International Journal of Technology and Design Education (2022) 32:2217–2237
https://doi.org/10.1007/s10798-021-09680-8

ORIGINAL RESEARCH ARTICLE

Exploring the role of situational flow experience in learning through design in 3D multi-user virtual environments

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Accepted: 5 June 2021 / Published online: 24 June 2021

Abstract

This study aims to examine the situational flow experiences of students creating 3D designs in 3D multi-user virtual environments. This time series quasi-experimental study included 40 volunteer junior students who studied at the Computer Education and Instructional Technology department and had taken the elective course of "Instructional Design". The participants in the role of a designer created 3D designs in the OpenSimulator application throughout the process. They worked in groups to solve authentic problems. At the end of each session, the students were applied a flow experience scale individually. As a result of the study, it was concluded that the participants' flow experience did not differ by gender and overall grade point average. Autotelic activity and disappearance of self-consciousness were the highest components of flow experience indicating that the designers felt immersed in the 3D design activities throughout the 15-week implementation process. Considering flow experience by weeks, it was found that conveying theoretical information to the students diminished their flow experience owing to lack of the concentration, control and feedback components, whereas giving feedback after letting them present what they worked on fostered their flow experience by increasing the clear goals and immediate feedback components. The results highlighted the importance of flow experience in design education.

Keywords Three-dimensional multi-user virtual environments design education · Learning through design · Flow theory · Collaborative learning problem-based learning approach constructionism

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Introduction

Three-dimensional multi-user virtual environments (3D MUVEs) are platforms structured with three-dimensional (3D) objects, where users can navigate effectively with the help of an avatar (Doğan & Tüzün, 2017). In these environments, users can interact with different objects and avatars which are their own representational characters and perform many actions such as walking, running, flying, jumping and dancing (Doğan et al., 2018). In the 21st century, 3D MUVEs are mentioned alongside concepts such as simulations and games. However, although the reflection of the authentic world may be designed in a virtual environment, since a real process involving defined relationships between objects cannot be imitated in any system, it would not be accurate to call this a simulation. Besides, since these environments do not have specific goals or specific rules to achieve a goal in their use, it would not be accurate to call them games (Doğan & Tüzün, 2017).

In 3D MUVEs, the properties of objects and users can be presented in different ways based on many different situations. These environments, therefore, can be used in many different fields from entertainment to education, trade to socializing. Among these fields, education in particular draws attention. The main reasons for the increased use of these environments in education may be listed as follows: offering interactive and collaborative environments, supporting different learning approaches, giving learners an opportunity to use their creativity, presenting the reflection of the outside world virtually without cost and eliminating dangerous situations, and allowing authentic tasks to be created. Moreover, communication is reinforced in 3D MUVEs due to fast and rich interaction, the ability to change the characters in line with determined strategies and goals and the control of the communicated information (van der Land et al., 2011).

Over time, 3D virtual environments have become customizable with designs in line with user requirements. The design of 3D virtual environments is a long process, and since the design of these environments requires a variety of higher-level learning skills, such as virtual environment design, creativity, problem-solving skills and spatial thinking, it is also associated with pedagogical approaches. One of these approaches is learning through design. Regarding this approach, it is known that people acquire new information as a result of their relationships with the world, especially while trying something new (Resnick, 1996). Having focused on how information is shaped and defined according to contexts and environments and how information is processed in people's minds, Papert and Harel (1991), while observing students who were creating sculptures out of soap using their hands, realized that their students were more engaged than dealing with abstract things such as solving a math problem. This realization stresses the importance of learning through design, which is a constructionist approach. On this matter, multimedia software may be used since it supports activities that engage students in knowledge construction through active, constructive, collaborative, intentional, conversational, contextualized and reflective learning (Jonassen, 1995). According to Csikszentmihalyi (1991), design is one of the important processes that provide flow experience, which is defined by the same author (1991) as becoming immersed in an activity mentally and/or physically. With design processes via multimedia software such as games and 3D MUVEs, tasks on different challenge levels are created for learners. These tasks require learners to use their relevant skills to overcome specific challenges. The balance between the challenge level of the task and skill level of the learners determines the learners' flow and engagement experiences (Ramondt, 1998). When this balance is achieved, students' motivation increases. The relationship between constructionism, learning through design and flow is shown in Fig. 1.

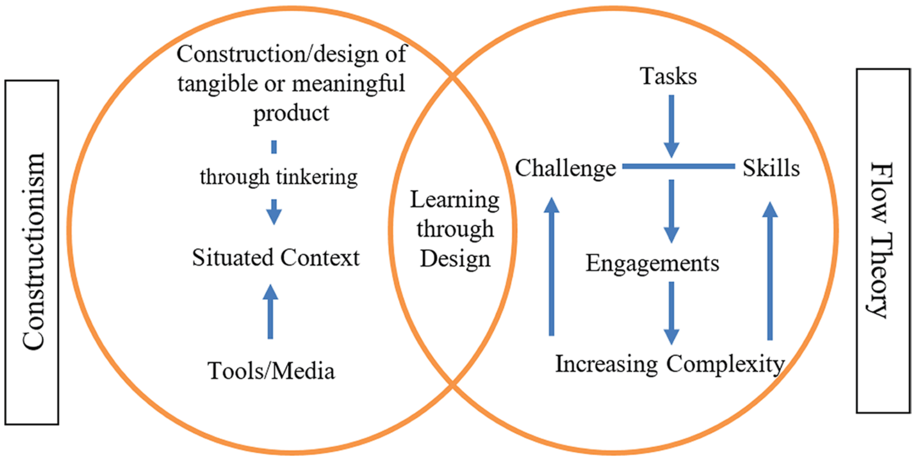

Fig. 1 Relationship between constructionism, learning through design and flow (adapted from Ramondt, 1998)

It goes without saying that the skill of spatial thinking is crucial for design education, especially for 3D designs. Regarding this issue, it is known that the mental rotation and 3D visualization skills of males are higher than those of females (Maeda & Yoon, 2013; Medina et al., 1998). In this respect, gender might be affecting what designers experience in 3D design process over the difference in spatial skills. Moreover, the balance between challenge and skill is a component of flow experience (Csikszentmihalyi, 1996), and designers' Overall Grade Point Averages (OGPA) might, in part, represent their overall design skills. In fact, the sample of this study had studied "instructional design", so, they had taken several courses about instructional design, as well as computer programming. Consequently, OGPA might be related to flow experience. In light of this information, this study aims to investigate the flow experiences of designers who concretely create educational environment designs in 3D MUVEs by working in groups. In the time-series study conducted with 40 university students in the role of instructional designers, the flow experiences of the participants during a 3D MUVE design process were examined throughout weeks. Furthermore, the effects of gender and OGPA were also investigated. In this context, firstly, the concepts of Learning through Design, Flow Theory, Flow Experience in 3D MUVEs and the Zone of Proximal Flow were explained, respectively.

