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A Landscape Design Method Proposal Supported by Augmented Reality

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Abstract

Design can be summarized as the process of finding solutions that begin in the human mind. This process leads to different outcomes depending on the designer's approach, creativity, and interpretation of the design problem. With the rise of digital technologies in the modern era, landscape architects have gained enhanced capabilities to understand spatial and visual compositions. Within the scope of this study, a new landscape design process was proposed by integrating augmented reality (AR) technology into traditional design workflows. Based on expert feedback and field implementation, it was concluded that AR technology offers significant advantages for evaluating preliminary designs in real space, enabling improved spatial perception, interaction, and communication. The findings indicate that AR-supported design enhances cognitive-emotional user engagement and provides valuable contributions to the iterative development and educational use of landscape design projects.

Keywords: *Augmented reality, landscape design, design methodology, design technology.*

Artırılmış Gerçeklik Destekli Yeni Bir Peyzaj Tasarımı Yöntemi Önerisi

Öz

Tasarım, insan zihninde başlayan çözüm bulma süreci olarak özetlenebilir. Bu süreç, tasarımcının konuya yaklaşımına, yaratıcılığına ve başlangıçta tanımlanan tasarım problemine bakış açısına bağlı olarak farklı sonuçlara yol açmaktadır. Modern dünyada dijital teknolojilerin artmasıyla birlikte, peyzaj mimarlarının peyzaj kompozisyonları ve mekânsal-görsel özellikler hakkında daha derin bir anlayış kazanma ihtimalinin arttığı görülmektedir. Çalışma kapsamında, geleneksel peyzaj tasarım sürecine artırılmış gerçeklik teknolojisi entegre edilerek yeni bir peyzaj tasarım süreci ortaya koyulmaya çalışılmıştır. Uzman geri bildirimleri ve saha uygulamaları doğrultusunda, artırılmış gerçeklik teknolojisinin tasarımların gerçek mekânda değerlendirilmesinde önemli avantajlar sağladığı; mekânsal algı, etkileşim ve iletişimi geliştirdiği sonucuna varılmıştır. Bulgular, artırılmış gerçeklik destekli tasarımın bilişsel ve duygusal kullanıcı katılımını artırdığını ve peyzaj tasarım projelerinin yinelemeli geliştirilmesi ile eğitim amaçlı kullanımına değerli katkılar sunduğunu göstermektedir.

Anahtar kelimeler: *Artırılmış gerçeklik, peyzaj tasarımı, tasarım metodolojisi, tasarım teknolojisi.*

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1. Introduction

Design is the process of questioning and searching for solutions that begin in the human mind and result in a product. This process leads to different results depending on the designer's approach to the subject, creativity and perspective on the design problem defined at the beginning. The concretization of this information with the imagination in the mind during the design process ensures the emergence of new information. This process is key to creative design. For the realisation of a new production of knowledge, the processes of visual thinking and visual expression must advance by establishing correct and sufficient relationships. In this way, the resulting product is pre-produced in the mind of an individual without being objective. It is only possible through conscious and effective management to achieve the design process with a viable product (Çınar, 2008; Yakın, 2012; Acar & Bekar 2017; O'Hare et al., 2018).

Landscape architects create healthy spaces for users by making effective designs that prioritise functional, aesthetic and ecological services. Landscape design, carried out without harming the environment, is the process of designing spaces with aesthetic and ideal solutions. The profession of landscape architecture is concerned with form and meaning which provides physically, functionally and aesthetically pleasing arrangement of various structural elements to achieve desired social, cultural and environmental outcomes (Vroom, 2006). With the design principles it is aimed to create spaces that meet the expectations of users. In this context, designs that support quality of life with the intersection of principles and expectations are presented to users at different working scales.

With the increase of digital technologies in the modern world, it seems that landscape architects are more likely to gain a deeper understanding of landscape compositions and spatial-visual features. The purpose of technology is to make people more efficient in performing a particular task. Thanks to technological advances, landscape architects can do more in less time, so that work that used to take a week can now be done in a day or even an hour (Ulman, 2012). The advancing technological development has also been reflected in the design process and it can be observed that different techniques have been developed today. Despite the recognition that digital methods are useful in the field of landscape architecture, in practise their potential is not yet sufficiently used in the design process. Landscape architects have always been keen to develop and use manual and digital media that can support thinking and communication about the spatial-visual features of landscape spaces (Liu, 2020). It is clear that there is a need to develop applications that demonstrate the potential of technology to break down the barriers to the use of digital methods in the landscape design process.

Technological opportunities and innovations in methods and design tools were incorporated into the design process to guide, facilitate and accelerate the process by considering traditional and new approaches in the design process. The use of virtual reality, augmented reality and mixed reality, as well as hardware and software innovations in the design process, offers many conveniences for understanding design and communication between users (Woessner et al., 2004; Koçer, 2019).

In particular, AR offers the advantage of enabling real-time spatial evaluation on-site, providing instant feedback between designer and space. This shifts the design review process from static visuals to dynamic, user-inclusive interactions. Unlike conventional classroom-based design evaluations, this study was conducted directly in the real-world context of the project site, allowing participants to experience the design within its actual spatial and environmental conditions. This approach represents an innovative shift in landscape design education and practice, offering a more immersive and context-sensitive method of design assessment. However, this transformation also requires new evaluation metrics and participatory methodologies that are yet to be fully developed in landscape design practices. The emergence of virtual reality (VR), augmented reality (AR) and mixed reality (MR) technologies has led to the development of affective and cognitive interfaces for design and modelling tools (Neroni et al., 2021). Thanks to the software and hardware developed in the field of technology, significant progress has been made in the VR, AR and MR areas.

Before starting to apply AR to the landscape architecture design process, it is important to understand what VR, AR and MR are and what they do. VR can be summarised as "a completely artificial, computer-simulated image". AR is defined as "a digital overlay of virtual objects with physical objects in real space so that people can interact with both at the same time". MR, which is a combination of AR and VR, is the result of merging the physical world with the digital world (Morimoto, 2022). The foundations of augmented reality were laid as early as 1969, with significant developments in the 1990s and early 2000s. However, the technology gained mainstream popularity particularly after 2010 with the widespread use of mobile devices and the emergence of application-based examples such as Pokémon GO and IKEA Place (Wu et al., 2013). Despite these advancements and the increasing public engagement with AR, the majority of landscape architecture-related studies using this technology remain at a conceptual or educational level. Therefore, there is still a considerable gap in research that investigates the integration of AR into structured and scalable workflows for real-life professional practice (Soydan & Benliay, 2020). There are examples of the use of virtual, augmented and mixed reality technologies in the entertainment industry, the military industry, museums, architecture, interior design, advertising, healthcare and other fields. AR is an innovative human-machine interaction with many potential applications in different fields, ranging from training activities to everyday life (Dini, 2015; Töre, 2017; Avzal, 2022; Bostancı, 2018; Ünal, 2017). VR and AR technologies can be widely used and provide practical support in all areas of landscape design. The re-emergence of the landscape design process not only provides the user with a strong visual impact and a real experience but also allows the design and management staff to evaluate and optimise the design proposal. Furthermore, these technologies significantly reduce the designer's working time and work pressure. They stimulate the designer's imagination and provide better solutions to identified problems (Xu et al., 2015; Morosi et al., 2018; Kerr & Lawson, 2020; Cascini et al., 2021; Kent et al., 2021; Hunter et al., 2021; Erdoğan et al., 2022; Matsangidou et al., 2022).

