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Modeling of an instructional design process based on the problem-based learning approach in three-dimensional multi-user virtual environments

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Abstract

In this study, the instructional design process in three-dimensional multi-user virtual environments (3D MUVEs) based on a problem-based learning approach was examined and authentic design experiences were shared. Besides, a design model was proposed to guide people who want to design these 3D MUVEs and to use these environments for educational purposes. The study group consists of students studying in the department of Computer Education and Instructional Technology Education in their junior year at a state university in Turkey. These students took the "Instructional Design" course one year ago before taking this course. 34 students participated in the study on a voluntary basis. The study using a formative research method of qualitative research methods was conducted in a 16-week practice as part of a course. During the implementation, the design process by 6 different groups was examined deeply. "Survey of Demographic Characteristics of Participants", "Creating of the Scenario and Problem Report", "Personal Project Reports", "Participant logs", "Reflection Reports", "Semi-Structured Interviews", "3D Design Evaluation Criteria", "Problem Evaluation Scale", "Expert Notes", "Personal Web Pages" and "email and instant messaging tools" were used in the data collection process. The data were collected from 193 data sources, resulting in 7 themes which are namely: determining the problem situation, determination of scenario, models of instructional systems development, transferring scenarios to the environment, teamwork, media design process, and use in educational environments. According to the themes that emerged from the experience of the participants, the 3D MUVEs design model based on a problem-based learning approach was proposed.

Keywords Three-dimensional multi-user virtual environments · Problem-based learning approach · Instructional design · Formative research

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1 Introduction

Multi-user virtual environments (MUVEs) are structured with three-dimensional (3D) objects, in which users can actively navigate with their avatars to different areas of the immersive environment (Doğan & Tüzün, 2017). Virtual environments consist of interactive, real-time, two-dimensional graphics or three-dimensional models in which places or environments are simulated via a computer and shaped based on user behavior (Montello et al., 2004). Three-dimensional virtual environments represent simulations, animations, three-dimensional multi-user virtual environments, and virtual reality while two-dimensional virtual environments generally represent web interfaces. Authentic life-like models are presented to participants in three-dimensional multi-user virtual environments and virtual reality environments. This study focuses on three-dimensional multi-user virtual environments. Although these environments have different designs, they have some common features. These features were defined by Muñoz et al. (2011) as follows:

- Avatar: Each user is represented with a character in these environments.
- Rules of the world: Each virtual world has its own unmodified rules.
- Shared environment: A virtual world has many users.
- Interaction and communication: User-user and user-world interaction takes place in real-time.
- Persistency: The virtual world is persistent regardless of if users sign in or sign out.
- Customization: Virtual worlds offer users to modify, develop, build, and customize content.
- Graphic Environment: Virtual worlds offer computer-based graphic 2D, isometric or 3D environments

The potential of virtual worlds for usage in an educational context increases because of offering free and authentic learning environments and increasing the learners' participation and motivation. Moreover, they offer learners the opportunity to play a role or interact with other users. Making customized designs, providing student-centered activities such as problem-based learning or inquiry-based learning, allowing social interaction and collaboration and providing real-time interaction may be included among the reasons why these environments are preferred in education (Doğan et al., 2018). In other words, virtual worlds draw attention in the field of education as they are different from 2D environments and support activities and interactions that cannot be performed in face-to-face courses. (Thackray et al., 2010). Additionally, they offer an experiential learning environment for learners (Parson and Bignell, 2017). In this context, firstly, the use of 3D MUVEs in education is explained.

1.1 3D Multi-User Virtual Environments (3D MUVEs) in Education

The easy accessibility of 3D MUVEs has made them a great tool for observing and understanding the relationship between pedagogical expertise and technological knowledge in these environments and approaching the critical factors of effective design and delivery of instruction (Warburton & García, 2016). If a 3D MUVE is designed appropriately, it has a great potential to provide a viable learning environment for higher levels of learning, thinking and doing such as critical thinking, problem-solving, creativity, inquiry and lifelong learning (Qian, 2019). 3D MUVEs' design and the instructional design process in different dimensions should be considered together to design effective educational 3D MUVEs. However, in some case studies, while making suggestions about how to design the environment physically (Dede et al., 2004; Warren et al., 2008), instructional design issues that are the answer to the question "How to teach in 3D virtual environments?" are not mentioned in the literature (Thackray et al., 2010). Although different processes are used in the development of 3D MUVEs and a traditional teaching environment, similar products may emerge in environmental designs. In a study by Warburton (2008), it was stated that there is no innovation and creativity in the design of 3D MUVEs that can be used by everyone, such as Second Life, in the teaching and learning process, and the designs of these environments are problematic. The reasons for the similarity of 3DMUVEs' design and lack of innovation in these worlds are defined to include technical issues, identity problems, cultural differences, collaborative work problems, time problems and financial problems.

One of the common mistakes made while designing in 3D MUVEs is that general and specific learning objectives are not identified for interaction. Only a "virtual space" is created without indeterminate learning outcomes and assessment plans in the designed 3D MUVEs. These environments without learning outcomes cause disappointment. Therefore, they are not used because they are not efficient. Lack of learning in these environments is not a result of 3D MUVEs' design, but it is a weakness of instructional design (Doğan, 2019).

Student-centered teaching approaches become important in 3D MUVEs where students are not only active but play a role (Dillenbourg et al., 2002). Therefore, instructional and environmental designs in these environments should be made according to student-centered approaches. A student-centered teaching approach is problem-based learning. It is used effectively in 3D MUVEs for conducting student-centered activities within the framework of an authentic problem, ensuring the interaction of small groups and being a guide as a teacher (Barrows, 1986). However, it is stated that there are very few studies on problem-based learning (PBL), instructional learning, didactic learning and interactive learning environments, while virtual worlds are used for more cooperative learning in education (Duncan et al., 2012). Besides, there are many literature reviews about 3D MUVEs, classifications and case studies according to the student-centered learning and teaching method based on different learning theories (Dillenbourg et al., 2002; Duncan et al., 2012; Warren et al., 2008), but there are a few studies on how to design these environments and how they should be taught in these environments (Dede et al., 2004; Warren et al., 2008) to be used in the education process. In other words, while the findings related to the implementations applied in 3D MUVEs, which have been designed in advance, are frequently included in the literature, there is no information about what kind of an instructional design process was carried out in these educational environments and what was considered while designing these environments. A few studies in the literature emphasize that designs were created in 3D MUVEs

(Dede et al., 2004; Warren et al., 2008; Kapp and O'Driscoll 2010). In these studies, 3D MUVEs such as Second Life that provide free or paid server services and object libraries are often used. However, when studies are considered in terms of design, it is stated that users or designers often come across technical problems and have difficulty in using the environment when there is no support for problems. From an educational design perspective, the models in which designs were created according to the problem-based learning approach in the literature do not provide detailed information on the characteristics of the process. As a result of examining studies in the literature, it is seen that there are models that prioritize the general design principles instead of models created by experiences obtained as a result of an implementation of the design process. Besides, although the features of 3D MUVEs have been improved in parallel with the development of technology, failure to pay attention to instructional design processes in the use of these environments is a problem that reduces the effectiveness of these environments in the learning process which cannot be solved. The main reasons for this situation may be the preference of 3D MUVEs where designers or users only get server service, cannot interfere and have limited usage rights, the lack of appropriate approaches and disregard for the instructional design process (Doğan, 2019).

