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A model for flipping electrical engineering with e-learning using a multidimensional approach

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Abstract: This paper proposes a model for supporting electrical engineering with e-learning. The model development is based on survey data collected from representative teachers and students studying in higher education institutions in Turkey. To develop the model, the study investigated the attitudes of the representative key stakeholders in the relevant higher education institutions towards e-learning by administrating questionnaires and interviews with teachers and students. The responses of the teachers and students were then compared. Based on the results, a model was proposed with a multidimensional approach to e-learning. The model flips electrical engineering to make sure that the students review, discuss, and explore course content before and after class. The proposed model encourages students to start with e-learning, to continue with the face-to-face learning setting on campus, and then to come back to e-learning for evaluating their learning in the classroom. Using this model, students can study at home and assess their learning before and after their attendance to campus lectures and enhance their learning with various types of learning, namely self-directed learning, self-assessment, teacher-directed learning, teacher assessment, computer-directed learning, and computer assessment. Similarly, model evaluation was conducted at the relevant higher education institutions. To evaluate the applicability of the model, a case-control study was conducted to determine whether the model had the intended effect on the participating students of the relevant institutions. As a result of the case-control study, the effects of e-learning, blended learning, and traditional learning were verified by teaching the use of MATLAB software. The overall scores indicated that e-learning and blended learning were more effective as compared to traditional learning. The results of our study indicated that the knowledge increase in e-learners seemed to be gradual because they tended to study daily by completing each activity on time.

Key words: Higher education, e-learning, educational game, E-learning readiness, electricity

1. Introduction

Information and communications technology (shortly known as ICT) has many implications for education, society, and economics [1]. The widespread impact of ICT is widely seen in several aspects of today's education, especially at the level of higher education institutions (HEIs). Laurillard [2] highlighted that the use of ICT in today's education creates a new kind of discipline for the discovery, articulation, and dissemination of knowledge within our society and therefore affects the knowledge and skills. She also pointed out that this new kind of discipline actually brings two disciplines together, namely technology and education. As a result of this new medium, many individuals and organizations have been interested in finding out how to bring these two fields together to take advantage of technology in learning and teaching knowledge and skills.

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To achieve this aim in the context of HEIs associated with the subject of electrical engineering, we conducted a research study to measure teachers' and students' readiness for e-learning and to analyze their views on e-learning in 2010 with teachers and in 2011 with students. The readiness and views of the teachers and students were then compared. Based on the comparison, we developed and evaluated a model for supporting electrical engineering with e-learning in 2012. Therefore, the purpose of this paper is to find out whether our model is applicable to HEIs. Additionally, we also examine whether there are significant differences among e-learning, blended, and traditional learning.

2. Flipped learning

Nowadays, a number of different modes of blended learning appear in higher education, especially flipped learning. Flipped learning (also called flipped teaching or flipped classroom) is a form of blended learning in which students start learning at home and then continue in class with teachers and other students. Hughes [3] highlighted that the flipped classroom is a pedagogical concept and method that replaces the standard lecture-in-class format because students have opportunities to review, discuss, and explore course content with the teacher and other students in class. Hughes [3] also noted that there are many ways that a classroom can be flipped. However, the most common way to apply the flipped classroom approach is to encourage students to view the recorded lectures or read course materials outside of class and then meet to engage in problem solving, discussion, and practical application exercises with their instructor and other students in class.

However, students in traditional approaches do not have such opportunities because the teacher plays the role of information conveyor, while the students assume a receiver role with primary responsibilities of listening and note-taking [4]. However, it is also important to note here that the instructor may apply various teaching styles in higher education but time constraints limit their teaching style to the traditional lecture format [5]. However, the flipped classroom approach can encourage students' learning both outside and inside of class. Strategies for flipping the classroom outside of class and inside of class may vary. Hughes [3] suggested that moving the lecture out of the classroom may involve selecting course content, deciding the organization of content, choosing multimedia to deliver content, creating materials, and making the materials available to students.