AR is basically a computer technology that allows digital objects to be superimposed on physical space and experienced spatially by the person (Milgram et al., 1994). This technology provides an interactive environment that helps users visualise digital content and models in their field of vision in a tangible way. AR also has the potential to provide the user with more interesting content by combining computer-generated virtual content and real-world images. With the help of this technology, users can experience a perceptually enriched view of the world that allows them to perceive more than they actually do, as well as to share and present their own ideas to others for their consideration. The use of augmented reality technology by various user groups has increased significantly in recent years as a result of its use with handheld devices. As a result, AR has become a practical and available tool for visualising virtual models in combination with the real world. In the field of landscape architecture, AR has a wide range of potential applications in areas such as design, education and production, where it is possible to involve the public (Soria, 2018; Bostancı, 2018; Vargün, 2019; İpek, 2020; Aksu & Ercoşkun, 2022; Avzal, 2022). AR-based design environment is a semi-immersive design environment in which the users can see the real world while performing feature modelling on a virtual product. This characteristic of AR provides more realism feeling to the users and makes the users feel safer and more comfortable while working on the product design (Kaufmann & Schmalstieg, 2003; Goudarznia et al., 2017; Portman et al., 2015; Broschart & Zeile, 2015).

The potentials that AR brings to the discipline of Landscape Architecture are listed as follows;
- in the areas of landscape architecture education, as a learning tool to accelerate spatial cognition processes,
- in the professional field, as an experimental research or design instrument,
- in the public sphere as a communicational tool to bridge spatial representations and foster common understanding between different stakeholders (Soria, 2018).

Although augmented reality has been used in design-related fields since the early 2010s, particularly in architecture, urban design, and landscape architecture education, it is often employed in a limited and presentation-oriented manner, especially at the undergraduate level. This study does not propose an entirely novel method, but rather aims to adapt and evaluate the existing AR-based approaches in a more structured and systematic design process. In this context, the originality of the study lies in its effort to critically examine the practical usability, visual effectiveness, and decision-making support potential of AR technology in the early stages of a real-world design process. In particular, this study differs from student-level applications by offering a structured evaluation model, reflecting on user feedback, and systematically documenting the stages of the design process with AR. Despite various research efforts, there remains a lack of studies that explore the integration of AR technologies into the structured design workflow of landscape architecture in real-life practice. Most existing studies are conceptual or education-focused, thus falling short of providing practical, scalable, and replicable workflows for practitioners.

With the study conducted in this context, it is aimed to search for an answer to the question of "How can augmented reality technology be brought into the landscape design process as a tool that makes a positive contribution beyond its existing uses?" In order to find an answer to the research question, the effects of AR technology on the landscape design process are investigated under the title of landscape design with the help of the PeyzAR application. In this context, the aim of the study is to investigate the potentials of AR technology in the landscape design process and to demonstrate the effects of this technology on the design process. The selection of Erzurum as the study area was not incidental. Erzurum's distinctive continental climate, its spatial openness, and the environmental dynamics of Atatürk University's western campus corridor present a unique and challenging design context. Moreover, the site was chosen due to its accessibility and suitability for on-site observations and real-time evaluations throughout the design process. These conditions made it an ideal setting to investigate how AR can enhance spatial decision-making and user experience in outdoor design contexts. In the study, landscape design projects of courtyards were evaluated using "AR-supported structured landscape design workflow" to explore an innovatively proposed method to manage traditional landscape design processes more effectively and systematically.

2. Material and Method

2.1. Material

The study area, Courtyard of Architecture and Design Faculty at Atatürk University, is located on the West Campus. The Faculty of Architecture and Design building consists of 6 blocks including the Biodiversity Application Research Centre. The total area of the faculty building is 7500 m^2 (Figure 1). In the organisation of the faculty, the departments of landscape architecture, city and regional planning, architecture and interior architecture provide educational services.

Figure 1. Atatürk University Faculty of Architecture and Design location map (Created by Authors)

Atatürk University Architecture and Design Faculty, which was chosen to be the study area, is located in Erzurum city centre. Atatürk University has a settled campus in the western corridor of Erzurum city, between Erzincan and Çat state highways. The university, which limits the development of the city to the west, is a closed campus that includes activities such as accommodation, sports fields, dormitories, mosque, commercial area, recreation area and hospital (Toy et al., 2018).

Building of the Architecture and Design Faculty has four courtyards between the classrooms and the offices of the faculty members. The yards are surrounded by building on three sides without roof top (Figure 2). Each of the courtyards is of 15 - meter width and 45 - meter length and covers a total area of 564 m2. The building height around the courtyard is 15 meters. There are 2 entrances into the faculty building from each courtyard. For 3D modeling, SketchUP program was used with student licenses provided by Atatürk University and Lumion program was used to obtain rendered images. The Unity program, which is a free and open source game development platform, and the Vuforia software development kit, which is also free and open source, were used to create the AR application. Samsung Galaxy S9 FE model tablet computer met the hardware needs in the research.

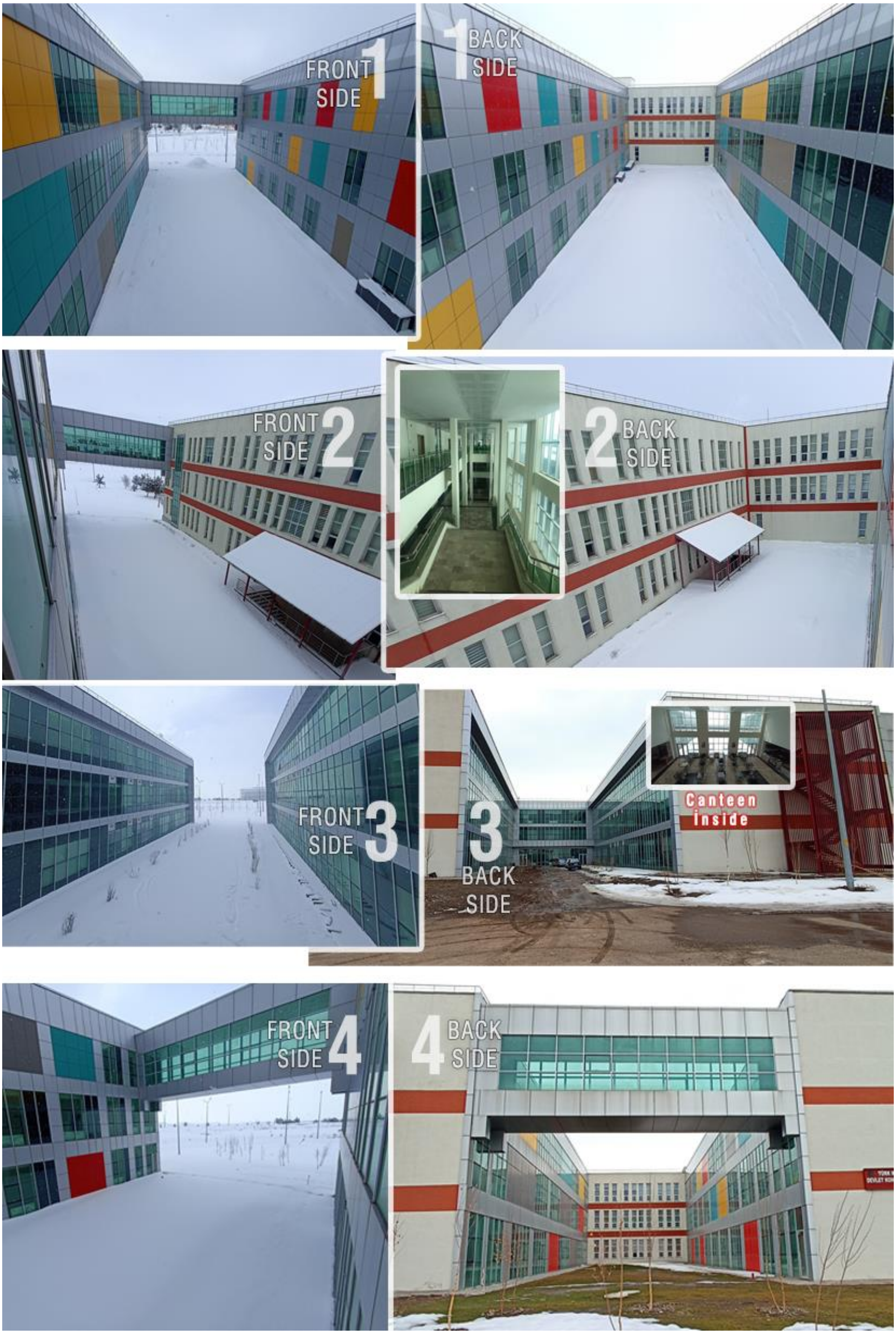

Figure 2. Courtyard gardens of the Architecture and Design Faculty (Created by Authors)

2.2. Method

In the context of the study, augmented reality (AR) technology was incorporated into the conventional landscape design process to create a novel method. The studies (Açıksöz et al., 2014; Shang et al., 2017; Shukri et al., 2017; Obeidy et al., 2018; Jiang, 2019; Cranmer et al., 2021) were used in the creation of the method. The landscape design process of the faculty courtyards consists of 6 stages (Figure 3).

