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Open Courseware-Based Logic Design Course

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Abstract

Logic Design is one of the core courses of many engineering programs and it provides a foundation for the subsequent hardware courses in the curriculum. In this study, a course design supported by open courseware for Logic Design is presented. In this regard, the syllabus, slides, laboratory manual handbook including experiment sheets and simulations, experiment videos, assignments and examples were prepared. The aim of this research is to determine the effect of supporting Logic Design course with digital open courseware on student achievement. It also aims to determine students' opinions regarding this approach. The study follows a mixed methods approach with the pretest-posttest control group experimental research design. The study was conducted at Manisa Celal Bayar University in Turkey in spring semester of the academic year 2017-2018 with 68 computer engineering students. While the students of the experimental group took the course supported with open courseware, only regular instruction was used in the control group. The quantitative data were collected from an achievement test including open-ended questions and surveys. The qualitative data were gathered by semi-structured focus group interviews. The findings were meticulously analyzed to provide suggestions for revision of the course. Finally, future work directions are discussed.

Keywords: *achievement; course design; open courseware; engineering education; logic design.*

Introduction

Logic Design is one of the core courses of many engineering degree programs such as Computer Engineering, Software Engineering, Electrical-Electronical Engineering and Mechatronic Engineering (Baneres et al., 2006; Oliver & Haim, 2009; Todorovich

& Vazquez, 2012). This course provides the foundation for state-level science (Wang & Zheng, 2017) and other hardware courses like Computer Architecture, Digital Computer Design, Embedded Systems, Microprocessors and Microcontrollers (Calazans & Moraes, 2001; Hamacher et al., 2012; Mohandes et al., 2006; Shoufan et al., 2015). ACM (2016) suggests this course under the name of Digital Devices as a core course in computer engineering curricula. Logic Design course also supports the common program outcomes of Departments of Computer Engineering and Electrical-Electronical Engineering at Manisa Celal Bayar University (CBU, 2018a; CBU, 2018b), which can be summarized as "to be able to use the knowledge about engineering and basic sciences in solving engineering problems; to be able to define, analyze and interpret engineering problems; to be able to design experiments related to engineering problems and analyze their results". Logic Design course can be given under different names in Turkey such as Digital Circuits and Systems, Logic Circuit Design and Digital Logic Design, depending on the department and the university (Atılım, 2018; Ege, 2018; Marmara, 2018).

Logic design includes both theoretical lessons and laboratory sessions. Teaching this course in a purely lecture-based format may be inefficient and insufficient (Alsadoon, Prasad & Beg, 2017; El-Din & Krad, 2011). Logic design "includes not only designing, simulating, and testing digital systems, but also acquiring, analyzing, and interpreting data and, whenever possible, using that data to correct or improve the design" (Stanisavljević et al., 2013, p.235). Therefore, this course requires hard work and a high level of attention. When the success level of students who enrolled into Logic Design course at Manisa Celal Bayar University (CBU), Department of Computer Engineering was checked, it was observed that 52.4% of 145 students in the academic year 2016-2017 and 61% of 132 students in the academic year 2017-2018 were successful. The percentages of successful students are relatively low. This can be explained by the fact that the course was rich in new concepts, theories and approaches of which students have very limited or no background knowledge at all (Shoufan et al., 2015). Another factor can be the crowded classrooms, decreasing the level of attention of students and resulting in a loss of motivation (Aye, 2018).

Due to being a design-oriented course, laboratory exercises are an essential part of Logic Design for consolidating learning and increasing success of students. However, because of the crowded classrooms, students have to work in groups in lab exercises, which hinders each student to be active during the experiments. As a result of remote monitoring and lack of opportunity for students to repeat experiments, most students experience problems such as loss of motivation and reduced level of success. Because of all these reasons, students have the perception that Logic Design is a difficult course (Hassan et al., 2011). Therefore, the traditional learning-teaching approach should be enhanced with new approaches to support the learning processes of learners in various fields (Aşıksoy & Ozdamli, 2017; Karakuş & Öztürk, 2016). In this regard, Internet technology and web-based applications have enhanced learning efficiency (Üzel & Özdemir, 2012) and increased motivation of learners (Demirli & Dikilci, 2003; Strommen, 1992). Multimedia enriched courses can increase the success level of students (Aşıksoy & Ozdamli, 2017; Hakkari et al., 2017; Rusanganwa, 2015; Zahra, 2016). Presenting efficient learning materials to students is crucial to provide effective educational solutions (Swigart & Liang, 2016). For this purpose, courses can be supported with open courseware (Cheung, 2018). Open courseware is defined as a "digitally published learning content including full and partial courses (syllabi, outlines, lectures in pdf or video, slides, reference lists, etc.), simulations, animations, tutorials, drills and practices, modules, podcasts, case studies, quizzes and tests" (Swigart & Liang, 2016, p. 308). Cheung (2018) suggests that students generally consider open courseware useful for learning purposes. The main benefits of open courseware are ease of use and reusability (Jung et al., 2016). They can be used again and again by students taking the same course from different universities and departments. Using open courseware reduces the time and cost of preparing course materials. Also, problems related to crowded classrooms can be minimized by using open courseware reinforcing learning processes of students. Supporting regular instruction with open courseware can help to allocate time for extra activities in face-to-face lessons and to make teacher-student relationships stronger (Caswell et al., 2008).

When literature regarding usage of technology-enhanced learning approaches in Logic Design course is examined, simulator design and usage (Alsadoon et al., 2017; El-Din & Krad, 2011; Nikolic et al., 2009; Roy et al., 2015; Stanisavljevic et al., 2013), web-based platform development (Baneres et al., 2014; Shoufan et al., 2015; Yilmaz et al., 2011) and multimedia enriched applications (Elrazig & Suliman, 2015; Kafes, 2014; Şeker, 2016; Zirve, 2014) have been observed as the main research fields. Roy et al. (2015) developed a virtual laboratory for Computer Organization and Logic Design courses to simulate experiments. Shoufan et al. (2015) proposed a web-based platform for visualization and animation of logic circuits that provides an environment for lecturers to create lecture notes, assignments and examples, and for students to practice circuit designs. Alsadoon et al. (2017) point out that using various simulators for Logic Design has a positive effect on the learning process. Baneres et al. (2014) provided a self-study platform that enables students to design their own circuits and get automatic feedback. Furthermore, open courseware usage is also common in the literature, especially in learning video design. Kafes (2014), Şeker (2016) and Zirve (2014) enriched logic design with multimedia to provide videos about different topics to students on YouTube platform. Hassan et al. (2011) and Yılmaz et al. (2011) suggested critical points for developing web pages of Logic Design course and provided web-based applications with different technologies.

A common point of multimedia enriched studies (Elrazig & Suliman, 2015; Kafes, 2014; Shoufan et al., 2015; Şeker, 2016; Zirve, 2014) is that they do not cover all topics of the course and focus on specific subjects. Therefore, in this study, open courseware including syllabus, slides, laboratory manual handbook including experiment sheets and related simulation studies, laboratory experiment videos, assignments and examples was prepared for all topics of the course. Therefore, the aim of this study is to investigate the effectiveness of using open courseware developed for Logic Design course. It is also aimed to support students to develop the abilities to design, analyze, interpret and solve engineering problems related to the course.

In accordance with these aims, the following research questions were formulated:

RQ.1 Is there any statistically significant difference in academic achievement of computer engineering students between the experimental group that took the Logic Design course supported with open courseware and the control group that followed regular instruction, based on pre-test and post-test scores?

RQ.2 What are the views of students regarding the course design supported with open courseware in comparison with the course based on regular instruction?

RQ.3 What are the views of students in the experimental group on the Logic Design course:

a) based on the benefits they received from the course?

b) based on the factors decreasing the efficiency of the course?

Method

Research Model

This study, which consists of quantitative and qualitative data, uses the mixed methods approach that includes multiple phases. The reason for choosing the mixed methods approach is based on the complexity and multidimensionality of the events and facts in learning environments (Yıldırım & Şimşek, 2013). Mixed methods research design includes procedures in which qualitative and quantitative methods are used together in a study to understand a research problem (Creswell & Plano Clark, 2011; Johnson & Onwuegbuzie, 2004). In a multi-phase mixed methods research design, which is a type of mixed methods design, a problem or a subject is examined in a sequence of independent studies or phases (Creswell, 2012).

This study, as depicted in Figure 1, consists of three phases. The phases aim to examine the effects of open courseware by using pre-test post-test control group experimental research design; analyze students' satisfaction levels with surveys; gather students' opinions regarding open courseware with semi-structured focus group interviews, respectively.

In the first phase of the study, the experimental process is performed. The studies that examined the relationships between dependent and independent variables are experimental designs. In order for a study to be experimental, it is necessary to assign the groups randomly, to take control of the effects of other non-investigated factors and to work directly to influence a certain variable (Büyüköztürk, 2012; Karasar, 2015). Experimental designs are the most appropriate methods to determine whether a process is effective (Frankel, Wallen & Hyun, 2012). In this study, pre-test post-test control group experimental research design was implemented to examine the effects of open courseware developed related to Logic Design course topics.

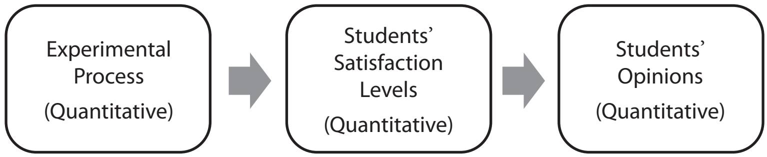


Figure 1. Phases of the Research Model

The experimental process of the applied research model is presented in Table 1. Students were randomly assigned to experimental and control groups. The pre-test helps to know the degree of similarity between the experimental and control groups before the experimental process (Hakkari et al., 2017). During the application, the control group followed the regular instruction, while the experimental group was supported with open courseware, in addition to regular instruction. The post-test was applied after the application process to examine the effects of open courseware on student achievement.

Table 1
Experimental Process Phase of the Research Model

Group Name	Method of assigning to groups	Pre-test	Application	Post-test
Experimental Group	Randomly assigned	Logic Design Achievement Instrument	Regular instruction supported with open courseware	Logic Design Achievement Instrument
Control Group	Randomly assigned	Logic Design Achievement Instrument	Regular instruction	Logic Design Achievement Instrument

In the second phase of the study, surveys were developed by the researchers and applied to the experimental and control groups. In the third phase, voluntarily given opinions of experimental group students were gathered and described by conducting semi-structured focus group interviews.

Study Group

The study was conducted with sophomore students taking the Logic Design course at the Department of Computer Engineering at CBU during the spring semester of the academic year 2017-2018. The number of students enrolled into the course was 132. Students who had taken the course for second time (or more than that) (52 students) were excluded from the study. The students who had taken the course for the first time were randomly assigned to control and experimental groups. Furthermore, 12 students were also excluded from the study due to not attending the course. So the study was conducted with 68 participants (34 students in the experimental and 34 students in the control group). The experimental group consisted of 9 female and 25 male students, while the control group consisted of 10 female and 24 male students (Table 2).

Table 2

Distribution of students according to gender

Group	Gender				Total
	Female		Male		
	f	%	f	%	
Control group	10	29.4	24	70.6	34
Experimental group	9	26.5	25	73.5	34

Cumulative grade point average (CGPA) scores of the students were used to examine whether there was a statistically significant difference between the groups before the experimental process. For this purpose, the CGPA scores of students for the semester before they took Logic Design course were used. Independent group t-test results for CGPA scores are presented in Table 3. There was no statistically significant difference between CGPA scores of the experimental and control group ($t(66)=0.002$, $p>0.05$). Students were randomly assigned to both groups and this finding supports the reason that experimental research design was applied in this study.

Table 3

Groups Statistics of CPGA Test

Group	N	Mean	sd	df	t	p
Control	34	2.3668	.68329	66	.002	.999
Experimental	34	2.3665	.69261			

In order to address the ethical issues, participants should be informed about the research purpose and process, and provide a voluntary participation approval (Erdoğan & Şengül, 2017; Smith, 1995). In this research, students in the experimental and control groups were asked to fill in a voluntary participation form. All students submitted the forms.

Data Collection Instruments

With the aim of quantitative data collection, an achievement instrument and surveys were used. Moreover, the qualitative data were gathered by recording semi-structured focus group interviews.

An Instrument for Measuring Academic Achievement of Logic Design Course

Logic design achievement instruments found in the literature consist of multiple choice questions (Ben-David Kolikant & Genut, 2017; Herman, 2011; Herman & Loui, 2011; Herman et al., 2010). However, the chance factor of multiple choice questions may prevent measuring how much the students learned (Peşman & Eryılmaz, 2010). Multiple choice questions cannot be enough to observe the abilities of students about analysis and design of logic circuits. Therefore, Logic Design Achievement Instrument (LDAI) that includes open-ended questions (Balci et al., 2019) was developed by the authors and used as a measurement instrument in this study.

Logic Design course includes the following topics: number systems, introduction to logic circuits, combinational logic circuits and sequential logic circuits. The LDAI includes the following topics: introduction to logic circuits, combinational logic circuits and sequential logic circuits. LDAI was used as a pre-test before the experimental process and as a post-test to evaluate students' achievement in Logic Design. The details of the achievement instrument are given below.

Due to Logic Design being a core course in many engineering departments, an acquisition list was prepared based on common topics taught in the Departments of Computer Engineering, Software Engineering, Electric-Electronics Engineering and Mechatronic Engineering of CBU, Okan University and Maltepe University. At first, a list of acquisitions with 37 items and a pool of 54 open-ended questions were developed. According to the views of the researchers, the numbers were updated as 20 items and 19 questions. In order to provide objective evaluation of the developed measurement instrument, a rubric was prepared. Evaluation of LDAI, which was applied as a pre-test and a post-test, was performed according to this rubric.

Table 4

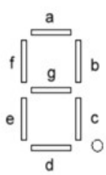
List of Acquisitions for Logic Design Course

1- Can perform Boolean arithmetic operations by using De Morgan's Laws.
2- Can express a problem/expression/function with truth tables.
3- Can draw the logic circuit of a function with three/four inputs (from a given Boolean expression) by using logic gates (AND, OR, NOT, XOR).
4- Can use universal logic gates (NAND, NOR).
5- Can write Boolean expression of a function when its logic circuit is given.
6- Can minimize Boolean expressions with De Morgan's Laws.
7- Can perform operations by using binary, gray, even/odd parity and seven segment codes.
8- Can express a logic statement in algebraic form with minimum terms / maximum terms (Sum Of Products / Product Of Sums) and can convert them to one another.
9- Can express a logic statement in numeric form.
10- Can minimize functions with three/four inputs using Karnaugh-Maps.
11- Can perform operations with functions that include don't care conditions.
12- Can minimize functions that have more than one output.
13- Can implement comparator and adder circuits by using logic gates.
14- Can perform operations with four input Decoder / Encoder circuits.
15- Can perform operations with four input Multiplexer / Demultiplexer circuits.
16- Can work with three input sequential circuits and create related state table and state diagram.
17- Can design digital logic circuits by using D type flip-flops.
18- Can design a counter circuit.
19- Can design a register circuit.

