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Research Paper

Development of VR Based Educational Material for Distance Education Technologies: Charged Electron Experiment

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ABSTRACT :*Distance education technologies and applications have recently become popular, especially due to the pandemic period that occurred in 2019. Distance education technologies, which offer learning environments independent of time and space, providing students with unlimited repetition and the opportunity to progress at their individual pace, have begun to stand out in all areas of education. Researchers working on information technologies are working on how popular technologies such as blockchain, artificial intelligence, metaverse, virtual reality can be integrated into distance education. Among these fields, virtual reality technology is one step ahead of other fields thanks to its hardware equipment such as virtual reality glasses used in virtual reality technology. The reason for this is that the glasses used in virtual reality can be obtained individually independent of time and space and virtual reality applications can be directly integrated into web technologies. In this study, it is explained in detail how the experiment showing the behaviour of charged electrons against each other was designed and prepared in order to provide students with the closest experiences to reality in distance education, and how it was integrated into distance education technologies. I hope that this Unity-based experiment will be a source of inspiration for many experiments and simulations in this field.*
KEYWORDS: *Distance education, distance education material, virtual reality, simulation*

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I. INTRODUCTION

Distance education is one of today's popular education methods and is the use of various educational methods and technologies to eliminate time and space limitations in order to carry out educational activities. While distance education provides an educational environment independent of time and space, it is also a structure that can eliminate inequality of opportunity and offer more flexible educational opportunities[1]. Since distance education can be used in different fields such as adult education, child education, parent education, on-the-job training, especially in colleges and universities, it can be said that its application areas are quite wide. In this context, distance education has a very dynamic structure compared to traditional methods and has an important place in terms of both disciplines and methods in teaching projects. When distance education methods are examined in detail, it is seen that they are divided into different subfields according to the educational methods and technologies used. For this reason, internet-based distance education methods draw attention as one of the most popular distance education methods today. Thanks to this method, which is offered especially under the leadership of computer technology, students can attend the courses offered whenever and wherever they want. Learning environments with audio, video, graphics-rich materials, two- or three-dimensional animation and structures for instant feedback provide students with a more permanent and enjoyable learning experience. In synchronous distance education, teachers and students interact simultaneously[2]. Therefore, synchronous distance education is independent of space but not independent of time. Just like in face-to-face classical education, teachers and students participate in educational activities simultaneously. Asynchronous education is one of the alternatives of distance education methods that promises to eliminate the need for temporal and spatial integration. In asynchronous distance education, time and space unity is not important. Students can participate in distance learning anytime and anywhere. For example, it is sufficient for students to connect to the system via the Internet using a computer, tablet or mobile phone to participate in the education[3].

The potential of virtual reality-based systems to revolutionise education has been a topic of discussion for years. It has been argued that by using virtual reality for simulation-based education, students and learners can acquire new skills in a simulated environment that allows for correction, repetition and non-dangerous failures, while at the same time providing access to interaction with expensive or inaccessible environments. Despite the considerable optimism surrounding virtual reality technology, it was based on assumptions rather than practical applications. With the exception of specialised training simulators for surgeons, pilots and military personnel, the level of development of VR technology has not reached a point where it can be effectively applied in education and training [4]. In education, virtual reality is used not only as a space where students can acquire the necessary knowledge, but also as an information space where they can interact with all kinds of virtual objects. In the educational environment, interacting with virtual objects facilitates the development of collective collaboration methods and gaining confidence in the presentation of individual projects. The process of creating interactive resources and selecting the tools that may be required poses a technological challenge for educators adopting new information technologies [5].

Progress in both the fields of education and technology has brought numerous benefits to humanity, including increased convenience and economic contribution. To facilitate the development of advanced technologies and guarantee their accessibility to a wider demographic, it is imperative to provide comprehensive education at the highest level. The term "educational technology" is defined as the concept of teaching and learning in an efficient technological environment. The main objectives of educational technology are twofold: firstly, to improve the quality of education and secondly, to optimise the learning process. Technology is expected to facilitate improvements in the teaching and learning process and at the same time increase the efficiency and convenience of educational systems [6].