Moreover, in-class strategies may involve answering students' questions at the beginning of class, facilitating individual or group activities, and summarizing key points. For instance, Zappe et al. [4] used iTunes U to post video records of lecture material with supplemental content to allow greater time for in-class problem solving and increase the opportunity for increased teacher-student interaction. However, it is highly important to note that there is no single model for the flipped classroom approach because the term is used to describe almost any class structure that provides strategies for learning outside and inside of class. As short video lectures are widely used for students' viewing at home, broadband technology plays an important role in the flipped classroom approach. Hence, the focus should be on models for supporting learning with e-learning.

3. Models

3.1. A model for flipping electrical engineering with e-learning

The model development was based on survey data collected from representative teachers and students in Turkey, whereas the model evaluation was conducted in the relevant HEIs in Turkey. To develop the model, the study investigated the attitudes of representative key stakeholders towards e-learning in Turkey by administrating questionnaires and interviews with teachers and students. The responses of the teachers and students were then compared. Based on the results, we proposed a model with a multidimensional approach to e-learning: 1) self-directed learning by studying e-books, 2) self-assessment by solving e-exercises, 3) teacher-directed learning by attending classroom sessions as an integral part of the blended learning, 4) teacher assessment by solving e-exercises, 5) computer-directed learning by playing e-games, and 6) computer assessment by solving e-exercises, as seen in Figure 1.

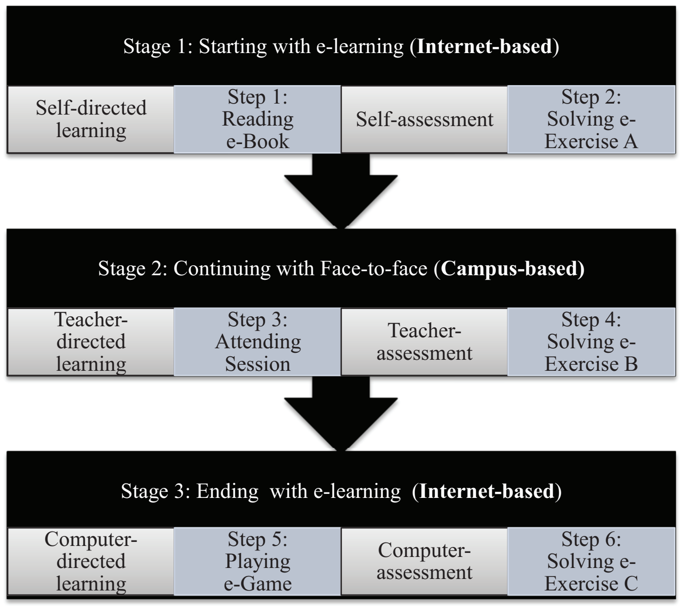

Figure 1. A model for flipping electrical engineering with e-learning.

As illustrated in Figure 1, students should start with e-learning, continue with the face-to-face learning setting on campus, and then come back to e-learning for evaluating things they have learned. The stages of such a model were identified after detailed analyses of our previous research studies [6–10], related literature, and discussion among the researchers. Using this model, students can study at home and assess their learning before they attend campus-based lectures. To evaluate the applicability of the model in different conditions, a case-control study was conducted to determine whether the model had the intended effect on the participating students in HEIs in Turkey. As the result of the case-control study, the effects of e-learning, blended learning, and traditional learning were verified.

3.2. A model for conducting a case-control study

However, evaluating the model based on the blended learning approach in Figure 1 as it is might not help us find out the pedagogical value of e-learning without comparing it with the campus-based learning and e-learning together. Hence, a case-control study should be conducted to determine whether the model in Figure 1 has the intended effect on participating students in HEIs in Turkey. Hence, a model for conducting a case-control study was developed to find out the effects of three types of learning, namely e-learning, blended learning, and traditional learning, as illustrated in Figure 2. As illustrated in Figure 2, at the beginning and at the end of each type of learning, pre- and postplacement tests were applied to find out the current knowledge of students about the content of the courses. Placement tests were mainly used to measure students' ability in order to put those students in a particular class or group. However, instead of assigning students into an appropriate group, we used the results of the placement tests to find out the rate of increment or decrement in students' learning after the end of each type of learning course.