Steps of the method;

1. Selection of the site, determination of the purpose and the problem

2. Data collection to determine the current situation (SURVEY)

3. Analysis and evaluation of the collected data

4. Landscape Design (Bubble Diagram, Final Project, Plantation Project)

5. Evaluation of the decisions in design in an AR environment

6. Implementation project

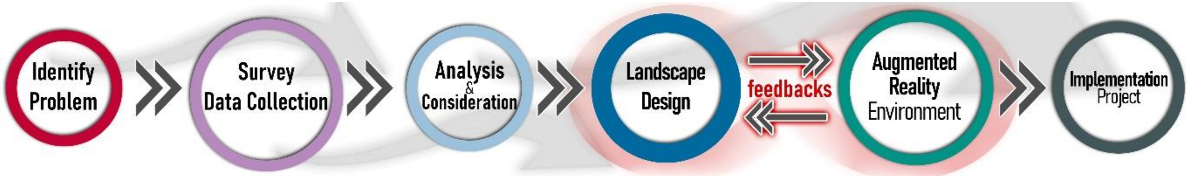

Figure 3. Research method scheme (Created by Authors)

2.3 Technical Setup of the AR Environment

In the development of the AR application, the Ground Plane tracking method offered by Vuforia was employed. This approach enables the placement of virtual 3D objects on horizontal surfaces detected in real-world environments, thereby supporting interactive and spatially accurate experiences through mobile devices. Unlike Image Target-based systems that require marker images, the Ground Plane method allows users to explore the landscape design model by physically moving around it, simulating an on-site experience. This setup allowed users to view and interact with the model in real scale and in real space, using their mobile device as a viewport. The AR application was designed to function independently of printed markers or visual tags, relying instead on surface detection and ambient light tracking provided by the Vuforia SDK. The interaction was designed as a walkable and spatial exploration experience rather than a static tabletop visualization.

2.4. Participant Group and Data collection

T The AR experience and the developed landscape design model were evaluated through feedback sessions with a small group of volunteers from academic and professional backgrounds in landscape architecture and design. Participants included both faculty members and students from the Department of Landscape Architecture at Atatürk University, Faculty of Architecture and Design. The faculty members were selected for their expertise in design-related subjects, while the students participated on a voluntary basis. As the study was conducted as an informal pilot rather than a statistically representative sample, its aim was to obtain preliminary insights into the functionality, clarity, and areas for improvement of the AR application.

Qualitative data were collected through face-to-face, semi-structured interviews using forms developed specifically for this study. These interviews explored participants' perceptions of model realism, spatial legibility, interaction ease, and the potential of AR in landscape design education. Rather than structured questionnaires or quantitative analysis, participants were encouraged to share their experiences openly. Conducted as a case study, the research aimed to collect subject-matter expert and student feedback that could guide future improvements and inform further studies on the integration of AR technology into landscape architecture design workflows.

3. Findings and Discussion

The findings of the study are presented in this section. Within the scope of the study, designs for the courtyards of the Architecture and Design Faculty at Atatürk University were created, and the impact of AR technology was investigated on landscape design process.

3.1. Selection of the Site, Determination of the Purpose and the Problem

Students, academic and non-academic staff, who use the area were questioned to ascertain the project's goals and the issues that call for redesigning the current space and investigations were conducted in the area. At this stage, it was determined that the courtyards remained unused for most of the time of the education, as there were no facilities in the area. Courtyards that serve as working areas offer users an important potential to spend their free time in harsh winter conditions. The main problems identified in Courtyards of the Faculty are as follows:

- In general, study areas are neglected. These areas lack the aesthetic quality of the visual environment which damages the image of the Faculty.
- There is no equipment for users of the area to seat, rest, enlighten etc.
- The courtyards are empty and unusable even though they have to be used in cold winter months.

3.2. Data Collection to Determine the Current Situation

In the second phase, survey studies and data collection process were completed to determine the current situation of the study area. A survey diagram was created by making observations in the area and obtaining digital documents (Figure 4).

Erzurum is one of the most elevated cities (1893 m) in Türkiye. The city is among the cities where the lowest average temperatures are prevalent and winters are long and snowy and summers are short and hot. The highest temperatures are recorded in July and August, with an annual average temperature of 5.5°C, based on data from the Directorate General Directorate of Meteorology. Winter months of December, January and February have the lowest temperatures. The average annual maximum temperature is 12.0°C and the average annual minimum is -1.5°C. The city has low average wind speeds (2.7 m/sec per year) due to its topographical structure, a hollow plain (Dursun et al., 2015).

Within the scope of the study, a survey study was conducted to determine the environmental analysis of the project area and the current situation of the landcover. For this aim, effective physical characteristics on the design, like the orientation of the area, its topography, prevailing wind direction and sun exposure were analysed. According to data from the survey, it was found that there is no slope in the area, it is surrounded on three sides by the faculty building, it is only partially sheltered from the wind and the sunshine duration is not enough. The predominant solar radiation direction of the study area is south and the predominant wind direction is southwest. No sources that could cause noise pollution and bad odours were found in the vicinity of the area.