For this reason, this study aims to guide educators and designers about what process should be followed and which components should be considered during the instructional design process in the design of open-source 3D MUVEs where the problem-based learning approach is used. In this context, the study is significant in terms of revealing the problems that educators and designers may come across in 3D MUVEs, determining the design principles that should be considered according to the problem-based learning approach and developing a design model that can be used to design effective 3D MUVEs according to the problem-based learning approach in these environments.

1.2 Problem and Research Questions

How should the process to be followed in the design of educational 3D MUVEs using the problem-based learning approach be?

- What are the components of the design/development process of 3D MUVEs created with teamwork using the problem-based learning approach?
- How should these components come together in a model framework to guide the design and development of 3D MUVEs using the problem-based learning approach via teamwork?

2 Method

The formative research method was used within the scope of this study. Formative research is a type of developmental research or action research to develop a design theory to design teaching processes and practices. Formative research has been developed based on formative assessment and case studies due to the insufficiency of quantitative research methods such as experiments, surveys, and correlational analysis in improving teaching design theory. Design theories in education are a guide in the implementation processes for the answer to the question "How is education done better?" (Reigeluth & Frick, 1999).

Formative research is divided into three groups as designed cases, in vivo naturalistic cases, and post facto naturalistic cases (Reigeluth & Frick, 1999). In this study, an in vivo naturalistic case was used, because it was aimed to collect data during the implementation regardless of a proposed or existing theory or model at the beginning of the implementation. The data were collected from the cases observed in the course process by the researchers, and the design model is presented in line with these data.

The authors were involved in the process with the roles of guide, observer, technical support, and lecturer during the research. The steps shown in Fig. 1 were followed in the implementation process within the scope of the "Innovative Technologies and Applications" course with third-year students.

2.1 Participants

The participants of this study included 34 Computer Education and Instructional Technology students at a large-scale public university in Turkey. Computer Education and Instructional Technologies departments in Turkey aim to teach students the skills to apply modern techniques and technologies for planning effective educational processes on all levels of education. In this context, the aim of such a department is to train students who can design and manage educational computer software and platforms. Therefore, these participants were selected in accordance with the purpose of the study. These 3rd-year students were attending the "Instructional Design" and "Programming" courses. 18 women and 16 men were involved in the study. The sample included one participant between the ages of 17 and 19, 32 participants between the ages of 20 and 24 and 2 participants between the ages of 25 and 30. The computer usage experience levels of the participants are presented in Table 1.

While 24 of the participants did not have any experience with 3D MUVEs, 8 participants had 1–3 years, 1 participant had 4–6 years and 1 participant had 10 years or longer experience of using 3D MUVEs (Table 2). In this context, the participants expressed their experiences in 3D games. They did not use 3D MUVEs to create virtual worlds.

Fig. 1 The stages of in vivo naturalistic case during the implementation process

Table 1 Distribution of the computer usage experience levels of the participants by class year and gender

Gender	1–3 year	4–6 year	7–9 year	10 + year	Total
Female	0	1	13	4	18
Male	0	1	2	13	16
Total	0	2	15	17	34

2.2 Data Sources

A total of 12 data collection tools were used in the study. These were the "Survey of Demographic Characteristics of Participants", "Creation of the Scenario and Problem Report", "Personal Project Reports", "Participant Logs", "Reflection Reports", "Semi-Structured Interviews", "3D Design Evaluation Criteria", "Problem Evaluation Scale", "Expert Notes", "Personal Web Pages" and "email and instant messaging tools". In Fig. 2, the data collection tools used during the research and their usage purposes are explained.

2.3 Three-Dimensional Multi-User Virtual Environment

OpenSimulator (OpenSim), selected for the design process, is an open-source 3D MUVE application. Users can either develop an environment themselves or use already developed environments with this application. The application was developed for the Windows, Linux and macOS operating systems. The participants individually used the OpenSim application for the first 8 weeks to get used to the application. In the design process, the OpenSim application was set up on a server that could be accessed 24/7 by the researcher to encourage the participants for collaborative work (Fig. 3).

As the main reason for preferring the OpenSimulator application during the implementation process, the application supports individual and multiple users, and it provides opportunities for all kinds of manipulation and editing. Besides, OpenSim has many features that justify the preference of this application. These features are: (1) it can be used on a server through viewer programs while it supports personal computers as a server; (2) All data such as 3D models' name and location and users' movement can be saved in the database; (3) 3D virtual worlds can be viewed through third-party software called a "Viewer" such as FireStorm, Singularity, Kokua, Hippo and Cool VL; (4) Designs can be exported for different 3D MUVEs such as Second Life. Additionally, 3Ds Max, Maya, Blender and SketchUp models can be imported in OpenSim; (5) The LSL/OSSL and C# programming languages can be used; (6) Animations can be

Table 2 Distribution of participants' 3D MUVEs experiences by gender

Gender	Do not use	1–3 year	4–6 year	10 + year	Total
Female	15	3	0	0	18
Male	9	5	1	1	16
Total	24	8	1	1	34

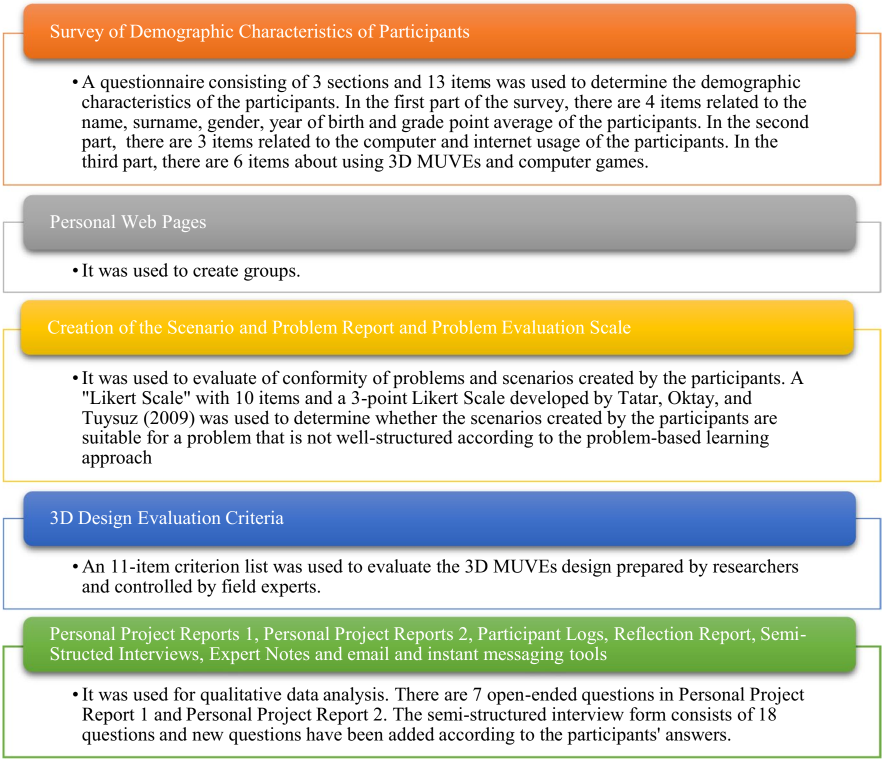

Fig. 2 Data collection tools

Fig. 3 First screenshot of design groups via the OpenSimulator application on the server

created; (7) NPC (Non-Player Character) can interact with other avatars; (8) Multimedia applications such as video and audio can be added; (9) HUD (Heads-Up Display) menus can be used on-screen; (10) Map, teleport and flying tools are available to facilitate navigation; (11) Users communicate by voice or text-based communication tools on real-time; (12) Users' logs can be saved; (13) Users' roles can be defined in terms of different levels of land ownership and access to land, and (14) depending on the server capacity, lands can be created based on their coordinates and sizes.