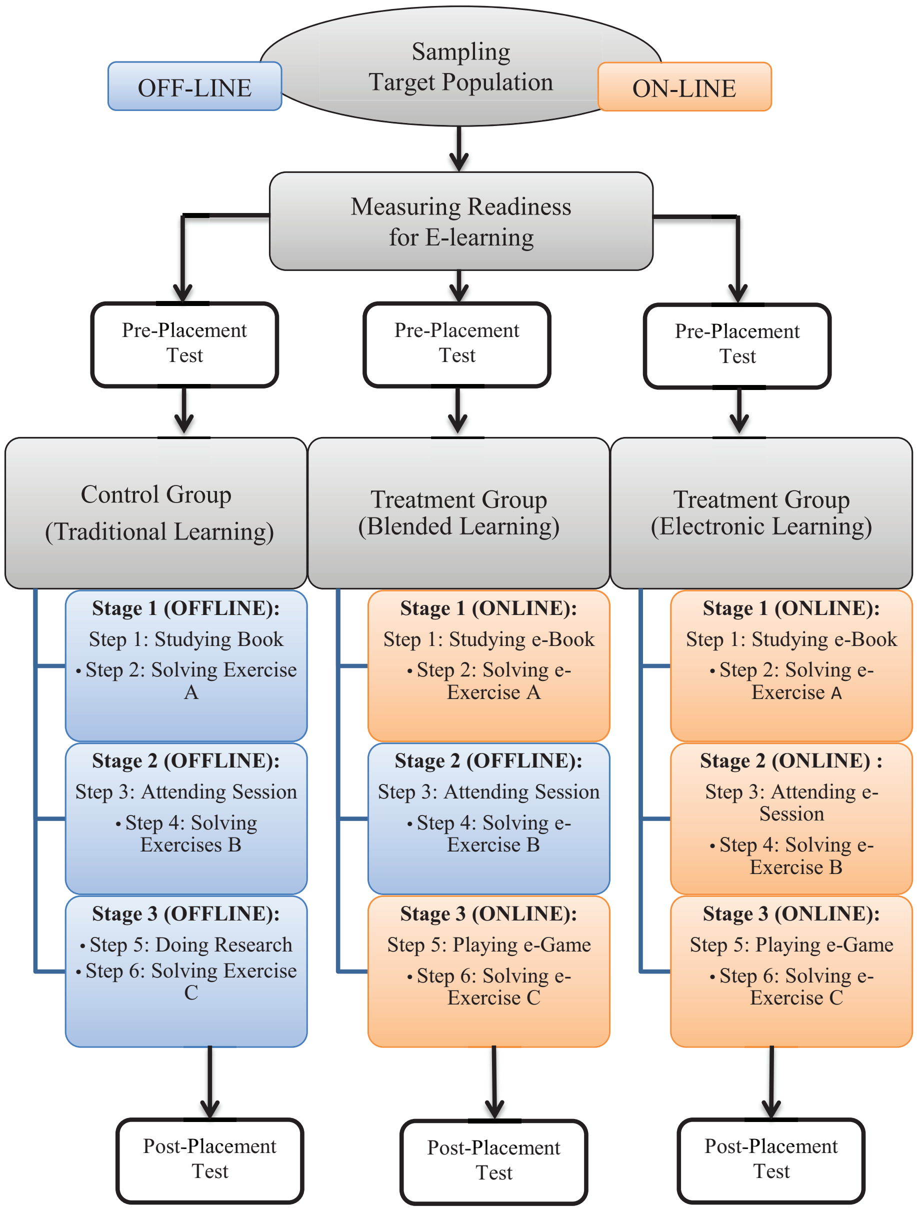

Figure 2. A model for conducting the case-control study.

4. Methodology

The participating institutions were determined by considering whether they were associated with the subject of electricity, especially the students of electrical engineering in 2012. Associate, bachelor, master, and PhD students in those institutions were chosen as participants in our case-control study. The sample needed for the study was calculated as 384 with 5% allowable error, 95% confidence level, and 0.5 degrees of variability because the number of students in the respective HEIs in 2012 in Turkey was assumed as the infinite population as they were unknown. Given the relative history of e-learning in Turkey, the students of all HEIs in 2012 associated with the subject of electricity in Turkey were invited by sending an invitation to their department secretary in order to obtain the desired level of confidence and precision. The responses of only 776 participants were valid. These 776 participants were sufficient for use to obtain the desired level of confidence and precision in our sampling. Table 1 displays the number of the participants for each mode of learning in Turkey and the UK. As seen in Table 1, the majority of the students selected the e-learning mode.

