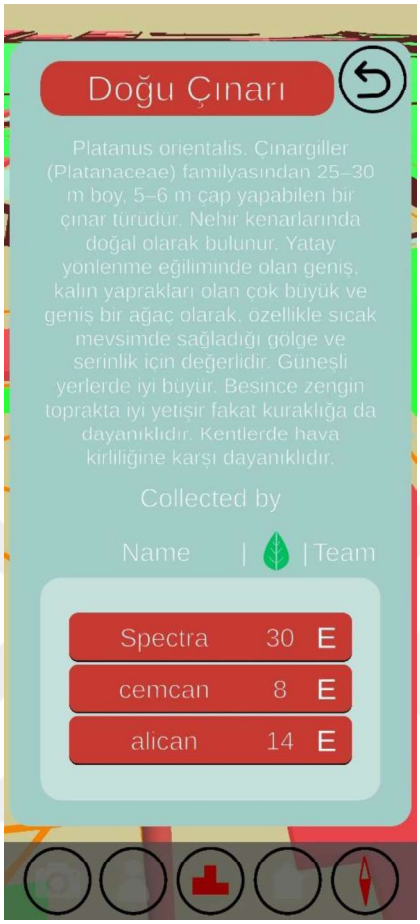


Figure 9: Plant Information Screen

4.5.2 *Map Style and Visualization*

The design of maps plays a critical role in the effectiveness of location-based games, influencing their usability (Bartling et al., 2022). For the METU Discover, an abstract map style is chosen where footways, streets, roads, green areas, parking areas, and buildings were distinguished by different colors and shapes. Moreover, location names are intentionally excluded to keep players focused on points of interest without any distracting details such as street names, building names etc. Points of interest (plants) are represented with leaf-shaped markers. This design approach follows the conventions seen in popular commercial location-based games such as Pokémon Go and Jurassic World Alive. While the overall structure of maps remains mostly immutable, PoI markers change colors based on the leading team at that point of interest.

Figure 10 shows a map view of the game. In this map, green areas correspond to the forest and other real-world green spaces, red areas represent buildings, thin lines indicate footpath, and thick lines represent car ways. The leaf marker shows the points of interest that users can interact with in the game.



Figure 10: Point of Interest Interaction Notification

OpenStreetMap is chosen as the data source for the map information due to its free accessibility and detailed guide about its data structure on its website (*Elements - OpenStreetMap Wiki*, n.d.). OpenStreetMap data model uses the following main components to represent places in the physical world:

- **Node**: Represents a specific point in the world defined by its longitude and latitude using the World Geodetic System 1984 (WGS1984) with each node assigned a unique ID number. Nodes can describe various objects, such as a traffic light or water fountain.

- **Way**: An ordered list of nodes forming a polyline, used to illustrate linear substructures like roads, overhead electrical lines, and pipelines. Ways also define the boundaries of an area, such as a parking lot or a building. In this case, the first and last nodes of the list are the same and it represents a closed loop also known as the "closed way.".

- **Relation**: Relation represents a connection between multiple data elements (nodes, ways, or other relations) and is used to define relationships, such as a bus route comprising roads (ways) and stops (nodes) or the boundary of the university campus.

- **Tags**: All the above data elements may be supplemented with tags, consisting of a "key" and a "value." Tags provide detailed information or specify the use of a particular element. For instance, a closed way tagged as "building=university" signifies a boundary representing a university building. Similarly, a way tagged as "bicycle=yes" indicates that a road can be utilized as part of a bicycle route. The OSM guide features a list of commonly used tags, but users can also add new tags.

The map information for the METU campus is obtained from the OpenStreetMap website. OSM allows users to export the map in “OSM XML” format for the specified area. The chosen border for METU Campus is N39.881 - N39.910 Latitudes and E32.772 - E32.796 Longitude. The OSM XML format uses an XML structure to store the main components (Node, Way, and Relation) for the specified area.

The exported file includes nodes, vehicle ways, footpaths, and building details contributed by the crowdsourcing community. However, node information representing points of interest from OSM has been excluded, as the points of interest are manually chosen for this study, independent of the OSM data. This approach mitigates potential biases associated with the distribution of points of interest in the current OSM dataset.

Unity game engine is used for visualizing points of interest and map information. The design choice of not using a generic map but creating a map based on the OSM datafile allows complete visual control over the map visuals as needed. The map information in the OSM data file is parsed to distinguish different types of ways and buildings. Open ways represent streets or footpaths, and closed ways represent different area types (green areas, parking lots, and buildings). These are further categorized based on the tags on each of them. Details of this categorization are shown in Table 5.

Table 5: Categorization of the OSM Ways

Type	Open Way	Closed Way	Tags
Street	Yes	-	highway
Footpath	Yes	-	footway, cycleway, steps, path, pedestrian
Green Area	-	Yes	forest, grass, leisure, natural
Parking Lot	-	Yes	parking
Building	-	Yes	building

Open ways are displayed as 2D Line Objects with varying thicknesses. Closed objects, such as green areas, parking lots, and buildings are automatically generated as new Mesh Objects, using a clipping algorithm to render convex shapes. Of these closed objects, green areas and parking lots are represented on the ground without any elevation. However, to visually distinguish buildings from the ground, a trial was made using height information from the map file. The "height" tag signifies the building's height, and the "building: levels" tag indicates the number of stories. Unfortunately, only 24 buildings on the campus have this height information in the OSM database. As a result, this approach was not feasible. Instead, all buildings are displayed at the same height from the ground for the final solution.

4.5.3 *Competition and Social Features of Game Elements*

Using competition to boost player interest is a common strategy. In location-based game study of Naghadeh (2022), two participants mentioned a leaderboard would be good addition to the game to increase the competition by allowing to see other player's score. METU Discover has competition in two aspects: individual competition and team-based competition. Throughout the game, players can see their status on the leaderboard screen. Players accumulate points for each plant they collect, and the more plants they collect, the higher they move up the leaderboard. They can also check other players' profile pages and see which plants they collected. Figure 11 shows the leaderboard screen.