2.4 Implementation Process

The implementation process was carried out in a computer laboratory with 40 computers. The students took the 16-week course called "Innovative Technologies and Applications" voluntarily. The researchers were involved in the implementation process as lecturers, guides, technical support staff, and observers. Theoretical knowledge, practical knowledge and know-how were taught to the participants. The implementation process is presented in Fig. 4.

Six design groups were created according to the participants' grades in the "Instructional Design" and "Programming" courses, gender of the participants and their class attendance levels. Two of these groups had 5 people, and four of them had 6 people.

2.5 Data Analysis

The Grounded Theory was used as a data analysis method in the analysis of the qualitative data in the study. There are 3 coding types in the Grounded Theory, which is used both as a research strategy and as a data analysis method. These coding types are defined as open coding, selective coding and theoretical coding by Glaser (1978). They are explained as open coding, axial coding and selective coding Strauss and Corbin (1990), and they are also defined as initial coding, focused coding and theoretical coding by Charmaz (2006). Although the naming schemes are different, the coding process generally starts by comparing the codes obtained from the data to each other. The coding process continues with the classification of data based on their similarities or differences. Finally, the codes and categories are combined, with a focus on the relationships of the codes and categories.

In the study, the data collection process was carried out in parallel with the implementation process. The qualitative data were obtained using multiple data sources. In the coding of the data stacks that were obtained, a comparison was made to different data sources, and a process analysis related to many situations in the process was determined. The study started with the coding of focus group interviews and individual interviews with the participation of 30 people for providing rich content to the coding process. Afterward, data obtained from the Reflection Reports, Personal Project Reports 1, Personal Project Reports 2, Expert Notes and email and instant messaging tools were coded. Open coding was performed during the coding process. In the initial coding process, from the designer's perspective, a pattern was created to answer the question "How should the design process be based on

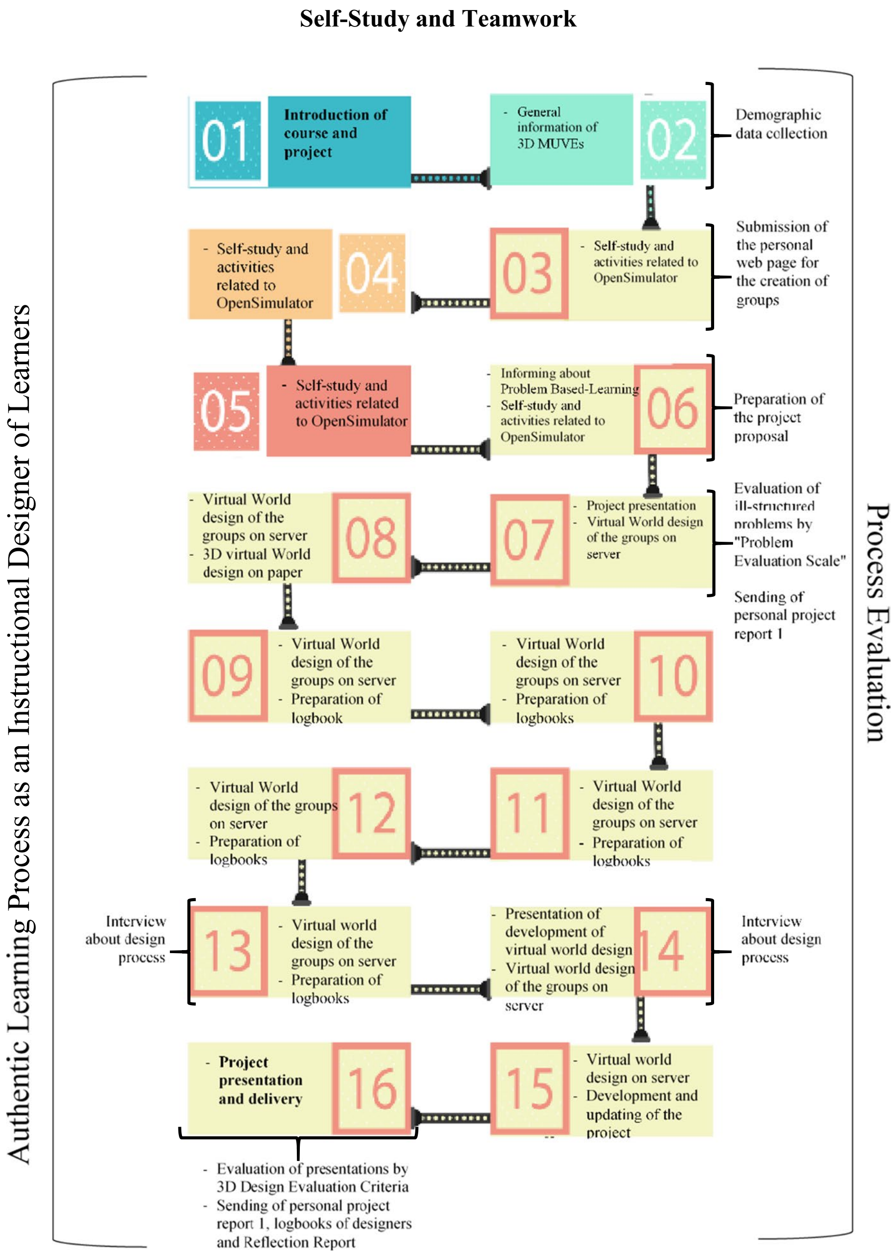

Fig. 4 Implementation process

the problem-based learning approach in 3D MUVEs?" Depending on the length of the data, coding was made by selecting a line, a paragraph or multiple paragraphs. Later, categories were created by associating the codes. Thus, the coding schemes were given a hierarchical form. After all, the related codes, categories and sub-categories were reviewed, and a code structure was created. The processes at the first and second stages were repeated for updating the code structure.