Table 1. The number of participants for each mode in Turkey.

Mode	Number	Percent
e-Learner	589	75.9
Blended learner	113	14.6
Traditional learner	74	9.5
Total	776	100.00

The participant students of the traditional group and blended group were selected from Selçuk University, which is located in the center of Turkey. The number of participants from Selçuk University is illustrated in Table 2. Only one student of the blended mode joined from Atatürk University under our observation to make sure that everything was working properly. As a result, 776 students participated in the research but 216 of them were from Selçuk University in order to conduct the blended and traditional learning modes. At the beginning of the case-control study, the readiness of the students who selected either the blended on e-learning mode was measured. Once they filled out the survey that measured their readiness for e-learning, an account was created for those students to be able to log into the e-learning platform, namely Moodle. In total, 702 accounts were created for those students who successfully completed the e-learning readiness survey at the beginning of the case study. Table 3 illustrates the overall mean and standard deviation scores of the participants' responses and the mean scores of items related to each factor such as technology and confidence in the E-learning readiness survey.

Table 2. The number of participants for each mode at Selçuk University.

Mode	Number	Percent
e-Learner	30	13.89
Blended learner	112	51.86
Traditional learner	74	34.26
Total	776	100.00

Table 3. Number, mean and standard deviation of items.

Factors	No. of items	M	SD
Technology	6	3.82	0.82
Experience	6	3.92	0.61
Confidence	5	4.15	0.63
Attitude 1	6	3.79	0.60
Attitude 2	6	3.50	0.63
Tradition	24	3.72	0.57
Institutions	3	2.42	1.71
Content	4	3.75	0.73
Acceptance	8	3.88	0.60
Training	5	2.38	0.70
Overall	73	3.53	0.39

Based on this result, it can be inferred that students in HEIs associated with the subject of electricity in Turkey, within the limits of the students surveyed, were overall ready for e-learning, although they might need some improvements. Mean scores for the factors can also be used to identify the areas of improvement for the participating students. The details of the items and factors were already published [6–10]. As the overall readiness of the participants in the blended and e-learning modes was sufficient, a case-control study was conducted. The number of the students participating in the case-control study was 776, whereas some of them left the case-control before completing. Table 4 illustrates the number of the participants who participated in the placement tests of the case-control study.

Table 4. The number of participants for each mode in Turkey.

Placement test	Learning mode	Course 1	Course 2	Course 3
At the beginning of the courses	e-Learner	340	260	-
	Blended learner	108	107	-
	Traditional learner	33	33	-
In the middle of the courses	e-Learner	121	82	64
	Blended learner	103	93	109
	Traditional learner	31	30	52
At the end of the courses	e-Learner	58	58	56
	Blended learner	109	109	98
	Traditional learner	52	52	32

5. Results and discussion

It was not possible to assess the pedagogical value of e-learning without evaluating it. Hence, a model for conducting a case-control study was developed to find out the effects of three types of learning, namely e-learning, blended learning, and traditional learning. Therefore, this section is divided into three parts. The first part reports the results of the preplacement test in the study, whereas the second part reports the results of the middle test. The results of the postplacement test are analyzed in the last part in detail.

5.1. Measuring students' knowledge at the beginning of the courses

At the beginning of each course including e-learning, blended learning, and traditional learning, the knowledge of the students about the course contents (e.g., programming with MATLAB) was measured using a placement test. In addition to the descriptive analyses of the results, one-way ANOVA was also used to verify the statistical significance of differences in mean scores between e-learners, blended learners, and traditional learners. To assess the knowledge of students about programming with MATLAB, six questions for each topic were designed using different types of questions such as a multiple choice, short answer, multiple short text, numerical input, and multiple numerical input. Table 5 illustrates the number of students taking the placement test and the mean score of their answers for each topic. Moreover, it also shows the results of one-way ANOVA to verify the statistical differences between e-learners, blended learners, and traditional learners. For Course 1 (fundamentals of MATLAB, 6 topics), the number of participants studying in HEIs in Turkey was 481. The participating students in Course 1 were categorized as follows: 70.69% e-learners, 22.45% blended learners, and 6.86% traditional learners. For Course 2 (programming with MATLAB, 6 topics), the number of participants studying in HEIs in Turkey was 400. The participating students in Course 2 were categorized as follows: 65.00% e-learners, 26.75% blended learners, and 8.25% traditional learners. For Course 3 (practices with MATLAB, 3 topics), the knowledge of students was not measured since the topics were designed specifically and it was new in the field of MATLAB. For example, Topic 13 was about reading data from an external file and analyzing and writing it on an external file. Topic 14 covers the control of a PIC16F628A to develop the hands-on skills of students and aims to teach how to switch on-off LEDs using a timer to control a race car or artificial arm, as seen in Figure 3. Since the topics were specific, it was expected that no students would have knowledge about those topics and therefore their knowledge at the beginning of the course was not measured and was assumed as 0.0.