Figure 11: Leaderboard Screen

The second aspect of the competition is between teams. During sign-up, each player selects one of two teams representing the two dormitory areas in the campus: West Dormitories and East Dormitories. METU campus has two dormitory regions, the first one is called East Dormitories also known as Numbered (Numaralılar) Dormitories due to most of the dormitories in the region having only the number as name. This part is the first dormitory area of the campus and part of the original plan of the campus. The second region, known as West Dormitories, is further from the center of the campus, the center shopping mall, and does not have a campus entrance close to it. They were built after 2001 (*İsa Demiray Yurdu | YURTLAR MÜDÜRLÜĞÜ*, n.d.) and they used to be known as Demiraylar, referring to names of the dormitories in that region. As far as I remember, common usage of these areas changed from unofficial Numaralılar and Demiraylar to East and West Dormitories with the campus map starting to refer to them as the East and West Dormitories. While these names are not official, they are commonly used by the students who reside, even influencing playful interactions like snowball fights between the two regions. So, this inherent structure is adapted to the game to create a second aspect of competition as teams. The anticipation was that linking teams to the actual locations where

players lived would enhance the sense of competition and sense of being part of the community.

4.5.4 *Augmented Reality Mode*

Augmented reality features are added to the game with an intention to enhance player immersion. When players approach a point of interest, they have the option to engage with the PoI using augmented reality. However, this feature is optional feature like the other popular games such as Pokémon Go and Jurassic World Alive, and users can still earn the same rewards without using AR. In this mode, a 3D marker appears above the plant they are searching for. While the map shows the location of a plant, it can be challenging to identify the specific one just by looking at the map itself. Augmented reality provides a visual aid in this context. Figure 12 shows an example of an augmented reality view.

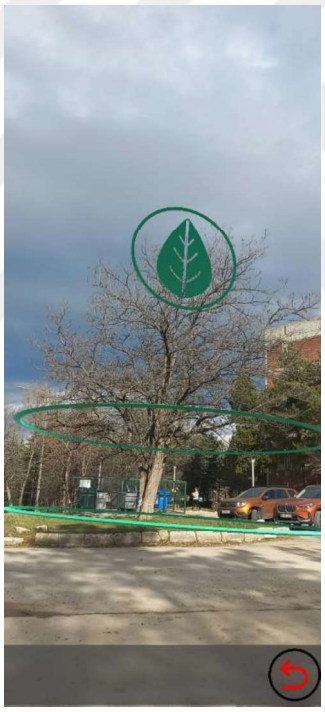


Figure 12: Augmented Reality Mode

To apply augmented reality features, ARCore Geospatial API (v1.40.0) by Google is used. ARCore Geospatial API allows developers to attach anchors in a 3D setting where users can interact with using the device camera. The API combines device sensors like GPS, magnetometer, and accelerometer with Google's Visual Positioning System (VPS), which relies on data from Google Maps Street View to accurately place the anchors in 3D environment.

In theory, placing an anchor object in the 3D environment requires the anchor's longitude, latitude, and altitude data. While the longitude and latitude information of the points of interest are already recorded and stored on the remote server for display in the 2D map view, altitude data is not recorded. The API has the ability to automatically determine the altitude based on latitude and longitude, utilizing Google Maps data (*Use Geospatial Anchors to Position Real-World Content on Unity | ARCore*, n.d.). When users switch to Augmented Reality mode, anchors are created automatically using the PoI location retrieved from the remote server. This approach of creating augmented reality objects in specific locations also fits the location-based AR type definition of Cheng & Tsai (2013)

4.5.5 *Data Management*

In the game, players can actively check their status relative to others and view everyone's collections, which makes it necessary to share information between players. This creates a multiplayer relationship among players. Firebase Realtime Database system, a remote data server is used to achieve this relationship.

When players initially open the game, they choose a name and a team, this information is stored on the remote server with a unique device ID. The game does not have a password authentication system; instead, user data is retrieved by matching the unique device ID when the player opens the game again.

Beyond viewing their own collection, each player can see others' collections and the leading team for any point of interest. When a player adds an object to their collection, their data on the remote server is immediately updated, affecting all other players. This system ensures data preservation against potential local device issues, such as application crashes or interruptions. The Firebase Realtime Database server not only stores player data but also contains the metadata for Points of Interest (PoI). This centralized database serves as a comprehensive repository, housing both player-related information and details about the PoIs in the game.

3.6. Usability Test Results

Data analysis revealed the following main themes for the usability test interviews:

- Location Accuracy
- Competition and Social Features
- Sense of Accomplishment
- Motivation
- User Experience

- Favorite Features

Location Accuracy: Location-based games rely heavily on accurate location representation. Players must comprehend the map, observe their avatar, and identify points of interest. Therefore, participants were asked about their perceptions of location accuracy.

All participants confirmed that their avatar's location was accurately displayed. However, one participant expressed dissatisfaction with the delay in map rotation:

> *There was a delay, but that delay was deliberately chosen; however, that delay tired me (PP2)*

Two participants reported issues with detecting tree locations:

> *It showed the buildings and everything correctly. When it moved forward, my character moved forward with me, but we struggled a bit with the location of the trees. It didn't accurately show the location of some trees. (PP7)*

Five participants did not provide feedback on the location of augmented reality anchor objects. However, two participants explained the problems they encountered with augmented reality object locations:

> *In those rings, I couldn't see the rings and went to an empty space. I thought I would earn an extra 5 points, but no points came. There were times when I couldn't understand which tree it was. (PP6)*

Competition and Social Features: Competition feeling is crucial to motivate players to continue the game. This sense of competition is fostered through the leaderboard, both for individual players and teams. To understand the effectiveness of these competitive elements in the game, participants were asked about their perception of the competition in the game.