With the analysis of the qualitative data collected from 193 different sources in the study, 1624 codes were initially obtained as a result of coding 121 pages of reflection reports, 84 pages of interview transcripts, 34 pages of participants logs, 25 pages of personal project reports 1, 33 pages of personal project reports 2, 10 pages of server technical supports' e-mail correspondence, 8 pages of students' e-mail correspondence, 7 pages of experts' notes, 6 pages of Scenario and Problem Reports in the NVivo 10 program created using the Times New Roman font, 12 font size and single line spacing. As a result of the detailed examination of the data, the categories and sub-categories were defined. Thus, 7 themes, 9 categories and 13 sub-categories were created (Table 3).

2.6 Validity and Reliability of the Study

In qualitative research, it is emphasized that there should be trustworthiness rather than validity and reliability. Research has 4 features as credibility, transferability, dependability and confirmability to be trustworthy (Guba & Lincoln, 1982).

The credibility of research represents internal validity in qualitative studies. In this context, the researcher should interact with the participants, observe the environment and examine the data sources for a long time to increase the credibility of a study (Yıldırım & Şimşek, 2013). If a researcher spends a long time with the sample, harmony and trust between the researcher and sample will develop (Lincoln & Guba, 1985). In the study, the researchers were together with the participants for 17 weeks. During the implementation process, the participants and the researchers talked face to face in the classes. At other times, the participants were able to reach the researchers 24/7 via e-mail, instant messaging and telephone and ask for help with their requests and difficulties they faced. At the end of the implementation process, 30 participants, apart from 4 participants, came to the interviews voluntarily. They also shared their views on the process in detail. This may be considered as an indicator of the trust and sincerity that the participants established with the researchers. In addition to long-term interaction, persistent observation is also important to ensure credibility (Lincoln & Guba, 1985). In this context, the researchers noted their weekly observations or experiences as experts in the process.

The most commonly known and used strategy in increasing the internal validity or credibility of a study is triangulation, which is defined as the comparison of the results of two or more data collection sources (Başkale, 2016). Within the scope of the study, the data were collected from the participants in different design groups, with different individual characteristics and using different data collection tools.

The credibility of a study is compromised in qualitative research if the data are misinterpreted, themes based on closed answers are created, and insufficient results are obtained (Başkale, 2016). At least 2 meetings were held with an educational technologist weekly to evaluate the activities and implementation process. Other activities for the next week were also decided in these interviews with the

Table 3 Quantitative data on the themes created as a result of data analysis

Theme	Category	Sub-category	Number of Codes	Number of References	Coding Fre-quency
Design groups	Creating design groups		1	23	35
	Distribution of tasks	Doing Research	1	14	17
		Preparing scenario	1	49	96
		Design	1	92	249
		Preparing report and presentation	1	59	112
	Interaction	In-group interaction	1	114	271
		Group harmony	1	42	49
		Group management	1	54	88
		Contributing to the group	1	126	485
Determining the problem			1	59	64
Determining the scenario			1	48	74
Instructional Systems Development Models			1	14	14
Transferring Scenarios to the 3D MUVE			1	43	59
3D MUVE design process	Usability		1	65	89
	Factors affecting the design process	Technical issues	1	76	139
		FireStorm (Viewer)	1	105	193
		Other issues	1	80	158
	Open Source Software		1	32	41
	Problem Based Learning (PBL)	Advantages of PBL	1	18	30
		Limitations of PBL	1	11	11
	Learning and Teaching Strategies		1	19	25
	Evaluation of Users		1	23	25
Use in Educational Environments			1	27	51

educational technologist. Moreover, the research design, the data collection tools and the data analysis process have been determined. Furthermore, the codes and categories obtained from the data stacks were reviewed by a specialist in qualitative data analysis before the findings were interpreted.

The generalization of research is expressed in the concept of transferability in qualitative research. In this study, a model was created according to the experiences in the design process, which was carried out for different purposes in 6 different groups according to the PBL approach in 3D MUVE. The model was also evaluated by experts in the field. The model provides insight for people to design 3D MUVEs effectively according to the PBL approach.

Purposive sampling is used to find out facts and events in qualitative research (Yıldırım & Şimşek, 2013). In this study, the participants were determined by this purpose as the instructional design process would be developed by PBL in 3D MUVEs.

The reliability of a research process is expressed by the concept of consistency in qualitative research. In this study, 6 different design groups were created for different purposes in the same process. Data were also collected with different data collection tools at the same periods from all participants. The data were encoded and checked in real-time by two researchers.

Reigeluth and Frick (1999) emphasized that a design theory or model must have effectiveness, efficiency and attractiveness to be preferred in different situations. In this study, in the process of creating a design theory, different scenarios were created in line with the purpose by 6 different design groups, and virtual worlds were designed according to these scenarios. The virtual worlds that were prepared by the design groups were satisfactory based on the evaluations of the researchers and different design groups. At the same time, an open-source server application called "OpenSimulator" was used to enable the design groups for teamwork because of its easily accessible resources and easy management of the 3D MUVE for both the design groups' members and the researchers. With this application, any problem that could occur in the world could be solved instantly. It is also possible to save time and resources by accessing various free 3D objects, scripts or sources.

3 Findings

In this part, the findings obtained by analyzing the collected data are presented based on the research questions of the study. Firstly, the codes and themes obtained as a result of the qualitative analysis of the data stacks are presented to answer the question "What are the components of the design/development process of 3D MUVEs designed by teamwork using PBL?" Then, the question "How should these components come together in a model framework to guide the design/development of 3D MUVEs designed by teamwork using PBL?" was answered to guide designers or educators, and an instructional design process was modeled.

The designers worked as a group on their group land named HU2, HU3, HU4, HU5, HU6, or HU7. The participants' group land, the number of people in the group, data sources and gender were specified in the coding of the participants. For example, there were 5 participants on the HU2 land. These participants' codes were HU2_I1m, HU2_I2f, HU2_I3m, HU2_I4f and HU2_I5f. Additionally, the instructor was coded as I_I1f, the instructor's field notes were coded as I_FN, and the server technical support was coded as TS.

3.1 Components of the Design/Development Process of Three-Dimensional Multi-User Virtual Environments Designed by Teamwork Using Problem-Based Learning

In this section, findings related to teamwork, determining the problem status, determining the scenario, instructional systems development models, transferring scenarios to virtual worlds, the design process of virtual worlds and its usage in education are presented in relation to the first research question based on coding the data obtained by analyzing 193 different data sources.

3.1.1 Teamwork

The design of virtual worlds takes a long time. So, teamwork becomes important in this process. If there are people available who have sufficient knowledge and different qualifications to design 3D MUVEs, and if people share tasks, the workload of the design group members will decrease, and the design process will proceed faster.

> HU3_I4m: We were 5 people. It was enough. The number of people in teamwork should not exceed 6 people.
> HU6_I4f: There was a person in the group who knew how to code. One of the group members said that you design these objects, and we shared tasks. Therefore, we were not worried that someone in our group did not do any task. We did our best.
> HU3_I5m: …" You do this. We shared tasks, whichever one could do a task more comfortably."

Throughout the design process, the designers were involved in many roles, including animators, graphic designers, experts on their respective subject, instructional designers, measurement and evaluation specialists, production directors and voice actors. These designers also researched their tasks and prepared scenarios, reports and presentations.

