Evaluation of the Use of MIDEP Card in Physical Programming Teaching[1]

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Abstract

Physical programming (PP) is defined as the design of interactive physical systems between the real and virtual worlds using a combination of software and hardware. A physical programming platform (PPP) defines a structure that includes hardware and software where such applications can be made. The aim of this study is to introduce the MIDEP computer card, which can be used at all levels of education, does not require a computer and can be used as a computer, and to evaluate its usability in physical programming training. In the study, which was designed with a one-group pretest-posttest experimental model, the evaluation process was carried out in two stages with two different study groups. The study group of the application consisted of teacher candidates in the first stage and K12 level students in the second stage. In data collection, academic achievement tests prepared separately for pre-service teachers and K12 level students and focus group interviews with students were utilised. The findings show that the training given by using MIDEP card and MIDEP workbook increased the academic achievement of the students in physical programming at a statistically significant level. In addition, as a result of the findings, it can be said that the projects and activities included in the training exhibited a balanced distribution in terms of the gains related to the sub-dimensions of hardware, software and Internet of Things, and that the tools and materials used allowed students without any experience to learn gradually from easy to difficult.

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Introduction

The concept of physical programming brings together hardware and software components within the framework of design and creative activities. Interactive physical systems that perceive the real world and combine software and hardware are increasingly favoured (Hodges et al., 2020). The hardware components used in physical programming interact with their environment through software (sound, light or temperature sensors, actuators such as LEDs, servos or speakers) and at the centre are microcontrollers that manage peripheral components such as sensors and actuators (Przybylla & Romeike, 2014). In this way, smart systems can be created that can exchange data with the outside world depending on the programme written on it. Thanks to these platforms that facilitate physical programming applications such as Arduino and make high processing power and networked automation applications such as Raspberry pi accessible to students of all ages, the teaching of STEM and many digital skills becomes interesting, cheap and sustainable (Kalelioglu & Sentance, 2020). Physical programming platforms are used in educational environments such as hands-on experiments and interactive art involving the perception and control of physical changes (Blikstein, 2013) but mostly in teaching skills related to programming and computer science. Especially in parallel with the developments in the field of Internet of Things (IoT), physical programming platforms that can be used in this field have many educational advantages. According to the studies conducted in this field, IOT trainings improve students' innovative and creative thinking skills (Osipov & Riliskis, 2013), increase their interest and motivation (Bogdanovic et al., 2014), provide the opportunity to learn by doing and experiencing (Hui-xiaoa & Shu-Sheng, 2011; Yaren et al., 2014). It shows positive results in project-based, problem-solving, collaborative or interdisciplinary studies (Charlton & Avramides, 2016; Maenpaa et al., 2015; Zhong & Liang, 2016). It creates positive effects with its integration into courses other than engineering courses (Kortuem et al., 2013; Yang & Yu, 2016) and brings innovation to open and distance learning (Altınpulluk, 2018).

SBCs, which are also defined as general purpose physical programming cards, are computers that can perform almost all the operations that normal computers that we use in daily life such as desktop or laptop can do, and at the same time consume less energy but have less working capacity than a normal computer. MIDEP is an SBC developed within the scope of the National Experiment Platform (MIDEP) project supported by TUBITAK (Scientific and Technological

Research Council of Turkey) and carried out with university-industry cooperation. MIDEP card has been developed to increase technological skills at all levels from secondary school to university with its Turkish interface. With the MIDEP card, many advanced applications such as robotics, internet of things, image processing, artificial intelligence can be performed as well as basic level applications with block programming without requiring electronics and software knowledge. MIDEP card can also be used as a computer.

This study was designed to introduce the MIDEP computer board, which can be used at all levels of education, does not require a computer and can be used as a computer, and to evaluate its usability in physical programming trainings. In the designed study, it is aimed to evaluate the use of the MIDEP card and MIDEP experiment book in physical programming trainings both at K12 level and with pre-service teachers. Within the scope of the research, answers to the following questions will be sought

1. To what extent will the developed card contribute to the academic achievement of the participants if it is used in the teaching of both teachers who will give physical programming education and students at k12 level?
2. What are the opinions of K12 level students about the use of the MIDEP card in teaching?