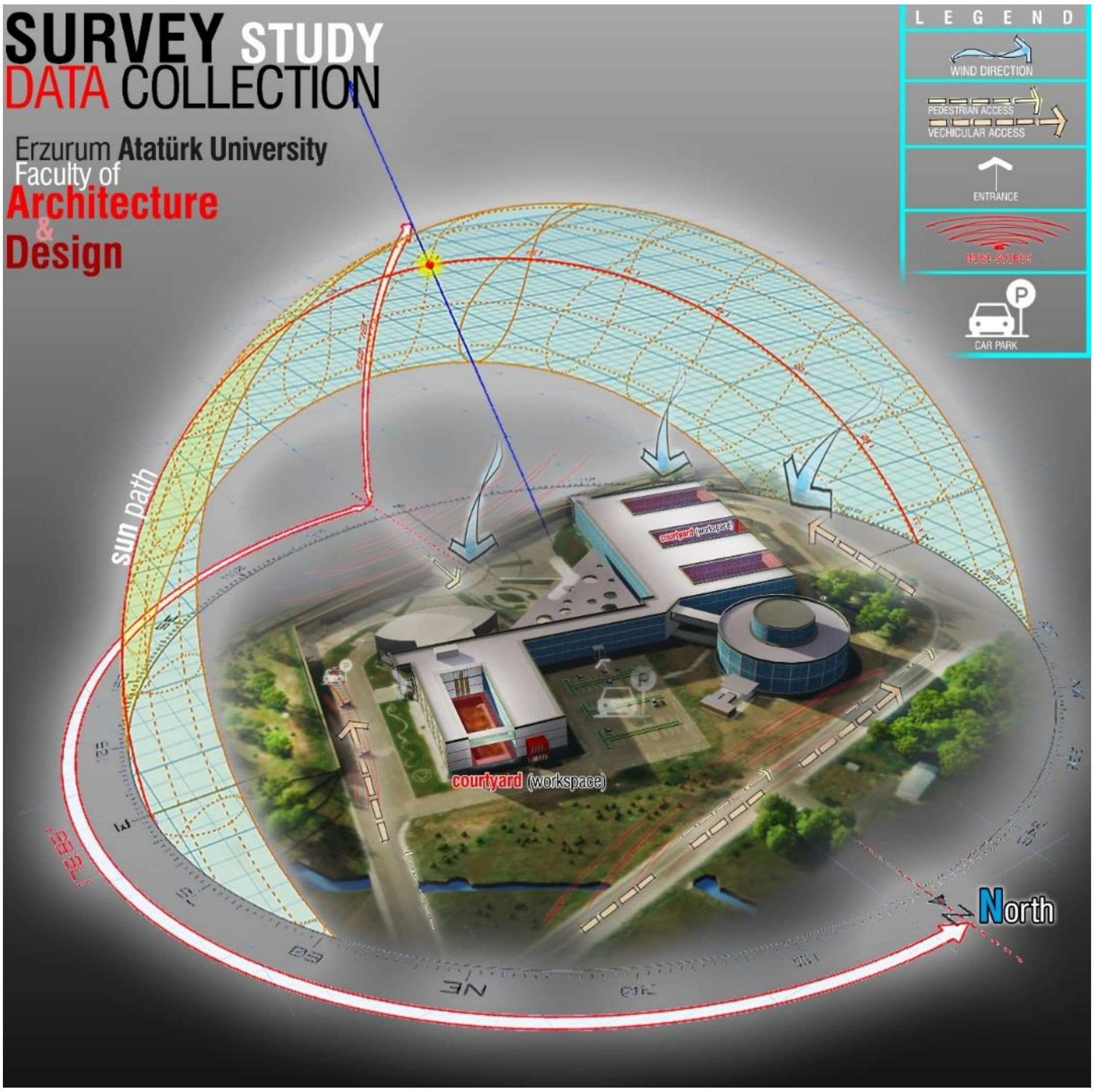

Figure 4. Survey Diagram of Architecture and Design Faculty (Created by Authors)

3.3. Analysis and Evaluation of the Collected Data

In the third phase, the current situation of the courtyards of the Faculty and the effects of environmental factors on the courtyards were investigated by carrying out analyses and assessments for the use of the space. Following the analyses and assessments, interviews were conducted with the users of the area. Subsequently, solutions to the problems identified in the courtyards were proposed in accordance with the identified trends and requirements of the users.

Courtyards are climatically responsive areas that may provide cooling effect for buildings in hot and humid climate areas (Nugroho et al., 2020) and indoor ventilation and daylighting (Yoon & Lim, 2020). In addition to its functions as a passive design strategy, the courtyard garden in the faculty building has essential means of providing a place for students and faculty members to refresh and have a connection with nature. Integration of both the environmental and recreative functions into courtyard design in today's contemporary buildings is critical to effectively meeting the needs of the various users. In achieving this goal, it calls for careful collaboration and consideration among the key players while designing and planning the courtyard projects (Idris et al., 2022).

The climate in the design area is one of the most crucial elements in outdoor landscape designs. Climatic factors such as precipitation, humidity, wind, temperature, etc. affect the content, texture and materials of the design (Yılmaz et al., 2013). Since at least five months of the nine-month school year were spent in harsh winter conditions design strategies for the Winter Garden were developed while designing the courtyard. Winter gardens, whether as an addition to an existing building or as a stand-alone structure, are transparent areas with glass as the primary structural component that protect users from the adverse effects of the environment. Winter gardens should complement the architectural design of the main building (Uysal, 1997; Özkır, 2004; Durmuş, 2006; Uzun, 2021).

The effects of environmental factors on the uses in the area were investigated and analysed using the data obtained. As a result of these analyses, solutions were proposed for the problems identified. As a result of the assessments carried out with students, academic and administrative staff, a "list of requirements" was prepared, which includes the uses for the needs in this area. The uses included in the list of requirements are as follows;

- Indoor spaces,
- Green spaces,
- Short and convenient planting with winter condition,
- Seating and lounging areas,
- Areas for eating and drinking,
- Compatible floor coverings.

The limitations and potentials of the study areas were made clear in order to produce the identified list of requirements. The disadvantage of the courtyard gardens is that they are on the north side of the Faculty and offer no view. However, considering that the courtyards will be used for short-term activities, it can be said that the effects of these disadvantages will not be felt. The courtyard garden in the third zone is connected to the faculty canteen. It can be predicted that this courtyard garden will have a positive effect on lunchtime crowdedness by supporting the existing canteen volume with its reinforcing elements.

3.4. Landscape Design (Bubble Diagram, Final Project, Plantation Project)

In the fourth phase, the results of the analyses defined the landscape design decisions in the concept of the winter garden for the users of the area. The ability of users to carry out social, cultural and recreational activities within the faculty grounds represents the landscape design goal of the study (Karaşah et al., 2016).

The fact that the courtyards are located within the boundaries of the existing building structure allows them to be used both as an alternative to the activities inside the building (eating, resting, sitting and having conversations) and as a complementary to the recreational activities outside the building. Natural elements such as the topographical structure, climatic conditions, shading, north-south direction and user requests and needs were all taken into account in the design of the courtyards. Since the courtyards are on a smooth plain the slope factor was not considered in the designs. Effective direction of the sun is south and so the indoor glass spaces were positioned in the courtyard centres. In this context, studies of courtyard and winter garden concepts were evaluated, taking into account the natural structure of the region. Using examples from the literature, 3D models were created with Bubble Diagram, Final and Plantation Projects.

3.4.1. Bubble diagram

The functions in the requirements list were categorized to create a "Bubble diagram." At this point, in the unscaled Bubble diagram, the uses are related to each other. Within the scope of the study, a need-activity-space relationship in accordance with information obtained from the literature and users (Table 1).

Table 1. Relation of need-activity-space

	NEED	ACTIVITY	SPACE
Education	Getting to know plants and landscape.	Walking among the plants,	Planted areas, outdoor seating, viewing areas.
Socialization	Meet new people, spending time with friends, have conversations and fun.	Sitting together, talking, greeting, sharing the same space	Seating areas, walking areas, indoor spaces.
Basic Needs	Eating, resting, feeling secure	Eating-drinking, sunbathing and giving shade	Eating and drinking areas, lawns, seating areas.

The functions shown in the requirements list are used in the bubble diagram around the connections between the outer edges of the courtyards and the entrances to the Faculty (Figure 5).

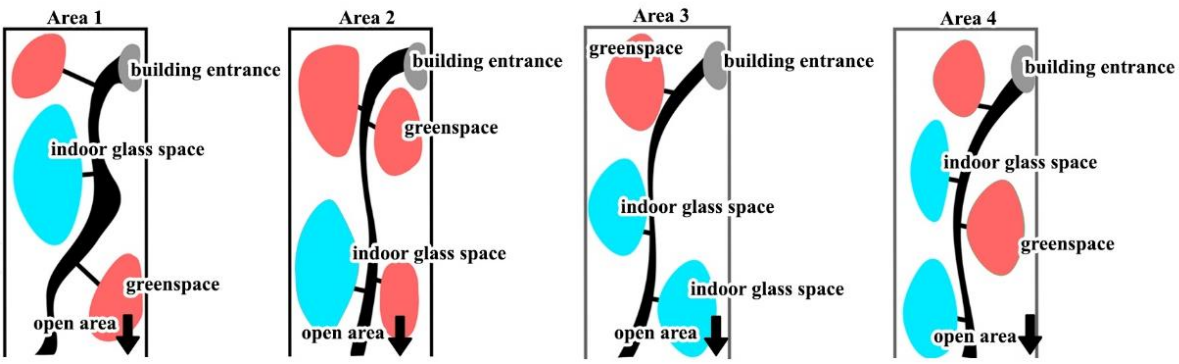

Figure 5. Faculty of Architecture and Design Courtyard Gardens bubble diagram (Created by Authors)

3.4.2. Final project

The final project was prepared at this stage, which show the main design choices, general shapes and functions at a scale.

In the final project phase of the courtyard of the Architecture and Design Faculty, impermeable grounds and pedestrian paths were designed to improve the accessibility of the courtyards. Following that, by considering the list of requirements, the closed windows, flower gallery stands, equipment components, green spaces and the areas used by the students, academic and administrative staff can use extensively were designed.

A different design was created for each courtyard. The designs do not include tall equipment that would obstruct the view and put additional stress on the structure of the area (Figure 6).