3.1.2 Determination of the Problem

Problem-based learning begins with the determination of a problem that is either well-structured or ill-structured. The scenarios to be created according to the problem and the solution to the problem are expected to be compatible with authentic life. Curricula are generally based on writing scenarios suitable for the problem. In this context, the "Computer Science" and "Information Technology and Software" course contents taught in primary and secondary education in Turkey were analyzed by the designer groups, and these groups focused on different learning outcomes.

HU2_Y1m: Our aim was to convey the effective usage of social media to the learners permanently.
HU3_R4m: We tried to explain the algorithm for the first grades of primary school by associating it with daily life.

The designers expected the target audience to decide on whether the virtual worlds were suitable for them when they were determining the problem. However, another consideration was the possibilities offered by the design tool.

HU2_I4f: We paid attention to whether the problem was suitable for a 3D MUVE, whether we could design it, how we should proceed, whether the process would be easy, whether there were possibilities, whether there were opportunities offered in the environment for the solution to the problem. Is this environment suitable for the target audience of the problem?

3.1.3 Determination of the Scenario

The designers, who started the process by identifying a problem, created a scenario by specifying solutions for an ill-structured problem. While the designers had concerns about what they could do in 3D virtual worlds, they preferred to create simpler and feasible scenarios instead of creative scenarios due to the intensity of the workload.

HU7_R1f: I was worried about using my creativity. …because I knew we would have problems implementing what we thought. No matter how helpful the instructor is, these environments require labor. So, I always tried to think of more practical, simple things.

One of the most challenging issues for the designers in the process of preparing scenarios was the design of collaborative learning activities. Learning outcomes and design tool features also forced the designers to create the scenarios. Another important issue in the preparation of the scenarios was the target audience. The design groups aiming to prepare scenarios suitable for the target audience updated their scenarios in the design process.

HU4_L4f: … We changed the scenario as a research group crashed with an airship to an island. The airship would fall apart as it fell on the island. Users would be asked to find and assemble these pieces…

3.1.4 Instructional Systems Development Models

A design process involving analysis, design, development, implementation and evaluation activities was carried out by the designers in 3D MUVEs regarding the design of learning outcomes in the curriculum according to PBL. The majority of the designers preferred to use the ADDIE model as an instructional systems development model. However, there were designers using the ARCS model. Instructional systems development models emphasize that systematic process steps in the process should be followed in a logical order.

> *HU5_I2f: …We can say that instructional design helped us in terms of planning. At first, we thought about what we could do. Then, we drew our opinion on a paper. Then, we logged in to the 3D MUVE. We designed objects one by one. We shared tasks.*

The designers stated that they progressed sequentially in the process using these models. Some designers thought that they forgot to apply the processes in the instructional systems development models because they focused too much on the design process. However, the researchers applied the ADDIE model to the design groups with their weekly tasks to prevent the designers from focusing only on 3D virtual world design.

3.1.5 Transfer Scenarios to the 3D Virtual World

Before the design process on virtual worlds, the designers tried to model a draft drawing on paper about the 3D virtual world being planned to be developed. This is important in terms of determining the needs of virtual world design and workload management. 3D virtual worlds have a feature called "Grid" that helps a designer to place objects on these worlds according to the X, Y and Z coordinates. However, the OpenSimulator and FireStorm applications do not have these features. For this reason, a guideline was sent by the researchers to guide the designers. Draft drawing allows one to eliminate confusion or disorder in loading and placing 3D objects into the design environment. If a draft drawing is not modeled at the beginning, the workload will increase, and time will be wasted.

> HU2_L2f: …we had a meeting with the draft task and agreed on what should be on the island. No matter how simple we drew our sketch, something started to come to life. I dreamed of the forest, the beach and the town. …because we had an empty island and avatars ...
> HU6_I3m: … We saw the scaling of the island area afterwards, and of course, we reduced the contents of the island. We removed the trees we added…

3.1.6 3D Virtual Worlds' Design Process

Objects created in mathematical or vector formats are brought together and presented as graphical structures with 3D virtual world design. A server rent via service providers, and generally, game engines are used to develop and design these worlds. Using open-source software in the design of 3D virtual worlds will provide designers with more opportunities than services via a service provider if there is a technical support. Besides, easy interface usage and learning of applications or programs provide a desired 3D virtual worlds design. All processes or any things that require interaction should be used easily and effectively by the target audience within a context or objectives such as computer software, websites, books and all kinds of electronic devices.

> HU4_R2f: It should proceed in line with the user's requests and characteristics.
> HU3_R2f: First of all, the characteristics of the target audience should be taken into consideration.

Everything that will guide the learning process along with usability should be planned to ensure an effective teaching process. Within the scope of this study, one of the main components mentioned by the designers was the compatibility of the virtual worlds and the goal. For this purpose, designs should be created according to the learning outcomes and scenarios as much as the objects used in the 3D design should be considered, because the harmony of objects is an important factor to avoid distracting the learners. The 3D MUVEs will become boring for users if they follow a linear path to solve the problem. Therefore, scenarios based on ill-structured problems and interaction in the environment will let the users learn by discovery and spend more time in the environment without limiting them. However, ill-structured problems may cause users to get lost or move away from the context. To prevent this, the guidelines need to be well-structured. Evaluation of users should also be determined.

The application of the design of 3D MUVE may seem like a complex structure for beginners or new users since they contain many features. The design process requires teamwork with 3D design tools. The designers started to design individually by learning the installation of applications in the design process. They stated that it was a difficult and complicated process to connect and run more than one application at the same time on the localhost.

OpenSimulator, an open-source server application, provides the opportunity to design in 3D MUVEs. The researchers were able to change settings with this application consisting of modules. They were also able to design without any restrictions. In comparison to Second Life or OsGrid, OpenSimulator is free and has access to free and editable objects, as well as offering the possibility of importing or exporting objects. Additionally, there are no copyright problems of 3D objects because of the open-source platform. Another benefit is expressed as the availability of information sources for the solution of problems encountered during the design process. Student safety is another problem in the use of 3D MUVEs where the server service is rented and used by everyone for educational purposes such as Second Life or OsGrid. Although the land on these environments is restricted for the entry of certain users, students will want to visit other lands or virtual worlds. If a person registers once, they can visit all lands or worlds without educational purposes. Therefore, OpenSimulator offers an important opportunity to ensure the safety of users. Using an open-source application provides an advantage in setting user authorizations and dealing with problems. OpenSimulator also offers code writing and animation preparation to a wide range of designers.

> HU2_I1m: It is good to use an open-source tool. You can find resources in many places…

HU4_I6m: …because it is free, more different things can be added. It would be difficult to add some objects, if paid. It could not be allowed because of copyrights.
HU2_I5f: We were simply writing code or something. We could add them because the tool is open-source.

3.1.7 Problem-Based Learning (PBL)

Problem-based learning involves creating a problem and finding solutions for the problem to reach a target. If daily life or authentic problems are created, ill-structured problems are used. 3D MUVEs will enable users to discover and learn about virtual worlds by experience when they provide a sense of reality and offer multiple solutions. According to the problem-based learning approach, it is stated that users may find virtual worlds boring as well-structured problems' tasks given in these virtual worlds will limit the discovery process of users.