Table 5. The results of preplacement tests in Turkey.

Topic		Max. range		Course 1			Topic		Max. range	Course 2		
				N	M	F (P)				N	M	F (P)
Fundamentals	1	0–9 points	M1	340	2.50	68.01 (0.00)	Programming	7	0–9 points	260	4.44	2.43 (0.08)
			M2	108	0.69					107	3.82	
			M3	33	0.00					33	4.01	
	2	0–12 points	M1	340	5.42	75.54 (0.00)		8	0–12 points	260	6.64	2.23 (0.11)
			M2	108	1.15					107	7.42	
			M3	33	0.00					33	7.17	
	3	0–15 points	M1	340	5.54	59.13 (0.00)		9	0–15 points	260	5.32	25.93 (0.00)
			M2	108	1.18					107	8.10	
			M3	33	0.00					33	8.83	
	4	0–18 points	M1	340	4.94	38.24 (0.00)		10	0–18 points	260	5.44	0.073 (0.93)
			M2	108	1.39					107	5.60	
			M3	33	0.00					33	5.27	
	5	0–21 points	M1	340	1.96	8.12 (0.00)		11	0–21 points	260	4.11	3.63 (0.03)
			M2	108	0.96					107	5.32	
			M3	33	0.00					33	5.30	
	6	0–24 points	M1	340	4.33	31.39 (0.00)		12	0–24 points	260	2.36	2.03 (0.13)
			M2	108	1.17					107	1.51	
			M3	33	0.00					33	1.21	
	T	0–100 points	M1	340	25.69	65.62 (0.000)		T	0–100 points	260	29.32	1.81 (0.16)
			M2	108	7.53					107	32.77	
			M3	33	1					33	32.79	

M1: e-learner, M2: blended learner, M3: traditional learner.

5.2. Measuring students' knowledge in the middle of the courses

After measuring the current knowledge of the students at the beginning of each course, three different courses were started using the blended, e-learning, and traditional approaches. For each topic, the blended learners and e-learners are first asked to study an e-book, which was specifically designed. For the traditional learners, the printed version of the e-book was handed out to those students or a sample of it was put in the photocopy room of the respective department. In the middle of each course including e-learning, blended learning, and traditional learning, the knowledge of students about the course contents (e.g., programming with MATLAB) were measured using a quiz. Table 6 shows the mean scores of the questions in the quiz for each topic and the overall results. In addition to the descriptive analyses of the results, one-way ANOVA was also used to verify statistical significance of differences in mean scores between e-learners, blended learners, and traditional learners.