Method

Research Design

In the study, which was designed with a one-group pretest-posttest experimental model, the evaluation process was carried out in two stages with two different study groups. In the first stage, a two-week training (4 lesson hours in total) was given to teacher candidates using the MIDEP card and booklet in order to determine the level of development of the developed card for pre-service teachers who had not been trained in this subject before and who would give physical programming education. In the second stage, a training consisting of a single session (4 hours) was given to two separate groups of K12 level students attending DENEYAP workshops. The development in all groups was evaluated with the data collection tools developed.

Research Sample

The study group of the application belonging to pre-service teachers consisted of 19 students who could apply the achievement test twice as pre-test and post-test among 31 pre-service teachers studying at Marmara University Computer Education and Instructional Technology Education (CEIT) Department. The determination of the study group was based on the fact that the teachers will teach physical programming to K12 level students when they graduate. The participants had previously taken basic electronics courses but had not received any training in physical programming.

The study group of K12 level students consisted of middle and high school students studying at different grade levels in Istanbul Beyoğlu Deneyap Workshop. The students had not taken any coding and electronics courses in Deneyap workshops before. However, some of the students stated that they participated in basic physical programming and coding activities in their schools. An announcement was made by Beyoğlu Deneyap Workshop for participation in the training, and the first 20 students who expressed their willingness to participate were included in the training (Table 1).

Table 1

Study Group

Department	Female	Male	Total
CEIT	10	9	19
K12	3	17	20

Research Instrument and Procedure

As a data collection tool, "Physical Programming Achievement Test" consisting of 31 multiple-choice questions was developed for teacher candidates and "Physical Programming Achievement Test (K12)" consisting of 20 questions was developed for K12 students and applied as pre-test and post-test in order to measure the achievements of the participant group on physical programming. In addition, a focus group interview was conducted with K12 students at the end of the application.

Physical Programming Achievement Test

This test was developed to measure the success of CEIT department students in physical programming and was applied as a pre-test and post-test. The test consists of 31 multiple choice questions. In the test, questions on hardware, programming and Internet of Things were included and the number of questions and the item specification table including the gains for the test are given in Table 2. The test was applied as a post-test 3 weeks after the pre-test.

Table 2

Achievement Test Item Specification

	Outcomes	Question No
Hardware	Knows the concept of physical programming	1
	Knows the concept of sensor and sensor types.	5,6
	Establishes circuit with Breadboard.	11,12,23,24
	Recognises Photo Resistors (LDR)	12,15,17,21,25
	Recognises the buzzer and knows what it does	16,25
	Recognise the distance sensor and know what it does	25
	Recognises servo motor and knows what it does.	25,19
	Recognises the DHT11 Heat-Humidity sensor.	15,16,21,23,24,25
	Recognises the LED, knows what is required for it to light up.	11,12,25
	Tests the application, finds hardware errors.	11,12
	Makes physical connections of FPP and input-output hardware to be used in an application.	11,12,23,24
	Knows FPP output hardware.	6,9,23,14
	Knows what a single board card is.	26
Programming	Recognises Ardunino IDE interface	3
	Adds libraries to Ardunino IDE according to need	4,19,20,23,27

	Knows the programming languages that can be used in Ardunino IDE	2
	Makes physical programming using variables and operators	8,13,14,18,22
	Makes physical programming using condition	7,8,14,22,27
	Makes physical programming using loops	9,13,22
	Recognises the necessary dwellings for time control	9,10,13,22
	FPP controls GPIO (general input-output pins) with the programme.	7,8,10,13,18,23,27
	Tests the application, finds software errors.	8,9,10,11,12,14,18
IOT	Knows the features of cloud platforms	29
	Knows how physical devices are mapped to cloud platforms.	31
	Shows examples for the Internet of Things	30
	Know what the Ubidots application is.	28

Physical Programming Achievement Test (K12)

This test was developed to measure K12 students' achievement in physical programming and was applied as a pre-test and post-test. The test consists of 20 multiple choice questions. Questions on hardware, programming and Internet of Things were included in the test and the number of questions and the item specification table including the gains for the test are given in Table 3.