To ensure content validity, feedback was obtained from six domain experts from different departments and universities, and necessary changes were made. The list of acquisitions was finalized with 19 items, as listed in Table 4. The final version of the achievement instrument consists of 15 questions and an example question is depicted in Figure 2. Each open-ended question in the instrument corresponds to at least one acquisition, while each acquisition can be measured by more than one question. The content validity index of the measurement instrument was determined as 0.84, which indicates that content validity was ensured.

For reliability analysis, achievement instrument was applied to 88 student volunteers from different engineering departments and universities that had taken and passed the Logic Design course in the previous academic semester/year. To calculate the reliability of this instrument, answers of 10 randomly selected students were evaluated by two domain experts based on the developed rubric. The maximum point for correct answers is 3, whereas the minimum point is 1 for partly correct answers for each question. Therefore, the maximum score that can be taken from LDAI is 45. The results of the Spearman's rho test indicated that the correlation values of the overall test and each item of the test were statistically meaningful (Balcı et al., 2019).

3. For the circuit that converts from binary code to seven-segment code, write the numerical expression **for output a** by completing the given truth table.



	Inputs (Girişler)				Outputs(Çıkışlar)						
Dec	A	B	C	D	a	b	c	d	e	f	g
0	0	0	0	0	1	1	1	1	1	1	0
1	0	0	0	1	0	1	1	0	0	0	0
2	0	0	1	0	1	1	0	1	1	0	1
3	0	0	1	1	1	1	1	1	0	1	1
4	0	1	0	0	0	1	1	0	0	1	1
5	0	1	0	1	1	0	1	1	0	1	1
6	0	1	1	0							
7	0	1	1	1							
8	1	0	0	0							
9	1	0	0	1							

Figure 2. An example question of LDAI

Surveys for the Experimental and Control Groups

In order to get feedback, surveys for the experimental and the control group were prepared. They were reviewed by four experts to make necessary changes and finalize them. The questionnaires were used to collect information about the following groups of topics:

- marking the documents students used and expressing the satisfaction level of the course material presented. Students in the control group had three options for these questions: slides, laboratory manual handbook and simulator, whereas students in the experimental group had two additional options: experiment videos and examples.
- which experiments were more challenging for the students;

– any technical problems experienced while using the platforms designed for the control and the experimental group. The experimental group had an extra question related to bandwidth problems for lab experiment videos.
– location and device usage information while accessing the platform of the course;
– general opinions and suggestions of the students in the experimental and the control group about the course, gathered by an open-ended question.

At the end of the term, these surveys were given to the students in the above mentioned groups. The application of a survey in each group guaranteed the feedback from the experimental and the control group, taking into account the materials they could access.

Semi-Structured Focus Group Interviews

The semi-structured focus group interview is a data collection instrument that is based on interaction of the individuals in a predetermined group by using predetermined topics, in which the answers of every individual can be heard by other group members and the opinions of other individuals can be shaped and expressed based on these answers (Yıldırım & Şimşek, 2013). In order to gather feedback on the effect of open courseware on achievement of students in the experimental group, a semi-structured interview form was prepared. To ensure that the questions were clearly written and served their intended purpose, they were reviewed by four experts and necessary changes were made to finalize the questions. Focus group interviews with 20 student volunteers were conducted at the end of the experimental process. Due to focus group interviews being performed with small groups consisting of 6-8 participants (Yıldırım & Şimşek, 2013), the interviews were conducted with 3 groups consisting of 7 (2 females, 5 males), 6 (2 females, 4 males) and 7 (2 females, 5 males) students, respectively. The focus group interviews were recorded in video format and later transcribed.

Logic Design Course Supported by Open Courseware

In order to provide the Logic Design course content more effectively, it is aimed to support the course with open courseware. For this purpose, syllabus, slides, laboratory manual handbook including experiment sheets and related simulation studies, laboratory experiment videos, assignments and examples were prepared as open courseware. While preparing these materials, the standards provided by Jung et al. (2016) to develop high quality open educational resources were used.

Slides were prepared based on logic design textbooks (Mano, 1979; Stallings, 2005). Extra exercises done in the class were not included in slides. A total of 4 assignments were given about number systems, introduction to logic circuits, combinational logic design and sequential logic, respectively. Assignments include a different number of questions and difficulty levels, depending on the acquisitions of the course content given in Table 4. Moreover, a laboratory manual handbook which includes laboratory rules, materials list for the experiments and 9 laboratory experiment sheets was designed. Each experiment includes "purpose & scope", "experiment materials list", "theoretical background", "preliminary lab", "experimental work" and "results and assessments" sections. Simulation studies were included in the preliminary lab sections of the experiments, because use of simulations is an effective way to visually explain the theoretical concepts and to improve the students' understanding of difficult topics (Alsadoon et al., 2017).

As part of open courseware, examples and videos for laboratory experiments were developed for the experimental group. The examples including many questions with different difficulty levels were prepared. For this purpose, 6 digital open course materials that include 67 questions in total were shared with students about the related topics after they were taught. The experiment videos were prepared for all lab experiments to let the students observe each stage of the experiment, recognize the mistakes they make, see optimum solutions and watch the experiments over and over again. 12 videos were prepared for 9 experiments. Average video length was 8:16, while video lengths varied from 2:57 to 10:50, depending on the content of the experiments. Videos consist of three sections: detailed explanations about preliminary work; installation of the circuit on breadboard; commentary of the circuit execution for different inputs, respectively. To demonstrate the sections of the videos, two screenshots of a video are presented in Figure 3.

Figure 3. Screenshots of a video a) installation of the circuit; b) observation of the circuit execution with oscilloscope.

Research Process

The study was conducted with students who took Logic Design course at the Computer Engineering Department of CBU. Logic Design is a one-semester (15 weeks) compulsory course for the sophomore engineering students which consists of 3 lectures and 2 laboratory sessions per week. The lectures cover theoretical aspects, while laboratory sessions provide practical experience about related topics.

In the first step of the study, open courseware was designed and developed. Then, the communication media for sharing these materials were prepared. For this purpose, a web page was used for the control group, while a learning management system (Moodle) was used for the experimental group to ensure the access only of the students belonging to this group by using their personal accounts.

The developed open courseware was made available to students on a topic-by-topic basis each week. Furthermore, all announcements and scores of the measurement instruments (exams, quizzes, assignments and lab experiments) were shared on the platforms for each group.

Experimental process took place during the academic semester for a period of 11 weeks. Regular instruction of the course was organized for the control group. That is to say, they participated in theoretical lessons and lab sessions face-to-face. They were responsible for preparing assignments, participating to the lab exercises, delivering the related lab and simulation reports and taking the exams. The assignments were prepared by teams of 4-5 students selected from the same group (either the control or the experimental group). Besides, students worked in pairs from the same group (control or experimental) in lab exercises; however, each student got an individual laboratory grade. To perform the simulation sections of the experiments, a web-based logic circuit simulator named "simulator.io (Simulator, 2018)", which is easy to use to build and simulate logic circuits, was used. Students manually draw structural schemes in the simulator, and verify the circuit design by simulating its behavior for various signal patterns (Stanisavljevic et al., 2013).

In addition to the open courseware provided to the control group, students in the experimental group had access to the examples and experiment videos on Moodle platform. Examples were made available at the end of related topics. Video links were shared via Moodle after the lab sessions. The decision of upload time of the videos is based on the work of Shoufan et al. (2015) with simulators that restricted usage of their simulator before submission deadline of assignments. In a similar manner, we shared experiment videos after lab exercises to prevent students from memorizing the steps of the video and let them be creative with their own circuit design.

The stages of the research process are demonstrated in Figure 4. The pre-test was administered during week 3 (at the beginning of experimental process). The post-test and the survey were administered during week 15 (after all the topics were taught). A week later, semi-structured focus group interviews were conducted with randomly selected students from the experimental group and video recordings were taken.

The experimental process is followed by the analysis of quantitative and qualitative data and evaluation of the findings.

Data Analysis

The instruments and analyses used to investigate the research questions are presented in Table 5. Logic Design Achievement Instrument and surveys for the experimental and control groups were used to collect quantitative data. Descriptive statistical analyses and mixed design ANOVA were performed to analyze the data collected with these measurement instruments. SPSS v22 was used to analyze the quantitative data.

On the other hand, semi-structured focus group interviews were conducted to gather qualitative data to analyze the learning processes of students and increase the efficiency of the course. Content analysis method was utilized for analyzing these data. Content analysis method includes creation of codes and themes, interpretation of the cause and effect relationships and presentation of findings in an organized way (Atman Uslu, 2013).

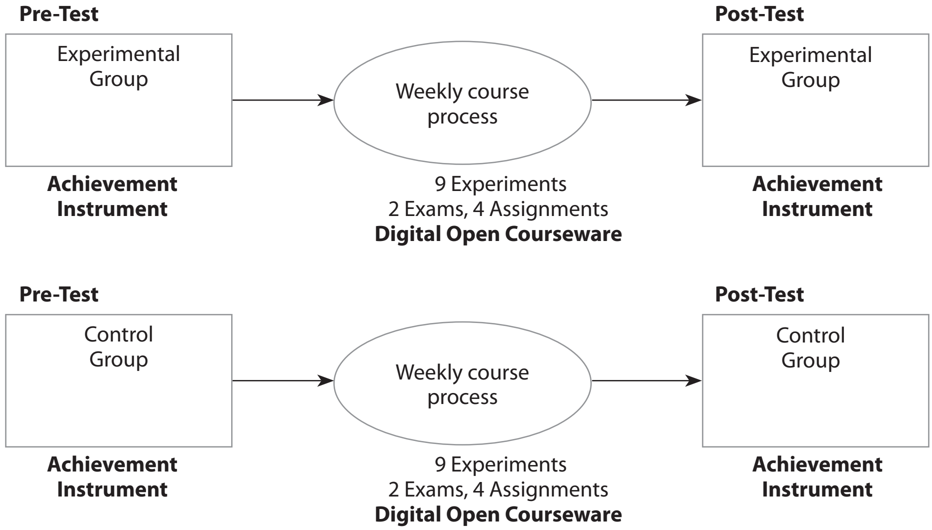


Figure 4. The stages of the research process according to groups

Table 5
The instruments and analyses used to investigate the research questions

Research Question	Instrument	Analysis
RQ.1	Logic Design Achievement Instrument (LDAI)	Descriptive statistics, Mixed design ANOVA
RQ.2	Survey	Descriptive statistics
RQ.3	Semi-structured focus group interview	Content analysis

Results

Results of the pre-test and post-test scores

For the first research question addressed in Table 5, LDAI achievement instrument was used as pre-test and post-test. LDAI includes 15 questions and the maximum number of points for correct answers is 3 for each question; therefore, the maximum score that can be taken from LDAI is 45. The descriptive data including N (number of participants), the minimum and maximum scores, the mean and standard deviation of pre-test and post-test for the control and the experimental group are presented in Table 6.

To answer RQ.1, mixed design ANOVA was carried out to evaluate the academic achievement levels of students in Logic Design course. The results shown in Table 7 indicate no statistically significant difference between the experimental and the control group ($F_{(1;66)}=0.410$; $p>0.05$). Based on the measurement time factor, statistically significant difference was found between the achievement test scores ($F_{(1;66)}=19670.259$; $p<0.001$). Moreover, it was identified that the measure of strength of relationship (eta square) has a large effect size ($\eta2 = .893$) (Cohen, 1998). This finding points out that the success level of students in both groups was increased.

Table 6

Descriptive data of pre-test and post-test results

Groups	Test	N	Minimum	Maximum	Mean	Std. Deviation
Control Group	Pre-test	34	0	2	.2565	.53245
	Post-test	34	1	41	23.7941	9.78180
Experimental Group	Pre-test	34	0	3	.4320	.77638
	Post-test	34	12	40	25.0000	7.36083

Table 7

The results of ANOVA on the students' pre- and post-test scores in accordance with the experimental and the control group

Source	Sum of Squares	df	Mean Square	F	p	η_p^2
Between Groups						
Group	16.220	1	16.220	.410	.524	.006
Error	2611.838	66	39.573			
Within groups						
Time	19670.259	1	19670.259	549.410	.000	.893
Group x Time	9.024	1	9.024	.252	.617	.004
Error	2362.968	66	35.803			

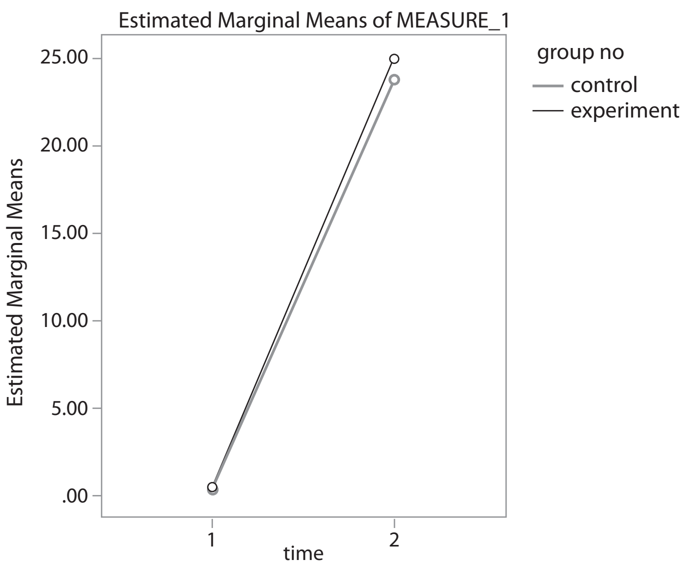


Figure 5. Chart showing the change of achievement scores by groups and measurement time

On the other hand, when group x time interaction was analyzed, no significant difference was found between the achievement scores of group (experimental and control) variables and measurement time (pre-test and post-test) variables ($F_{(1;66)}$=9.024; p>0.005). This result is demonstrated graphically in Figure 5. The pre-test scores were close to each other in the experimental and the control group; the post-test scores of the experimental group were found to be slightly higher than those of the control group. However, there is an increase in the achievement scores of both groups. In this regard, even though the results indicated no significant difference, the experimental group's mean score is higher (25 to 23.7941 out of 45), standard deviation is lower (7.36083 to 9.78180) and the minimum score is higher (12 to 1) than the control group's scores. Thus, the experimental group has benefited from the experimental process.