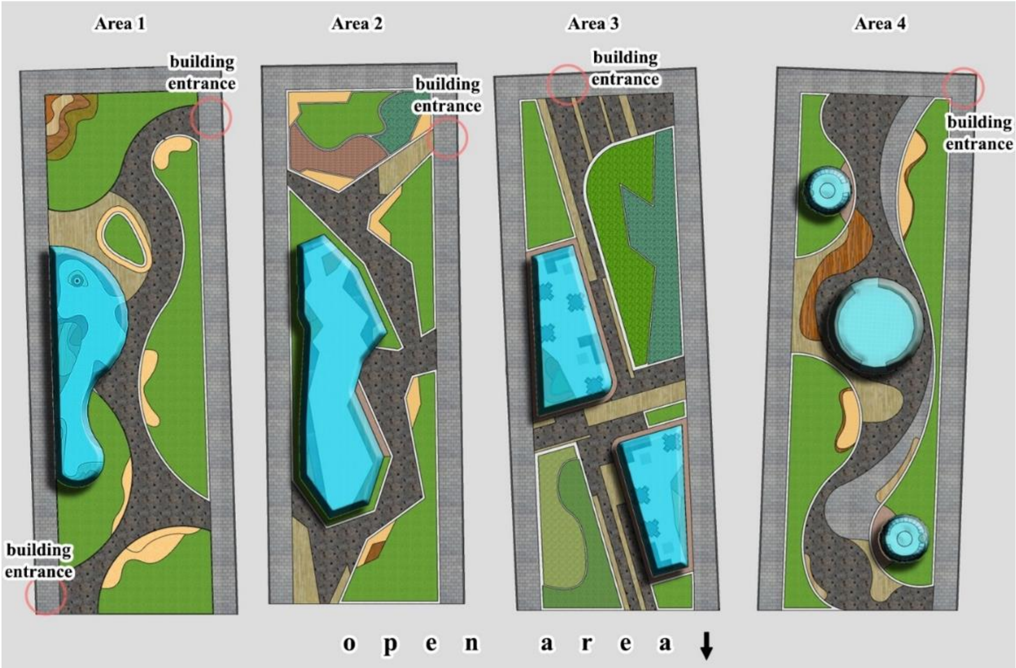

Figure 6. Final Project for the Courtyard of Architecture and Design Faculty (Created by Authors)

3.4.3. Plantation project

The harsh winter climate and high summer temperatures in Erzurum and its surroundings have a negative impact on plants. The winds blowing from the southwest of the city have a negative impact on the vegetation in the university campus. In addition, Atatürk University, which is located between 1750 m and 1900 m altitude, also has negative effects of altitude on plants (Toy et al., 2018). Plants suitable for natural vegetation and adapted to the climatic conditions of Erzurum were used for planting the Courtyard. The ecological, aesthetic and functional qualities of the plants were taken into account when planning the plantation project. Plant characteristics such as colour, texture, scale, line and form were used to support and reinforce the structural design and to define the space (Gökçek, 2020).

In the preparation of the plantation project, shrubs and groundcovers were selected so that they would not interrupt the connection between the faculty building and the courtyards or block natural light in faculty classrooms and offices (Figure 7).

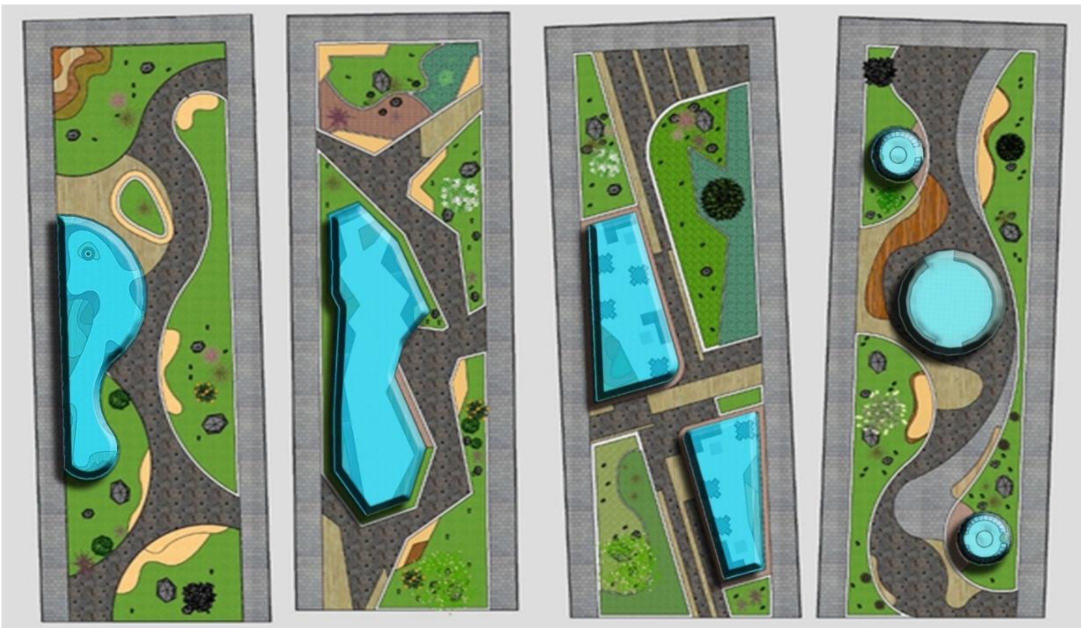

Figure 7. Plantation Project in the courtyard of Architecture and Design Faculty (Created by Authors)

The following table contains the Latin names of the plants used in the design, their actual photos and a 3D – rendered image created specifically for use in an AR environment (Table 2).

Table 2. Real photos and render images of plants (Created by Authors)

Real photo	Render image of the 3D model used in the study	Real photo	Render image of the 3D model used in the study
			
Cornus Alba "Sibirica"		*Juniperus foetidissima* Wild.	
			
Syringa vulgaris		*Pyrus salicifolia*	
			
Buxus sempervirens		*Rosa hemisphaerica J. Herrm*	
			
Cotinus coggygria		*Juniperus Virginniana 'Skyrocket'*	
			
Nepeta x faassenii		*Viburnum opulus*	
			
Ephedra major Host.		*Berberis thunbergii*	
			
Daphne oleoides			

3.4.4. 3D render images

To make the AR environment experienceable and technologically efficiency, intensive data loading was avoided during modelling. Figure 8 shows the final renderings of the completed landscape projects for the summer and winter seasons.