Three participants agreed on the lack of competition in the game. One of them specifically pointed out the absence of information about the teams in the game as the reason for the lack of competition:

> *Not really, because I didn't understand which team is what color and what my purpose is in the game. If there were clear rules at the beginning, like if it was stated on a rules page that, for example, the Eastern team is this color, the Western team is another color, and so on, my competitive spirit against the opposing team could have increased. (PP1)*

Three participants felt a sense of competition in the game. None of the reported competition feelings was based on the teams. Two of them mentioned that the competition feeling arose from seeing the names of other players they already knew:

> *Yes, especially when I saw the names of my friends, I tried to quickly add the plant to my own collection, thinking that they had already scanned this tree. (PP6)*

Other participants who felt the competition mentioned that it was caused by a desire to explore more:

> *Honestly, I enjoy both being knowledgeable and a bit of competition. If there's a challenge, I always push myself a bit further, but I was also curious about exploration. (PP5)*

One participant stated that he saw the elements of competition, but he did not seek competition in this genre:

> *While playing, I saw that there were elements of competition, but I wouldn't seek competition in such a game. I wouldn't look for competition in a game like this. It's not something competitive for me because I'm also doing personal development here. I wouldn't be very competitive in this game. (PP2)*

Sense of Accomplishment: Participants were asked what is missing in the game and which features need improvement. Three participants mentioned the lack of a sense of accomplishment in the game. They stated that when they interact with a point of interest and add it to their collection, they do not experience a sense of accomplishment:

> *The part that gives information about the tree and the part that shows what I've found could be more interactive. For instance, there could be a sound like "ding" when I discover each tree. (PP1)*

Another participant stated that:

> *I think the biggest drawback is the lack of a sense of achievement in the game. It could be a sound, then maybe the leaderboard having a colorful structure, or as I mentioned earlier, there could be a circle indicating the entry into the treasure area around the trees. These were missing. (PP3)*

User Experience: Participants were asked about whether they encountered problems when navigating the menu. All participants reported that they had not experienced problems with the navigation. The main reason for not having problems is defined as the simplicity of the menu:

> *The interface is very basic, by the way. I didn't have any difficulty because there were very few buttons. (PP6)*

Apart from the navigation users reported the problems with the user interface. One user reported that she could not understand the usage of the navigation mode change button. Five participants expressed their dislike of the color scheme. One participant mentioned that buttons did not feel like buttons. One participant especially mentioned the contrast between the colors on the map and the colors on the menu. She stated that:

> *So, using such vibrant colors on the map all of a sudden and then seeing such dark tones in the leaderboard bothered me (PP5).*

Participants also mentioned the lack of instructions in the game. Both during the gameplay and interviews:

> *I wish the game would guide me in the first entry, telling me what I needed to do. Because if you hadn't told me, I wouldn't have understood what I needed to do. I mean, I press the map, but I don't know where to go. If there were rules or guidance on the main page while I was here, it could have been more informative. (PP1)*

Three participants mentioned that they would like to see the image of the plants on the plant information screen.

Motivation: Motivation is required for the players to continue playing the game and explore different points of interest and new regions of the campus. Two participants mentioned the lack of motivation in the game. One participant stated that a physical award to the top players might motivate the players. She stated that:

> *For me, there needed to be a goal in motivation, and that goal was not there. I learned the plant species. So, what? I will not play and walk to learn the plant species. I need extreme motivation, like, you know, something like giving a JBL speaker to the top 3 people on the monthly leaderboard. (P6)*

Favorite Features: Participants were asked about their favorite feature and two players mentioned that they particularly enjoyed the augmented reality mode. One of them explained that in these words:

> *My favorite feature was exploring with the camera. I really liked the aspect of using the camera. It was beautiful to directly explore, and if I had only been navigating on the map without using the camera, I would have gotten bored. (PP5)*

Two participants highlighted their favorite features such as the ability to see their friends' names and points, as well as engaging in competition with their friends. One participant's favorite feature is the game that asked about which dormitory areas he is from and seeing the difference between exploration and plant types discovered by the different teams. He explained as follows:

My favorite feature was actually when it asked me which dormitory I was in, somewhat meaninglessly. Because I was able to see the difference between the tree species discovered by people in other dormitories and the tree species I discovered. So, even though there is a small distance between us, I learned that we explore differently. It was nice to see that. (PP2).

Other favorite features are the accuracy of the map service and game giving a similar feeling to Pokémon Go.

3.7. Usability Improvements Based on the Usability Test Results

Following feedback from participants in the pilot study, game features were modified to fix the identified usability issues. Several users highlighted a lack of instructions in the game, which also impacted the sense of competition between teams, as players struggled to comprehend team dynamics. To address this, an instruction page was introduced, providing explanations for various aspects of the game such as the Map Screen, Profile Screen, Team information, etc. This instructional screen appears when a new user opens the game for the first time and later it is also accessible from the main menu. Figure 13 shows a page of instruction screen.



Figure 13: Instructions Screen

Participants expressed a lack of a sense of accomplishment when interacting with a point of interest. In the pilot version when a user interacts with a point of interest, the plant detail screen opens immediately, providing details along with a list of other players who have collected the same tree. In response to this feedback, a modification was made to the pilot version. In the new version, a pop-up screen has been added to show the player's status, indicating how many plants they have collected and how many plants are left to collect. The pop-up screen can be seen in Figure 14.



Figure 14: New Plant Interaction Pop-up Screen

Participants also highlighted an issue with the color scheme. There was a mismatch between the cheerful colors on the map screen and the grayish colors in the menu. To solve this, the colors in the menu part have been completely changed to better align with the colors in the map screen. Additionally, none of the participants who experienced a sense of competition mentioned team-wise competition. To increase team-wise competition, team status has been added to the updated leaderboard view. Figure 15 shows both the pilot and the final version of the leaderboard screen.



Figure 15: Pilot and Final Version of the Leaderboards

CHAPTER 4

RESULTS

Data analysis of the interviews with the participants conducted to the main study revealed the following main themes:

- Location Accuracy and Map
- User Experience
- Points of Interest
- Augmented Reality
- Environment
- Motivation
- Exploration and Sense of Belonging to METU Campus
- Competition and Social Features
- Improvement Suggestions

Location Accuracy and Map: Most participants agree that location service works correctly for the user location and points of interest locations on the map:

> *It (location accuracy) was quite high quality; I can even say more accurate than Google Maps. (P3)*

One participant reported the problem he encountered with the map:

> *When I compared the map here with the one on Google, I had a bit of difficulty figuring out where the paths were. For example, in front of the computer*

engineering department, the road was blocked, but that's usually where people pass through. (P7)

Two participants reported the problem with the AR object locations:

Perhaps the reason for augmented reality not working correctly could be the location. We are looking from the close, but maybe the location is not accurate and that's why AR is deviating. (P4)

User Experience: All the participants stated that they did not have any problem with navigating the menu. Two participants stated that buttons were not intuitive:

Sometimes, the icons didn't seem intuitive. I didn't quite understand that the icons below were for the leaderboard. For example, I didn't understand what the compass icon was initially. I couldn't understand how the compass worked from the instructions. I understood it when I used it. I also didn't immediately grasp the scoreboard at first glance. (P4)

Two participants reported that they did not understand how the leading team changes occur on a point of interest. One participant mentioned that user-controlled rotation of the map is opposite of Pokémon GO and he was surprised at first.