One of the most important criteria in learning is permanent learning. In order to realise permanent learning, students need to be stimulated with multiple senses and rich course materials. Theoretical learning activities will be transformed into practical learning activities as the realistic and interactive presentation of course materials will cause learning processes by doing and experiencing on students. In distance education, it is not possible to practice and practice in face-to-face education. In order to eliminate this limitation, virtual reality technology can be combined with distance education and many difficulties experienced can be eliminated. Thanks to virtual reality technology, students will be able to apply the individualised learning model. Students can learn at their own pace with unlimited repetition opportunities. In addition, virtual reality technology provides great convenience for disadvantaged student groups. Experiments, which are expensive and risky to perform, can be performed easily and safely with virtual reality technology, eliminating the limitations in both distance learning and face-to-face education[7].

II. LITERATURE REVIEW

The popularity of distance education technologies in recent years has influenced other engineering fields to carry out more research and development studies to contribute to this field. Among these fields, virtual reality technologies make great contributions to the preparation of new experimental environments and the discovery of new teaching platforms. Many studies carried out with the support of virtual reality technologies have provided more permanent learning on students. In this section, existing studies on the development of virtual reality-supported educational materials and the creation of virtual reality-based learning environments, which is the main objective of this study, are examined. Both software and hardware costs constitute an important financial expense in the use and application of virtual reality technologies. The hardware used includes virtual reality glasses, controllers, hardware powerful computers and sensors specially developed for the purpose. In order for the learning experiences to be created with the combination of these hardware to be effective in users and to exceed standard learning, 3D designs and graphics must be operational in real time[8]. Virtual reality development platforms such as Unity, Godot, Unreal Engine should be used to ensure communication between the software created and the hardware used[9]. In the literature, there are many studies examining the effects of virtual reality-based educational materials, educational environments and electronic studios on students' learning performances. It has been determined that such methods increase the retention of students' learning and their motivation to learn. In addition, it has been concluded that they play an important role in understanding the subjects that are stated to be difficult to understand and eliminating complexities[7]. In addition to its contributions to learning, the use of virtual reality-based applications in providing experiences that are very costly to experience and in the realisation of applications that are risky to experience shows how valuable virtual reality technologies are in education[10]. In their studies in the fields such as individualised learning and individual learning speeds, researchers have stated that in virtual reality-based learning environments, students can adjust their visual, psychomotor and auditory learning senses according to their own speed, create the desired number of repetition opportunities and act according to their individual learning speeds. This increases the effectiveness and efficiency of the education received[11]. Although there are so many positive aspects provided by virtual reality-based applications, there are also negative aspects such as financial financing difficulties and lack of technical support that may be experienced in establishing this system. In the researches conducted, the problems experienced in the implementation of virtual reality-based systems due to the high costs of establishing the infrastructure, insufficient personnel in the provision of technical equipment and technical support have been investigated[8]. In addition to this, it is claimed that even if all financial conditions are completed, there will be great difficulty in the adaptation and preparation or training of educators and educational contents to these technologies. It has been suggested that the solution can be overcome with in-service trainings[9]. One of the main objectives of this study is to demonstrate that these negative views and opinions are unfounded and to show that educational contents can be easily integrated into distance education contents with current technologies. Unlike all these negativities, there are studies expressing concerns about the health and physiology of users. It is claimed that the use of virtual reality glasses by users for a long time may lead to physiological disorders and visual impairments. Due to these concerns, research on the ideal duration of use of these devices continues[12]. The elimination of technical problems that may arise during the use of the developed platforms reveals the necessity of regular maintenance and update services.