HU6_I4f: A really beautiful tool to solve real-life problems, but we had an ill-structured problem. There was no single solution.
HU6_I6m: If we don't give the user the necessary directions, the user may not be able to solve the problem. They can get bored. If we design a very open world, users can deviate from their purpose.

3.1.8 Teaching and Learning Strategies

As an answer to the question "What kind of virtual worlds should be designed to make the learning process more effective", learning strategies that will facilitate self-learning become as important as virtual world design. The time spent in interactive 3D MUVEs is important to not turn them into abandoned virtual worlds. Teaching and learning strategies play an important role in these environments where socialization is important. For this reason, strategies where users will be active should be selected.

HU2_I5f: … we have given priority to interaction with the virtual world. Maybe, it will be one week or two if there are individual activities. Then, users will log out because there is no one in the virtual world. It is important to socialize.
HU7_I4m: Case study… For example, we designed an accident. We can ask the child to comment on it.

3.1.9 Evaluation of Learners

The designers stated that all activities' logs could be saved to evaluate formative assessments in 3D MUVEs. Additionally, they emphasized that the logs of questions and tasks should be saved to evaluate a user's performance.

HU6_I2m: Process evaluation should be done. I would look at system logs…

3.1.10 Use in Face-to-Face Education Environments

3D MUVEs are facilitative for lecturers and learners in performing expensive, complex or dangerous classroom activities. These environments include complex problems and solutions in an authentic world with role-playing, problem-based activities or case studies methods. These environments also provide permanent learning because they are allowed to embody 3D objects. The designers stated that 3D MUVEs would increase the motivation of the learners, they would and learn with fun because these environments drew the attention of the learners and allowed some activities that they could not perform in daily life.

> *HU2_I2f: … Let me live in virtual worlds. In these virtual worlds, what people dream of comes true. Therefore, using these virtual worlds in education will provide more motivation for the student…*
> *HU3_I1f: I think the student feels more realistic in these virtual worlds. So, they feel like there are experiences. Although I am this age, the environment has affected me. I felt like I was in that environment, not in interaction with a machine. So, it was so much fun.*

3.2 Instructional Design Model in Three-Dimensional Multi-User Virtual Environments Based on the Problem-Based Learning Approach

In this section, findings related to the second research question are presented. General design principles and problems encountered in 3D MUVEs' design are frequently mentioned in the literature. However, especially in environments used for educational purposes, what is considered in the design of these environments that is used in experimental studies and which pedagogical approaches are used are not addressed. Moreover, the preparation of interactions that are suitable for learning outcomes in 3D MUVEs' design and the lack of evaluation processes cause the users to become disappointed after using these environments several times. The case that these environments are not used, and the users cannot learn in these environments is the result of a disregarded instructional design process. Therefore, it is important how an instructional design process is followed during 3D MUVEs' design processes. Before starting the design process, determining a pedagogical approach and designing environments according to the determined approach will help use these environments effectively. In this context, a design model that will guide designers and lecturers is proposed for designs according to the problem-based learning approach in 3D MUVEs. An Instructional Design Model in Three-Dimensional Multi-User Virtual Environments Based on the Problem-Based Learning Approach was created based on the experiences of the participants, and this model consisted of 6 stages (Fig. 5). These stages included determination of the problem situation, scenario design, instructional and technical analysis, instructional and technical design, evaluation and updating.

There were different numbers of sub-dimensions at each stage of the model. While the stages are shown with different colors and shapes, the sub-dimensions

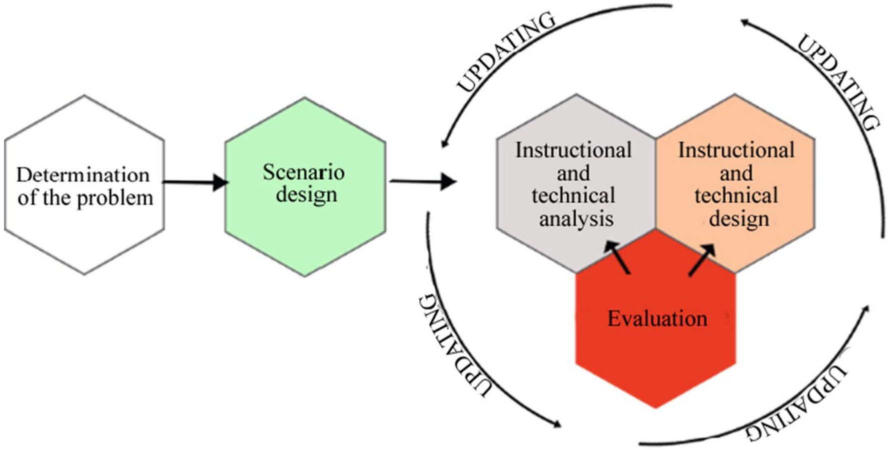

Fig. 5 Instructional design model in three-dimensional multi-user virtual environments based on the problem-based learning approach

of the stages and their relationship to each other are shown with arrows. While a linear process was initially followed in the model, the model turned into a nested spiral structure as the process progressed (Fig. 6).

Determination of the Problem Designing educational 3D MUVEs based on the problem-based learning approach is a process that takes time and requires groups of different competencies to come together. This process should be started by creating a complex problem situation with different solutions, in other words, a problem situation should be ill-structured. General, distant and specific goals, cognitive, affective and psychomotor skills of the target audience should be considered with the determined learning outcomes. Instructional designers and field experts play an

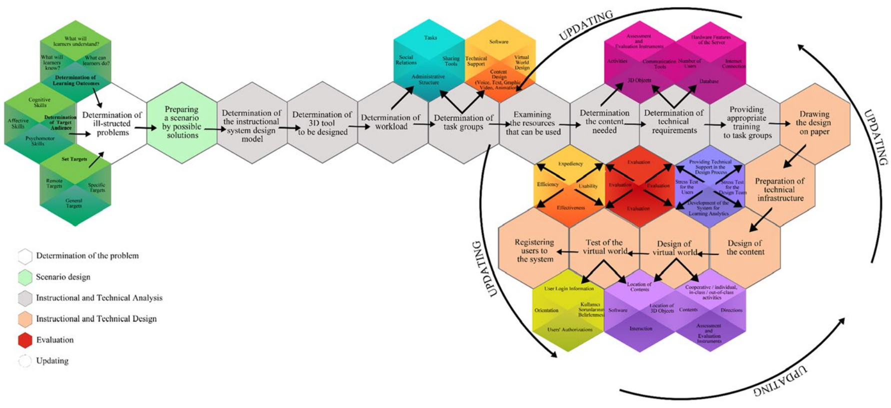

Fig. 6 Instructional design process in three-dimensional multi-user virtual environments based on the problem-based learning approach

important role in this entire process, from the determination of learning outcomes, creating scenarios, creating content and environment and structuring the evaluation process.