Learning through design

Although it is emphasized that there is a strong relationship between the constructionism approach and design and learning, and rich content should be presented in the learning process due to its various activities such as production, construction and programming, design and learning have not been seen as close concepts. Design and learning approaches have different origins. Traditionally, design theorists have focused on the resulting product and argued that constraints affect product designs. Learning theorists, on the other hand, have been more concerned with the process than the product. In recent years, both learning and design approaches consider meaning-making as a basic process. In this regard, this process involves creating the relationship between design, designer and objects. Designers reveal what objects mean to both themselves and others and whether the properties of the object and the context in which it is used are consistent. The relationships that designers obtain about objects and situations form the focus of design theories. Design, therefore, is considered as a process since it involves creating not only the object but also its meanings in the context.

Design theories and constructionism approaches overlap since they focus on meaning-making. At the same time, more attention has been paid to the roles of the product and work through learning approaches. Papert's Constructionism (Papert & Harel, 1991) goes beyond Piaget's Constructivism Learning Theory (Piaget, 1976) and focuses on products. In this approach, it is emphasized that sharable products developed by students make it easier for these students to make meanings. This process is named learning through design. Unlike traditional problem-solving processes and unlike solving the problem created by the teacher or given to the student, in this approach, students are expected to create designs involving development of goals and problems. The problem to be solved is determined by the students, not by the teachers or by experts. In learning through design processes, defining the problem and developing goals in problem-solving are a part of the curriculum. The actions performed during the process are more important than the resulting product. In other words, although students' final projects might be unsatisfying, learning occurs since the students participate in the process (Kafai, 1996). On the other hand, the issue of what students feel has importance in learning through design processes.

Flow theory

Being defined as a holistic feeling that individuals have in their behavior with all their interests, flow has been suggested to explain the concept of internal motivation in a broader manner (Csikszentmihalyi, 2000). Therefore, flow is a subjective situation like motivation (Csikszentmihalyi, 2005). Flow experience may occur while playing computer games (Kara & Çağıltay, 2013), playing chess (Abuhamdeh & Csikszentmihalyi, 2009), writing introductory computer programming codes (Demir & Seferoğlu, 2021a; 2021b) and during other activities depending on the individual's interest. In flow experience, a high level of attention is achieved almost effortlessly (Csikszentmihalyi & Nakamura, 2010).

Flow is often defined by the compatibility between an individual's skill and the challenge of the work one performs. It is the expected result that the skill of the individual is compatible with the challenge of the work one performs. The individual, thus, enters the zone of flow. In the zone of flow, enjoyment is experienced on the highest level. If the skill of the individual is higher in comparison to the demand of the work one performs, the individual starts to get bored. In the exact opposite situation, in other words, if the demand of the work is higher than the skill of the individual, then tension begins. In both cases, the individual leaves the zone of flow (Csikszentmihalyi, 1991; 2000). In this case, the individual cannot have enjoyment. However, this model of flow is criticized on the grounds that it only makes a three-channel examination. In models suggested later, flow was divided into eight channels by the balance between the challenge and the skills of the individual. At this point, the channels of getting bored and tension take different names by division within themselves. Besides, in this model, challenges and skills are discussed on an intermediate level. The 8-channel flow model, on the other hand, was criticized for the following issues: focusing on the balance between the challenge of the work and the skill of the individual by more than what is adequate, ignoring the other components by flow, and the fact that it is problematic to determine what it means to have a moderate challenge/skill in the model. In parallel with these criticisms, it is seen that the concept of flow is generally discussed in a multi-dimensional manner (Moneta, 2012). Another discussion at this point is how many components the concept of flow has. Nevertheless, here, it is observed that in general that the dimensions specified by Csikszentmihalyi are being embraced (Özkara & Özmen, 2016). Csikszentmihalyi (1996) shows the balance between challenge and skill, disappearance of self-consciousness and change of time perception as a prerequisite for flow experience and emphasizes that there should be a total of nine conditions:

1. clear goals
2. immediate feedback
3. balance between challenge and skill
4. merging of action and awareness
5. exclusion of distractions from consciousness
6. no worry of failure
7. disappearance of self-consciousness
8. distortion of sense of time
9. autotelic activity

The aforementioned conditions can occur independently of each other (Tozman et al., 2015). Another important point to be mentioned about flow is whether flow is dispositional/trait flow or situational flow. Flow that is experienced independently of personal situations is named dispositional/trait flow, while flow resulting from the interaction of the individual with the situation/context is named situational flow (Jackson et al., 2001). The expression of situational flow is preferred within the scope of this study.