Results of the survey

In order to answer RQ.2, two surveys were administered to the experimental and the control group, respectively. 31 of 34 participants from the experimental group and 32 of the 34 participants from the control group completed the surveys. The results were interpreted based on four groups of questions by comparing the findings according to the experimental and the control group. The fifth category of the survey which contains an open-ended question was also analyzed and discussed here and interpreted with the findings of focus group interviews in the related section.

The statistics on the usage of course materials in the experimental and the control group are presented in descending order in Table 8 and Table 9, respectively. It is observed that slides (30 of 31 participants) were the most frequently used material type by the experimental group students, while lab manual handbook (28 of 32 participants) was the most frequently used one by the control group students. When the additional materials of the experimental group were analyzed, it was detected that examples were used by 80.6% (25 of 31) of students, while experiment videos were used by 58.1% (18 of 31) of students. The usage of examples was as high as the usage of the common course materials, as presented in Table 8 and Table 9. However, the number of students who used experiment videos was the lowest when compared with the usage of other material types.

Table 8

Materials usage statistics of the experimental group students

Material Type	Used		Not Used	
	Frequency	Percent	Frequency	Percent
Slides	30	96.8	1	3.2
Lab Manual Handbook	28	90.3	3	9.7
Examples	25	80.6	6	19.4
Simulator	24	77.4	7	22.6
Experiment videos	18	58.1	13	41.9

To determine the satisfaction levels of students, 5-point Likert rating scale was used: "strongly disagree"(1), "disagree"(2), "somewhat agree"(3), "agree"(4), "strongly agree"(5). The satisfaction levels with course materials used by the experimental and the control group are presented in descending order in Table 10 and Table 11, respectively. It was observed that examples were related to the highest satisfaction level by the experimental group students, while lab manual handbook was related to the highest satisfaction level by the control group students. The satisfaction level order of the control group given in Table 11 was in the same order as the usage frequency order in Table 9.

Table 9

Materials usage statistics of the control group students

Material Type	Used		Not Used	
	Frequency	Percent	Frequency	Percent
Lab Manual Handbook	28	87.5	4	12.5
Slides	25	78.1	7	21.9
Simulator	22	68.8	10	31.3

Table 10

Satisfaction level with course materials by the experimental group students

Material Type	N	Mean	Std. Deviation
Examples	31	3.84	1.157
Lab Manual Handbook	31	3.81	.703
Slides	31	3.65	1.082
Simulator	31	3.35	1.050
Experiment videos	31	3.19	1.108

Table 11

Satisfaction level with course materials by the control group students

Material Type	N	Mean	Std. Deviation
Lab Manual Handbook	32	3.53	.983
Slides	32	3.44	1.045
Simulator	32	3.41	.875

When the additional materials of the experimental group were analyzed, it was observed that examples were related to the highest satisfaction level, whereas experiment videos were related to the lowest satisfaction level. While examples were the third most commonly used course material type (Table 8), students' satisfaction level with them was the highest (Table 10). This finding indicates that, even though examples were not the most commonly used material type, they were related to the highest satisfaction level. Moreover, experiment videos were used by the lowest number of students and their satisfaction level with them was the lowest. These findings are proportional to each other. Possible reasons for this finding are discussed with the findings of the focus group interviews.

The students were also asked to order the difficulty levels of the experiments they performed during laboratory exercises. The results are listed in Table 12 and Table

13 by using the mean values in the descending order for the experimental and the control group, respectively. Difficulty perceptions of students in the experimental group increased with each experiment and "E9 - Counters" was perceived as the most difficult one. On the other hand, the order of difficulty perceptions of the students in the control group was the same for the first six experiments and changed for the last three experiments, while "E7 - Multiplexer, Demultiplexer" was perceived as the most difficult experiment.

The statistics regarding the number of each experiment video viewed were in correlation with the difficulty perceptions of students. As the difficulty of the topics increased, the number of views of the related videos also increased. However, the video for experiment 1 was the most frequently watched video, which can be due to the curiosity factor.

Students were also asked about the possible problems they might encounter while accessing the web platform of the course. The findings revealed that none of the students in either group had any problems when accessing the web platforms designed for them. However, 3 students in the experimental group and 2 students in the control group had problems related to their Internet connection. Students in the experimental group had an extra question about possible bandwidth problems when watching experiment videos. Only 1 student indicated this issue, which was parallel with the finding related to Internet connection problems.

Table 12

Difficulty levels of lab experiments according to the experimental group students

Lab Experiment No. & Subject	N	Mean	Std. Deviation
E9- Counters	31	5.61	3.273
E8- Flip Flops	31	4.90	3.360
E7- Multiplexer, Demultiplexer	31	3.87	2.986
E6- Decoder, Encoder	31	2.94	2.337
E5- Adders, Subtractors	31	2.71	2.085
E4- SOP/POS Forms	31	2.23	1.606
E3- Seven-Segment Display	31	2.06	1.590
E2- Logic Gates (AND, OR, NOT, NAND, NOR)	31	1.71	1.270
E1- Logic Gates (XOR, XNOR)	31	1.55	1.410

Web platform access locations and device types for the experimental and the control group students were also investigated. The findings for the first question were parallel for both groups as they mostly accessed the web platform from home, rather than the campus or office. However, the findings for the second question were slightly different. Even though PCs were the most commonly used devices for both groups, a lower number of the experimental group students used PCs, as some of them preferred notebooks, tablets and mobile phones.

The survey also included the open-ended question "What are your opinions and suggestions for the course in general?" 22 out of 32 control group students answered the open-ended question, while 19 of 31 students in the experimental group responded to this question. The benefits received from the process and the obstacles to the efficiency of the course mentioned by the students in both groups are listed below.

Table 13

Difficulty levels of lab experiments according to the control group students

Lab Experiment No. & Subject	N	Mean	Std. Deviation
E7- Multiplexer, Demultiplexer	32	4.66	3.086
E9- Counters	32	4.34	3.318
E8- Flip Flops	32	4.31	3.487
E6- Decoder, Encoder	32	3.03	2.389
E5- Adders, Subtractors	32	2.87	2.196
E4- SOP/POS Forms	32	2.47	2.229
E3- Seven-Segment Display	32	2.16	2.201
E2- Logic Gates (AND, OR, NOT, NAND, NOR)	32	1.69	1.655
E1- Logic Gates (XOR, XNOR)	32	1.69	2.023

Benefits received from the process:

- Benefit of common course materials: 3 students from each group expressed their satisfaction with the course materials shared with both groups.
- Benefit of open courseware: 6 of the experimental group students mentioned specifically that examples and lab experiment videos were well-prepared and beneficial for their learning processes.

Obstacles to the efficiency of the course:

- Insufficient lab sessions duration: 6 of the experimental group students and 2 of the control group students stated that the time allocated for lab exercises was not enough to complete the experiments.
- Insufficient number of lab assistants: 3 of the experimental group students and 2 of the control group students indicated that since there were too many teams in lab groups, they had to wait for the lab assistant to check their circuit designs and answer their questions. For this reason, they suggested that having 2 lab assistants at the lab would be more efficient.
- Difficulty of the course content: 5 of the control group students mentioned that they had lost track of the course due to the difficulty of the second half of the course content. However, no feedback was received from the experimental group students related to this issue.
- Upload timing of lab experiment videos: 1 of the experimental group students mentioned that he had difficulties while doing the lab experiments due to the related videos being uploaded after the lab exercises.

Also, 4 of the experimental group students suggested that increasing the number of examples would increase the efficiency of the course. Moreover, 3 control group students and 2 experimental group students suggested that solving more exercises about real life problems in theoretical lectures could be more useful to comprehend the content.

Results of the semi-structured focus group interviews

In order to answer RQ.3, the qualitative data gathered from semi-structured focus group interviews with experimental group students were analyzed by performing content analysis. Two categories and three themes under each of them were determined. Some noteworthy opinions of the students were quoted according to the focus group interview session number and student code (FGIx-Sty). As the first category, the benefits consist of three themes and each theme is described below.

– Benefit of sharing open courseware on Moodle platform - students expressed their satisfaction with receiving materials on Moodle in an organized way.

> "Sharing experiments, examples, lab manual handbook, assignments and announcements via Moodle as a single source provided enhanced accessibility." (FGI1-St1, St2, St3, St7, FGI3-St14, St16, St17, St20)
>
> "This course used the Moodle platform in a very active way. This made it possible for us to check the course page regularly at least once a week for lab manual handbook, slides, examples and everything related to the labs and assignments." (FGI1-St5, St6, FGI2-St8, St9, St12, St13, FGI3-St15, St16, St19)

– Benefit of the examples - students declared that examples were useful to associate theory and practice.

> "To me, the most useful materials shared with us were the examples. They helped me practice the theoretical information I learned at the class. I comprehended the subjects better after studying the examples." (FGI2-St8, St10, St13)
>
> "It was useful to have examples related to real life problems such as the tank example. We can associate theory and practice more easily if the number of examples like this increases." (FGI2-St11)

– Benefit of the experiment videos - students stated that experiment videos were well-prepared and beneficial to their learning processes.

> "Watching experiment videos helped me recognize the mistakes I made during lab exercises. That improved my performance in the subsequent lab activities. It was very useful for me. Especially for the difficult topics after the midterm." (FGI1-St6)
>
> "I could perform the experiments successfully in lab exercises, so I didn't need to watch the experiment videos. However, I checked some of the videos out of curiosity or to remember how we performed some operations. Some parts of the videos made me realize that I didn't have to try that hard during the lab exercises; there were easier and shorter solutions." (FGI1-St2)

Three themes of the second category, obstacles to the efficiency of the course, are explained below.

– Insufficiency of lab exercises duration - students stated that the time allocated for lab exercises was not enough to complete the experiments.

"The duration planned for the first couple of experiments was enough, but we were not able to complete the experiments on time, as the experiments became more and more complicated. The time restrictions put pressure on us." (FGI2-St8, St9, St10, St11, St12, St13, FGI3-St14, St15, St16, St17, St18)

– Insufficient number of lab assistants - students indicated that since there was just one lab assistant, they had to wait for their circuit designs to be checked.

"The lab assistant tried to pay attention to all of us. But we had to wait for the lab assistant to check our circuit designs and answer our questions. Having 2 lab assistants present at the lab could have been more efficient." (FGI1-St2, St3, St5, St6, St7, FGI2-St8, FGI3-St14, St15, St19)

– Inefficiency caused by not sharing videos before lab exercises - students mentioned that they had difficulties while performing the lab experiments due to the related videos being uploaded after the lab exercises.

"Not being able to watch the experiment videos before the lab exercises caused delays. It took a lot of time to find and correct the mistakes we had made in circuit design and implementation. If we had been able to watch the experiment videos before the lab exercises, we could have been familiar with the circuit we are implementing and recognize our mistakes more easily and faster and complete the experiment in a shorter time. Videos could provide preliminary information and we could understand what we would do in a better way." (FGI1-St2)

Also, students declared that as a part of preliminary work, simulator studies were useful to comprehend how their circuit designs will work.

"Performing simulations of the circuits before lab exercises shortened the time required when implementing logic circuits. Simulations helped us check whether the circuit we designed will function correctly after the implementation. We could also implement the logic circuits by following the logic diagram we constructed with the simulator." (FGI1-St1, St3, St6)

Moreover, all the students who participated in FGI1 stated that they had had difficulties, especially in the topics taught after the midterm. Students also stated that especially experiments 8 and 9 had complicated circuit designs and were difficult to implement (FGI1-St6). These two findings are parallel because the experiments 8 and 9 cover the topics after the midterm. This is also supported with the results of the survey for both groups as those experiments were determined as the 1st and 2nd difficult experiments by the experimental group, while they were perceived as the 2nd and 3rd difficult experiments by the control group, respectively. Also, the experiment videos related to these experiments were among the most frequently watched videos.

The feedback gathered from the open-ended question of the survey also supported the findings of the focus group interviews. Students in the experimental and the control group stated that the open courseware available to them was beneficial to their learning processes. Also, two common findings were determined from the survey and focus group interviews related to lab exercises: the insufficient duration of lab exercises and insufficient number of lab assistants. The findings from the focus group interviews related to examples and experiment videos were also supported by the experimental group students' responses to the open-ended question of the survey.

Discussion and Conclusion

Logic Design course provides the basis for state-level science in electrical engineering, electronic science and technology, information and communication engineering, control science and engineering, computer science and technology (Wang & Zheng, 2017). The course also supports the common program outcomes of these departments, such as developing the skills of designing experiments by analyzing problems, interpreting and solving problems and analyzing the results.

In this study, the effect of Logic Design course supported by open courseware on students' academic achievements was studied. In accordance with the syllabus of the course, the materials such as slides, laboratory manual handbook including experiment sheets and related simulation studies, experiment videos, assignments and examples were developed for the topics to be covered weekly. Students were able to access the developed materials and all related announcements through the web platforms prepared for the course.

A multi-phase mixed methods research design was utilized in this study. A pre-test post-test control group experimental research design was implemented in the first phase to examine the effects of open courseware. For this purpose, LDAI developed by Balcı et al. (2019) was applied as the pre-test and post-test. In the second and the third phase, opinions of students were collected by conducting surveys and semi-structured focus group interviews, respectively.

The results of the first phase that correspond to research question RQ.1 were evaluated by performing mixed design ANOVA. The results of mixed design ANOVA show that no statistically significant difference was observed between the experimental and the control group ($F_{(1;66)}$=0.410; $p>0.05$). Therefore, there was no significant difference in terms of pre-test and post-test scores between the groups. When measurement time factor was analyzed, it was seen that there was a significant difference in the achievement levels of students in both groups. The effect size was found to be large ($\eta 2$ =.893). This finding was an expected outcome because the preliminary information levels of the students before the experimental process were relatively low. Mixed design ANOVA results also indicated no significant difference between the achievement scores of group variables (experimental and control) and measurement time variables (pre-test and post-test) ($F_{(1;66)}$=9.024; $p>0.005$). The overall findings of mixed design ANOVA point out that the success level of students in both groups increased in a statistically significant way.

Regarding the post-test statistics, even though the experimental group's mean score is higher (25 to 23.7941 out of 45), standard deviation is lower (7.36083 to 9.78180) and the minimum score is higher (12 to 1) than the control group's scores, the differences were not enough to provide a statistically significant difference. Therefore, it can be concluded that the experimental process did not make a statistically significant effect on the achievement scores of students in the experimental group. The positive or negative effects on student achievement can result from the manner in which the approach is applied, the quality of the open courseware used, or the time the materials were shared with students.