Points of Interest: Points of interest in this game are the plants chosen on the campus. Participants reported their comments about the points of interest. One participant found the number of PoIs (30) is low and can be increased with the addition of the Yalıncak area (forest area of the campus):

If there are different types on the Yalıncak side, I would want to explore those if you add them. (P2)

Lastly, one participant reported having a problem with reaching one of the PoIs which requires walking through the muddy trail:

One of the plants was in a really bad location. The plant near Şok in the West was in a place where I had to pass through a lot of mud. The weather was rainy the other day, and it was in the forest. (P3)

One participant liked that iconic trees were chosen as points of interest.

Augmented Reality: Participants were asked about whether did they used AR features and if they used them, what were their experiences. Six out of eight participants reported that they used AR mode, and four participants reported that they had encountered problems with the exact locations of the plants in the AR mode. One participant stated that even though the augmented reality mode had accuracy problems, he says that he can easily identify the trees due to the choice of specific trees:

These trees were obviously different, like in games where you can interact with a bright item. I think trees in the game were like that. Still, I looked (in the AR). In the worst-case scenario, it showed close to the tree. Although it wasn't fully accurate, it still worked. (P4)

The same player also defined the AR mode as his favorite feature in the game. But says that if he aims to collect all the plants in the game competitively, he would not use the AR mode.

Environment: Players were asked whether they learned the new plant types and their environment awareness changed after playing the game. They were also asked about the type of plant that was the most interesting for them.

As for the game's effect on environmental awareness, five out of eight participants said that game did not affect their environmental awareness. One of them mentioned that if he played the game for a longer time, it would affect his environmental awareness. Three participants mentioned the increase in their awarenesses. One participant specifically mentioned that game help him to be aware of the biodiversity in the campus:

It made me aware of biodiversity. (P7)

All participants mentioned they learned at least one different type of plant they were not aware of before the game. Six participants reported the surprise due to the plants they encountered is more diverse than what they initially thought. Two participants were surprised about the trees with the fruits. They stated:

If someone had told me there was a mulberry tree in the EE (Electrical Engineering) section, I wouldn't have believed it. But it turns out there is indeed a mulberry tree. (P4)

I didn't know there were so many fruit trees on campus. (P3)

Three participants were surprised about the different types of pines. They stated that:

I thought there were pine trees everywhere, but it turns out there aren't. (P6)

It was interesting to learn that the big pine tree in front of the computer building is not actually called a pine tree. (P4)

Distinguishing between Black Pine and Scots Pine was the most interesting for me. I thought Scots Pines were only present in the forest area. (P5)

Trees around the Electrical and Electronical Department have name tags pinned on them. Two participants reported they have noticed these name tags for the first time while playing the game.

However, one user reported that the game did not increase his knowledge about the environment but if he continues to play, it may increase.

> *Maybe if I played more, it would change, but I don't think it has changed now. (P2)*

Motivation: Participants were asked what their motivation was to continue the game. Seven participants mentioned that drive to continue the game is learning new plants in the campus. Four of these seven participants also mentioned that they like to learn the plants in their daily routines. They expressed their surprise when they realized that different plant species existed in areas they already knew. They explained as follows:

> *It was more of a sense of "what is here." Okay, there are trees, but because we don't pay attention in our daily lives, we don't realize it even though I've been on campus for a long time. (P2)*

> *I guess learning about the trees here motivated me. Oh, there's a poplar here, there's an apricot there. Learning was nice. It was great to know what was on the paths I constantly passed through. That was my biggest motivation. (P1)*

Another participant mentioned the surprise when he realized that he thought he knew the types of trees but was surprised to see there are actually more types of trees.

> *Due to the tight schedule of the final's week, I approached it a bit like a task. But besides that, what kept me going was the realization that those trees were in very specific locations, and I hadn't noticed. The motivation to learn about those trees, actually. It seemed like there were pines everywhere, but it turns out that's not the case. The motivation to learn about those trees kept me going. (P6)*

Only one participant had completely different motivation, he defined his motivation as to collect all the plants in the game and he was the only player who collected all the plants.

Exploration and Sense of Belonging to METU Campus: Game solely focused on the METU campus and its features designed provide to an exploration behavior for players and increase their sense of belonging to campus. Therefore, questions related to explorations were asked to players, such as, whether they changed their routine, they plan to continue exploring campus after the game etc. asked to players. Most of the participants changed their normal walking routines to interact with points of interest. Two participants stated that they explored new places on the campus they have not been to before. One participant stated that:

I went to the West dormitories for the first time. (P3)

One participant expressed that he likes the game because it is a specialized game focused on the METU campus and plant types in it:

> *And the best thing is that I liked that this was an experience that was personalized according to METU and directed to someone from METU. For example, the distinction between West and East Dormitories or the chosen tree species. (P7)*

Participants were further asked whether their view of the campus has changed after playing the game and they want to explore the campus more after playing the game. Seven participants reported that they want to explore more of the campus. One participant stated that he would like to explore the forest area of the campus. One participant stated that he would like to continue playing the game after the weather gets better:

> *If I could still play the game, I want to go and collect those trees when the weather gets a bit warmer. (P7)*

Two participants, both have spent 10 years on campus, stated that they already like the campus very much and the game only concreted this view.

> *(My love for the campus) didn't change much; I still love it a lot. I continue to love it. I said what a beautiful place it is. (P4)*

Three participants said that they learned new things about the campus, and it surprised them. One of them explained as follows:

> *I didn't know there were so many different plants on campus; I thought it was just grass and trees. Things that looked similar from the outside turned out to be different species. So, my appreciation for the campus increased. I already loved it, and now I love it even more. (P3)*

One participant expresses that her knowledge about the plants in the campus has increased and she explains that her sense of belonging to campus increased with the increase of the information related to campus:

> *I share everything about ODTÜ with people from outside. Being able to convey these details everywhere, knowing those places, enhances my sense of belonging here. (P8)*

Competition and Social Features: Social features and competition features are added to METU Discovery to increase player interest in the game. To understand the effects of competition participants were asked whether they felt competitive during the game.

Three participants stated that they have not felt any competition during the game and when their motivation in the game is asked, some participants reported their main motivation as to learn more about the trees on the campus.