Flow experience in 3D MUVEs

3D MUVEs, which enable learners to discover and use their creativity, contribute to the learners in learning by experiencing the outcome of an event with applied activities (Faiola et al., 2013; Koffman & Klinger, 2007). Through features such as controllability, arousing curiosity, aiming at individual interests and enabling users to experience a sense of presence, virtual worlds allow users to experience flow in 3D virtual environments. In virtual worlds, learners can control their movements and the viewpoint of their characters. Being also perceived as a game-based learning environment, virtual worlds stimulate users' sense of wonder about using the system. Additionally, the internal motivation of users increases as they feel that they can find a new and an enjoyable way in the learning process. If they are not motivated to apply the necessary effort, they cannot learn in these environments (Tüzün et al., 2019). The immersive nature of 3D virtual worlds also makes users feel like they are inside the environment (Hassell et al., 2012). However, they use 3D virtual worlds not to experience flow or feel the sense of being there but for fun and becoming immersed (Bartle, 2007). Huang et al. (2010) determined that users' flow experiences during navigation in 3D MUVEs were associated with skills, challenges, interactivity and telepresence. The interaction of avatars with each other in these environments, as well as the interaction with objects while navigating and structuring the 3D environment, affects the users' flow experience (Hoffman & Novak, 2009). In these environments, how users process the information acquired through these environments in their cognitive processes also affects their flow experience (Goel et al., 2013). In 3D virtual environments, through the tasks given, users are facilitated to engage more, and immediate feedback based on user performance increases users' flow experience (Pagano, 2013). In their study investigating the effect of environmental features on flow experience in learning through virtual worlds, Choi and Baek (2011) concluded that the factors of interactivity and representational fidelity predict flow.

The zone of proximal flow

To enable student learning in 3D MUVEs, Lambropoulos and Mystakidis (2012) presented a novel pedagogical framework, entitled the "Zone of Proximal Flow", which integrates Vygotsky's (1978) Zone of Proximal Development Theory and Scaffolding Theory with Csikszentmihalyi's (2000) ideas about Flow. The zone of proximal flow is defined as the area where flow takes place in the zone of proximal development. Therefore, to ensure the optimal flow, groups should consist of individuals with different skills, and there should be in-group assistance. In this regard, unlike flow experience, the zone of proximal flow is defined as a social variable rather than an individual variable. On the other hand, this seems to be more appropriate to the nature of 3D MUVEs.

The purpose of the study and research questions

This study aims to investigate the flow experience of participants in the role of instructional designers in 3D MUVEs in the process of learning through design by performing group activities. In light of this information, in the study, answers to the following research questions were sought.

When university students in the role of instructional designers create designs in 3D MUVEs to solve authentic problems within the framework of learning through design,

1. Do their flow experiences show a statistically significant difference by a) gender and b) overall grade point averages (OGPA)?
2. How does the flow that they experience change over weeks by components?
3. Does the flow that they experience show a statistically significant difference over weeks?

Method

Research design

This study was carried out with a time series design as a quasi-experimental method. The time-series design involves performing repetitive measurements at certain times before and after the intervention (Fraenkel et al., 2012, p. 276). In this research process, the data were collected eight times from the same group at different times using the same measurement tool.

Study group

The sample of the study consisted of 40 junior university students in total, who studied at the Computer Education and Instructional Technology department at a public university in Turkey. The students were enrolled in a 15-week elective course related to 3D MUVE design. Most of them were female students ($N = 22$, 55%), whereas the male students were in the minority ($N = 18$, 45%). The ages of students ranged from 20 to 30 ($M = 22.18$, $SD = 1.693$). Table 1 shows the demographic information of the sample.

As seen in Table 1, in terms of gender, the participants showed an almost homogeneous distribution. However, regarding overall grade point average (OGPA), an accumulation between 3.00 and 3.25 ($N = 19$, 47.5%) and a decrease in 3.26 and above ($N = 8$, 20%) drew attention. Additionally, the overwhelming majority of the sample did not use 3D environments. When we examined the daily average internet usage times, most of the participants were found to use the internet for 4–6 hours per day ($N = 22$, 55%). Finally, it was noteworthy that close to three-quarters of the participants played computer games to some extent ($N = 25$, 62.5%). To summarize the characteristics of the sample, it was a group familiar with the internet and PC games but unfamiliar with 3D environments. This information was used to create the design groups homogeneously.

Setting

The implementations were carried out in a computer laboratory with 40 identical all-in-one computers on which the required software such as OpenSimulator was installed. The official lecturer of the course in which the data were collected was also one of the authors of this study. The students were already familiar with the computer laboratory and the lecturers since they had taken a course from them in the laboratory. All students, designing instructional 3D virtual environments in the role of instructional designers in the study, had taken the course "Instructional Design" in previous semesters, and so, they knew the basics of instructional design.

Data collection instruments

A "Personal Information Form" was used to collect the personal information of the students, while the "Flow Scale" was used to identify their situational flow experience levels.

Table 1 Characteristics of the sample

Variable	Category	N	Percentage (%)
Gender	Female	22	55
	Male	18	45
Overall Grade Point Averages (OGPA)	2.99 and below	13	32.5
	3.00–3.25	19	47.5
	3.26 and above	8	20
Weekly 3D environment use	Never used	34	85
	Used before	6	15
Average Daily Internet Usage	1–3 hours	9	22.5
	4–6 hours	22	55.0
	7 hours and more	9	22.5
Weekly PC Game Play	Never play	15	37.5
	1–2 hours	8	20
	3–4 hours	8	20
	5 hours and more	9	22.5

Personal information form

To determine the personal information of the participants, a 13-item questionnaire that was developed by the researchers and consisted of three parts was used. The first part consisted of four items related to the participants' name and surname, gender, year of birth and OGPA, while the second part covered three items about the participants' computer and internet usage status, and the third part included six items about the participants' use of 3D MUVEs and computer games.

Situational flow scale

Within the scope of the study, to measure the participants' levels of situational flow experience, the 7-point Likert-type Situational Flow Scale that was developed by Sahranç (2008) was used after getting the necessary consent. The scale was developed and validated with university students. The scale consists of seven items listed under a single factor. Each item in the scale measures the following features: (1) Skill-challenge balance, (2) Clear goals, (3) Immediate feedback, (4) Concentration and focus, (5) Control, (6) Disappearance of self-consciousness, (7) Autotelic experience. One can get the minimum and maximum scores of 7 and 49 in the scale. A high score indicates that the individual's flow experience is high. The Flow Scale explains 47.21% of the total variance. The Cronbach's alpha reliability coefficient of the scale was reported as .80.