In order to analyze possible reasons behind the findings of the first phase of the followed research model, we checked the findings of the second and third phases. The second phase was involved with RQ.2 and surveys were conducted to gather feedback from the experimental and the control group students. The students remarked in the surveys that open courseware shared with both groups was useful for their understanding of the course. This finding is parallel with previous studies, as Cheung (2018) suggested that students generally consider open courseware useful for learning purposes. When the feedback of additional materials provided to the experimental group was analyzed, it was observed that even though the examples were the third most commonly used material type, they resulted in the highest satisfaction level in students. Therefore, the experimental group students perceived examples as the most satisfactory open courseware. However, the perceptions of students related to experiment videos were the opposite. Experiment videos were considered the least used material type, resulting in the lowest satisfaction level. This might have been a factor for not observing a statistically significant difference between the academic achievement of students in the experimental and the control group.

Qualitative data collected in the third phase by conducting semi-structured focus group interviews with the experimental group students were analyzed to answer RQ.3. Students' opinions regarding the followed approach were categorized as benefits and obstacles with each category including three themes. The first theme of the benefits category involves Moodle platform. Students mentioned that sharing all open courseware and announcements via Moodle, which was used actively as a single source, provided enhanced accessibility. The other two themes indicated the benefits received from each additional material type provided to the experimental group. Regarding the second theme, students stated that examples were the most useful material type that helped them to practice theoretical information. They also mentioned that having examples related to real life problems made it easy for them to comprehend the topics; thus, they asked for the number of examples to be increased. As part of the third theme pointing out the benefits of the open courseware, students expressed that experiment videos helped them recognize the mistakes they made during lab exercises and provided easier and shorter solutions. Since students perceive technological education environments as more convenient for learning (Aşıksoy & Özdamlı, 2017), using examples and watching experiment videos might have had a positive effect on the opinions and academic achievement of the students. Also, students suggested that simulator studies were useful to observe the behavior of the circuit, in response to different input combinations, and made it easier to comprehend theoretical concepts. This finding is supported by the studies of Alsadoon et al. (2017), Roy et al. (2015) and Stanisavljevic et al. (2013).

On the other hand, obstacles category includes 2 themes related to lab exercises and 1 theme about experiment videos. As the first theme, students stated that the time allocated for lab exercises were not enough to complete the experiments on time and time restrictions put pressure on them. In the second theme, they mentioned that having one lab assistant caused delays in getting their circuit designs checked. The third theme reflected the view of students on the inefficiency caused by the upload times of the experiment videos. They stated that if they had been able to watch the experiment videos before lab exercises, they could have been more familiar with the circuits they would implement and recognize their mistakes more easily and complete the experiments faster. Therefore, students associated the difficulties and delays they had while performing lab experiments with the fact that the related videos were uploaded after the lab exercises. This reflection and the limited usage of experiment videos obtained from the survey might have had a negative effect on the experimental process and therefore, might have contributed to the lack of statistically significant gain on academic achievement of the students in the experimental group.

Another point to consider regarding the evaluation of the effect of the applied teaching method can be the success rates of students who were enrolled into the course in the last two years. 52.4% of 145 students who took the Logic Design course at CBU Department of Computer Engineering in the academic year 2016-2017 were successful. However, 61% of 132 students in the academic year 2017-2018 passed the course. The increase in the percentage of students who passed the course can be seen as the effect of the course design supported by open courseware on the academic success of the students. However, this implication takes into account the success of all students taking the course. In this regard, it should be noted that even though a pre-test post-test control group experimental research design was followed in this study, some of the developed open courseware was provided to both groups. The feedback gathered from the open-ended question of the surveys also supports that this year students in both groups benefited from the followed course design.

To summarize the findings of the entire analysis, it can be concluded that both the experimental and the control group students perceived the open courseware they were able to access useful for learning purposes. This result is parallel with the existing researches that studied the effectiveness of open courseware (Cheung, 2018; Mohandes et al., 2006).

Most of the related studies about logic design focus on tool development such as simulators and web-based platforms by using deterministic approaches (Alsadoon et al., 2017; Baneres et al., 2014; El-Din & Krad, 2011; Roy et al., 2015; Shoufan et al., 2015; Stanisavljevic et al., 2013). However, this study follows an instrumentalist perspective and offers a course design based on the acquisitions aimed to be made by the students. For evaluation purposes, there are studies using logic design achievement instruments consisting of multiple choice questions (Ben-David Kolikant & Genut, 2017; Herman, 2011; Herman & Loui, 2011; Herman et al., 2010). In this regard, it should be noted that this study is the first one in the literature conducted for Logic Design course that uses an achievement instrument including open-ended questions. Therefore, its findings can pave the way for new studies in the future.

The feedback of students obtained from the focus group interviews and the surveys were important for the evaluation of the followed approach and the revision of the course for the following years. In this regard, the following suggestions were made by students during focus group interviews to revise the course:

> "Better communication and collaboration could have been provided if the forum feature of Moodle was activated for this course. We could have asked questions, checked what other students shared and supported each other more efficiently." (FGI1-St2)
>
> "The number of examples including real life problems and current topics could be increased." (FGI3-St15, St17)
>
> "It would have been better if the examples had been provided weekly instead of once in 2-3 weeks based on the topics taught." (FGI1-St6)
>
> "Term projects related to current topics can be assigned." (FGI2-St8, St9)
>
> "It could be better if there were also videos explaining examples. We might have been able to repeat the topics and reinforce subjects that we could not comprehend in face-to-face lessons." (FGI1-St6)

Logic Design course can be taught the following year by taking into consideration these suggestions. Therefore, the course designed in this study can be revised by utilizing the forum feature of Moodle, increasing the number of examples, providing examples related to real life problems and current topics, uploading examples every week, assigning term projects and providing videos for examples.

New research studies can be designed and conducted based on the feedback received from students. In this regard, for the design of next year's course, providing experiment videos before lab exercises can prevent the disadvantage of timing difficulties in lab exercises and also can help the lab assistant to better coordinate the lab sessions. Thus, the three themes in the obstacle category of focus group interview findings can be improved by offering a new course design in which experiment videos will be provided before lab sessions. So, the lab manual handbook can be updated for each lab task to include two circuit designs. The experiment video for the first circuit design can be shared with students before the lab sessions and the second circuit can be implemented on breadboard by students during lab sessions.

The Logic Design course proposed by this study can be seen as a foundation for future studies in the field. More emphasis can be given to student-oriented approaches. Therefore, new course designs based on peer learning and collaborative learning, in which students will work together and be more active, can be conducted. A project-oriented approach can also be followed. In this regard, it is planned to enhance the prepared open courseware, revise the course provided in this study according to the findings and conduct a new research study in the following academic year. After these enhancements, the open courseware can be used by different departments and universities that offer Logic Design course. Another future work guideline can be conducting longitudinal studies in different institutes.

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Kolegij Logički dizajn temeljen na otvorenim obrazovnim materijalima

Sažetak

Logički dizajn jedan je od glavnih kolegija mnogih inženjerskih smjerova te predstavlja osnovu daljnjih kolegija u području hardverskih tehnologija. U ovome istraživanju prikazano je kako je nastava kolegija Logički dizajn osmišljena uz pomoć otvorenih obrazovnih materijala. U skladu s tim, pripremljen je nastavni plan i program, slajdovi, priručnik za laboratorijske vježbe s pripadajućim opisima eksperimenata i simulacija, videosnimke eksperimenata, zadatci i primjeri. Cilj je ovoga istraživanja utvrditi utjecaj provedbe kolegija Logički dizajn uz pomoć otvorenih nastavnih materijala na uspjeh studenata. Također je cilj i saznati mišljenja studenata o takvom nastavnom pristupu. Istraživanje je provedeno pomoću metode mješovitoga pristupa eksperimentalnom istraživanju, s predtestom i posttestom za kontrolnu skupinu. Istraživanje je provedeno na Sveučilištu Manisa Celal Bayar u Turskoj tijekom ljetnoga semestra u akademskoj godini 2017./2018., na uzorku od 68 studenata inženjerstva. Dok su studenti iz eksperimentalne skupine kroz ovaj kolegij prolazili uz pomoć otvorenih nastavnih materijala, za kontrolnu skupinu održana je samo uobičajena nastava. Kvantitativni podatci prikupljeni su pomoću testa postignuća koji se sastojao od pitanja otvorenoga tipa i upitnika. Kvalitativni podatci prikupljeni su pomoću polustrukturiranih intervjua s fokusnom grupom. Rezultati su detaljno analizirani kako bi se dobile sugestije za reviziju kolegija. Na kraju se raspravlja o smjernicama za daljnji rad.

Ključne riječi: *Logički dizajn; nacrt kolegija; obrazovanje na tehničkim fakultetima; otvoreni nastavni materijali; postignuća.*

Uvod

Logički dizajn jedan je od temeljnih kolegija mnogih studijskih programa u različitim inženjerskim smjerovima, poput Računalnog inženjerstva, Softverskog inženjerstva, Električnog i elektroničkog inženjerstva i Mehatronike (Baneres, Clariso, Jorba i Montse, 2014; Mohandes, Dawoud, Al Amoudi i Hussain, 2006; Oliver i Haim, 2009; Todorovich i Vazquez, 2012). Ovaj je kolegij osnova za znanost na nacionalnoj razini (Wang i Zheng, 2017) i za ostale hardverske kolegije poput Računalne arhitekture, Digitalnog računalnog dizajna, Ugradbenih računalnih sustava, Mikroprocesora i Mikrokontrolera (Calazans i Moraes, 2001; Hamacher, Vranesic, Zaky i Manjikian, 2012; Mohandes i sur., 2006; Shoufan, Lu i Huss, 2015). ACM (2016) predlaže da bi ovaj kolegij, pod imenom Digitalni uređaji, trebao biti temeljni kolegij u kurikulu računalnoga inženjerstva. Logički dizajn kao kolegij također je u skladu sa zajedničkim ishodima programa koji se provode na Odsjeku za računalno inženjerstvo i Odsjeku za električno i elektroničko inženjerstvo na Sveučilištu Manisa Celal Bayar (CBU, 2018a; CBU, 2018b), a koji se mogu sažeti kao „moći koristiti znanje o inženjerstvu i temeljnim znanostima pri rješavanju tehničkih problema; moći definirati, analizirati i interpretirati tehničke probleme; moći osmisliti eksperimente povezane s tehničkim problemima i analizirati njihove rezultate". Kolegij Logički dizajn može se u Turskoj naći i pod drugim imenima, kao što su Digitalni sklopovi i sustavi, Dizajn logičkoga sklopa i Digitalni logički dizajn, ovisno o odsjeku i sveučilištu (Atılım, 2018; Ege, 2018; Marmara, 2018).

Logički dizajn uključuje teorijsku nastavu i laboratorijske vježbe. Izvođenje nastave ovoga kolegija isključivo u obliku predavanja može biti neučinkovito i nedovoljno (Alsadoon, Prasad i Beg, 2017; El-Din i Krad, 2011). Logički dizajn „uključuje ne samo dizajniranje, simulaciju i testiranje digitalnih sustava, nego i dobivanje, analizu i interpretaciju podataka te, kada god je to potrebno, korištenje tih podataka kako bi se popravio ili unaprijedio dizajn" (Stanisavljevic, Pavlovic, Nikolic i Djordjevic, 2013, str. 235). Stoga ovaj kolegij zahtijeva naporan rad i visoku razinu pažnje. Kada se provjerila razina uspješnosti studenata koji su odabrali kolegij Logički dizajn na Odsjeku za računalno inženjerstvo na Sveučilištu Manisa Celal Bayar (CBU), uočeno je da je 52,4 % od ukupno 145 studenata u akademskoj godini 2016./2017. i 61 % od 132 studenta u akademskoj godini 2017./2018. bilo uspješno. Postotak uspješnih studenata relativno je nizak. To se može objasniti činjenicom da je kolegij sadržavao veći broj novih pojmova, teorija, pristupa o kojima studenti nisu puno znali ili uopće nisu ništa znali (Shoufan i sur., 2015). Drugi faktor može biti činjenica da u skupinama ima previše studenata, što loše utječe na njihovu pažnju i rezultira gubitkom motivacije (Aye, 2018).

Zbog činjenice da su laboratorijske vježbe kolegij usmjeren na dizajn, one su ključan dio Logičkog dizajna koji omogućava usustavljivanje naučenoga i vodi boljem uspjehu studenata. Međutim, zbog velikoga broja studenata u skupinama, studenti na laboratorijskim vježbama moraju raditi u grupama, što svakome od njih otežava aktivnost u eksperimentima. Kao rezultat promatranja eksperimenata iz daljine i nedostatka prilika da ponove eksperimente, većina ih gubi motivaciju te im je razina uspješnosti niža. Zbog svega toga studenti stvaraju predodžbu o Logičkom dizajnu kao jako teškom kolegiju (Hassan, Yusof i Salleh, 2011). Stoga bi se tradicionalni pristup učenju i poučavanju trebao unaprijediti pomoću novih pristupa i tako unaprijediti način na koji studenti uče u različitim područjima (Aşıksoy i Ozdamli, 2017; Karakuş i Öztürk, 2016). U tom su smislu internetska tehnologija i mrežne aplikacije obogatile proces učenja i učinile ga uspješnim (Üzel i Özdemir, 2012) te podigle razinu motivacije studenata (Demirli i Dikilci, 2003; Strommen, 1992). Kolegiji obogaćeni multimedijom mogu povećati njihovu razinu uspješnosti (Aşıksoy i Ozdamli, 2017; Hakkari, Yeloğlu, Tüysüz i İlhan, 2017; Rusanganwa, 2015; Zahra, 2016). Kako bi se studentima omogućila učinkovita obrazovna rješenja, neophodno je prezentirati im adekvatne nastavne materijale (Swigart i Liang, 2016). U tu se svrhu kolegiji mogu obogatiti otvorenim nastavnim materijalima (Cheung, 2018), koji se definiraju kao „digitalno objavljeni nastavni sadržaji koji uključuju cijele kolegije i neke dijelove kolegija (nastavne planove i programe, nacrte, predavanja u pdf ili video formatu, slajdove, popis literature itd.), simulacije, animacije, lekcije, vježbe i praktične vježbe, module, podcaste, studije slučaja, kvizove i testove" (Swigart i Liang, 2016, str. 308). Cheung (2018) smatra da studenti općenito smatraju otvorene nastavne materijale korisnima u procesu učenja. Glavna prednost otvorenih nastavnih materijala je njihovo lako korištenje i mogućnost ponovnoga korištenja (Jung, Sasaki i Latchem, 2016). Studenti koji su odabrali isti kolegij na različitim sveučilištima ili odsjecima mogu te materijale uvijek iznova koristiti. Korištenje otvorenih nastavnih materijala smanjuje vrijeme i trošak pripremanja novih nastavnih materijala. Također, problemi koji nastaju zbog prevelikoga broja studenata u skupinama mogu se svesti na najmanju moguću razinu jer primjena otvorenih nastavnih materijala može unaprijediti proces učenja. Ako kombiniraju uobičajeni način izvođenja nastave s primjenom otvorenih nastavnih materijala, nastavnici mogu osigurati vrijeme za dodatne aktivnosti na fizičkoj nastavi i poboljšati svoj odnos sa studentima (Caswell, Henson, Jensen i Wiley, 2008).