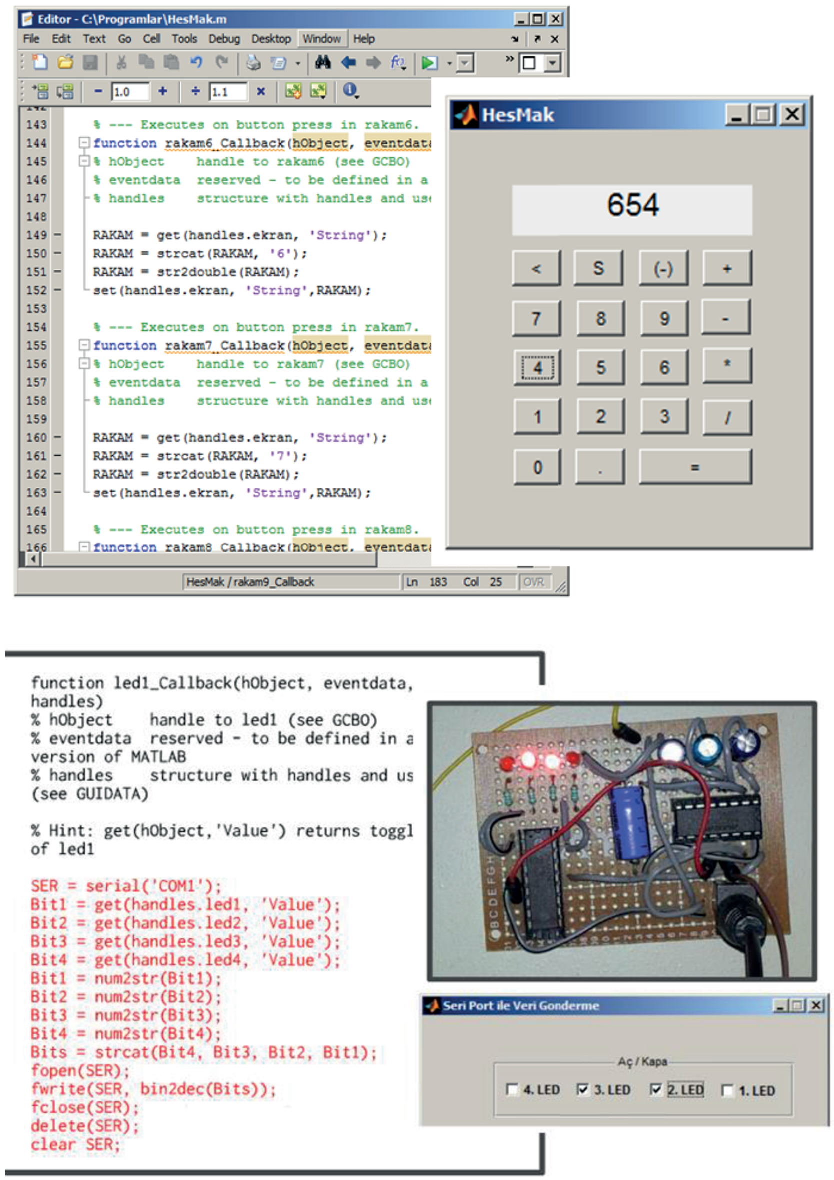

Figure 3. Calculator design and PIC16F628A control with MATLAB.

Similarly, to assess the knowledge of students about programming with MATLAB in the middle of the courses, 6 questions for each topic were also designed using different types of questions such as a multiple choice, short answer, multiple short text, numerical input, and multiple numerical input. As illustrated in Table 2, 275 students studied the e-book or the printed version of it (i.e. Step 1), solved e-exercise A (i.e. Step 2), attended the lectures on campus or online (i.e. Step 3), and solved e-exercise B (i.e. Step 4) for each topic in Course 1 (i.e. fundamentals of MATLAB); 220 students studied in Course 2 (i.e. programming with MATLAB) and 233 students studied in Course 3 (i.e. practices with MATLAB).

Table 6. The results of the quiz in Turkey.

Topic		Max. range		Course 1			Topic		Max. range		Course 2		
				N	M	F (P)					N	M	F (P)
Fundamentals	1	0–9 points	M1	121	6.57	99.585 (0.000)	Programming	7	0–9 points	M1	82	7.48	99.432 (0.000)
			M2	103	3.13					M2	93	3.83	
			M3	31	1.95					M3	30	2.87	
	2	0–12 points	M1	121	11.48	65.586 (0.000)		8	0–12 points	M1	82	7.88	43.410 (0.000)
			M2	103	7.44					M2	93	3.45	
			M3	31	6.97					M3	30	1.99	
	3	0–15 points	M1	121	9.95	140.247 (0.000)		9	0–15 points	M1	81	10.15	19.665 (0.000)
			M2	103	1.97					M2	93	6.63	
			M3	31	0.40					M3	30	5.04	
	4	0–18 points	M1	121	15.99	64.041 (0.000)		10	0–18 points	M1	82	16.02	69.411 (0.000)
			M2	103	9.90					M2	93	4.45	
			M3	31	7.62					M3	30	5.10	
	5	0–21 points	M1	121	16.31	111.381 (0.000)		11	0–21 points	M1	82	15.73	105.802 (0.000)
			M2	103	5.30					M2	93	2.43	
			M3	31	2.94					M3	30	1.05	
	6	0–24 points	M1	121	13.45	126.521 (0.000)		12	0–24 points	M1	82	12.48	47.911 (0.000)
			M2	103	0.55					M2	93	3.11	
			M3	31	0.65					M3	30	2.00	
	T	0–100 points	M1	121	74.75	269.084 (0.000)		T	0–100 points	M1	82	70.71	143.384 (0.000)
			M2	103	29.29					M2	93	24.90	
			M3	31	21.52					M3	30	19.05	
Topic		Max. range		Course 3									
				N	M	F (P)							
Practice	13	0–27 points	M1	64	24.19	22.045 (0.000)							
			M2	109	13.75								
			M3	52	13.93								
	14	0–33 points	M1	64	27.84	37.183 (0.000)							
			M2	109	12.05								
			M3	52	11.15								
	15	0–39 points	M1	64	31.88	37.179 (0.000)							
			M2	109	14.01								
			M3	52	9.13								
	T	0–100 points	M1	64	84.91	50.818 (0.000)							
			M2	109	40.81								
			M3	52	35.22								