Implementation process

To examine the change in the participants' flow experience in the 3D MUVE learning through design process, longitudinal research was conducted. During the 15-week study, the participants used the OpenSimulator application, an open-source 3D MUVE, for individual and group work. While the participants studied individually for the first 7 weeks, as of the 8th week, they started their environment designs with group work. The groups were formed by the lecturers of the course considering the diversity of the students in terms of gender, overall grade point averages (OGPA), grades in programming and instructional design courses which they took in previous semesters since the characteristics of the group members would affect the flow experience (Demir & Seferoğlu, 2021b). In the implementation process that started with 43 people at the beginning, after the groups were formed, 3 students left the course. At the beginning, while 8 groups were formed based on the course achievement levels and genders of the participants, including 5 groups of 5 people, and 3 groups of 6 people, after 3 people left, the number of members in one of the 5-person groups decreased to 3, and the number of members in one of the 6-person groups decreased to 5. In the design process, the designers used "Problem-Based Learning (PBL)" as a theoretical framework. Project topics that were previously determined with subject-matter experts were distributed to the groups by lot. During the design process, the students and subject-matter experts stayed in touch with each other. The students focused only on the 3D design process. The project topics of the participants are given below.

- *Tree identification* It was planned to introduce trees that exist in a certain ecosystem. The target audience was university students.

- *Online course orientation in distance education* An environment where basic Turkish words are taught to foreign students was designed through the distance education center of a public university.
- *Library orientation* A library at a public university was modeled to be used in introductory trainings about the library for university freshmen.
- *Hospital orientation* A hospital at a public university was modeled to be used in introductory trainings about the hospital for university freshmen.
- *Pharmacy* It was designed for the teaching of the students of the faculty of pharmacy.
- *Virtual patient (the topic was given to two different groups)* It was designed for the teaching of the faculty of medicine students.
- *Dentistry* It was designed for the teaching of dentistry students.

During the 15-week course, the flow scale was administered eight times at the end of each session. The coverage of different topics was taken into consideration in selection of the weeks when the scale was applied. The scale was applied in the paper-and-pencil form. A short flow scale was preferred to minimize the practice effect (Fraenkel et al., 2012, p. 276). Figure 2 summarizes the implementation process.

The weeks when the flow scale was applied and the topics covered in these weeks are as follows:

(a) Week 2: General terms related to 3D MUVEs were explained, how these environments were going to be used in instruction was mentioned, and some 3D MUVE examples were shown. Additionally, technical information about the OpenSimulator software was introduced. The participants used this application both individually and in groups. In the first weeks, the users were asked to experience the environment individually to get used to the environment. For this reason, the installation of the necessary programs for the operation of the environment on personal computers and their connections with the database were explained.

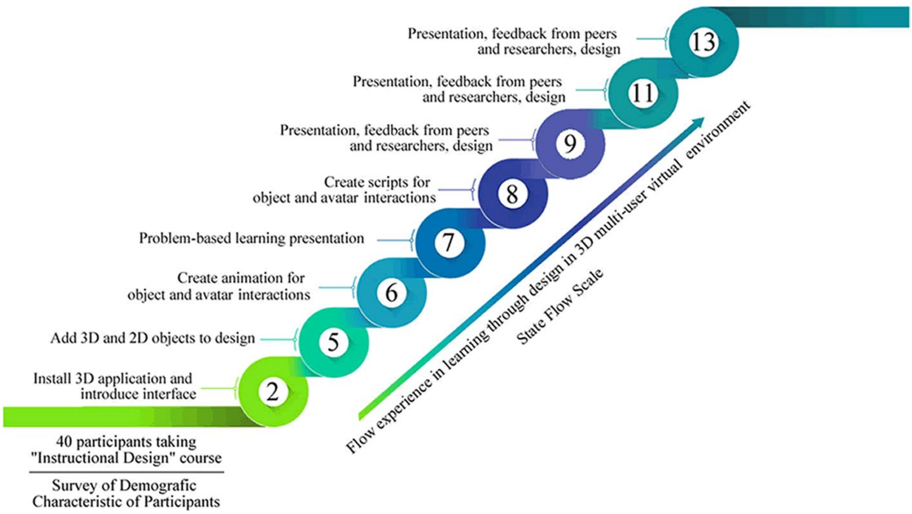

Fig. 2 Implementation process

(b) Week 5: The participants who started to get used to the interface of the OpenSimulator software and learn how to create 3D designs began to master how to customize their designs by adding multimedia materials such as audio, video and images to the environment. Information was given on properties added to objects and how lighting and region/estate settings in the OpenSimulator could be made.
(c) Week 6: One of the elements increasing the interaction of users in the OpenSimulator software is animations. Therefore, third-party programs were shown to the participants in which they could prepare animations for OpenSimulator. Besides, how to import these into the application and how to use them with the characters were explained.
(d) Week 7: In addition to the design in the OpenSimulator software, pedagogical approaches underpinning design in OpenSimulator are also important. For this reason, in the 7th week of the design process, theoretical information about the Problem-Based Learning (PBL) approach was conveyed to guide the participants. In this context, well-structured and ill-structured problem situations, projects on how to use these in 3D MUVEs and previous examples were shown.
(e) Week 8: In the OpenSimulator software, codes called "Scripts" are written to enable the participants to interact with objects. Although the participants were familiar with programming languages, they did not have any information about the specific programming language called the Linden Script Language (LSL) used in the OpenSimulator platform. Therefore, the participants were explained how to write code in LSL and how to add these codes to objects.
(f) Week 9: The participants, who started the design process with their groups by putting their designs on paper as of the 8th week, began working on the server in accordance with the sketches on paper in this week. They worked as a group on an island devoted to them on the server. Firstly, they started the design of the island by deciding on the objects they needed. In this week, they also shared their first oral presentation to share design ideas. The lecturers gave feedback to the design groups.
(g) Week 11: Although their purpose was clear before starting the design process, as the design process progressed, the participants began to make changes in their goals and scenarios. During the collaborative work on the server, they continued their design process by adjusting the group dynamics and changing scenarios. In this week, they shared the progress of their designs with the lecturers and other design groups.
(h) Week 13: The design groups made oral presentations to share information about the progress of their designs. The lecturers gave feedback to the design groups.