Kada se analizira postojeća literatura o pristupima učenju uz pomoć tehnologije u kolegiju Logički dizajn, može se primijetiti da su glavna područja istraživanja uglavnom dizajn i upotreba simulatora (Alsadoon i sur., 2017; El-Din i Krad, 2011; Nikolic, Radivojevic, Djordjevic i Milutinovic, 2009; Roy, Ghosh i Mandal, 2015; Stanisavljevic i sur., 2013), razvoj mrežnih platformi (Baneres i sur., 2014; Shoufan i sur., 2015; Yılmaz, Sazak i Sarı, 2011) i aplikacije koje uključuju multimediju (Elrazig i Suliman, 2015; Kafes, 2014; Şeker, 2016; Zirve, 2014). Roy i suradnici (2015) izradili su virtualni laboratorij za računalnu organizaciju i kolegije u području logičkoga dizajna kako bi napravili simulacije eksperimenata. Shoufan i suradnici (2015) izradili su mrežnu platformu za vizualizaciju i animaciju logičkih sklopova koja predavačima predstavlja okruženje za izradu bilješki o predavanjima, zadataka i primjera, a studentima omogućava vježbu za izradu sklopova. Alsadoon i suradnici (2017) naglašavaju da korištenje različitih simulatora u kolegiju Logički dizajn ima pozitivan utjecaj na proces učenja. Baneres i suradnici (2014) osmislili su platformu za samoučenje koja omogućava studentima da izrađuju vlastite sklopove i dobiju automatski povratnu informaciju. Nadalje, otvoreni nastavni materijali također se često spominju u literaturi, posebno u nastavi videodizajna. Kafes (2014), Şeker (2016) i Zirve (2014) obogatili su logički dizajn multimedijom kako bi studentima omogućili gledanje videomaterijala o različitim temama na YouTubeu. Hassan i suradnici (2011) i Yılmaz i suradnici (2011) predložili su neke važne smjernice za izradu mrežnih stranica za kolegij Logički dizajn te su postavili mrežne aplikacije s raznovrsnim tehnologijama.

Ono što je zajedničko studijskim programima u kojima se koristi multimedija (Elrazig i Suliman, 2015; Kafes, 2014; Shoufan i sur., 2015; Şeker, 2016; Zirve, 2014) jest to da ne pokrivaju sve teme programa i fokusiraju se na određene kolegije. Stoga su za ovo istraživanje pripremljeni otvoreni nastavni materijali koji pokrivaju sve teme kolegija, a uključuju nastavni plan i program, slajdove, priručnik za laboratorijske vježbe s radnim listovima za eksperimente i simulacije, videomaterijale o laboratorijskim eksperimentima, zadatke i primjere. Stoga je cilj ovoga istraživanja ispitati koliko su učinkoviti otvoreni nastavni materijali izrađeni za kolegij Logički dizajn. Cilj je također dati priliku studentima da razviju svoje sposobnosti dizajniranja, analize, interpretacije i rješavanja tehničkih problema vezanih uz teme kolegija.

U skladu s tim ciljevima, formulirana su sljedeća istraživačka pitanja:

1. Postoji li statistički značajna razlika u akademskim postignućima studenata računalnoga inženjerstva između eksperimentalne skupine, koja je kolegij Logički dizajn odrađivala uz pomoć otvorenih nastavnih materijala i kontrolne skupine, koja je imala uobičajenu nastavu, na temelju rezultata na predtestu i posttestu?
2. Kakva su mišljenja studenata o načinu izvođenja nastave pomoću otvorenih nastavnih materijala u usporedbi s uobičajenom nastavom?
3. Kakva su mišljenja studenata u eksperimentalnoj skupini o kolegiju Logički dizajn:
   a) s obzirom na prednosti ovakvoga kolegija?
   b) s obzirom na faktore koji smanjuju uspješnost kolegija?

Metode

Model istraživanja

Ovo istraživanje, koje se sastoji od kvantitativnih i kvalitativnih podataka, koristi mješoviti istraživački pristup koji uključuje nekoliko faza. Razlog za odabir mješovitoga pristupa leži u kompleksnosti i višedimenzionalnosti događaja i činjenica u okruženjima za učenje (Yıldırım i Şimşek, 2013). Mješoviti model istraživanja uključuje postupke u kojima se kvalitativne i kvantitativne metode koriste zajedno u istraživanju kako bi se razumio problem istraživanja (Creswell i Plano Clark, 2011; Johnson i Onwuegbuzie, 2004). U istraživanju u kojemu se koristi mješoviti pristup s više faza, problem ili tema ispituje se nizom nezavisnih studija ili faza (Creswell, 2012).

Ovo istraživanje, kako je opisano na slici 1, sastoji se od tri faze. Faze imaju za cilj ispitati utjecaj otvorenih nastavnih materijala pomoću primjene predtesta i posttesta u kontrolnoj skupini, analizirati razinu zadovoljstva studenata pomoću upitnika, prikupiti mišljenja studenata o otvorenim nastavnim materijalima pomoću polustrukturiranih intervjua s fokusnim grupama.

U prvoj fazi istraživanja provodi se eksperimentalni proces. Istraživanja u kojima se ispitivala veza između zavisnih i nezavisnih varijabli bila su eksperimentalnoga tipa. Kako bi se istraživanje smatralo eksperimentalnim, potrebno je nasumičnim odabirom razvrstati ispitanike u skupine, kontrolirati utjecaj ostalih faktora koji se ne ispituju i djelovati tako da se izravno utječe na određenu varijablu (Büyüköztürk, 2012; Karasar, 2015). Eksperimentalni dizajn najpogodnija je metoda kada se određuje je li proces uspješan (Frankel, Wallen i Hyun, 2012). U ovom istraživanju primijenjeno je eksperimentalno istraživanje s predtestom i posttestom u kontrolnoj skupini kako bi se ispitao utjecaj otvorenih nastavnih materijala izrađenih za teme koje se obrađuju u sklopu kolegija Logički dizajn.

Slika 1

Eksperimentalni proces primijenjenoga modela istraživanja prikazan je u tablici 1. Studenti su nasumičnom metodom podijeljeni u eksperimentalnu i u kontrolnu skupinu. Predtestom je utvrđen stupanj sličnosti između eksperimentalne i kontrolne skupine prije eksperimentalnoga postupka (Hakkari i suradnici, 2017). Tijekom primjene toga pristupa, za kontrolnu skupinu organizirana je uobičajena nastava, dok je u eksperimentalnoj skupini uobičajena nastava obogaćena otvorenim nastavnim sadržajima. Posttest je proveden nakon toga kako bi se ispitao utjecaj otvorenih nastavnih materijala na postignuća studenata.

Tablica 1

U drugoj fazi istraživanja izrađeni su upitnici koji su podijeljeni eksperimentalnoj i kontrolnoj skupini. U trećoj fazi prikupljena su dobrovoljno predana mišljenja studenata iz eksperimentalne skupine te su opisana kroz polustrukturirane intervjue s fokusnim grupama.

Skupina koja je sudjelovala u istraživanju

Istraživanje je provedeno na skupini studenata druge godine na Odsjeku za računalno inženjerstvo Sveučilišta Manisa Celal Bayar koji su odabrali kolegij Logički dizajn tijekom ljetnoga semestra akademske godine 2017./2018. Broj studenata koji su odabrali ovaj kolegij bio je 132. Studenti koji su po drugi put pohađali ovaj kolegij (ili više od dva puta) (52 studenta) nisu sudjelovali u istraživanju. Oni koji su pohađali kolegij prvi put nasumično su svrstani u kontrolnu i eksperimentalnu skupinu. 12 studenata je isključeno iz istraživanja jer nisu dolazili na nastavu. Tako je istraživanje provedeno na uzorku od 68 sudionika (34 studenta u eksperimentalnoj i 34 studenta u kontrolnoj skupini). Eksperimentalna skupina sastojala se od 9 studentica i 25 studenata, dok se kontrolna skupina sastojala od 10 studentica i 24 studenta (tablica 2).

Tablica 2

Kako bi se odredila statistički značajna razlika između skupina prije provedbe eksperimentalnoga procesa, korištene su ukupne prosječne ocjene studenata koje su imali u semestru prije nego su odabrali kolegij Logički dizajn. Grupni rezultati nezavisnoga t-testa ukupnih prosječnih ocjena prikazani su u tablici 3. Nisu utvrđene statistički značajne razlike između ukupnih prosječnih ocjena studenata u eksperimentalnoj i kontrolnoj skupini ($t(66) = 0{,}002$, $p > 0{,}05$). Studenti su nasumično dodijeljeni objema grupama, a ovaj rezultat ide u prilog razlogu zbog čega je u istraživanju korišten dizajn eksperimentalnoga istraživanja.

Tablica 3

Kako bi se udovoljilo etičkim standardima istraživanja, sudionici bi trebali biti informirani o cilju i procesu istraživanja i dati svoj dobrovoljni pristanak (Erdoğan i Şengül, 2017; Smith, 1995). U ovom istraživanju studenti su ispunili obrazac o dobrovoljnom sudjelovanju u istraživanju. Svi su studenti predali ispunjeni obrazac.

Instrumenti za prikupljanje podataka

S ciljem prikupljanja kvantitativnih podataka, korišteni su instrumenti za mjerenje postignuća i upitnici. Kvalitativni podatci prikupljeni su snimanjem polustrukturiranih intervjua s fokusnom grupom.

Instrument za mjerenje akademskih postignuća u kolegiju Logički dizajn

Instrumenti za mjerenje akademskih postignuća u kolegiju Logički dizajn koji se spominju u literaturi sastoje se od pitanja višestrukoga izbora (Ben-David Kolikant i Genut, 2017; Herman, 2011; Herman i Loui, 2011; Herman, Loui i Zilles, 2010). Međutim, faktor pogađanja točnoga odgovora u pitanjima višestrukoga izbora može dati krivu sliku o tome koliko su studenti uistinu naučili (Peşman i Eryılmaz, 2010). Pitanja višestrukogaa izbora ne mogu biti dovoljna da bi se promatrale sposobnosti studenata pri analizi i dizajnu logičkih sklopova. Stoga su autori ovoga istraživanja izradili i u njemu koristili Instrument za mjerenje postignuća u kolegiju Logički dizajn (Balcı, Çiloğlugil i İnceoğlu, 2019), koji se sastoji od pitanja otvorenoga tipa.

Kolegij Logički dizajn uključuje sljedeće teme: brojevne sustave, uvod u logičke sklopove, kombinatoričke logičke sklopove i sekvencijalne logičke sklopove. Instrument za mjerenje postignuća u kolegiju Logički dizajn obuhvaća sljedeće teme: uvod u logičke sklopove, kombinatoričke logičke sklopove i sekvencijalne logičke sklopove. Koristio se kao predtest prije provedbe eksperimentalnoga procesa i kao posttest za procjenu postignuća studenata u kolegiju Logički dizajn. Detalji o instrumentu za mjerenje postignuća objašnjeni su u daljnjem tekstu.

Kako je Logički dizajn osnovni kolegij u studijskim programima u različitim područjima inženjerstva, pripremljen je popis očekivanih usvojenih znanja na temelju zajedničkih tema koje se obrađuju u sklopu toga kolegija na Odsjeku za računalno inženjerstvo, Odsjeku za softversko inženjerstvo, Odsjeku za električno i elektroničko inženjerstvo te Odsjeku za mehatroniku na Sveučilištu Manisa Celal Bayar, Sveučilištu u Okanu i Sveučilištu u Maltepeu. Prvo je izrađen popis očekivanih znanja koji se sastojao od 37 odrednica na kojima je izrađen skup od 54 pitanja otvorenoga tipa. U skladu sa stajalištima istraživača, brojevi su promijenjeni te je tako na popisu bilo 20 odrednica i 19 pitanja. Kako bi se omogućila objektivna evaluacija izrađenoga mjernog instrumenta, pripremljena je rubrika. Evaluacija Instrumenta za mjerenje postignuća u kolegiju Logički dizajn, koji je primijenjen kao predtest i kao posttest, provedena je pomoću te rubrike.

Kako bi se osigurala valjanost sadržaja, povratna informacija zatražena je od 6 stručnjaka u tome području, a koji rade na različitim odsjecima i sveučilištima, nakon čega su napravljene potrebne promjene. Lista usvojenih znanja finalizirana je tako da je konačan broj odrednica bio 19, kako je prikazano u tablici 4. Konačna verzija instrumenta za mjerenje postignuća sastoji se od 15 pitanja i primjera, a primjer pitanja opisan je na slici 2. Svako pitanje otvorenoga tipa u instrumentu odgovara barem jednoj odrednici usvojenoga znanja, a svaka se odrednica može mjeriti pomoću više pitanja. Indeks valjanosti sadržaja mjernoga instrumenta bio je 0,84, što upućuje na to da je valjanost sadržaja osigurana.

Pri provedbi analize pouzdanosti, instrument za mjerenje postignuća primijenjen je na skupini od 88 studenata koji su se dobrovoljno javili, a odabrali su i položili ispit iz kolegija Logički dizajn na različitim odsjecima i sveučilištima tijekom prethodne akademske godine ili prethodnoga semestra. Kako bi se izračunala pouzdanost ovoga instrumenta, odgovore 10 nasumično odabranih studenata procijenila su dva stručnjaka, pomoću izrađene rubrike. Za svaki točan odgovor studenti su mogli dobiti maksimalno 3 boda, dok su za djelomično točne odgovore mogli dobiti minimalno 1 bod. Stoga je maksimalan broj bodova koji su mogli dobiti pomoću Instrumenta za mjerenje postignuća u kolegiju Logički dizajn bio 45. Rezultati Spearmanova rho testa korelacije pokazali su da su korelacijske vrijednosti ukupnoga testa i svake stavke testa bile statistički značajne (Balcı i sur., 2019).

Tablica 4

Slika 2

Upitnici za eksperimentalnu i kontrolnu skupinu

Kako bi se dobila povratna informacija, pripremljeni su upitnici za eksperimentalnu i kontrolnu skupinu. Prethodno su ih pregledala četiri stručnjaka te su napravljene potrebne promjene i konačna verzija. Pomoću upitnika prikupile su se informacije o sljedećim skupinama tema:

- označavanju dokumenata koje su studenti koristili i razini njihova zadovoljstava prezentiranim nastavnim materijalima korištenima u kolegiju. Studenti u kontrolnoj skupini imali su tri varijante ovih pitanja: slajdove, priručnik za laboratorijske vježbe i simulator, dok su studenti u eksperimentalnoj skupini imali i dvije dodatne mogućnosti: videosnimke eksperimenata i primjere.
- težini eksperimenata
- tehničkim problemima koje su studenti imali dok su koristili platforme izrađene i za kontrolnu i za eksperimentalnu skupinu. Eksperimentalna skupina imala je

dodatno pitanje koje se odnosilo na probleme sa širinom frekvencijskoga pojasa (engl. *bandwidth*) u videomaterijalima u kojima se prikazuju eksperimenti.
– lokaciji i korištenju uređaja za pristup platformi za učenje
– mišljenjima i prijedlozima studenata u eksperimentalnoj i kontrolnoj skupini o kolegiju, koji se prikupljaju pomoću pitanja otvorenoga tipa.