Three participants mentioned they felt the competition was due to seeing the other players' high scores on the leaderboard. One stated that:

> *"Another Player" had made 11, so I thought, let me check a few more on the way back. Then I saw the "Another Player" had done 28. I felt the competition because of the player widening the gap. (P1)*

Two participants mentioned the rivalry between the teams as their reason for competition. One stated that:

> *When I saw the colors for the first time, I felt that competition, because I'm familiar with Ingress. But seeing the east-west dormitories added character to the situation. (P7)*

On the other hand, one participant complained that he did not understand the naming of the teams (East and West Dormitories). Stating:

> *I didn't understand (the names). I would understand if it used İsa Demiray or Dormitory 2 or Sunshine. (P4)*

To understand the effects of these social aspects of the game on players, participants were asked whether they played the game alone and if they had met anyone while playing. None of the participants met anybody new during the gameplay. Also, all participants except one reported that they played by themselves without the assistance of others. One participant mentioned he started the game with someone else but continued playing by himself. When asked to describe the difference in experience:

> *Playing with someone else is, of course, more enjoyable; you can chat while walking. (P3)*

Favorite Feature: Participants were asked their favorite features in the game. Most favored feature is learning information about the plants in the campus which favored by the five participants. One stated that (also focusing on the animation):

> *The best part for me was the animation that appeared after finding a tree, clicking on it, and then seeing the tree's information. In other words, learning about the tree. (P6)*

One participant (who is the only participant who collected all the plants) favors the leaderboard as the favorite feature with focusing on the individual competition.

One participant states his favorite feature is Augmented Reality and selection of the trees:

> *I think augmented reality was great, but it was the main feature, right? And I think the selection of trees was very good. It wasn't random. They were specific landmark trees, so it was very nice. It was instructive. For example, I knew how a mulberry tree looked, and now I know how an apricot tree looks a bit. I saw dried apricots on the tree. (P4)*

Another participant stated that his favorite feature is that the game encourages players to explore the campus.

Improvement Suggestions: Participants were asked whether they have any suggested feature for the application. Most suggested feature was the addition of picture of the plants in the plant information screen. One participant explained:

> *Maybe it would be nice to have a photo or visualization where that information is written, such as a photo of the tree. It doesn't necessarily have to be a photo of the tree there, but it would be better remembered if the thing that distinguishes it from others could be shown in a photo. For example, I cannot fully understand the explanation there, but it would be easier to recognize it when I see it there and say "oh, that's it" when I see it later. (P8)*

One participant asked for the zoom in – zoom out feature for the map view. Another participant suggests getting a notification when they were passing by a point of interest, even when they are not playing the game. Two participants asked for changes to the map screen for the plants that they have collected. Lastly, one participant suggested that the game can be part of the orientation for the newcomers to campus.

CHAPTER 5

DISCUSSION AND CONCLUSION

A location-based augmented-reality game focused on the flora of the METU campus is developed in this study. The steps in the design and development of the game are explained and the game's effect on players' plant awareness, and their sense of belonging to the campus is investigated with the interviews. The following sections includes the discussion of results according to following research questions:

- RQ1: What are the user's thoughts about METU Discover in terms of user experience?
- RQ2: What are the user's thoughts about METU Discover in terms of sense of belonging?
- RQ3: What are the user's thoughts about METU Discover in terms of plant awareness?

Also, based on the experience I gathered during the design and development of METU Discover, combined with the suggestions from the participants, design recommendations for location-based augmented reality games are presented.

5.1. What are the user's thoughts about METU Discover in terms of user experience?

Usability issues were investigated in both the usability test and main study. During the usability test, participants provided feedback on usability issues and after that changes were made to the game based on the feedback. In the main study, the same usability questions were asked to new participants, and it allowed us to understand the effects of the changes made in the game to usability.

Improvements in some aspects of usability were quite evident. The lack of a sense of accomplishment was a major issue in the usability test. To address this, a screen that congratulates the player and shows their current status has been added for the main study. Interestingly, in the main study, none of the participants mentioned the lack of a sense of achievement, which means the addition was successful.

The color scheme difference was one of the issues in the usability test, but after improvements were made, it was not mentioned in the final study. participants did not provide any suggestions for the colors in the final study, indicating that the colors seem to be working correctly in the final version.

Additionally, an instructions screen was added to the game based on feedback from participants who reported not knowing what to do and having difficulty understanding some features. With these additions, players' understanding of the features significantly increased.

From these findings, it might be recognized that even small changes can have a significant impact on users and usability. Although none of these changes (congratulations pop-up screen, matching color scheme, instructions) were chosen as favorite features, they are essential for the game to work seamlessly. These elements serve as crucial parts in the game. Even though users may not choose them as their favorites, their absence is noticeable.

Another insight derived from the answers is that using similar design and features to other location-based games and applications helps make the game feel more intuitive. Users, even without prior experience in location-based games, are familiar with location-based applications such as Google Maps. This familiarity creates expectations for certain features. For instance, the absence of zoom in-out functionality in the game was noted, and participants expected it due to their familiarity with this feature in other applications. Incorporating familiar design elements can enhance user experience and meet the expectations set by popular location-based applications.

Participants with prior experience in location-based games immediately recognized similarities such as team colors and differences like map orientation direction. Using similar features can help these players quickly adapt to the game. For instance, the game employs an abstract stylized map rather than a generic style map, aligning with the map style commonly seen in popular LBGs. None of the participants reported issues with the type of map. It's worth noting that while the immutable map was acceptable, some users expected feedback on the map related to the plants they had collected, a feature present in popular LBGs.

However, one participant encountered an issue with the map. In a specific area, a footpath goes under a building, and in the game, it appeared as if the road was blocked by the building. While this is not a common occurrence, it did happen in the game. Therefore, careful consideration and validation of map visualization are necessary to include potential edge cases.

The augmented reality mode in the game uses the ARCore API to place anchors in real-life locations, allowing players to view 3D anchors that depict the plant (point of interest) locations through the camera. Some participants used it and one user said that AR mode is his favorite feature in the game. However, in general, participants tend not to use the AR mode, and participants often reported encountering problems when using augmented reality. I think if it worked seamlessly without problems, it would have been used more. The inaccuracy in the AR mode may be caused from limitations in the API and the GPS sensors in smartphones. The ARCore API combines device sensors like GPS with

Google's Visual Positioning System (VPS), which relies on data from Google Maps Street View for accurate anchor placement. However, since most points of interest in the campus were outside the VPS-covered area, this could be a reason for inaccuracies in the AR mode.