Scenario Design By the ill-structured problem, the scenario should be prepared according to the possible solutions. The instructional designer should also make the necessary arrangements in the scenario together with the field expert. When the design process begins and progresses, changes will affect the planning of this process. For this reason, the field expert and the instructional designer must be involved in the entire process. The points to be considered during the scenario preparation process involving the field expert and the instructor designer are as follows: (1) What the learners want to learn should be considered. (2) How to evaluate the learning process should be decided. (3) A list of what the learners want to learn should be made. (4) Considering the context of learning, how to design the virtual world should be planned. (5) Guidelines should be prepared for the learners to know what to do in the environment, and a decision should be made on where the guidelines will be placed in the environment. (6) Compelling and interesting scenarios should be created for learners. (7) It should be examined how the learners will transfer and relate the information in the scenarios to other information. (8) It should be noted whether the scenarios will match the curriculum. (9) A chance should be given to students to show what they have learned through assessment or other means in the virtual worlds. (10) Learning objectives should be specified for learners (Savin-Baden, 2010).

Instructional and Technical Analysis Another important component in the planning of the design process is the determination of the instructional systems development model. This model will help realize the solution of pedagogical needs. It will also ensure the emergence of a quality product at the scheduled time. Additionally, by going beyond the interaction of the users with the content, the content will be made individually interesting, and the users will be provided with learning in a pedagogical framework. If there is an ill-judged instructional design process in virtual world design, the real classroom environment will only be replaced by a digital classroom environment, and real people will only be replaced by avatars in a discussion with real people in a face-to-face classroom using a presentation program. In this case, the real value of 3D MUVE, which is a simulation of a face-to-face classroom, will not be understood. Instead, faster and safer virtual world designs than they are that allow interaction by trial and error for a common purpose will reveal the real potential of 3D MUVEs (Kapp & O'Driscoll, 2010).

The technology to be used before starting virtual world design also needs to be determined. The following factors should be considered in the selection of the application to be used as a development tool for the design process: (1) Having a technical support team that can use the development tool, (2) providing flexible opportunities of the development tool, (3) managing user authorizations, (4) ensuring the safety of the learner in educational virtual worlds, (5) no restrictions on copyrights, (6) providing wide opportunities in finding and using resources, (7) transferring the designs to different virtual worlds, (8) cost-effective, (9) 24/7 accessibility, (10) enabling the design team to collaborate, (11) accessibility from anywhere, (12) development tool familiarity of designers.

Although it is difficult to find people with both technical and pedagogical skills at the same time in development of a 3D MUVE, their designs require teamwork as the process will take time. For this reason, it is important to define the group's tasks by determining the workload in the design process. In the case of working with a crowded design team, task descriptions should be made, for example, how the social communication within the group will be, how the information will be shared, how and by whom the design team will be managed. While the design group managers will enable the design team's activities to go in a coordinated manner during the design process, they will encourage different people to speak the same language and work on the same educational aim (Kapp & O'Driscoll, 2010). If a small 3D MUVE is designed, one person may be performing multiple tasks. However, if a larger virtual world is to be designed, a main team including 3D and 2D graphic designers, programmers and producers should be created (Bartle, 2003). It should be ensured that there is a technical team with sufficient knowledge about the applications to be used, as well as designers who can create 3D objects and virtual worlds, a content design team that can prepare all kinds of visual and audio content and a software team that plays a key role in increasing the interaction in the environment during the distribution of tasks. Additionally, designing or determining the objects needed, designing instructions, preparation of animations and non-player characters, creating scripts to interact with objects and using a 2D graphic on-screen called the HUD menu by virtual world design principles will play an important role in an effective design process. Controlling the native language, preparing the evaluation process, determining testers who will take part in the usability test of virtual worlds and having technical support are also very important for the design process.

Although content is known as king in 3D MUVE design, the context is defined as a kingdom (Kapp & O'Driscoll, 2010). Determining context-appropriate resources, content needed and technical requirements before the design process will help designing an effective environment. Moreover, trainings needed before starting the design process should be given to the design team. It is important to determine the 3D models, communication tools, activities and assessment and evaluation instruments to be used in creating the contents and determining the technical requirements accordingly. Besides content, the number of people who will use the virtual world, the internet connection speed, database and hardware features of the server are important for the efficient use of a virtual world. Otherwise, users will often encounter technical problems. For this reason, it will be appropriate to determine the technical details as a priority. After users start using the virtual world, increasing the technical features or moving to a different server will cause a loss of both time and workforce.

Instructional and Technical Design At the instructional and technical design stage, the virtual world to be designed as the first job should be detailed on paper by the design team. Creating the virtual world draft on paper will ensure both real-time design and fast and planned collaborative work by the design team. With setup of the technical infrastructure by the technical team, the design team will begin to transfer the draft on paper into a 3D MUVE. In this process, the technical team should solve the problems encountered fast, conduct stress tests for users and the virtual world's objects and develop systems for learning analytics. Additionally, activities, content, assessment and evaluation instruments should be designed by the context. Individual or collaborative activities, audio or visual and moving or static objects affect the virtual world design, the interaction and scripts in 3D MUVEs. After the virtual world design, usability, effectiveness and efficiency of the virtual world should be tested. During the usability test, testers who have the same characteristics as the target audience should be defined to the system, orientation should be given to the users, and the problems encountered by the users during use should be identified. What is more, if necessary, users' authorizations should be increased or restricted. After the usability tests, virtual worlds should be updated, real users should be defined in the system, and orientation should be provided for the users.

Evaluation Throughout the whole process after the task group definition, every process performed with the instructional designer and field experts should be evaluated.

Updating The designed virtual worlds should be made ready for use by updating through the whole process after the task group definition process.

4 Discussion and Conclusion

Today, the necessity of making instructional and virtual world designs in 3D MUVEs based on student-centered learning comes to the fore. It is stated that these virtual worlds are generally used for cooperative learning in education (Duncan et al., 2012). One of the student-centered teaching approaches is the problem-based learning (PBL) approach, but there are very few studies on PBL. Additionally, it seems that there is not enough attention in the literature on how to design 3D MUVEs using the problem-based learning approach. Design is an important factor in ensuring the effectiveness of these environments. In these environments, instructional design and virtual world design should be handled in two different dimensions. In this context, instructional designers should create virtual worlds by design principles in order to develop meaningful learning activities in 3D MUVEs. It is important to pay attention to the design of the architectural environment in order to be effective in instructional design (Tokel & Cevizci Karataş, 2013).