Table 3

K12 Achievement Test Item Specification Table

Outcome group	Question No
Hardware	1,2,5,6,7,8,9,10,14,15
Programming	1,3,4,11,12,13,16,17

Internet of Things	18,19,20

Focus Group Interview

The focus group interview was conducted with K12 students at the end of the implementation. The interview lasted between 10-15 minutes with each group. The following questions were asked to the students in the interview and the interview was video recorded.

1. What are your thoughts about physical programming?
2. What are your thoughts about making physical programming applications with the MIDEP card?
3. What are your thoughts about using the MIDEP card as a computer?

Data Analysis

In data analysis, firstly, it was checked whether the collected data exhibited normal distribution. For the data that were found to be normally distributed, t test was used in the pre-test - post-test comparisons of the groups. Friedman test, one of the non-parametric comparison tests, was used in the comparisons made for the sub-dimensions of the achievement test.

The data obtained from the focus group interview conducted in the study were reported by content analysis. Themes and codes were used in the process of analysing the data. In this context, firstly, the data were processed and then the processed data were coded. Then, themes were found in accordance with the coded data and finally the themes were organised and interpreted.

MIDEP Card General Specifications

MIDEP is an SBC that can be used both in industry and for educational purposes such as raspberyy pi, tinkerboard. It has ARM based imx8M processor and comes with linux based ubuntu system pre-installed. By connecting the screen, keyboard and mouse to the MIDEP card, it can be operated as a mini computer and can be connected to the wired (ethernet) or wireless (wi-fi) internet. It can also perform physical programming applications by exchanging data with the outside world via gpio pins or Arduino sensor board. MIDEP board and its peripherals are shown in Figure 1 and Figure 2.

Figure 1

MİDEP Board

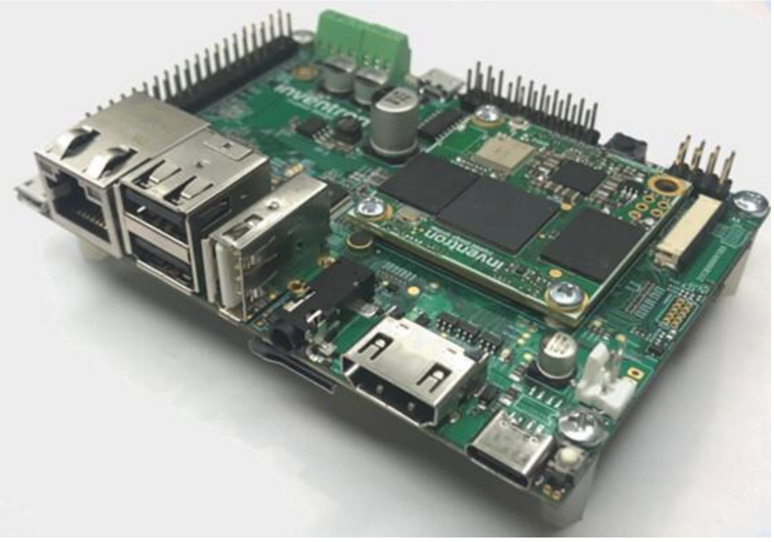
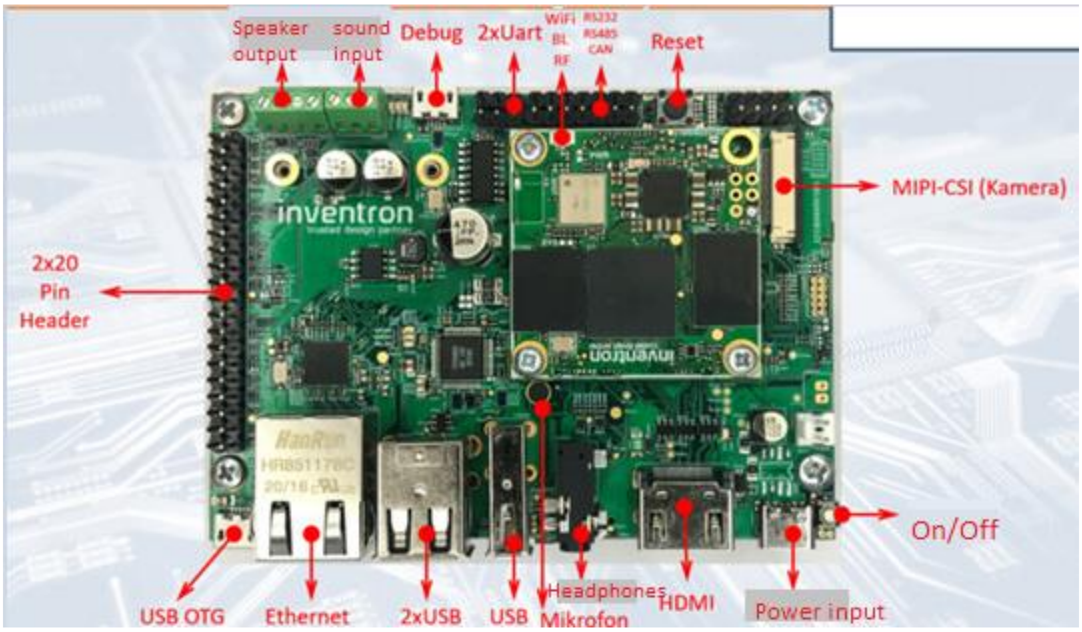