Consequently, the usage of AR mode is considered more of an auxiliary mode by most users. This aligns with the approach in popular commercial location-based games like Pokémon Go, where AR mode is considered an auxiliary feature rather than a necessity. One participant, who expressed AR mode is his favorite, mentioned that if he would aimed to collect all the plants, he would not use it. This aligns with the behavior of the user who collected all the plants, as he stated not using the AR mode at all. This observation shows that users perceive AR as an auxiliary mode, especially when it comes to the competitive aspect of collecting all the plants. This result aligns with the findings of Laato, Inaba, et al. (2021), suggesting that the AR mode was not considered essential and disturbed the progression.

The game's interface was entirely in English, but information about the plants was provided in Turkish to facilitate quick comprehension. Surprisingly, in both the usability test and main studies, none of the users mentioned this discrepancy. This could be due to Turkish METU students receiving education in English and using Turkish in their daily lives, leading them to be accustomed to using both languages seamlessly.

Location-based games inherently possess social features, and additional social elements were added into the game, such as leaderboards and structured teams. The game also allows players to check other users' profiles to see their collections. However, contrary to expectations and existing literature on location-based games, most social interactions anticipated in the game did not occur. Studies on LBGs like Pokémon GO, suggest that players often engage in group play, with a minimal preference for solo play (Colley et al., 2017; Söbke et al., 2017; Vella et al., 2019). In contrast, METU Discover players predominantly played the game alone, and no player reported meeting other players during gameplay.

The minimization of social interaction can be attributed to several factors. Firstly, only two participants were friends prior to the game, reducing the likelihood of starting the game together. Secondly, the relatively low number of players reduced the likelihood of social interactions. Additionally, the gameplay spanned a total of six days, with each player initiating the game at different times, thereby diminishing the chance of player encounters. Moreover, the gameplay occurred during the winter season, coinciding with the final exam week at the university. One participant specifically expressed a desire to play more if the weather were better. It is worth noting that if all participants had started the game at similar times and in better weather conditions, these expected social interactions would likely have occurred.

The team aspect, which is based on real-world location and relates to players, was added to enhance potential interaction and rivalry among players. In the usability test, none of

the participants mentioned the teams as a reason for a sense of competition, stating that they did not understand the team logic in the game. Fortunately, with the addition of the team-based color scheme and an instruction screen with team information, participants generally understood the team logic, and some players expressed that they felt the competition between the teams.

Most of the players expressed their motivation to continue the game to learn about various plants on the campus. However, a unique player stood out, expressing the goal of collecting all available plants, making him the sole player to achieve this. Interestingly, this player identified the leaderboard as his favorite feature. This divergence in gameplay behavior highlights the need for diverse features to satisfy distinct player preferences. While some prioritize learning; others prefer completion and competition, as reflected in leaderboard rankings, more compelling aspects of the game.

Alha et al. (2019) found in their study on Pokémon Go that the primary factor motivating players to continue the game is progression, encompassing "personal goals, advancement, joy of discovery, collecting" elements. This contrasts with the player motivation observed in METU Discover. Despite the similar gameplay mechanics between two games, the distinctive feature of METU Discover, connecting points of interest to real plants and providing information about plants, significantly influences players' motivation, diverging from the progression-driven approach observed in Pokémon Go.

5.2. What are the user's thoughts about METU Discover in terms of sense of belonging?

Studies showed that location-based games increase the sense of belonging of the players (Lawler-Sagarin et al., 2023; Vella et al., 2019). Vella et al. (2019) mentioned that exploration and discovery can provide the foundation for the developing sense of belonging to a place. The game aims to enhance this sense of belonging by teaching players about the rich and diverse flora of campus and encouraging exploration throughout the campus. Points of interest are specifically chosen from various areas, including West Dormitories, East Dormitories, central department area and Technopolis.

Almost all participants changed their daily walking routines to discover and locate the plants in the game. Newcomers to the campus expressed that they explored new places in the campus which is a behavior also observed on the different studies on Pokémon Go (Colley et al., 2017; Lawler-Sagarin et al., 2023). On the other hand, participants who had spent a longer time on campus did not explore any new locations during the game. This was expected, as individuals who stayed longer had more opportunities to discover various areas of the campus. However, even though they did not encounter new locations during the game, they expressed a desire to explore more of the campus afterward, such as the forestry that extends the campus.

Another common theme is the surprise expressed by participants who, despite spending a long time on campus, continue to notice new things. Players, who were not new to the campus, shared their experiences of discovering new aspects and expressed their surprise during the gameplay. Also, a participant who spent longer time on the campus (the PhD student) expressed that he did not understand the naming of the teams, showing a difference of the culture between the newcomers and oldcomers in naming the same locations.

One participant mentioned that her knowledge about the plants on campus increased due to the game, and she explained that her sense of belonging to the campus also increased with the growth of information related to the campus. She connects the sense of belonging to the campus with the knowledge about the campus that she can share with other people. Having more knowledge, therefore, increases her sense of belonging.

5.3. What are the user's thoughts about METU Discover in terms of plant awareness?

The game was developed with the goal of increasing players' awareness of plants. Wandersee & Schussler (1999) explain one of the potential reasons for plant blindness as people having less knowledge about plants than animals. Pany et al. (2022) pointed out that increased knowledge about the diversity of plants may cause people to understand the important roles of plants in the environment and increase their awareness of plants. To do that, various types of plants from different areas of the campus were manually selected to show the biodiversity on campus. Participants mentioned that they appreciated the selection of iconic trees. This shows that manually chosen PoI method is fitting for this kind of game.

When participants were specifically asked about changes in their environmental awareness, most of them stated that it did not change. However, this could be due to the vagueness of the used term. One participant specifically mentioned that his environmental awareness increased, while another focused on the heightened awareness of different species.

Participants emphasized their main motivation in the game was to learn more about the environment and different species. The most favored feature of the game was learning about the different trees on campus. Users were pleasantly surprised to discover the diversity of plants on campus. Since the METU forest is mostly composed of pine trees, students not interested in nature might have assumed that it's the only species on campus. Therefore, they were particularly amazed to learn about the presence of fruit trees and the distinctions among different types of pines within the pine family (Pinaceae).