Figure 3 shows the design examples of the participants in 3D MUVEs at the end of the process.

Data analysis

First of all, the data were transferred to and arranged in the Excel 2016 spreadsheet software and imported to SPSS 24. The lost data were filled in by the linear trend at point method. Afterwards, merges were made to avoid less than five observations in the categories with the purpose of avoiding large differences between the categories, leading to unreliable results. The total flow experience points of weeks were obtained by averaging the items of the Flow Scale of each week. Gender and OGPA were the independent variables, whereas situational flow experience was the dependent variable. Median, arithmetic mean, standard error of mean, standard deviation, frequency and percentage were used to

Fig. 3 Design examples in 3D MUVEs

describe the data. Finally, the normality of the distribution of the data was checked using Shapiro–Wilk test for all variables. Since it was observed that the data did not show a normal distribution, among non-parametric tests, Mann–Whitney U and Kruskal–Wallis H tests were used for the cross-sectional data, and Wilcoxon signed-rank test and Friedman test were used for the longitudinal data. For the pairwise comparisons after a statistically significant Friedman test, Wilcoxon signed-rank tests were performed as the post-hoc test to reveal the directions of the differences. To control the inflation of type I error rate, Bonferroni *p-value* correction was applied (Armstrong, 2014), which yielded a $p_{adjusted}$ value of .05/28 = .00178. The threshold level of significance was determined as .05. If a statistically significant difference was reached as a result of the tests, Cohen's *d* effect size was calculated to determine the significance of this difference in practice. According to Cohen (1988), an effect size between .1 and .3 means small, between .3 and .5 means medium and higher than .5 means large effect.

Findings

In this section, the findings are presented in titles by the order of the research questions.

Comparison of flow experienced by designers in 3D MUVEs by gender and OGPA

Table 2 shows the findings obtained using Mann–Whitney U test for the first research question. As seen in Table 2, the female participants (*Median* = 5.79, *M* = 5.72, *SD* = .87) were found to experience flow on a significantly higher level than the male participants (*Median* = 5.34, *M* = 5.04, *SD* = .88) in Week 8 ($U = 101.500$, $p = .009$, $d_{Cohen} = .912$). According to Cohen (1988), this effect size was on a large level. No significant difference was found for the other weeks.

Table 2 The change of flow experience over weeks by gender

Weeks	Gender [a]	Median	M	SD	Mean Rank	U	*p*
Week 2	Female	5.31	5.39	.55	21.30	180.500	.633
	Male	5.29	5.17	1.08	19.53		
Week 5	Female	5.86	5.73	.41	22.50	154.000	.230
	Male	5.57	5.24	1.04	18.06		
Week 6	Female	5.71	5.66	.58	23.23	138.000	.101
	Male	5.35	5.28	.79	17.17		
Week 7	Female	5.14	4.97	1.04	21.27	181.000	.643
	Male	4.86	5.05	.86	19.56		
Week 8	Female	5.79	5.72	.87	24.89	101.500	.009**
	Male	5.34	5.04	.88	15.14		
Week 9	Female	5.71	5.51	.86	21.52	175.500	.539
	Male	5.50	5.32	.87	19.25		
Week 11	Female	5.86	5.78	1.02	23.11	140.500	117
	Male	5.55	5.44	.71	17.31		
Week 13	Female	6.00	6.08	.36	23.52	131.500	.069
	Male	5.79	5.84	.49	16.81		
Mean of Weeks	Female	5.55	5.60	.41	23.11	140.500	.118
	Male	5.47	5.30	.60	17.31		

Cohen's d effect size of week 8 is .912 (large level)

$^{**}p < .01$

[a]Female = 22, Male = 18

To analyze the comparison of the flow experienced by the participants in the 3D MUVEs according to OGPA, the findings obtained using Kruskal–Wallis H test are presented in Table 3. As seen in Table 3, the flow experience of the participants in the 3D MUVEs did not show a statistically significant difference based on the variable of OGPA.

Descriptive findings regarding change of flow experienced by designers in 3D MUVEs over weeks by components

As seen in Table 4, a significant decrease was observed in the students' flow experience in the 7th week's practice. However, an increase in the 8th week drew attention. This increasing trend continued in the 11th and 13th weeks. When the trends were analyzed on the basis of the components, it was seen that the disappearance of self-consciousness and autotelic experience components were relatively high. The components of skill-challenge balance, concentration and focus, and control, on the other hand, were found to be relatively low.

To better analyze the trends in the participants' flow experience, Fig. 4 was plotted based on Table 4. In Fig. 4, the skill-challenge balance plot indicated that the challenge of the task encountered was higher than the skill level of the individual except for the 7th week where theoretical information about PBL was conveyed to the participants. Especially when it came to the completion stage of the project, it was observed that the challenge of the tasks to be performed while completing the objects that were expected to take

Table 3 The change of flow experience over weeks by OGPA

Weeks	OGPA	Median	M	SD	Mean Rank	Chi-square (χ^2)	*p*
Week 2	2.99 and below[a]	5.29	5.20	.98	19.19	.553	.758
	3.00–3.25[b]	5.43	5.31	.81	21.32		
	3.26 and above[c]	5.20	5.24	.54	17.93		
Week 5	2.99 and below	6.00	5.64	.72	22.77	1.367	.505
	3.00–3.25	5.57	5.38	.94	18.00		
	3.26 and above	5.86	5.63	.47	20.29		
Week 6	2.99 and below	5.71	5.43	.64	19.04	.152	.927
	3.00–3.25	5.61	5.46	.85	20.63		
	3.26 and above	5.57	5.57	.33	20.07		
Week 7	2.99 and below	4.86	4.88	1.06	19.46	3.017	.221
	3.00–3.25	5.14	5.24	.71	22.61		
	3.26 and above	4.57	4.45	1.14	13.93		
Week 8	2.99 and below	5.38	5.10	.82	15.77	3.402	.183
	3.00–3.25	5.54	5.51	1.09	20.97		
	3.26 and above	5.86	5.68	.61	25.21		
Week 9	2.99 and below	5.86	5.42	1.01	22.08	5.532	.063
	3.00–3.25	5.41	5.19	.80	15.97		
	3.26 and above	5.86	5.94	.45	27.07		
Week 11	2.99 and below	5.57	5.62	.64	19.73	.064	.968
	3.00–3.25	5.71	5.64	.90	20.45		
	3.26 and above	5.71	5.38	1.28	19.29		
Week 13	2.99 and below	5.86	5.88	.42	18.00	1.931	.381
	3.00–3.25	5.86	5.95	.45	19.45		
	3.26 and above	6.00	6.16	.43	25.21		
Mean of Weeks	2.99 and below	5.50	5.40	.51	19.12	.130	.937
	3.00–3.25	5.50	5.46	.56	20.29		
	3.26 and above	5.52	5.51	.42	20.86		