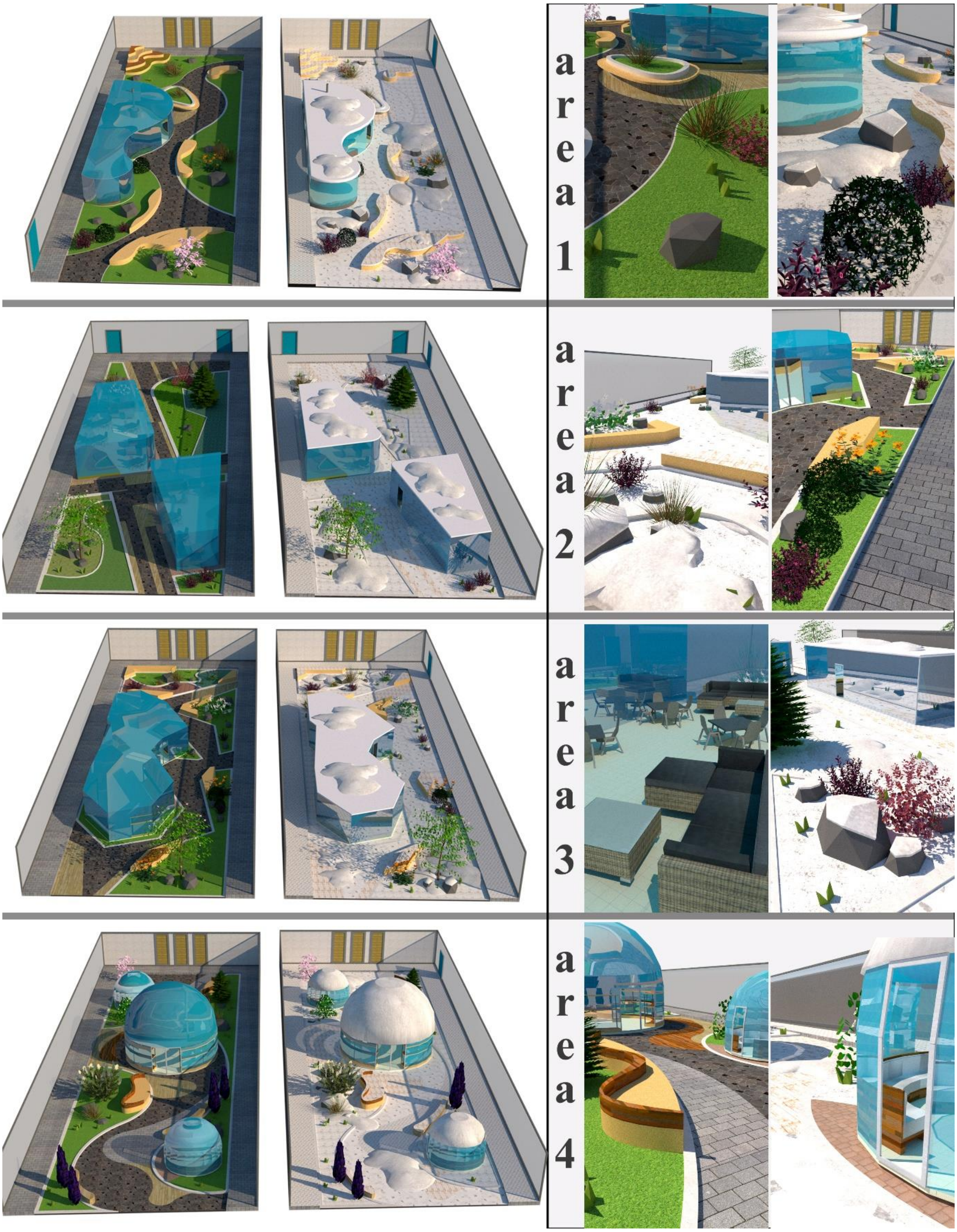

Figure 8. Courtyard Gardens landscape design 3D rendered images (Created by Authors)

3.4.5. Quality of 3D modeling in AR environment

In the AR-based design process, while the perception and spatial experience were significantly improved, the level of detail in both structural and vegetative elements remained limited. The primary reasons for this limitation include technical constraints related to 3D modeling software and file optimization requirements in AR environments. To ensure smooth performance on mobile devices, simplified models were preferred to avoid excessive data load, which in turn limited the textural richness and geometric complexity of plant elements. Additionally, during the modeling phase, licensing restrictions at the undergraduate education level—such as access only to student versions of professional software—also contributed to the relatively low detail of some components.

Moreover, although high-quality plant models are available on platforms like SketchUp's 3D Warehouse, many of these require licensing or incur additional costs, which made their use impractical in this study. For future improvements, expanding the plant database with custom-modeled vegetation and using optimized assets designed specifically for AR rendering are planned. These improvements will help enhance the visual fidelity of the landscape elements without compromising the app's performance.

3.5. Evaluation of the Design Decisions in an AR Environment

In traditional landscape design projects, 3D models and animations are created to better perceive the area. However, the rendered images and animations have some shortcomings in the user's emotional and cognitive perception of the space. In order to eliminate these shortcomings, the fifth phase integrated AR technology into the traditional landscape design process. Unlike renderings and animations, users who experience landscape design projects in the AR environment can perceive them more effectively on a cognitive and emotional level. For this purpose, 3D models of the landscape design project were imported into the Unity program to evaluate the design decisions in the AR environment. In the next phase, the outputs of the application on the Android platform were taken with the .apk file extension. The name of the application was set as ***"PeyzAR".***

Developed based on the Ground Plane system, the 'PeyzAR' application consists of 22 distinct interactive scenes designed for user engagement in augmented reality environments. Models are called on the perceived ground in the GroundPlay section, which allows users to move inside the modelled designs. In the GroundPlay section, the users had emotionally and cognitively stimulation experiences since they were allowed to interact with the designs in real space. Figure 9 provides screenshots of the PeyzAR application's user interface.

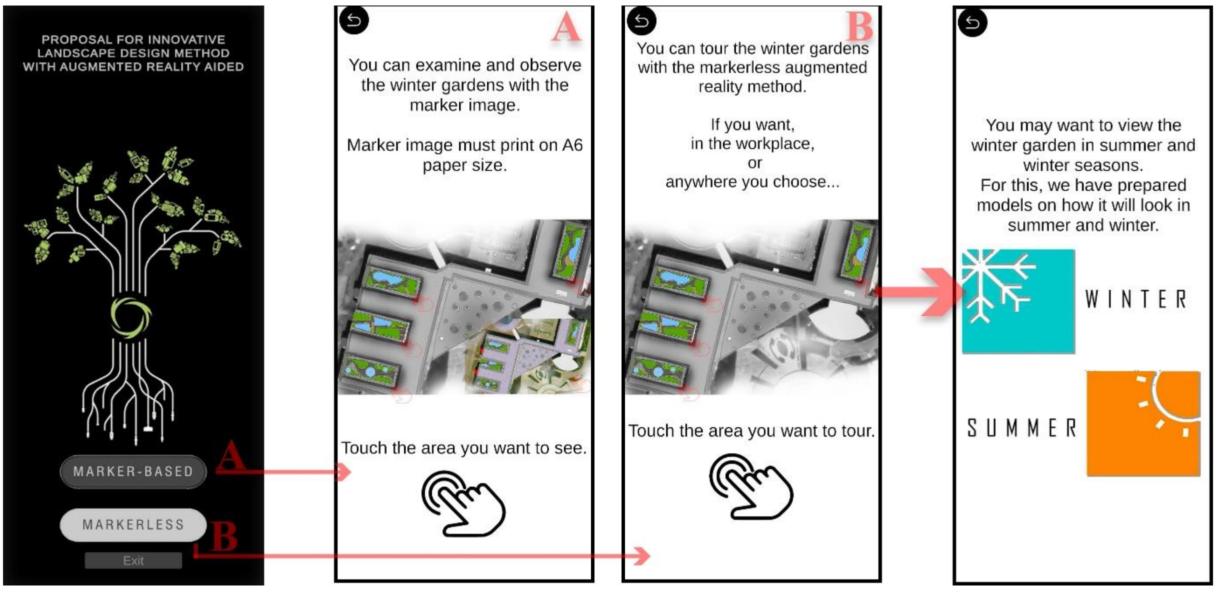

Figure 9. PeyzAR application interface (Created by Authors)

Potential users of the courtyards experienced the 3D designs in real space via the PeyzAR application on their mobile phones and tablet computers. During the experimentation phase of the designs, technical problems were reported as the failure in displaying the content of AR in the right places on the device's screen and opening the app on low-powered devices. Despite the technical problems, there are no deficits in understanding design-space relationships when using AR.

Those who have experienced the application were asked to give feedbacks about the difficulties, shortcomings and weaknesses, how well it works on devices, what the end user needs and their opinions and suggestions for improving the application. Potential users' opinions on the designs and models were generally positive.

It is important to note that the data collected during this phase were based on in-person interviews and verbal feedback rather than systematic surveys or statistically structured tools. Therefore, the results do not represent a quantitatively generalizable dataset, but instead reflect a set of qualitative insights derived from user experiences.

This qualitative feedback helped to understand user behavior, expectations, and preferences in a natural interaction environment with AR content. The information gathered also highlighted practical aspects of AR usability that are often overlooked in controlled experiments, thereby offering a more grounded understanding of user engagement.

The feedback from users is listed below in general terms;

- Unlike 3D renderings and animations, experiencing designs in real space creates a much more exciting, impressive and authentic feeling.
- The relationship between space and design can be easily established in an augmented reality environment with various perspectives.
- It is an impressive experience to walk in the models and interact with the actual environment.
- In order to better perceive the realism of the AR environment, the shadow and texture qualities in 3D models can be improved.
- Students and academics who used the PeyzAR application wanted to incorporate AR technology into their designs.
- The users of the application felt that the courtyards lacked plantings and recommended the addition of seasonally appropriate flower beds.