The main outcome of the game for the players is an increased awareness of the biodiversity within the campus. This realization aligns with the objectives of events like TürSay, where the goal is to enhance knowledge about the biodiversity in the area. Thus, location-based

augmented reality games such as METU Discover can effectively contribute to achieving this aim. Further study is required to understand the effects of this increased awareness of biodiversity on plant awareness. Such games may also be helpful in increasing plant awareness, but it requires further study for a comprehensive understanding.

5.4. Limitations in the Study

- METU Discover is developed for the Android operating system, therefore potential participants who use different mobile operating systems could not join the study.
- Study conducted during the winter season, coinciding with the final exam week at the university which reduces the number of potential participants and playtime of the participants.

5.5. Design Suggestions for Location-Based Augmented Reality Games

Based on the findings in this study, following approaches can be applied to the design and development of other location-based augmented reality games:

- Emulate the design and features of popular location-based games to facilitate a smoother onboarding process for players.
- Consider positioning augmented reality as an optional feature rather than a primary one, given potential inconsistencies that may arise in location-based AR.
- Integrate diverse features within the game to cater to different player preferences, enhancing its appeal to a broader audience.
- Test map for the edge cases or use an established map rendering library.
- Consider different weather conditions and high seasons while checking accessibility of all points of interest.
- Conduct usability tests as early as possible.
- Consider the weather status before the study.

5.6. Future Studies

Following features can be added for the future studies that use the METU Discover:

- **Seasonal Plant Pictures:** Pictures of the plants which show the same plant in different seasons and focusing on the distinguishing features can be added. So that, players can distinguish the plants that change over the year and learn their different features.

- **Orientation Integration:** One player suggested that the game could be part of the campus orientation for newcomers. In that case, the game's effect on the newcomers can be studied in detail with the high number of participants.

- **Mutable Map Features:** Points of interest in the map can change shape or color after the player has collected them. This visual cue can help players differentiate between collected and uncollected PoIs, aiding in route planning.

- **Quantitative Methods:** The current version of the study is an exploration study using a qualitative method, however quantitative methods can also be applied. Utilizing scales to measure potential effects, such as sense of belonging ("Brief Sense of Community Scale" (Peterson et al., 2008)) and plant awareness ("Plants as living organism" and "Knowledge about plant" scales (Pany et al., 2022)), before and after game sessions might contribute to further understanding of the phenomenon.

- **Control vs. Experimental Groups:** Two groups of participants (control and experimental) can be used to understand the effects of different features in the game such as augmented reality, leaderboard, or the effect of two languages in the game. One group can use a version with this feature while the other group can use a version without this feature. In this case, both qualitative and quantitative methods can be used for comparisons to better illustrate the phenomenon.

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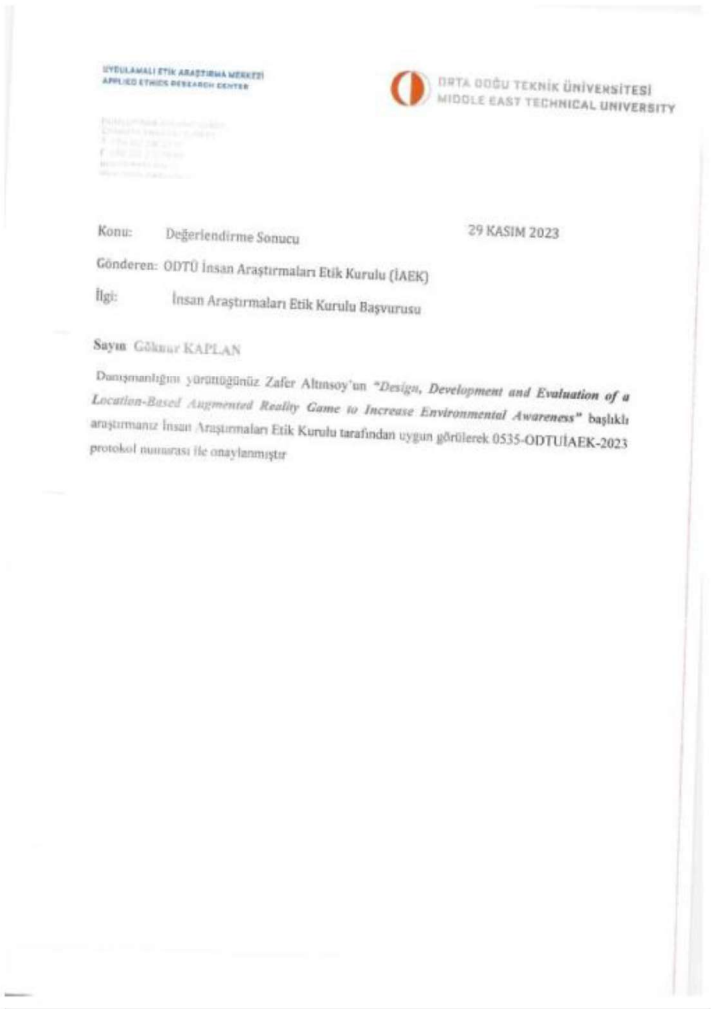
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APPENDICES

APPENDIX A

APPROVAL OF THE METU HUMAN SUBJECTS ETHICS COMMITTEE



UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Konu: Değerlendirme Sonucu

29 KASIM 2023

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Gökmar KAPLAN

Danışmanlığını yürüttüğünüz Zafer Altınsoy'un *"Design, Development and Evaluation of a Location-Based Augmented Reality Game to Increase Environmental Awareness"* başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek 0535-ODTÜİAEK-2023 protokol numarası ile onaylanmıştır

APPENDIX B

INFORMED CONSENT FORM FOR PILOT STUDY

PİLOT ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Çokluortam Bilişimi Yüksek Lisans öğrencisi Zafer Altınsoy tarafından Doç. Dr. Göknur Kaplan danışmanlığındaki yüksek lisans tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı geliştirilmiş konum tabanlı artırılmış gerçeklik oyununun kullanıcıların çevresel farkındalığına etkilerini ve oyunla ilgili deneyimlerini anlamaktır.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz, sizden bu çalışma kapsamında geliştirilen bir mobil oyunu, araştırmacı eşliğinde, düşüncelerinizi sesli şekilde dile getirerek oynamanız beklenmektedir. Yaş, cinsiyet, eğitim durumu, oyun tecrübeniz gibi bilgileri içeren bir demografik form doldurarak yaklaşık 30 dakika sürecek yüz yüze bir mülakatta sizlere oyundaki deneyimlerinize dair sorular yöneltilecektir. Daha sonra içerik analizi ile değerlendirilmek üzere cevaplarınızın ses kaydı alınacaktır.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Cevaplarınız tamamıyla gizli tutulacak, sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardan elde edilecek nicel bilgiler toplu halde değerlendirilecek, nitel veriler ise anonimleştirilerek raporlanacak ve bilimsel yayımlarda kullanılacaktır. Sağladığınız veriler gönüllü katılım formlarında toplanan kimlik bilgileri ile eşleştirilmeyecektir.