5.3. Measuring students' knowledge at the end of the courses

After applying the quizzes for each course, a 3-week break was applied for Course 1 and Course 2. However, for Course 3, an electronic game was designed and applied to find out the effect of electronic games on the students' knowledge for blended learners and electronic learners. For traditional learners, instead of offering an e-game, a research study was conducted. However, it is important to note here that the knowledge that blended learners and e-learners got from playing the e-game was completely the same as the knowledge that traditional learners obtained with the research study. In addition, the knowledge level was much more advanced in the e-game and in the research study. The e-game was designed to encourage students to learn while playing. A printed screen of the e-game is illustrated in Figures 4 and 5.

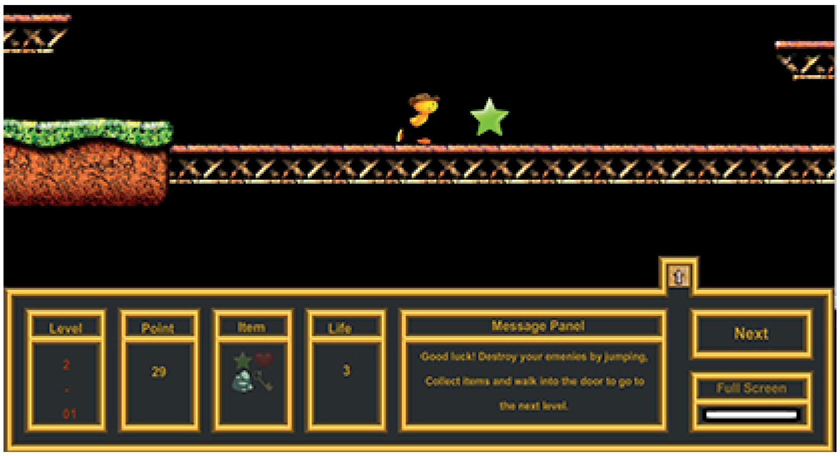

Figure 4. Getting the item (e.g., STAR).

Figure 5. Getting the knowledge after the item.

For example, as shown in the figures, when the user picks up the item STAR, a piece of new knowledge about serial communication appears as illustrated in Figure 5 on the bottom right of the screen. The game was designed to encourage students to learn about WHAT, WHY, HOW, and WHERE for each concept by collecting four items, namely a ROCK, HEART, STAR, and KEY, respectively. For example, it is aimed to teach students “What is serial communication?” when they collect the item ROCK. After collecting the four items, the students were encouraged to go up to the next level. Table 7 shows the mean score of the final exam for each topic and the overall results of each course. It is noted that the final exam was applied for Course 1 and Course 2 after 3 weeks and after the quiz. However, the final exam for Course 3 was applied after applying the

Table 7. Postplacement tests in Turkey.