In addition to the general comments, feedbacks for each courtyard design and their appearance in different seasons are given below. Images are taken from the GroundPlay based section.

Participants suggested the addition of a secondary entrance to the enclosed glass structure to improve circulation and user accessibility. The central courtyard was identified as a potential space for stepped seating units, which could enhance social interaction and resting opportunities. Furthermore, it was recommended to increase the number of outdoor seating elements to support various user needs and encourage longer stays in the area (Figure 10).

Figure 10. Courtyard 1 AR images and user feedback (Created by Authors)

The enclosed glass volume in this courtyard was perceived as a single, undivided space. Experts proposed separating this structure into two distinct zones to promote a sense of warmth, privacy, and community. This division could support different user activities and enhance the flexibility of the interior layout, aligning with diverse design intentions (Figure 11).

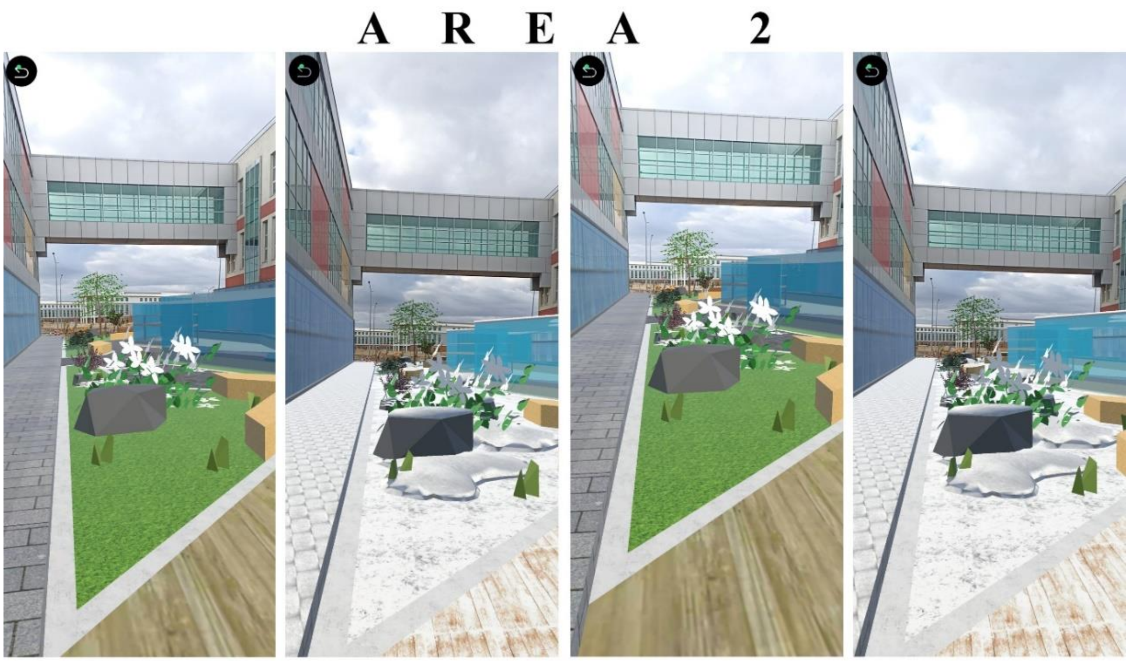

Figure 11. Courtyard 2 AR images and user feedback (Created by Authors)

Feedback for this courtyard emphasized the need for increased privacy between the eating and seating areas. The use of partition elements, such as privacy screens, was recommended to establish visual and functional boundaries. Additionally, participants noted that the open space could accommodate more outdoor seating, improving usability during high-traffic periods (Figure 12).

Figure 12. Courtyard 3 AR images and user feedback (Created by Authors)

The central spherical structure was considered visually dominant in relation to the scale of the courtyard. Experts suggested reducing its height to achieve a more balanced spatial composition. They also recommended increasing the number of interior seats to maximize functionality and meet potential user demand (Figure 13).

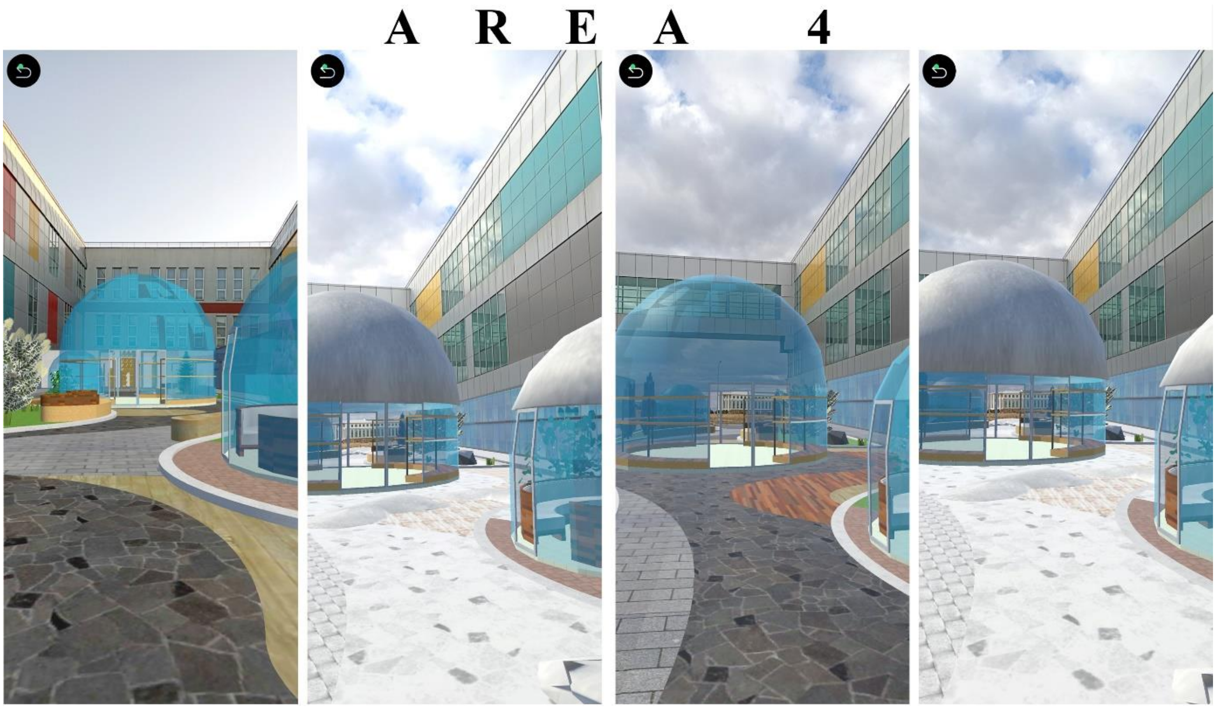

Figure 13. Courtyard 4 AR images and user feedback (Created by Authors)

3.6. Suggested Implementation Project

The suggested implementation project developed in the sixth phase did not include structural technical details, as the primary goals of the study were to allow users to experience the designs in the AR environment and provide feedback (Figure 14).