[a,b,c]The numbers of observations in the cells were 13, 19 and 8, respectively

place in the 3D design, animation, script writing, creating interactive menus and evaluation process was higher than the skill levels of the individuals with the exception of the last week of the semester. What the participants wanted to do started to become clear as of the 8th week and reached its peak value in the last week. This increased the clear goals component. The participants were provided with immediate feedback by the lecturers for every question they asked about their tasks in all weeks. Therefore, there was a steady increase in the immediate feedback component except for the 6th and 7th weeks. This component reached its peak in the 13th week. It was determined that the students had some hardship in gathering their attention between the 7th and 9th weeks, especially in the 7th week as a result of their passive status owing to theoretical information delivery. The 7th week had a similar impact on the control component. Furthermore, the students seemed to lose control to some extent in the last three weeks possibly due to their hurry to finish the project on time. Possibly because of the same effect, it was seen that the participants experienced a steady decrease in the disappearance of self-consciousness component in the last three weeks. In general, they became immersed in the tasks during the design process.

Table 4 The change of flow experience over weeks by components

Week	Components of flow							Mean of weeks
	1	2	3	4	5	6	7	
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	
Week 2	5.0 (.9)	5.3 (1.4)	5.0 (1.2)	4.9 (1.3)	5.0 (1.1)	6.2 (1.2)	5.7 (1.5)	5.3 (.8)
Week 5	5.1 (1.3)	5.3 (1.2)	5.3 (1.0)	5.4 (1.4)	5.3 (1.2)	5.9 (1.1)	6.2 (1.0)	5.5 (.8)
Week 6	5.4 (.8)	5.4 (1.0)	5.1 (1.1)	5.4 (1.2)	5.4 (1.1)	5.9 (1.2)	5.8 (1.1)	5.5 (.7)
Week 7	5.1 (1.1)	5.0 (1.1)	4.8 (1.2)	4.4 (1.7)	4.6 (1.3)	6.2 (.9)	4.9 (1.5)	5.0 (1.0)
Week 8	5.2 (1.2)	5.4 (1.1)	5.3 (1.4)	5.0 (1.7)	5.3 (1.4)	6.2 (1.0)	5.5 (1.3)	5.4 (.9)
Week 9	5.2 (1.2)	5.5 (1.0)	5.3 (1.0)	5.0 (1.6)	5.1 (1.4)	6.0 (1.2)	5.8 (1.1)	5.4 (.9)
Week 11	5.1 (1.5)	5.8 (1.0)	5.5 (1.2)	5.6 (1.2)	5.4 (1.3)	5.9 (1.3)	6.0 (1.1)	5.6 (.9)
Week 13	6.0 (.7)	6.2 (.6)	6.1 (.8)	6.0 (.8)	5.6 (.9)	5.9 (1.2)	6.0 (1.0)	6.0 (.4)
Mean of components	5.2 (1.1)	5.5 (1.0)	5.3 (1.1)	5.2 (1.4)	5.2 (1.2)	6.0 (1.1)	5.8 (1.2)	5.5 (.5)

Standard errors of the means are presented in "Appendix"

1 = Skill-challenge balance, 2 = Clear goals, 3 = Immediate feedback, 4 = Concentration and focus, 5 = Control, 6 = Disappearance of self-consciousness, 7 = Autotelic experience

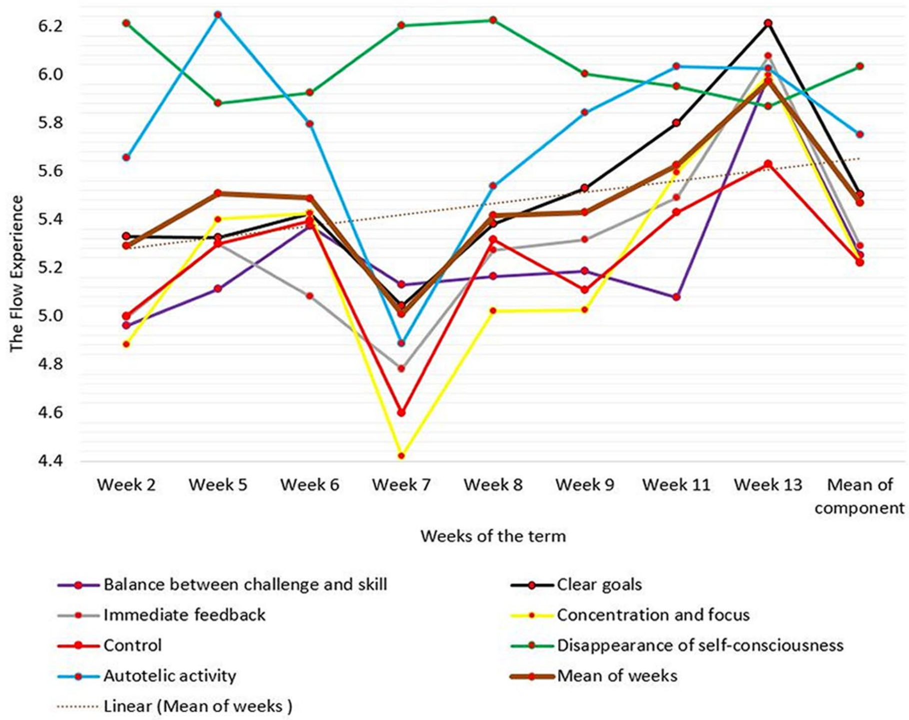

Fig. 4 The change of flow experience over weeks by components

It is interesting to note that the disappearance of self-consciousness component showed an opposite pattern compared to the other components of flow. Examining the autotelic experience component, it may be expressed that the participants were active not only physically but also cognitively in the first and last weeks. To sum up, although a floating plot was seen in all the components of the flow experience, it was evident that there was a slow but steady upward trend towards the end of the semester. To ascertain whether these floating plots showed statistically significant differences or not, the flow experiences of the designers in the 3D MUVEs were compared by the weeks.