Topic		Max. range		Course 1 N	M	F (P)	Topic		Max. range		Course 2 N	M	F (P)
Fundamentals	**1**	0–9 points	M1	58	7.11	3.39 (0.04)	Programming	7	0–9 points	M1	58	8.24	10.64 (0.00)
			M2	109	6.42					M2	109	7.82	
			M3	52	6.07					M3	52	6.80	
	2	0–12 points	M1	58	11.03	7.82 (0.00)		8	0–12 points	M1	58	10.80	8.14 (0.00)
			M2	109	10.29					M2	109	10.07	
			M3	52	9.00					M3	52	9.35	
	3	0–15 points	M1	58	14.04	27.09 (0.00)		9	0–15 points	M1	58	12.15	1.95 (0.14)
			M2	109	12.39					M2	109	11.59	
			M3	52	10.13					M3	52	10.94	
	4	0–18 points	M1	58	16.68	31.27 (0.00)		10	0–18 points	M1	58	15.47	21.79 (0.00)
			M2	109	13.54					M2	109	13.02	
			M3	52	10.93					M3	52	9.97	
	5	0–21 points	M1	58	15.21	17.35 (0.00)		11	0–21 points	M1	58	14.84	18.56 (0.00)
			M2	109	11.96					M2	109	11.56	
			M3	52	10.05					M3	52	8.75	
	6	0–24 points	M1	58	19.44	37.99 (0.00)		12	0–24 points	M1	58	22.24	13.68 (0.00)
			M2	109	14.62					M2	109	14.90	
			M3	52	11.11					M3	52	14.00	
	T	0–100 points	M1	58	84.51	43.58 (0.00)		T	0–100 points	M1	58	83.74	24.22 (0.00)
			M2	109	70.23					M2	109	68.97	
			M3	52	58.29					M3	52	59.80	

Topic		Max. range		Course 3 N	M	F (P)
Practice	13	0–27 points	M1	56	23.90	13.74 (0.00)
			M2	98	19.56	
			M3	32	19.55	
	14	0–33 points	M1	56	28.15	52.07 (0.00)
			M2	98	15.63	
			M3	32	15.87	
	15	0–39 points	M1	56	27.33	25.31 (0.00)
			M2	98	17.42	
			M3	32	16.55	
	T	0–100 points	M1	56	80.39	46.03 (0.00)
			M2	98	53.60	
			M3	32	52.97	

e-game for blended and e-learners and the research study for traditional learners. The overall results of Course 1 displays that the mean score of e-learners (M = 84.48) was much better than those of blended learners (M = 70.75) and traditional learners (M = 58.29). The same pattern also remained for the students in Turkey based on the separate results. Significant difference between e-learners, blended learners, and traditional learners was also found for the overall results in Turkey. The overall results of Course 2 were also computed, as illustrated in Table 3. A similar pattern was discovered between e-learners, blended learners, and traditional learners. Table 3 indicates the rate of knowledge increase of the students after the end of each course. It shows that the knowledge increase of the blended (M = 42.36) and traditional learners (42.96) after a 3-week break had increased the knowledge of those students significantly because they were much better than e-learners (M = 2.72). The same pattern also remained for Course 2 for the students in Turkey.

6. Conclusion

The main goal of this paper was to first develop an e-learning model in electrical engineering and evaluate it using empirical studies in Turkey with limited participation. In order to develop the e-learning model, the perspectives of students and teachers in HEIs associated with the subject of electricity were obtained using different data collection techniques, namely questionnaires and interviews. To develop the e-learning model, a conceptual framework was developed for achieving the first goal of this study: measuring students' and teachers' readiness for e-learning (Step 1); selecting and developing an e-learning platform, namely Moodle (Step 2); developing e-learning materials including e-books, e-exercises, presentations, and games (Step 3); training students for e-learning (Step 4); and delivering e-learning (Step 5). After developing the e-learning model, it was evaluated based on empirical studies in Turkey. The pedagogical value of e-learning, blended learning, and traditional learning was evaluated by teaching three different courses regarding MATLAB software. As a result of the case-control study, the effects of e-learning, blended learning, and traditional learning were verified. There were significant differences among the groups. According to the overall scores, e-learning and blended learning were more effective as compared to traditional learning. The results of our study indicated that the knowledge increase in e-learners seemed to be gradual because they tended to study daily by completing each activity on time. However, the traditional learners did not have the same pattern because they usually did not read the core text and did not solve e-exercises regularly before classroom sessions. The results of preplacement, postplacement, and middle tests also justified these assumptions.

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