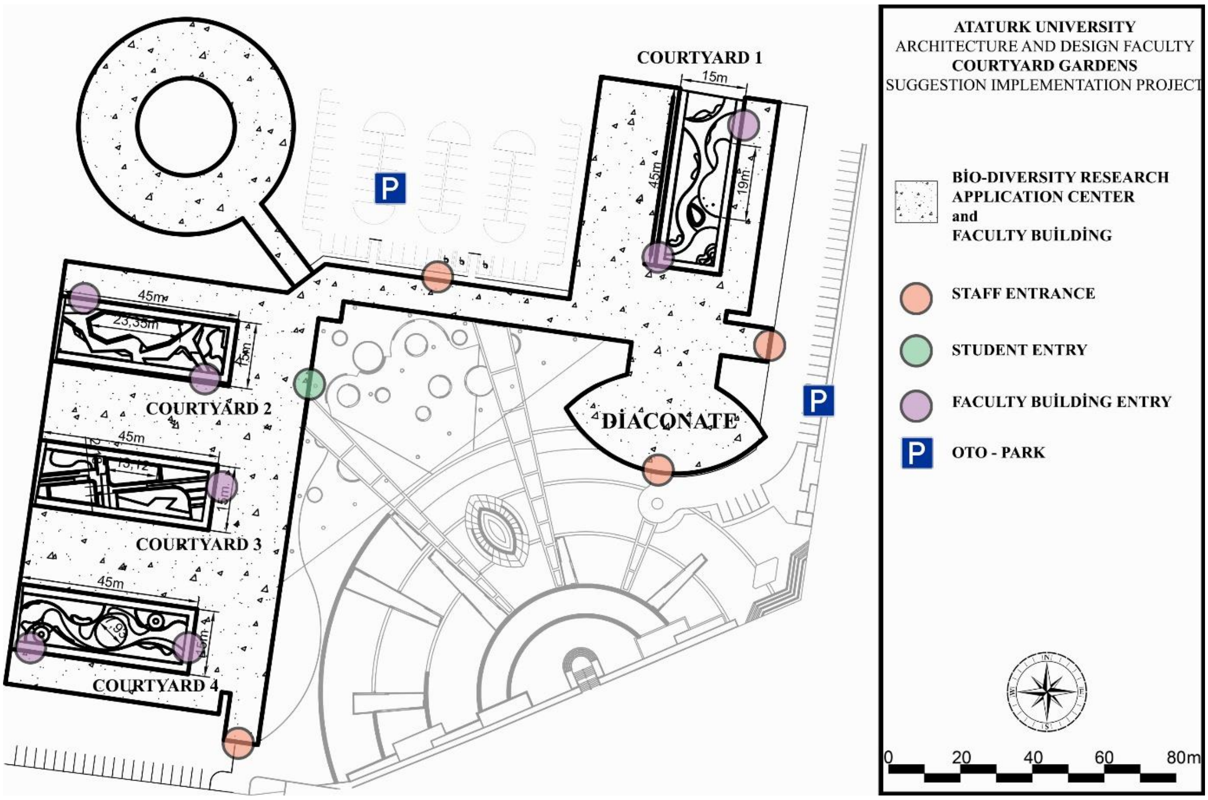

Figure 14. Architecture and Design Faculty Courtyard Gardens Suggesting Implementation Project (Created by Authors)

4. Conclusion and Suggestions

The definition of "design" in the Britannica dictionary is "the process of mental or material work to produce a product". The Larousse dictionary defines design as "the aim, intention, plan, project, idea of accomplishing something set forth with sketchy lines to achieve it". In accordance with this definition, design defined as imagining the form of something and creating a design or model (Hasol, 1995). It is possible to expand the definitions of design and design action. However, to fully understand design, it is essential to compare design activities and actions across disciplines and to know how various disciplines view design. Design involves definite and ambiguous concepts, organized and disorganized thinking styles, imagination and mechanical calculations. In this context, design is the subject of disciplines such as architecture, interior architecture, industrial production, urban planning, and landscape architecture, where the designer must achieve an aesthetically and functionally pleasing result (Lawson, 2006).

The traditional design process is described as a process of developing and shaping design thinking through methods such as hand or computer-aided drawing and visualization and model building (Turan, 2009). New opportunities for process management and production emerged with the integration of evolving technology into the design process. It is believed that with the provision of these opportunities design efficiency can reach up to a new threshold. When examining the processes of landscape design, it becomes clear that many of the steps can incorporate into modern technologies. In parallel with technological progress, the development and application of various methods take place in response to the challenges of conventional design processes. As information technologies advance, AR technology becomes increasingly more important as a tool for design works. Although it was challenging to implement ARin the past, its applicability and usability have improved with the advance of mobile devices at present. AR can be used to display a more useful reality on top of the existing reality. So, these benefits provide very effective ways to draw people's attention to a particular subject.

In this study, it is aimed to develop landscape design processes and demonstrate an innovative, contemporary design process using the potential of AR technology. In this context, a proposal for a landscape design for the courtyard of the Architecture and Design Faculty of Ataturk University was created. The developed design was transferred to the AR environment and PeyzAR application was created. The Unity game engine and C# were used for the application. ImageTarget and GroundPlay methods are used in "PeyzAR" Augmented Reality environment. Drainage, soil structure, fertilization and irrigation were not considered in the designs presented in this study. The study was limited to the landscape design of the courtyards and the incorporation of AR technology into the design process.

In the landscape design of courtyards, a list of requirements was created for the opinions of the academic staff, administration and students. The list of requirements created was used to design the spaces. Indoor spaces were created to allow users of the courtyard to use the area year-round. The designs created spaces that better meet users' needs for socializing, resting and recovering from the stresses of daily life. The primary framework of the design is based on supporting formal education. In this direction, landscape design projects were created by establishing connections between plants, closed glass spaces and impermeable grounds.

The "PeyzAR" augmented reality application created for the Courtyards of Architecture and Design Faculty produced the following results;

- By enabling 3D objects that can be perceived within certain parameters in the virtual environment to be experienced in the real environment, it creates different emotional-cognitive perspectives.
- Before moving on to the application stage, it enables users to experiment with designs that are expensive or difficult to implement in the real world in the actual space.
- By incorporating the elements such as sound, smell, temperature and others into the perception of the Design-Space relationship, it provides an environment that is more effective and understandable than the virtual environment.
- The 3D materials created as the part of the application can be used in regions with similar climatic and topographical conditions by providing the opportunity to experience the designs in other locations.

It was determined that the use of augmented reality (AR) technology as an innovative method in the landscape design process can help eliminate the shortcomings and weaknesses by experiencing the draft designs in 3-Ds in real space before turning them into implementation projects. It was seen that augmented reality technology can be integrated into traditional landscape design processes and applied to other design projects since it can reduce the time required and cost to prepare projects in a beneficial process.

However, it is important to note that although this study provides a strong technical infrastructure and demonstrates a successful application of AR technology, the method developed was based primarily on the authors' own experiences in producing AR images and expert interviews. Therefore, the methodology should be further enhanced by incorporating the difficulties and needs that other designers, especially those with limited AR experience, may encounter during the design process. In future studies, more comprehensive user feedback from a wider group of practitioners can be included to make the method more inclusive, adaptable and user-oriented.

As a result of the potential that augmented reality applications have demonstrated in both the daily and scientific fields, it was observed that they will play an important role in the development of design processes within the framework of modern understanding. This study differs from previous ones by not only integrating augmented reality technology into the landscape design process, but also by critically evaluating the method’s applicability beyond individual competence. In addition, the study has prepared the ground for other studies to be carried out with augmented reality technology in the future.

Inferences and Guidelines for Future Applications

The findings obtained through expert interviews and practical testing reveal that integrating AR technology into landscape design processes offers not only a visual enhancement but also a shift in how spatial understanding and user interaction are perceived during the design phase. This study distinguishes itself from previous research by emphasizing the designer experience during the AR integration phase and identifying the practical challenges of implementation.

Compared to earlier applications in the literature, this research introduces a step-by-step experimental design process that reflects real-world usability within an educational context. The method enables designers to test and revise virtual models in-situ before physical implementation—offering considerable time and cost savings. Moreover, the expert-based assessment revealed a greater sense of spatial realism and user engagement when compared with static 3D renderings.

To guide future designers and practitioners, the following recommendations are proposed:

- AR technology should be integrated in early conceptual design phases to allow iterative prototyping in real space.
- Multisensory inputs such as ambient sound or environmental cues can be progressively added to improve user immersion and comprehension of space.
- A standardized workflow or tutorial set should be developed to help designers without prior AR development experience navigate the technical setup.
- Stakeholder involvement through interactive AR-based feedback sessions is encouraged to align designs more closely with user needs.
- The adaptability of AR content across different landscape conditions (climatic, topographic) should be further explored to enhance the reusability of design components.

Acknowledgements and Information Note

The article complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article. There is no conflict of interest.

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