Comparison of flow experienced by designers in 3D MUVEs by weeks

To answer this research question, first of all, Friedman test was performed with the flow score means of each week to determine whether the flow experienced by the participants differed by the weeks. For practical reasons, the general flow score means of the weeks were compared rather than the means of the individual components. As a result of this test, it was concluded that the flow experienced by the designers in the 3D MUVEs differed significantly by the weeks (χ^2 (7) = 37.425, p = .000). Wilcoxon signed-rank tests were conducted between the weeks to determine the direction of the differences. Table 5 presents the results of the post-hoc Wilcoxon signed-rank tests.

As seen in Table 5, as a result of performing post-hoc Wilcoxon signed-rank tests with Bonferroni correction, it was revealed that the flow experience measured in the 13th week practice differed from 2nd (Z = 4.296, p = .000), 5th (Z = 3.311, p = .0009), 6th (Z = 3.420, p = .0006), 7th (Z = 4.687, p = .000), 8th (Z = 3.507, p = .000) and 9th (Z = 3.604, p = .000) weeks. The differences favored the 13th week. Moreover, the flow experienced in the 7th week practice was found to be lower than the practice in the 11th week (Z = 3.366, p = .0008).

Results and discussion

Within the scope of this study, while the participants were asked to create instructional designs in a 3D MUVE, it was aimed to analyze the change in the flow experience of the participants by gender, OGPA, components and the weeks of the course.

Change of flow by gender and OGPA

According to the results of the study, the flow experience of the participants did not vary by the variables of gender and OGPA. The only exception about gender was the finding that, in the 8th week, the female participants had a higher flow experience level in comparison

Table 5 the results of comparison of flow experience by weeks using post-hoc Wilcoxon signed-rank tests

Weeks	2	5	6	7	8	9	11	13
*The difference	13	13	13	11, 13	13	13	7	2, 5, 6, 7, 8, 9
The direction	2 < 13	5 < 13	6 < 13	7 < 11, 13	8 < 13	9 < 13	7 < 11	2, 5, 6, 7, 8, 9 < 13

*As a result of Bonferroni correction, the p value was adjusted to .00178 to the male participants. In the relevant week, the participants had to interact with objects in a 3D MUVE without knowing the syntax of the application's unique programming language by writing programs with block-based programming tools. The Linden Script Language (LSL) has traditional code statements and complex syntax rules, so, it is difficult to learn for students. However, block-based programming tools allow students to recognize blocks instead of recalling syntax to support inexperienced used in their first programming steps (Tumlin, 2017). Block-based programming eliminates syntax complexity as it uses a drag-and-drop feature (Çınar et al., 2019). Additionally, block-based programming languages support constructionism by tinkering (Maloney et al., 2010) which helps female users gain valuable information about the features of a novel environment and increases their self-efficacy (Spieler, 2018). Considering all these, it may be asserted that the female participants' programming skills were more compatible with the challenge of the work in comparison to the male participants. This may have caused the female participants to experience more flow. However, since there was no difference in flow experience in the other weeks of measurement by gender, it may be concluded that gender does not have an overall effect on flow experience during 3D designing in MUVEs.

It was noteworthy that there was no significant difference in flow experience according to the variable of OGPA. In fact, flow experience is directly related to the skills of individuals (Csikszentmihalyi, 1991). However, it should be noted here that, OGPA measures not only the skill of the individual but also a combination of intelligence, perseverance and diligence in general. In this sense, the OGPA of the sample of this study might not have been directly related to their design knowledge and skills in 3D MUVEs. Moreover, the balance between challenge and skill is just one of many factors that form flow experience (Csikszentmihalyi, 1991). In this context, it makes sense that flow experience did not change by OGPA.

Change of flow by components

When the participants' flow experiences were analyzed by the components, it was concluded that the designers experienced every flow component in the design process to some extent. In general, there was a continuous increase towards the end of the semester, notwithstanding fluctuations. On the other hand, it is known that there is no need for all components of flow to occur to achieve flow (Csikszentmihalyi, 1991). It was stated that, in cases where the clear goals, skill and challenge balance and immediate feedback components of flow are present, the other components follow (Csikszentmihalyi, 2004; 2005).

One cannot become immersed into action without having any idea of the goal one must accomplish (Csikszentmihalyi, 2014). Consequently, the lack of a clear goal for one's action hinders the emergence of a full flow experience (Guo, 2004). In this study, the clear goal of the designers was to create a 3D MUVE through a group study. Aside from the clear goal, challenging tasks that increase the individual's skills to a certain extent reveal the flow (Snyder & Lopez, 2007). At this point, the concept of over-learning in education is another factor that plays a critical role in students' skills to reach the flow. In over-learning, the mind integrates actions and envisions them, instead of performing many actions (Csikszentmihalyi, 1991). Throughout the design process of this study, the participants faced various challenges. To overcome these challenges, they acquired new information and learned a new software every week. Nonetheless, flow experience does not occur only with the balance between the challenge and the individual's skill (Guo, 2004). One does not have the opportunity to evaluate their own performance in the process (Csikszentmihalyi, 2014). In cases where one has not received feedback regarding the accuracy of their action in the process, one moves away from having a mental flow experience and begins to worry about whether their actions are correct or not (Guo, 2004). In short, continuous feedback should be provided to focus the attention of individuals on higher-level tasks (Kiili, 2005). In this study, the participants presented the environments they designed and received feedback from the lecturers and their peers. Furthermore, the questions asked by students to the lecturers and vice versa during the design process had the characteristics of feedback. This feedback helped them re-determine their goals.