In addition, professional service procurement, research and development studies are required for equipment use and security vulnerabilities that may occur[13]. It has been found that an education process that starts and continues smoothly plays an important role in student motivation[14]. As it was carried out in this study, a material was prepared that allows visualisations of virtual reality-based complex machines and students to interact with these visuals. Thanks to the prepared material, it was determined that it contributed to a better understanding and permanence of the subject[10]. Continuity of education is very important for students' motivation, concentration and sequential learning. In cases where face-to-face education has to be terminated due to force majeure such as widespread diseases and natural disasters, distance education method is used to eliminate the negativities to be experienced. The Covid-19 pandemic, which emerged in December 2019 and affected all countries in the world, as well as causing change and transformation in many fields, clearly revealed the importance of distance education. Researchers designed a 3D classroom environment for this period by using virtual reality technology to ensure equal opportunity and continuity in education for students who are in quarantine at home due to the Covid-19 outbreak[15].

III. VR BASED EDUCATION MATERIAL INFRASTRUCTURE

The educational material to be prepared for distance education is designed to work both in web technologies and VR glasses. In order to give this capability to the material

3.1. Unity Platform

Unity is a versatile and powerful real-time 3D development platform that is widely used to create interactive experiences including games, simulations and VR/AR applications on various platforms such as mobile, desktop and consoles. It provides a robust integrated development environment (IDE) that includes tools for 2D and 3D rendering, physics, animation, and user interface design with scripting done in C# using mainly Mono or .NET framework[16], [17]. To use Unity, developers usually start by downloading and installing the Unity editor, creating a new project and using the editor's features to design scenes, implement game logic through scripting, and build the project for the desired platform. In addition, Unity's asset store offers a large library of pre-made assets and plugins that accelerate development and prototyping by providing ready-made resources.

3.2. Development of the Training Material

Simulation design and coding was carried out using Unity design and coding platform. The simulation was compiled and exported with WebGL to run both on VR glasses and web pages. To run WebGL files locally, you need a web server. However, since some browsers prevent direct uploads over the file protocol (file://) due to security policies, it was necessary to prepare a local server with Python and node.js collaboration. Afterwards, WebGL structure files (index.html, Build folder, TemplateData folder, etc.) were uploaded to the prepared hosting area. Iframe structure was used to place the simulation on the designated monitoring page in the distance education platform. This is because the iframe tag points to the URL where the WebGL structure is hosted. Figure 1 shows the compilation phase of the project for WebGL.

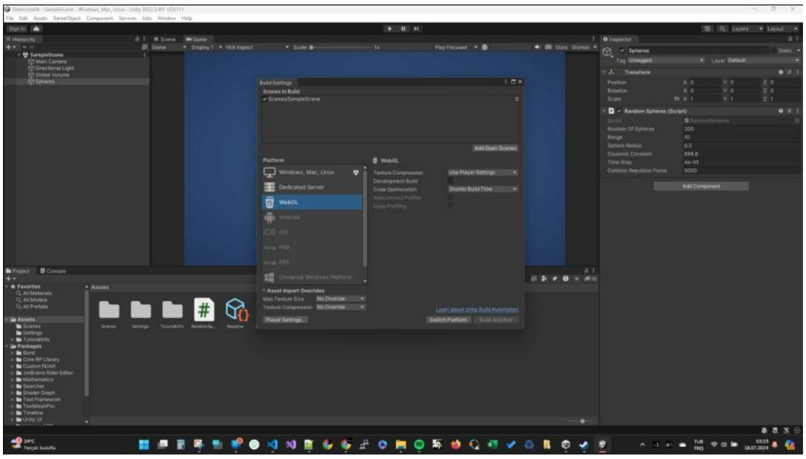

Figure 1: WebGL compilation for the application to run on the web

In the experiment simulation, the interactions of positively and negatively charged electrons against each other were simulated. The electrons prepared in 3D represent positive and negative charges in blue and yellow. The image in the Unity scene is shown in Figure 2.