Na kraju semestra studentima u gore spomenutim skupinama podijeljeni su upitnici. Upotreba upitnika u objema skupinama jamčila je povratnu informaciju od svake skupine, o materijalima kojima su mogli pristupiti.

Polustrukturirani intervjui s fokusnim grupama

Polustrukturirani intervju s fokusnom grupom je instrument za prikupljanje podataka koji se temelji na interakciji među pojedincima iz unaprijed određene skupine korištenjem unaprijed određenih tema. Odgovore svakog pojedinca mogu čuti ostali članovi skupine, što može utjecati na formiranje i izražavanje njihovih mišljenja (Yıldırım i Şimşek, 2013). Kako bi se prikupile povratne informacije o utjecaju otvorenih nastavnih materijala na postignuća studenata u eksperimentalnoj skupini, pripremljen je nacrt polustrukturiranoga intervjua. Četiri stručnjaka pregledala su taj nacrt kako bi se osigurala jasnoća pitanja i kako bi pitanja odgovarala originalnoj svrsi. Nakon toga napravljene su određene izmjene i pripremljena je konačna verzija. Intervjui s fokusnom grupom, koja se sastojala od 20 dobrovoljaca, provedeni su na kraju eksperimentalnoga procesa. Zahvaljujući činjenici da su se grupni intervjui provodili s malim skupinama od po 6-8 sudionika (Yıldırım i Şimşek, 2013), intervjui su provedeni s 3 grupe od 7 studenata (2 ženskoga, a 5 muškoga spola), 6 studenata (2 ženskoga, a 4 muškoga spola) i 7 studenata (2 ženskoga, a 5 muškoga spola). Intervjui s fokusnim grupama snimljeni su u videoformatu i kasnije transkribirani.

Kolegij Logički dizajn uz otvorene nastavne materijale

Kako bi se studentima omogućio što učinkovitiji sadržaj za kolegij Logički dizajn, cilj je obogatiti ga uz pomoć otvorenih nastavnih materijala. U tu su svrhu u obliku otvorenih nastavnih materijala pripremljeni nastavni plan i program, slajdovi, priručnik za laboratorijske vježbe s pripadajućim listovima za provedbu eksperimenata i simulacija, videosnimke laboratorijskih eksperimenata, zadatci i primjeri. Tijekom pripreme svih tih materijala smjernica su bili standardi koje su dali Jung i suradnici (2016) o kvalitetnim otvorenim obrazovnim materijalima.

Na temelju udžbenika o logičkom dizajnu pripremljeni su slajdovi (Mano, 1979; Stallings, 2005). Dodatni zadatci koji su se odrađivali na fizičkoj nastavi nisu bili uključeni u slajdove. Ukupno su zadana 4 zadatka – jedan o brojevnim sustavima, jedan o uvodu u logičke sklopove, jedan o kombinatoričkom logičkom dizajnu i jedan o sekvencijalnoj logici. Zadatci su obuhvaćali različit broj pitanja i razina težine, ovisno o usvojenim sadržajima kolegija prikazanima u tablici 4. Nadalje, izrađen je priručnik za laboratorijske vježbe koji sadrži pravila koja vrijede u laboratoriju, popis materijala potrebnih za eksperimente i 9 radnih listova za provedbu eksperimenata. U svakom eksperimentu naveden je njegov „cilj i opseg", „popis potrebnih materijala", „teorijska podloga", „uvodni laboratorijski zadatak", „eksperimentalni rad" te „rezultati i ocjena". Simulacije su također uključene u pripremne odjeljke o laboratorijskim eksperimentima jer su one učinkovit način za vizualno objašnjavanje teorijskih pojmova i mogu pomoći studentima pri boljem razumijevanju kompliciranih tema (Alsadoon i sur., 2017).

Kao dio otvorenih nastavnih materijala za eksperimentalnu skupinu, izrađeni su primjeri i videosnimke laboratorijskih eksperimenata. Pripremljeni su primjeri koji uključuju mnogobrojna pitanja različite težine. Za tu je svrhu pripremljeno 6 otvorenih nastavnih materijala koji uključuju ukupno 67 pitanja. Ti su materijali podijeljeni studentima, ovisno o temama koje su obrađivali. Videosnimke eksperimenata pripremljene su za laboratorijske vježbe kako bi omogućili studentima promatranje svake faze eksperimenta, prepoznavanje vlastitih pogrešaka, uočavanje najboljih rješenja i ponovno gledanje eksperimenata, kad god im je to potrebno. Pripremljeno je 12 videomaterijala za 9 eksperimenata. Prosječna duljina trajanja videomaterijala je 8:16 minuta, dok je pojedinačna varirala između 2:57 i 10:50, ovisno o sadržaju eksperimenta. Videomaterijali sastoje se od triju dijelova: detaljnoga objašnjenja pripremnoga rada; postavljanja sklopa na maketi; komentara o puštanju sklopa u rad s različitim ulaznim informacijama. Kao prikaz dijelova videomaterijala, na slici 3 mogu se vidjeti dvije snimke zaslona u kojima se prikazuje sadržaj videomaterijala.

Slika 3

Istraživački postupak

Istraživanje je provedeno na uzorku studenata koji su odabrali kolegij Logički dizajn na Odsjeku za računalno inženjerstvo na Sveučilištu Manisa Celal Bayar. Logički dizajn je kolegij koji traje jedan semestar (15 tjedana) te je obvezan za studente druge godine. Sastoji se od 3 sata predavanja i 2 sata laboratorijskih vježbi tjedno. Predavanja pokrivaju teorijske aspekte, dok se na laboratorijskim vježbama stječe praktično iskustvo o obrađenim temama.

U prvom koraku istraživanja osmišljeni su i izrađeni otvoreni nastavni materijali. Zatim su pripremljeni komunikacijski mediji za dijeljenje tih materijala. U tu je svrhu korištena mrežna stranica za kontrolnu skupinu, dok je u eksperimentalnoj skupini korišten sustav za upravljanje učenjem (Moodle), kako bi se osigurao pristup samo studentima iz eksperimentalne skupine putem njihovih osobnih računa.

Izrađeni otvoreni nastavni materijali postavljali su se i učinili dostupnima studentima svaki tjedan, vezano uz temu koju su obrađivali. Nadalje, sve objave i rezultati mjernih instrumenata (ispita, kvizova, zadataka i laboratorijskih eksperimenata) podijeljeni su na platformi za svaku skupinu.

Eksperimentalni proces odvijao se za vrijeme akademskoga semestra tijekom razdoblja od 11 tjedana. Za kontrolnu skupinu organizirana je normalna nastava, što znači da su pohađali predavanja o teorijskom dijelu i fizički sudjelovali u laboratorijskim vježbama. Bili su odgovorni za rješavanje zadataka, sudjelovanje u laboratorijskim vježbama, predavanje izvješća o provedenim laboratorijskim vježbama i simulacijama te polaganje ispita. Zadatke su pripremali timovi od 4 do 5 studenata odabranih iz iste skupine (ili iz kontrolne ili iz eksperimentalne). Osim toga, studenti su radili u parovima unutar iste skupine (kontrolne ili eksperimentalne) tijekom laboratorijskih vježbi. Međutim, svaki je student dobio svoju ocjenu iz laboratorijskih vježbi. Za izvedbu zadataka simulacije u sklopu eksperimenata korišten je mrežni simulator logičkih sklopova pod nazivom „simulator.io (Simulator, 2018)" koji je lako izraditi i simulirati logičke sklopove. Studenti su ručno crtali strukturne sheme u simulatoru i provjeravali svoje nacrte tako što su simulirali njihov rad za različite oblike signala (Stanisavljevic i sur., 2013).

Kao dodatak otvorenim nastavnim materijalima koji su se koristili u kontrolnoj skupini, studenti u eksperimentalnoj skupini imali su pristup i primjerima i videosnimkama eksperimenata na Moodle platformi. Primjeri su im bili dostupni na kraju teme. Poveznice na videomaterijale podijeljene su preko Moodle platforme nakon laboratorijskih vježbi. Odluka da se baš u to vrijeme postave videosnimke temelji se na radu Shoufana i suradnika (2015) na simulatorima koji su ograničavali upotrebu njihova simulatora prije roka za predaju zadataka. Na sličan način podijelili smo i videosnimke eksperimenata nakon laboratorijskih vježbi kako bismo spriječili da studenti napamet nauče korake prikazane u videosnimci i potaknuli ih na kreativnost u izradi vlastita logičkog sklopa.

Koraci u istraživačkom procesu prikazani su na slici 4. Predtest je proveden tijekom 3. tjedna (na početku eksperimentalnoga procesa). Posttest i upitnik provedeni su tijekom 15. tjedna (nakon što su obrađene sve teme). Tjedan kasnije, provedeni su polustrukturirani intervjui s fokusnim grupama koje su sačinjavali nasumično odabrani studenti iz eksperimentalne skupine. Intervjui su bili snimljeni u videoformatu.

Eksperimentalni proces popraćen je analizom kvantitativnih i kvalitativnih podataka i evaluacijom rezultata.

Analiza podataka

Instrumenti i analize koje su korištene kako bi se istražila pitanja postavljena u istraživanju prikazani su u tablici 5. Za prikupljanje kvantitativnih podataka korišteni su Instrument za mjerenje postignuća u kolegiju Logički dizajn i upitnici za eksperimentalnu i kontrolnu skupinu. Provedene su deskriptivne statističke analize i mješovita ANOVA kako bi se analizirali podatci prikupljeni tim mjernim instrumentima. Za analizu kvantitativnih podataka korišten je SPSS v22.

S druge strane, provedeni su polustrukturirani intervjui s fokusnim grupama kako bi se prikupili kvalitativni podatci za analizu procesa učenja kod studenata i kako bi se poboljšao sam kolegij. Metoda analize sadržaja korištena je pri analizi ovih podataka. Ta metoda obuhvaća izradu kodova i tema, interpretaciju uzročno-posljedičnih veza i prezentaciju rezultata na pregledan način (Atman Uslu, 2013).

Slika 4

Tablica 5

Rezultati

Rezultati predtesta i posttesta

Za prvo pitanje postavljeno u istraživanju, koje je prikazano u tablici 5, korišten je Instrument za mjerenje postignuća u kolegiju Logički dizajn kao predtest i kao posttest. Taj instrument sastoji se od 15 pitanja, a maksimalan broj bodova za točne odgovore za svako pitanje je 3 boda pa je 45 bodova maksimalan broj bodova koji se pomoću ovoga instrumenta može dobiti. Deskriptivni podatci, koji uključuju N (broj sudionika), minimalne i maksimalne rezultate, srednju i standardnu devijaciju kod predtesta i posttesta za kontrolnu i eksperimentalnu skupinu prikazani su u tablici 6.

Tablica 6

Da bi se odgovorilo na prvo pitanje istraživanja, provedena je mješovita ANOVA kako bi se procijenila akademska postignuća studenata u kolegiju Logički dizajn. Rezultati prikazani u tablici 7 ne pokazuju statistički značajnu razliku između eksperimentalne i kontrolne skupine ($F_{(1;66)} = 0{,}410$; $p > 0{,}05$). Na osnovi vremenskoga faktora mjerenja, utvrđena je statistički značajna razlika u rezultatima testa postignuća ($F_{(1;66)} = 19670{,}259$; $p < 0{,}001$). Štoviše, utvrđeno je i da mjerenje snage veze (Eta kvadrat) ima jaku veličinu učinka ($\eta 2 = 0{,}893$) (Cohen, 1998). Taj rezultat pokazuje da je razina uspješnosti studenata u objema skupinama bila povećana.

Tablica 7

S druge strane, kada se analizirala interakcija između grupe x i vremena, nije uočena značajna razlika između grupnih varijabli rezultata na testu postignuća (za eksperimentalnu i kontrolnu skupinu) i varijabli vremena mjerenja (predtest i posttest) ($F_{(1;66)} = 9{,}024$; $p > 0{,}005$). Ovaj je rezultat grafički prikazan na slici 5. Rezultati predtesta bili su sličnih vrijednosti i kod eksperimentalne i kod kontrolne skupine. Rezultati posttesta eksperimentalne skupine bili su nešto bolji nego rezultati kontrolne skupine. Međutim, postoji porast u vrijednosti rezultata na testu postignuća kod obiju skupina. Iako rezultati nisu pokazali značajnu razliku, srednji rezultat eksperimentalne skupine je viši (25 do 23,7941 od 45), standardna devijacija je niža (7,36083 do 9,78180), a najmanji rezultat je viši (12 do 1), u usporedbi s rezultatima kontrolne skupine. Stoga se može reći da je eksperimentalna skupina imala koristi od eksperimentalnoga procesa.

Slika 5

Rezultati upitnika

Kako bi se odgovorilo na drugo pitanje postavljeno u istraživanju, korišteni su upitnici izrađeni posebno za eksperimentalnu i posebno za kontrolnu skupinu. 31 od 34 sudionika iz eksperimentalne skupine i 32 od 34 sudionika iz kontrolne skupine popunilo je upitnike. Rezultati su interpretirani na temelju četiriju skupina pitanja, usporedbom rezultata eksperimentalne i kontrolne skupine. Peta kategorija upitnika, koja se sastoji od pitanja otvorenoga tipa, također je analizirana i o njoj će se ovdje raspravljati. Protumačena je pomoću rezultata intervjua s fokusnim grupama u zasebnom odjeljku.

Statistički podatci o upotrebi nastavnih materijala u eksperimentalnoj i u kontrolnoj skupini prikazani su padajućim redom u tablicama 8 i 9, za svaku skupinu posebno. Može se uočiti da su slajdovi (kod 30 od 31 ispitanika) najčešće korištena vrsta materijala u eksperimentalnoj skupini, dok je priručnik za laboratorijske vježbe (kod 28 od 32 sudionika) bio najčešće korištena vrsta materijala u kontrolnoj skupini. Kada su analizirani dodatni materijali za eksperimentalnu skupinu, uočeno je da je primjere koristilo 80,6 % (25 od 31) studenata, dok je videosnimke eksperimenata koristilo 58,1 % (18 od 31) studenata. Upotreba primjera bila je jednaka upotrebi uobičajenih nastavnih materijala, kako je prikazano u tablicama 8 i 9. Međutim, broj studenata koji su koristili videosnimke eksperimenta bio je najniži, u usporedbi s upotrebom ostalih vrsta materijala.