Individuals do not enjoy doing the same thing for a long time. For this, activities should lead to development and discovery to create flow (Csikszentmihalyi, 1991). In this study, the participants completed a different task of designing a 3D environment each week. They produced solutions to overcome challenges, and they implemented and evaluated these solutions. In the process of learning through design, designers think closely about ideas and concepts, and consequently, learn to produce the desired results (Mishra & Girod, 2006). In fact, design projects enable students to be active participants, and they offer opportunities for collaboration, deep thinking and creative problem-solving. For this reason, the participants enjoyed the design experiences with different challenge levels, so they became intrinsically motivated. That is to say, it is known that an individual with flow experience has positive motivation to work (Kalaycı et al., 2011). Because of these matters, the participants concentrated on design projects, felt that they were in control and lost self-consciousness during the 3D MUVE design processes.

Change of flow by weeks

In the study, it was seen that the flow experience in the 7th week differentiated towards a negative direction, while the flow experience in the 13th week differentiated in a positive way. This may have been due to the theoretical knowledge given to the participants about PBL in the 7th week. It was especially noteworthy that the concentration and focus, control and immediate feedback factors of flow were the lowest factors in the 7th week. The more concentration a task requires in terms of attention and workload, the more it is adopted by the individual (Sweetser & Wyeth, 2005). In this context, it may be considered that there was a significant decrease in the flow experience of the participants due to the low interaction, control and immediate feedback of the theoretical knowledge transferred. On the other hand, regarding the 13th week, the fact that the participants introduced the projects they were working on to the lecturers and their peers was effective. In this week, the groups were given feedback by both the lecturers and theirs peers, leading the way for them to improve their projects. It is well known that feedback on performance promotes the flow experience (Pagano, 2013). In line with this, it was concluded that the clear goals and immediate feedback factors of flow were the two highest factors in the 13th week.

Conclusion, recommendations and limitations

This study aimed to explore the role of situational flow experience in a 15-week design education course where students in the role of instructional designers strived to find design solutions to authentic problems by designing 3D MUVEs in groups drawing on the constructionism, learning by doing, problem-based learning (PBL) approach and the zone of proximal flow theoretical frameworks. Forty university students were enrolled in the study. The novelty of this study was that it handled the situational flow experiences of designers studying in groups during 3D MUVE design tasks based on several theoretical frameworks to solve authentic problems across one semester. The results revealed that gender and OGPA had no significant effect on the students' flow experience. Moreover, the emergence of autotelic experiences and the disappearance of self-consciousness during the design process led to an increase in the flow experience of the students. However, the designers encountered various tasks on different levels of challenge, and this caused fluctuations in their flow experiences. For instance, the participants creating designs in 3D MUVEs diverged from the flow experience due to lack of feedback, control and concentration when theoretical knowledge was conveyed. Conversely, they experienced a relatively high level of flow thanks to clear goal and feedback when they presented their projects. In summary, transfer of continuous feedback from the lecturers and peers to the designers, setting clear and realistic goals and adjusting challenge levels in the design process enabled the participants to focus on what they were doing and not to lose control over their actions.

While it is stated that the flow experience of designers in 3D MUVEs varies over weeks, it should be kept in mind that the mean value of the flow experience in the 7th week, which was the week with the lowest flow experience level, was on a high level as 5 points. Another point to be noted here is that the difference between the weekly flow means was minor. The mean value of the 13th week with the highest flow experience was 6. This mean value was only 1 point higher than the mean value of the 7th week.

In this study, the individual flow experiences in the groups were examined. In future studies, "group flow experience" rather than individual flow experience in groups might be studied. In this context, the effects of variables such as group cohesiveness and atmosphere on group flow experience may be investigated. Besides, researchers may examine the impact of students' group flow experiences on the quality of their designs. As far as practitioners in the field of design education are concerned, practitioners should make students more active by giving them control during classes and provide frequent feedback to students' projects so that the students can enter the zone of proximal flow. Additionally, researchers may adjust the challenge levels of learning tasks based on the skill levels of students, and accordingly, set clear goals. This way, students can focus on learning a task, have an autotelic experience and lose self-consciousness.

This study had several limitations. First, this study was carried out with 40 participants who were reached by the convenience sampling method. Therefore, the findings of this study may only be generalized to samples that have characteristics similar to this sample. In this study, each component of flow was measured with only one scale item. The reason for this preference was to minimize a potential fatigue effect. For this reason, the components of the concept of flow may be measured with more items in future studies. Moreover, flow experience was measured using a scale since it was easy to apply repetitively. In future studies, the authors recommend that flow may be handled with physiological measurements such as heart rate and sweating.

Appendix

Standard error of the mean (SEM) of the flow experience over the weeks by the components

Week	Components of flow							Weeks
	1	2	3	4	5	6	7	
	SEM	SEM	SEM	SEM	SEM	SEM	SEM	
Week 2	.146	.215	.196	.202	.179	.183	.230	.131
Week 5	.210	.193	.156	.222	.186	.175	.158	.124
Week 6	.126	.163	.180	.192	.177	.188	.169	.111
Week 7	.176	.179	.193	.267	.213	.148	.245	.150
Week 8	.197	.179	.219	.271	.213	.159	.204	.147
Week 9	.182	.155	.165	.254	.226	.186	.177	.136
Week 11	.239	.151	.192	.198	.198	.198	.177	.142
Week 13	.113	.096	.126	.134	.149	.183	.154	.070
Components	.174	.158	.174	.221	.190	.174	.190	.080

1 = Skill-challenge balance, 2 = Clear goals, 3 = Immediate feedback, 4 = Concentration and focus, 5 = Control, 6 = Disappearance of self-consciousness, 7 = Autotelic experience

Declarations

Ethical 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 Informed consent was obtained from all individual participants involved in the study.

Conflict of interest 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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