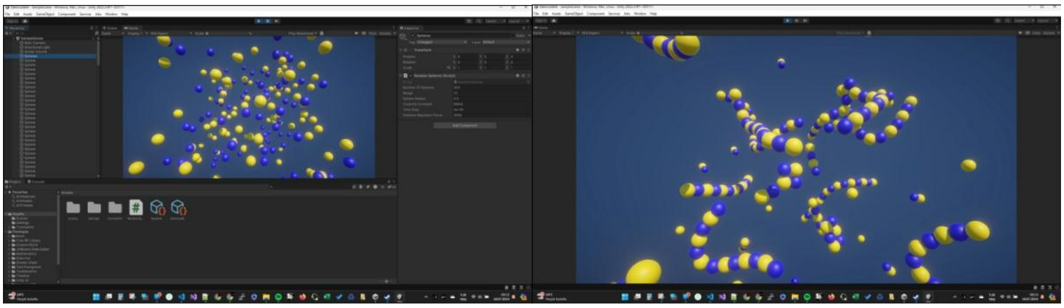

Figure 2: Action of charged electrons on the stage

The workflow chart followed in the creation of the training simulation is shown in Figure 3.

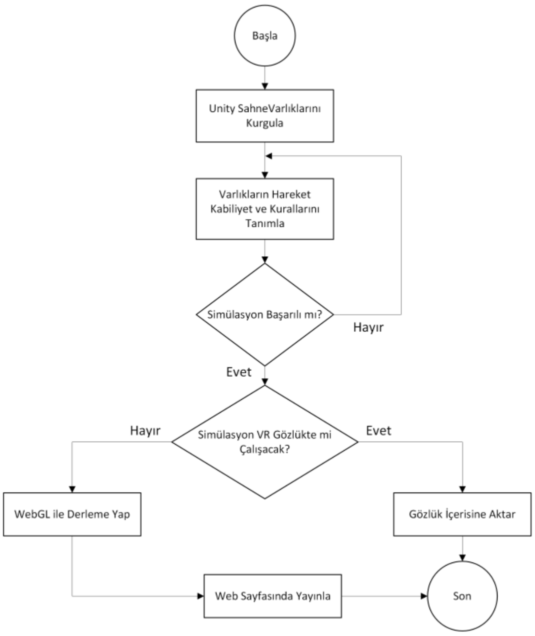

Figure 3: Workflow chart followed in the creation of the training simulation

The hardware specifications, operating system specifications and software specifications of the training material are shown in Table 1.

Table 1: Hardware and software features on which the training material was developed

CPU	Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz 2.59 GHz
RAM	64,0 GB (usable: 63,8 GB)
System Type	64 bit, x64 processor
Operating System	Windows 11 Pro version 23H2
İS building	22631.3880
Unity	2022.3.4f1
Visual Studio Code	1.91.1

The codes prepared for the realisation of the scene actions in the Unity environment are shown in Algorithm 1 table.

Algorithm 1 Creation and movement codes prepared for the training material

```
void Start()
for (int i = 0; i < numberOfSpheres; i++)
        CreateRandomSphere();
void Update()
    ApplyCoulombForces();
    ResolveCollisions();
    UpdateSpherePositions();
void CreateRandomSphere()
    Vector3 newPosition;
int attempts = 0;
bool positionFound = false;
do
      newPosition = new Vector3(
      Random.Range(-range, range),
      Random.Range(-range, range),
      Random.Range(-range, range)
    positionFound = true;
foreach (Vector3 pos in positions)
if (Vector3.Distance(newPosition, pos) < sphereRadius * 2)
        positionFound = false;
break;
    attempts++;
while (!positionFound && attempts < 100);
if (positionFound)
      positions.Add(newPosition);
      GameObject sphere = GameObject.CreatePrimitive(PrimitiveType.Sphere);
      sphere.transform.position = newPosition;
      spheres.Add(sphere);
      Renderer renderer = sphere.GetComponent<Renderer>();
      renderer.material = new Material(Shader.Find("Universal Render Pipeline/Lit"));
bool isPositiveCharge = Random.value > 0.5f;
      charges.Add(isPositiveCharge);
if (isPositiveCharge)
        renderer.material.color = Color.blue;
else
        renderer.material.color = Color.yellow;
void ApplyCoulombForces()
for (int i = 0; i < positions.Count; i++)
     Vector3 force = Vector3.zero;
for (int j = 0; j < positions.Count; j++)
if (i != j)
          Vector3 direction = positions[i] - positions[j];
float distance = direction.magnitude;
float forceMagnitude = coulombConstant * (charges[i] == charges[j] ? 1 : -1) / (distance * distance);
          force += direction.normalized * forceMagnitude;
   positions[i] += force * timeStep;
void ResolveCollisions()
for (int i = 0; i < positions.Count; i++)
for (int j = i + 1; j < positions.Count; j++)
          Vector3 direction = positions[j] - positions[i];
float distance = direction.magnitude;
if (distance < sphereRadius * 2)
          Vector3 collisionForce = direction.normalized * collisionRepulsionForce *   (sphereRadius * 2 - distance);
            positions[i] -= collisionForce * timeStep;
            positions[j] += collisionForce * timeStep;
void UpdateSpherePositions()
for (int i = 0; i < spheres.Count; i++)
```

```
                spheres[i].transform.position = positions[i];