Za određivanje razine zadovoljstva studenata korištena je Likertova skala od 5 stupnjeva: „uopće se ne slažem" (1), „ne slažem se" (2), „donekle se slažem" (3), „slažem se" (4), „u potpunosti se slažem" (5). Razine zadovoljstva nastavnim materijalima korištenima u eksperimentalnoj i kontrolnoj skupini prikazane su padajućim redom u tablicama 10 i 11, za svaku skupinu posebno. Uočeno je da su primjeri kao vrsta materijala povezani s najvišom razinom zadovoljstva studenata u eksperimentalnoj skupini, dok je priručnik za laboratorijske vježbe povezan s najvišom razinom zadovoljstva studenata u kontrolnoj skupini. Razine zadovoljstva studenata kontrolne skupine prikazane u tablici 11 imaju isti poredak kao i poredak frekvencija upotrebe prikazan u tablici 9.

Tablica 8

Tablica 9

Tablica 10

Tablica 11

Kada su analizirani dodatni materijali korišteni u eksperimentalnoj skupini, uočeno je da su primjeri rezultirali najvišom razinom zadovoljstva, dok su videosnimke eksperimenata bile povezane s najnižom razinom zadovoljstva studenata. Iako su primjeri bili treća po redu najčešće korištena vrsta materijala (tablica 8), kod studenata su bili povezani s najvišom razinom zadovoljstva (tablica 10). Ovaj rezultat pokazuje da, iako primjeri nisu najčešće korištena vrsta materijala, povezani su s najvišom razinom zadovoljstva studenata. Nadalje, videosnimke eksperimenata koristio je najmanji broj studenata te je njihova razina zadovoljstva vezana uz njih bila najniža. Ovi rezultati su proporcionalni. O mogućim razlozima koji to objašnjavaju bit će više riječi kada se bude raspravljalo o rezultatima intervjua s fokusnim grupama.

Studenti su isto trebali poredati eksperimente koje su provodili na laboratorijskim vježbama po težini. Rezultati su prezentirani u tablicama 12 i 13, pomoću srednjih vrijednosti prikazanih padajućim redom, posebno za eksperimentalnu i posebno za kontrolnu skupinu. Studenti iz eksperimentalne skupine smatrali su da se razina težine eksperimenata povećava sa svakim sljedećim eksperimentom. Smatrali su da je najteži od njih „E9 – brojači". S druge strane, poredak eksperimenata po težini, prema studentima iz kontrolne skupine, bio je isti kod prvih šest eksperimenata, no drugačiji kod zadnja tri eksperimenta. Eksperiment „E7 – multipleksor, demultipleksor" ocijenjen je kao najteži eksperiment.

Statistički podatci o broju pregleda videosnimke svakog eksperimenta u korelaciji su s težinom eksperimenta, onako kako je percipiraju studenti. Kako su teme postajale kompleksnije i teže, tako je rastao i broj pregleda videomaterijala vezanih za te teme. Međutim, videosnimak prvoga eksperimenta bio je najgledaniji video, što se može pripisati faktoru znatiželje.

Studenti su također trebali dati osvrt na moguće probleme s kojima su se susreli prilikom pristupa mrežnoj platformi kolegija. Rezultati su pokazali da nijedan student ni iz jedne skupine nije imao problema s pristupom mrežnoj platformi izrađenoj za njih. Međutim, troje studenata iz eksperimentalne i dvoje studenata iz kontrolne skupine imalo je problema s internetskom vezom. Studenti u eksperimentalnoj skupini imali su dodatno pitanje o mogućim problemima sa širinom frekvencijskoga pojasa pri gledanju videosnimki eksperimenata. Samo je jedan student naveo taj problem, što je u skladu s odgovorom o problemima s internetskom vezom.

Tablica 12

Tablica 13

Također su ispitane i lokacije i uređaji s kojih su studenti iz eksperimentalne i kontrolne skupine pristupali mrežnoj platformi. Rezultati vezani uz prvo pitanje bili su jednaki kod obiju skupina, jer su uglavnom platformi pristupali od kuće, a ne iz kampusa ili uz ureda. Međutim, rezultati vezani uz drugo pitanje bili su nešto drugačiji. Čak iako su osobna računala bila najčešće korištena vrsta uređaja za pristupanje mrežnoj platformi, manji broj studenata iz eksperimentalne skupine koristio je osobna računala, jer su se neki od njih radije koristili prijenosnim računalima, tabletima i mobitelima.

Upitnik je također uključio i pitanje otvorenoga tipa: „Koje je tvoje mišljenje i kakve prijedloge možeš dati o kolegiju općenito?" U kontrolnoj skupini je 22 od 32 studenta odgovorilo na ovo otvoreno pitanje, a u kontrolnoj skupini na njega je odgovorilo 19 od 31 studenta. Koristi od cijeloga procesa i prepreke za uspješnost kolegija koje su studenti iz obiju skupina spomenuli prikazane su u daljnjem tekstu.

Koristi koje su imali od procesa:

- koristi od zajedničkih nastavnih materijala: 3 studenata iz svake skupine izrazilo je zadovoljstvo nastavnim materijalima koje su koristile obje skupine.
- koristi od otvorenih nastavnih materijala: 6 studenata iz eksperimentalne skupine izričito je spomenulo da su primjeri i videosnimke eksperimenata bili dobro pripremljeni i korisni u procesu učenja.

Prepreke za uspješnost kolegija:

– Laboratorijske vježbe ne traju dovoljno dugo: 6 studenata iz eksperimentalne skupine i 2 studenata iz kontrolne skupine navelo je da vrijeme predviđeno za laboratorijske vježbe nije dovoljno da bi se dovršili eksperimenti.
– Nedovoljan broj asistenata u laboratorijskim vježbama: 3 studenta iz eksperimentalne skupine i 2 studenta iz kontrolne skupine navelo je da su, zbog toga što je na laboratorijskim vježbama bilo previše studentskih timova, morali čekati da asistenti provjere njihove modele sklopova i odgovore na njihova pitanja. Zato smatraju da bi 2 asistenta u laboratoriju dovela do boljih rezultata.
– Težina nastavnoga sadržaja: 5 studenata iz kontrolne skupine spomenulo je da su izgubili korak s kolegijem zbog težine druge polovice nastavnoga sadržaja. Međutim, studenti iz eksperimentalne skupine nisu dali povratnu informaciju o ovoj temi.
– Vrijeme postavljanja videomaterijala o eksperimentima: 1 student iz eksperimentalne skupine spomenuo je da je imao poteškoća dok je provodio laboratorijske eksperimente zbog toga što je nekoliko bitnih videomaterijala postavljeno nakon provedenih laboratorijskih vježbi.

Također, 4 studenta iz eksperimentalne skupine smatra da bi veći broj primjera poboljšao uspješnost kolegija. Nadalje, 3 studenta iz kontrolne skupine i 2 iz eksperimentalne skupine smatraju da bi više primjera o svakodnevnim životnim problemima u teorijskim predavanjima bilo korisno za bolje razumijevanje sadržaja.

Rezultati polustrukturiranih intervjua s fokusnim grupama

Kako bi se odgovorilo na treće pitanje postavljeno u istraživanju, primjenom analize sadržaja analizirani su kvalitativni podatci prikupljeni putem polustrukturiranih intervjua s fokusnim grupama koje su se sastojale od studenata iz eksperimentalne skupine. U njima su određene dvije kategorije i tri teme. Navode se neka bitna mišljenja studenata, prema broju intervjua s fokusnom grupom te pod posebnom šifrom studenta (FGIx-Sty). Prva kategorija obuhvaćala je koristi, a sastojala se od triju tema. Svaka tema je opisana u daljnjem tekstu.

– Korist od dijeljenja otvorenih nastavnih materijala na Moodle platformi - studenti su izrazili zadovoljstvo što su na Moodle platformi dobivali materijale na organizirani način.

> „Dijeljenje eksperimenata, primjera, priručnika za laboratorijske vježbe, zadataka i obavijesti putem Moodle platforme kao jedinstvenog izvora poboljšalo je dostupnost tih svih materijala." (FGI1-St1, St2, St3, St7, FGI3-St14, St16, St17, St20)

> „U ovome kolegiju Moodle platforma se koristila vrlo aktivno. To nam je omogućilo da redovito provjeravamo stranicu kolegija, barem jednom tjedno, i pregledavamo priručnik za laboratorijske vježbe, slajdove, primjere i sve što je vezano uz laboratorij i zadatke." (FGI1-St5, St6, FGI2-St8, St9, St12, St13, FGI3-St15, St16, St19)

– Korist od primjera – studenti su izjavili da su primjeri bili jako korisni za povezivanje teorije i prakse.

„Meni su najkorisniji materijali koji su nam bili dostupni bili primjeri. Pomogli su mi provježbati teorijske informacije koje sam naučio na nastavi. Shvatio sam gradivo bolje nakon proučavanja primjera." (FGI2-St8, St10, St13)

„Bilo je korisno imati primjere povezane sa stvarnim životnim problemima, kao što je primjer o spremniku. Možemo bolje povezati teoriju i praksu ako se poveća broj ovakvih primjera." (FGI2-St11)

– Korist od videosnimki eksperimenata – studenti su naveli da su ovakvi videomaterijali bili dobro pripremljeni i korisni u procesu učenja.

„Gledanje videomaterijala o eksperimentima pomoglo mi je prepoznati vlastite pogreške u laboratorijskim vježbama, što mi je pomoglo da popravim svoj rad u daljnjim aktivnostima u laboratoriju. Bilo mi je jako korisno, pogotovo kod teških tema u sljedećem semestru." (FGI1-St6)

„Mogao sam uspješno provesti eksperimente tijekom laboratorijskih vježbi pa nisam morao gledati videomaterijale o njima. Međutim, neke od njih sam provjerio iz znatiželje ili kako bih se podsjetio kako smo provodili neke operacije. Neki dijelovi videa pomogli su mi shvatiti da se nisam trebao toliko mučiti tijekom laboratorijskih vježbi jer postoje lakša i brža rješenja." (FGI1-St2)

Tri teme druge kategorije, prepreka uspješnosti kolegija, objašnjenje su u daljnjem tekstu.

– Laboratorijske vježbe nisu dovoljno dugo trajale – studenti su naveli da vrijeme dodijeljeno laboratorijskim vježbama nije bilo dovoljno kako bi se dovršili eksperimenti.

„Vrijeme isplanirano za prvih nekoliko eksperimenata bilo je dovoljno, ali mi nismo uspjeli dovršiti eksperimente na vrijeme jer su vremenom postajali sve kompliciraniji. Vremenska ograničenja stavljala su pritisak na nas." (FGI2-St8, St9, St10, St11, St12, St13, FGI3-St14, St15, St16, St17, St18)

– Nedovoljan broj asistenata u laboratoriju – studenti su naveli da su morali čekati da im se pregleda model sklopa jer je u laboratoriju bio prisutan samo jedan asistent.

„Asistent je pokušavao posvetiti vrijeme svakome od nas. No, morali smo čekati da provjeri naš rad i odgovori nam na pitanja. Bilo bi puno učinkovitije da postoje dva asistenta u laboratoriju." (FGI1-St2, St3, St5, St6, St7, FGI2-St8, FGI3-St14, St15, St19)

– Propust nastao zbog nedijeljenja videomaterijala prije laboratorijskih vježbi – studenti su spomenuli da su imali poteškoća s provedbom eksperimenata u laboratoriju zato što su videomaterijali postavljeni na platformu nakon laboratorijskih vježbi.

„Nemogućnost da pogledamo videosnimke eksperimenata prije laboratorijskih vježbi izazvala je kašnjenja. Trebalo je dosta vremena kako bi se pronašle i

> popravile pogreške koje smo napravili u izradi sklopova i njihovom puštanju u rad. Da smo mogli pogledati videosnimke eksperimenata prije laboratorijskih vježbi, bolje bismo se upoznali sa sklopovima koje trebamo izraditi i lakše i brže prepoznali vlastite greške te eksperimente dovršili u kraćem roku. Videomaterijali pružili bi nam početne informacije i mogli bismo razumjeti što možemo bolje uraditi." (FGI1-St2)

Također, studenti su izjavili da je, kao priprema za rad, proučavanje simulacija korisno za bolje razumijevanje rada sklopova.

> „Simulacije rada sklopova prije laboratorijskih vježbi skratile su vrijeme potrebno za puštanje logičkih sklopova u rad. Simulacije su nam pomogle provjeriti hoće li sklop koji smo izradili dobro funkcionirati. Također smo mogli pustiti logičke sklopove u rad pomoću logičkoga dijagrama koji smo izradili pomoću simulatora." (FGI1-St1, St3, St6)

Nadalje, svi studenti koji su sudjelovali u FGI1 naveli su da su imali poteškoća, posebno s onim temama koje su se obrađivale u drugom dijelu semestra. Studenti su također izjavili da su eksperiment broj 8 i eksperiment broj 9 imali iznimno teške nacrte sklopova i bilo ih je teško izraditi (FGI1-St6). Ova su dva rezultata paralelna jer ti eksperimenti obuhvaćaju teme koje se obrađuju u drugom dijelu semestra. Tome u prilog idu i rezultati upitnika za obje skupine jer su ti eksperimenti istaknuti kao prvi i drugi najteži eksperiment među studentima iz eksperimentalne skupine, dok su ih studenti iz kontrolne skupine naveli kao drugi i treći najteži eksperiment. Videosnimke ovih eksperimenata bile su među najgledanijim videomaterijalima.

Povratna informacija dobivena putem pitanja otvorenoga tipa u upitniku također je išla u prilog rezultatima intervjua s fokusnim grupama. Studenti u eksperimentalnoj i u kontrolnoj skupini naveli su da su otvoreni nastavni materijali koji su im bili dostupni bili korisni u procesu učenja. Također su utvrđena i dva zajednička rezultata dobivena upitnikom i intervjuima s fokusnim grupama - laboratorijske vježbe nisu dovoljno dugo trajale i u laboratoriju nije bio dovoljan broj asistenata. Rezultati intervjua s fokusnim grupama povezani s primjerima i videosnimkama eksperimenata također su dobili uporište i u odgovorima studenata iz eksperimentalne skupine na pitanja otvorenoga tipa u upitniku.