In the design of 3D MUVEs, the design dimension is generally focused on, and the instructional design process and the pedagogical approaches that are used are ignored. Based on these problem situations mentioned in the literature, this study focused on how to follow an effective educational 3D MUVE in line with the designers' experiences. Therefore, in the study, the answer to the question "How to design a 3D MUVE to make the learning process more effective" was investigated. An instructional design process, in which instructional design, design and pedagogical approaches are handled together, was modeled. In this context, this study is significant to guide educators and designers with open-source applications using the problem-based learning approach in the design of 3D MUVEs. Looking at the technologies used for this purpose in the literature, it is noteworthy that these technologies are far from learning or theoretically based designs and are used only as an applied technology. Although using and developing a new environment is exciting and interesting for many people, there are a few critical approaches to how, why, when and where applications are implemented. There is a need for pedagogies that integrate the tool and message used in the design of environments (Savin-Baden, 2010). Otherwise, it is stated that the media or environment that is used will not be effective alone, the media will affect learning and motivation with the effect of innovation at first (Clark, 1983, 1994), but it will not affect learning and motivation without its interaction with the methods and skills used (Kozma, 1994). With the technologies or environments used in education, it is aimed to both realize learning and provide a solution to an educational problem. Only the technologies used will not provide learning (Ojstersek & Kerres, 2010). In the literature, it is observed that studies on 3D MUVEs have focused on the technological and pedagogical aspects of these environments, but their limitations or the difficulties encountered outside the technical problems during their use in an educational environment have not been adequately addressed. Additionally, what should be considered in the design of the environments used and the pedagogical approaches used are not sufficiently addressed (Doğan et al., 2018). As long as pedagogical approaches are not included with the tool used in the design of 3D MUVEs as an aid for the learning process, these environments will turn into once used "Virtual Ghost Towns". In this context, not only the tool used in these environments but also the methods used with the tool come to the fore. Therefore, content and virtual world design should be considered as a whole within the scope of scenarios created in 3D MUVEs whose design requires a long process. Designing scenarios and events for 3D MUVEs is different from face-to-face scenarios developed for use in a discussion forum. The design team generally focuses on the scope of information and content rather than the complexity of scenarios involving the learning process and problem, since it is difficult to understand what this means at the beginning (Savin-Baden, 2010). The development of 3D MUVEs is much more complicated than preparing a few slides or a few multiple-choice questions. The design process of 3D MUVEs requires instructional designers to change their conventional skills. Creating both the learning environment and the content in the process requires more effort in terms of time and resources as these need to be matched with activities and interactions (Kapp & O'Driscoll, 2010).

Where to start the design in the design and development of 3D MUVEs may be extremely challenging, and there are many issues and factors related to design processes (Kapp & O'Driscoll, 2010). In these environments, it is necessary to pay attention to the instructional design in order to achieve the learning outcomes. In studies on 3D MUVEs in the literature, it has been stated that the learning process is shaped by scenarios or tasks (Doğan et al., 2018). In this context, one of the approaches that may be used in virtual world design is the problem-based learning approach. Problem-based learning is a teaching method that addresses the knowledge and skills that students will use in solving ill-structured problems that they may encounter in the authentic world (Russell, 2019). Effective, complex and challenging scenarios must be designed to create successful and usable designs by using the problem-based learning approach in the design of 3D MUVEs. Often in these environments, there is a tendency to focus on information and the scope of the content rather than on the complexity of problem scenarios and management of the learning process (Savin-Baden, 2010). However, learning activities and approaches that will provide a theoretical background should guide the design of learning environments (Minocha & Reeves, 2010).

Although different processes are used in the development of 3D MUVEs than development of a conventional teaching environment, similar products may emerge in environment designs. It is stated that similar 3D MUVEs designs are problematic without innovation and creativity (Warburton, 2008). Considering these situations, it is stated that there will be usability problems in 3D MUVEs, and users will not log in to the environment for a second time. Therefore, the designed virtual worlds will resemble a ghost town and be empty (Kapp & O'Driscoll, 2010). Everything that can come to mind in daily life such as computer software, websites, books, all kinds of electronic devices that require any process or interaction should be used easily and effectively by the target audience within a certain context or purpose. The effectiveness, efficiency and user satisfaction of the product are defined as usability by target users within the framework of the determined context and objectives (International Organization for Standardization [ISO] 9241–11, 2018). In this context, in 3D MUVEs, while the ability of users to access the content they are looking for affects the effectiveness of these environments, the easiest and fastest access to the content they want to access will be an indicator of the efficiency of these environments. The positive experiences of users in these environments will also be an indicator of user satisfaction. It is frequently stated in the literature that 3D virtual worlds are not easily used by their users (Beaumont et al., 2014; Omale et al., 2009; Parson & Bignell, 2017). Not knowing how to design in virtual environments will cause users to have negative experiences and difficulty in using these environments. Factors such as realism, easy navigation and access to designed information have an impact on the usability of the environment (Kapp & O'Driscoll, 2010). In virtual environments that are designed, the interface that enables the users to interact with the virtual environments directly affects these environments' usability (Cunha and Morgado 2010). These environments without learning outcomes and disappointment are not used again, because they are not efficient. Lack of learning in these environments is not a result of 3D MUVEs, but a weakness of instructional design. It is necessary to pay attention to the instructional design in order to achieve the desired learning outcomes. Even if the goal is to encourage informal learning in 3D MUVEs, the interaction between students needs to be increased.

In summary, the efficiency of 3D MUVEs without learning outcomes and disappointment depends on the instructional design process, as well as the architectural design of these environments. It is necessary to pay attention to the instructional design to achieve the desired learning outcomes. When studies in the literature are examined, although they are generally focused on the design process of 3D MUVEs, pedagogical approaches and instructional design are not mentioned in the design models put forward with general design principles. For this reason, in the study, a model was put forward as a result of the designers' experiences with teamwork based on the problem-based learning approach in 3D MUVEs. The Instructional Design Model in Three-Dimensional Multi-User Virtual Environments Based on the Problem-Based Learning Approach had 6 dimensions. These dimensions were the determination of the problems, scenario design, instructional and technical analysis, instructional and technical design, evaluation, and updating. The instructional design process, which starts with a linear structure in 3D MUVEs, turns into a complex and spiral structure. A well-planned instructional design process will contribute to both effective designs and the quality of the designed 3D MUVEs to achieve learning outcomes and ensure continuity in the use of these environments.

5 Limitations of the Research

Thirty-four students with instructional design and programming knowledge participated in the research voluntarily and had a design experience in 3D MUVEs for 16 weeks. The group designs of the virtual world started with determination of an ill-structured problem within the framework of the problem-based learning approach. During the design process, the participants developed content, produced 3D objects, prepared animations and HUD (Heads-Up Display) menus and tried to learn the Linden Script Language (LSL) programming language in a short time. The server was available for 3 months, and the participants designed for 8 weeks by teamwork. Even though the students in the role of the designers could access the server 24/7, the slow internet speed at the dormitory or cafes slowed down the students' design processes. Moreover, the use of a Voice over IP (VoIP) service from a different server and 34 requests to connect to an external server in the 3D MUVE has caused the intensity and slowdown of the server in some periods.

6 Future Work

Within the framework of an ill-structured problem situation in 3D MUVEs, the designers create virtual world designs according to the harmony of their skills and tasks with different levels of difficulty. In this process, the participants in the role of a designer are busy with something concrete. In this context, researchers may investigate the flow experience of designers in 3D MUVEs.

In the process of using 3D MUVEs, people may experience nausea and dizziness problems. For this reason, studies examining the effect of movements or the speed of navigation on motion sickness in virtual environments may be conducted.

Declarations

Ethical and Conflict of Interest Statements We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. On behalf of the Co-Author, the corresponding Author shall bear full responsibility for the submission.

Informed consent was obtained from all individual participants involved in the study.
We know of no conflicts of interest associated with this publication, and there has been no significant financial support for this study that could have influenced its outcome.

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