Katılımınızla ilgili bilmeniz gerekenler:

Çalışma, genel olarak kişisel rahatsızlık verecek sorular içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz

cevaplama işini yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda çalışmayı uygulayan kişiye, çalışmadan çıkmak istediğinizi söylemek yeterli olacaktır.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için yüksek lisans öğrencisi Zafer Altınsoy ya da ODTÜ öğretim üyelerinden Doç. Dr. Göknur Kaplan ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad Tarih İmza

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APPENDIX C

INFORMED CONSENT FORM FOR MAIN STUDY

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Çokluortam Bilişimi Yüksek Lisans öğrencisi Zafer Altınsoy tarafından Doç. Dr. Göknur Kaplan danışmanlığındaki yüksek lisans tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı geliştirilmiş konum tabanlı artırılmış gerçeklik oyununun kullanıcıların çevresel farkındalığına etkilerini ve oyunla ilgili deneyimlerini anlamaktır.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz, sizden bu çalışma kapsamında geliştirilen bir mobil oyunu oynamanız beklenmektedir. Çalışmaya katılmayı kabul etmeniz halinde çalışma kapsamında geliştirilen oyunu bir hafta süre boyunca oynamanız ve yaş, cinsiyet, eğitim durumu, oyun tecrübeniz gibi bilgileri içeren bir demografik form doldurarak yaklaşık 30 dakika sürecek yüz yüze bir mülakata katılmanız istenecektir. Daha sonra içerik analizi ile değerlendirilmek üzere cevaplarınızın da ses kaydı alınacaktır.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Cevaplarınız tamamıyla gizli tutulacak, sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardan elde edilecek nicel bilgiler toplu halde değerlendirilecek, nitel veriler ise anonimleştirilerek raporlanacak ve bilimsel yayımlarda kullanılacaktır. Sağladığınız veriler gönüllü katılım formlarında toplanan kimlik bilgileri ile eşleştirilmeyecektir.

Katılımınızla ilgili bilmeniz gerekenler:

Çalışma, genel olarak kişisel rahatsızlık verecek sorular içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz

cevaplama işini yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda çalışmayı uygulayan kişiye, çalışmadan çıkmak istediğinizi söylemek yeterli olacaktır.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için yüksek lisans öğrencisi Zafer Altınsoy ya da ODTÜ öğretim üyelerinden Doç. Dr. Göknur Kaplan ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad Tarih İmza

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APPENDIX D

DEMOGRAPHIC QUESTIONS

Demografik Bilgi Formu

1) Cinsiyetiniz:
2) Doğum Yılınız:
3) Eğitim Düzeyiniz:
4) Herhangi bir konum tabanlı oyunla (Geocaching, Ingress, Pokémon Go vb.) daha önce deneyiminiz oldu mu? Varsa, lütfen detaylandırın.

5) Düzenli olarak video oyunları oynar mısınız? Evet ise, genellikle keyif aldığınız türleri belirtin ve haftada ortalama kaç saat video oyunları oynadığınızı belirtin.

APPENDIX E

INTERVIEW QUESTIONS

Ön Çalışma Soruları

1) Oynarken eğlendiniz mi?
2) Oynarken rekabet hissettiniz mi?
3) Oyunun genel oynanışı hakkındaki görüşleriniz nelerdir?
4) Konum servisinin doğruluğu konusunda herhangi bir sorun yaşadınız mı?
5) Menü içinde gezinme konusunda herhangi bir sorun yaşadınız mı?
6) Neyi eksik buldunuz?
7) Ne iyileştirilebilirdi?
8) Sizce, başka neler eklenmeliydi?
9) En sevdiğiniz özellik neydi?
10) Eklemek istediğiniz başka bir şey var mı?

Teşekkürler..

Ana Çalışma Soruları

1) ODTÜ'de kaç yıldır öğrencisiniz?
2) Kaç yıldır kampüste eğitim görüyorsunuz?
3) Kampüs içinde yurtta mı yoksa kampüs dışında mı yaşıyorsunuz?
    a. Kampüs dışındaysa hangi semtte yaşıyorsunuz?
4) Oyunu yalnız mı yoksa biriyle birlikte mi oynadınız?
    a. Birlikte oynadıysanız, kimle? Kaç kişiyle?
5) Oyun oynarken yeni insanlarla tanıştınız mı?
6) Ortalama oyun süreniz ne kadardır?
7) Oyunu kaç kez oynadınız?

8) Oyunu oynamaya devam etmenizi sağlayan ana motivasyon neydi?
9) Oyunu oynamak size nasıl hissettirdi?
10) Normal yürüme rotanızı yollarınızı ağaç görmek için değiştirdiniz mi?
11) Oyun oynarken daha önce ziyaret etmediğiniz yeni alanlar oldu mu?
    a. Evetse, nereler?
12) Kampüsteki hangi ağaçlar/bitkiler en çok ilginizi çekti?
13) Kampüsteki ağaçların/bitkilerin isimlerini ve özelliklerini öğrendiğinizi düşünüyor musunuz?
14) Ağaçlarla/bitkilerle etkileşimde bulunmak ve onları öğrenmek sizi nasıl etkiledi?
    a. Çevreye dair duyarlılığınız değişti mi? Nasıl?
15) Oyunu oynadıktan sonra ODTÜ'ye ve/veya kampüse dair düşünceleriniz değişti mi?
16) Oyunu oynadıktan sonra kampüsü daha fazla keşfetmek istiyor musunuz? Neden?
17) Eklemek istediğiniz başka bir şey var mı?

Teşekkürler..