```

The Start method is called once at the beginning of the simulation. It starts the simulation by generating a certain number of spheres (numberOfSpheres) at random positions in a defined range. The Update method is called once for each frame. It updates the system by applying Coulomb forces, solving collisions and updating the sphere positions according to the results. The CreateRandomSphere method creates a sphere at a random position within the range. It tries to place the sphere in a position that does not conflict with existing spheres (works for up to 100 attempts). If a valid location is found, it adds the location to a list and creates a sphere game object at that location. Assigns a material and colour based on a random charge (positive or negative). The ApplyCoulombForces method calculates and applies Coulomb forces between spheres. For each sphere, it calculates the force applied by each other sphere. The force is attractive or repulsive depending on whether the charges are opposite or the same. The positions of the spheres are updated according to the calculated forces and a time step. The ResolveCollisions method resolves collisions between spheres. It checks whether the distance between any two spheres is less than twice the sphere radius. If a collision is detected, it calculates a thrust to separate the spheres and adjusts their positions accordingly. The UpdateSpherePositions method updates the visual positions of the sphere game objects. It sets the position of each sphere game object to the corresponding position calculated in the simulation. This script simulates a system of spheres interacting through Coulomb forces and resolving collisions to avoid overlapping. The positions are updated every frame, creating a dynamic system in which the spheres move according to their loads and collisions.

IV. DISCUSSION AND CONCLUSION

The integration and use of VR technology with e-studio infrastructures in educational technology contributes to significant progress. Immersive and interactive learning environments offered in e-studios with VR infrastructure cannot be provided by traditional education methods. With virtual reality, students interact directly with the content in order to learn complex concepts better, and with this situation, the retention of the learned information is ensured. For example, in the virtual laboratory in this study, students' experimentation without taking risks encouraged both their curiosity and deeper learning of the subjects. The implementation of virtual reality-based e-studios has many challenges as well as good aspects. For many institutions, the initial set-up cost, including VR hardware and software, can be a highly prohibitive factor. Ongoing costs such as maintenance, refurbishment and technical support of hands-on experiments should also be considered in distance education. The need for technical experts is also very important for the effective use and management of the infrastructure.

User comfort and ergonomic use is another problem area in the use of VR technologies. Prolonged use of virtual reality can cause physiological disorders, eye disorders and negatively affect the learning experience. Some of the negative situations can be eliminated when VR sessions are timed appropriately, and users are trained on the correct use of VR technology. Equipping e-studios with VR infrastructure offers interactive and immersive learning environments to enhance education. Even if technical difficulties and initial costs are an issue, VR-based e-studios become a very important investment when students' participation and learning outcomes are considered. The development and use of VR educational materials with platforms such as Unity etc. shows that such systems are practically applicable. VR technology is constantly developing, and this development will expand the applications in education and training and provide more effective learning tools. Future studies will focus on the realisation of interactive experiments instead of the demonstrative experiment in this study.

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