Rasprava i zaključak

Kolegij Logički dizajn predstavlja osnovu za znanost na nacionalnoj razini u području električnoga inženjerstva, elektronike i tehnologije, informacijskoga i komunikacijskoga inženjerstva, računalnih znanosti i tehnologije (Wang i Zheng, 2017). Kolegij je također u skladu sa zajedničkim obrazovnim ishodima na tim odsjecima. Neki od ishoda su: razvoj vještina izrade eksperimenata pomoću analize problema; interpretiranje i rješavanje problema te analiza rezultata.

U ovom istraživanju ispitan je utjecaj kolegija Logički dizajn, potpomognut otvorenim nastavnim materijalima, na akademska postignuća studenata. U skladu s nastavnim planom i programom kolegija, izrađeni su različiti materijali, poput slajdova, priručnika za laboratorijske vježbe s radnim listovima za eksperimente i zadatke simulacije, videosnimke eksperimenata, zadaci i primjeri, po temama koje su se obrađivale svakog tjedna. Studenti su tim materijalima i svim obavijestima mogli pristupati preko mrežne platforme izrađene za kolegij.

U istraživanju je primijenjen dizajn mješovitih metoda s višestrukim fazama. Proveden je eksperimentalni proces s predtestom i posttestom za kontrolnu skupinu tijekom prve faze, kako bi se ispitao utjecaj otvorenih nastavnih materijala. U tu su svrhu Balcı i suradnici (2019) izradili Instrument za mjerenje postignuća u kolegiju Logički dizajn koji je primijenjen kao predtest i posttest. U drugoj i trećoj fazi prikupljena su mišljenja studenata pomoću upitnika i polustukturiranih intervjua s fokusnim grupama, u svakoj fazi zasebno.

Rezultati prve faze koji se odnose na prvo pitanje postavljeno u istraživanju procijenjeni su pomoću mješovite ANOVA analize. Rezultati mješovite ANOVA analize pokazali su da nije uočena statistički značajna razlika između eksperimentalne i kontrolne skupine ($F_{(1;66)} = 0,410$; $p > 0,05$). Stoga nije pronađena ni značajna razlika u rezultatima između te dvije skupine na predtestu i posttestu. Kada je analiziran faktor mjerenja vremena, uočeno je da postoji značajna razlika u razinama postignuća studenata obiju skupina. Utvrđeno je da je veličina učinka velika ($\eta 2 = 0,893$). Taj je rezultat očekivan jer su prethodni rezultati studenata, prije provedbe eksperimentalnog procesa, bili na niskoj razini. Rezultati mješovite ANOVA analize nisu upućivali na značajnu razliku između rezultata postignuća u grupnim varijablama (kod eksperimentalne i kontrolne skupine) i vremena mjerenja varijabli (predtest i posttest) ($F_{(1;66)} = 9,024$; $p > 0,005$). Ukupni rezultati mješovite ANOVA analize pokazuju da je razina uspješnosti studenata statistički značajno povećana kod obiju skupina.

Što se tiče statističkih podataka o posttestu, čak iako je srednja vrijednost rezultata eksperimentalne skupine viša (25 do 23,7941 od 45), standardna devijacija niža (7,36083 do 9,78180), a minimalni rezultat viši (12 do 1) nego kod kontrolne skupine, razlike nisu dovoljno velike da bi predstavljale statistički značajnu razliku. Stoga se može zaključiti da eksperimentalni proces nije imao statistički značajan utjecaj na postignuća studenata iz eksperimentalne skupine. Pozitivan ili negativan utjecaj na postignuća studenata može biti rezultat načina na koji se određeni pristup provodi, kvalitete otvorenih nastavnih materijala koji se koriste ili vremena kada se materijali podijele studentima.

Kako bi se analizirali mogući razlozi za rezultate prve faze primijenjenoga modela istraživanja, provjerili smo rezultate druge i treće faze. Druga faza bila je povezana s drugim pitanjem istraživanja, a upitnici su provedeni kako bi se dobila povratna informacija od studenata iz eksperimentalne i iz kontrolne skupine. Studenti su u upitnicima naveli da su otvoreni nastavni materijali koji su podijeljeni objema skupinama bili korisni za razumijevanje sadržaja kolegija. Ovaj je rezultat u skladu s ranijim istraživanjima. Cheung (2018) je primijetio da studenti općenito smatraju otvorene nastavne materijale korisnima u procesu učenja. Kada su analizirane povratne informacije koje je dala eksperimentalna skupina o dodatnim materijalima, uočeno je da, iako su primjeri bili treća po redu najčešće korištena vrsta materijala, oni su kod studenata bili povezani s najvišom razinom zadovoljstva. Dakle, studenti iz eksperimentalne skupine smatraju da su primjeri najkorisniji otvoreni nastavni materijal. Međutim, mišljenja studenata o videosnimkama eksperimenata bila su suprotna. Pokazalo se da su videosnimke eksperimenata bile najrjeđe korištena vrsta materijala, što je rezultiralo najnižom razinom zadovoljstva kod studenata. To je možda jedan od faktora odgovoran za to što nije uočena statistički značajna razlika između akademskih postignuća studenata u eksperimentalnoj i kontrolnoj skupini.

Kvalitativni podatci prikupljeni tijekom treće faze, koja je uključivala polustrukturirane intervjue s fokusnim grupama sastavljenima od studenata iz eksperimentalne skupine analizirani su kako bi se došlo do odgovora na treće pitanje istraživanja. Mišljenja studenata o primijenjenom pristupu kategorizirana su kao koristi i prepreke, a svaka se kategorija sastojala od 3 teme. Prva tema u kategoriji koristi obuhvaća Moodle platformu. Studenti su spomenuli da je dijeljenje svih otvorenih nastavnih materijala i obavijesti putem Moodle platforme, koja je aktivno korištena kao jedinstveni izvor, dovelo do veće dostupnosti materijala. Ostale dvije teme pokazale su korist od svake dodatne vrste materijala koja je bila dostupna studentima iz eksperimentalne skupine. Što se tiče druge teme, studenti su naveli da su primjeri najkorisnija vrsta materijala i da su im pomogli vježbati teorijske informacije. Također su spomenuli da primjeri koji su povezani sa svakodnevnim životnim problemima vode boljem razumijevanju tema. Zato smatraju da broj primjera treba povećati. U trećoj temi koja ističe koristi od otvorenih nastavnih materijala, studenti su naveli da su im videosnimke eksperimenata pomogle prepoznati vlastite pogreške u izvođenju laboratorijskih vježbi i da su im pokazale lakša i brža rješenja. Budući da studenti smatraju da je tehnološki napredno obrazovno okruženje pogodnije za učenje (Aşıksoy i Özdamlı, 2017), korištenje primjera i gledanje videosnimki eksperimenata moglo je imati pozitivan utjecaj na mišljenja i akademska postignuća studenata. Također su studenti predložili da je proučavanje simulacija bilo korisno u promatranju rada logičkoga sklopa kada postoje različite ulazne kombinacije. Ono im je pomoglo bolje razumjeti teorijske pojmove. Ovom rezultatu idu u prilog istraživanja Alsadoona i suradnika (2017), Roya i suradnika (2015) i Stanisavljevica i suradnika (2013).

S druge strane, kategorija prepreka uključuje dvije teme povezane s laboratorijskim vježbama i jednu temu o videosnimkama eksperimenata. U prvoj su temi studenti naveli da vrijeme određeno za laboratorijske vježbe nije bilo dovoljno da se eksperimenti završe na vrijeme i da je to na njih stavljalo pritisak. U drugoj su temi spomenuli da su njihovi modeli logičkih sklopova bili kasno provjereni zbog toga što je na laboratorijskim vježbama bio prisutan samo jedan asistent. Treća tema je odražavala mišljenja studenata o nepovoljnom vremenu kada su videosnimke eksperimenata postavljene na platformu. Smatrali su da bi bili bolje upoznati sa sklopovima koje su sastavljali, da bi vlastite pogreške bolje prepoznali i brže dovršili eksperiment da su mogli pogledati videomaterijale prije samih laboratorijskih vježbi. Studenti su povezali poteškoće i kašnjenja u izvedbi laboratorijskih eksperimenata s činjenicom da su videosnimke eksperimenata postavljene na platformu nakon laboratorijskih vježbi. Ovakav stav i ograničena upotreba videosnimki eksperimenata iskazani u upitniku mogli su imati negativan utjecaj na eksperimentalni proces i tako doprinijeti nedostatku statistički značajnoga napretka u akademskim postignućima studenata iz eksperimentalne skupine.

Drugi faktor koji je potrebno razmotriti pri evaluaciji utjecaja primijenjene nastavne metode mogla bi biti stopa uspješnosti studenata koji su upisali kolegij u posljednje dvije godine. 52,4 % od 145 studenata koji su odabrali kolegij Logički dizajn na Odsjeku za računalno inženjerstvo Sveučilišta Manisa Celal Bayar u akademskoj godini 2016./2017. bilo je uspješno. Međutim, 61% od 132 studenata u akademskoj godini 2017./2018. položilo je ispit iz tog kolegija. Porast postotka studenata koji su položili ispit iz ovoga kolegija može se smatrati rezultatom organizacije kolegija uz pomoć otvorenih nastavnih materijala i njihovoga utjecaja na akademski uspjeh studenata. Međutim, ovakvo tumačenje uzima u obzir uspjeh svih studenata koji su pohađali kolegij. U tom smislu trebalo bi napomenuti da iako je u istraživanju korišten eksperimentalni dizajn s predtestom i posttestom u kontrolnoj skupini, neki od izrađenih otvorenih nastavnih sadržaja bili su dostupni objema skupinama. Povratna informacija dobivena pomoću pitanja otvorenoga tipa u upitniku također ide u prilog tvrdnji da su studenti u obje skupine imali koristi od odabranoga modela istraživanja.

Kao sažetak rezultata cjelokupne analize, može se zaključiti da i studenti iz eksperimentalne i studenti iz kontrolne skupine smatraju da su otvoreni nastavni materijali kojima su mogli pristupiti korisni u procesu učenja. Taj je rezultat u skladu s postojećim istraživanjima koja su se bavila učinkovitošću otvorenih nastavnih materijala (Cheung, 2018; Mohandes i sur., 2006).

Većina sličnih istraživanja o logičkom dizajnu fokusirana je na razvoj alata kao što su simulatori i mrežne platforme, primjenom determinističkih pristupa (Alsadoon i sur., 2017; Baneres i sur., 2014; El-Din i Krad, 2011; Roy i sur., 2015; Shoufan i sur., 2015; Stanisavljevic i sur., 2013). Međutim, ovo istraživanje prihvaća instrumentalističku perspektivu i koristi plan kolegija temeljen na sadržajima koje studenti moraju usvojiti. Kada se radi o evaluaciji, postoje istraživanja koja koriste instrumente za mjerenje akademskih postignuća u kolegiju Logički dizajn, a koja koriste pitanja višestrukoga izbora (Ben-David Kolikant i Genut, 2017; Herman, 2011; Herman i Loui, 2011; Herman i sur., 2010). U tom smislu treba napomenuti da je ovo istraživanje prvo u literaturi koje se bavi kolegijem Logički dizajn, a koje koristi Instrument za mjerenje postignuća uz pitanja otvorenoga tipa. Stoga ono može otvoriti put novim, budućim istraživanjima.

Povratne informacije dobivene od studenata putem intervjua s fokusnim grupama i upitnika bile su važne za evaluaciju primijenjenoga nastavnog pristupa i za izvođenje nastave istoga kolegija u sljedećim godinama. Vezano uz to, studenti su tijekom intervjua s fokusnim grupama naveli sljedeće prijedloge za ponovno održavanje kolegija:

„Da se u ovom kolegiju na Moodle platformi aktivirala opcija foruma, ostvarila bi se bolja komunikacija i suradnja. Na taj bismo način mogli postavljati pitanja, provjeriti što ostali studenti dijele i dati bolju podršku jedni drugima."(FGI1-St2)

„Broj primjera koji uključuju i stvarne primjere iz svakodnevnoga života i aktualne teme trebao bi biti veći." (FGI3-St15, St17)

„Bilo bi bolje da su primjeri bili postavljani svaki tjedan umjesto jednom svaka 2-3 tjedna, ovisno o temi koja se obrađivala." (FGI1-St6)

„Mogli bi se tijekom semestra zadati projekti vezani za aktualne teme." (FGI2-St8, St9)

„Bilo bi bolje da su bile dostupne videosnimke u kojima se objašnjavaju primjeri. Mogli smo tako ponoviti teme i sadržaje koje nismo shvatili tijekom predavanja." (FGI1-St6)

Kolegij Logički dizajn može se sljedeće godine izvoditi tako da se u obzir uzmu ove sugestije. Stoga bi kolegij razrađen tijekom ovoga istraživanja mogao biti ponovljen i dopunjen korištenjem foruma na platformi Moodle, većim brojem primjera, primjerima povezanima sa stvarnim problemima i aktualnim temama, postavljanjem primjera svaki tjedan, zadavanjem projekata i postavljanjem videosnimki eksperimenata.

Na temelju povratne informacije dobivene od studenata mogu se osmisliti i provesti nova istraživanja. Tako se već sljedeće godine u nastavi kolegija mogu postaviti videosnimke eksperimenata prije laboratorijskih vježbi, što bi spriječilo vremenska ograničenja tijekom laboratorijskih vježbi i što bi pomoglo asistentima bolje koordinirati laboratorijske vježbe. Tako se tri teme u kategoriji prepreka mogu popraviti na temelju rezultata intervjua s fokusnim grupama. Potrebno je ponuditi novi način organizacije kolegija u kojemu će se videosnimke eksperimenata postavljati prije provedbe laboratorijskih vježbi. Tako se priručnik za laboratorijske vježbe može dopuniti tako da svaka laboratorijska vježba uključuje dva modela sklopa. Videosnimka eksperimenta s prvim modelom sklopa može se podijeliti sa studentima prije laboratorijskih vježbi, a drugi sklop može se prikazati tijekom laboratorijskih vježbi.

Kolegij Logički dizajn postavljen na način opisan u istraživanju može se smatrati temeljem budućih istraživanja u tom području. Veći bi naglasak trebalo staviti na pristup orijentiran na studenta. Stoga bi novi nastavni planovi kolegija trebali biti temeljeni na vršnjačkom učenju i suradničkom učenju, u kojima studenti rade zajedno i u kojima su aktivniji. Projektni pristup također se može primijeniti. S tim u vezi planiraju se unaprijediti već pripremljeni otvoreni nastavni materijali, revidirati nacrt kolegija prikazan u ovom istraživanju i doraditi u skladu s rezultatima istraživanja te provesti novo istraživanje iduće akademske godine. Nakon ovih poboljšanja, otvoreni nastavni materijali mogu se koristiti u različitim odsjecima i na različitim sveučilištima u kojima se izvodi nastava iz kolegija Logički dizajn. Još jedna smjernica – mogla bi biti provedba longitudinalnih istraživanja na različitim institutima.

Zahvala

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