Figure 2

Top View Of MIDEP Card

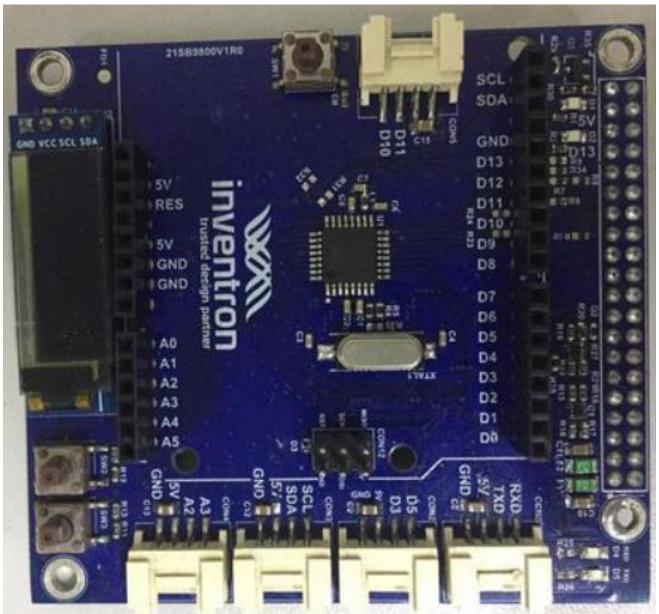


MIDEP Arduino Sensor Board

MIDEP arduino sensor board carries the pin configuration of the Arduino UNO model on it. In addition, it has an OLED screen, 3 buttons and 5 grove ports where digital, analogue, bluetooth and I2C units can be connected (Figure 3).

Figure 3

MİDEP Arduino Kartı Üst Görünüş



Results

Evaluation Results Related To Pre-Test Post-Test Comparisons Of Teachers Candidates' Achievement Test

Table 4 includes the test results of the evaluation over 100.

Table 4

Descriptive Statistics for Achievement Test Results

		Pre Test			Post Test		
	N	**Max**	**Mean**	**Standard Deviation**	**Max**	**Mean**	**Standard Deviation**
Hardware	19	56,25	28,61	16,71	68,75	48,02	14,44
Programming	19	50,00	25,14	16,29	66,67	47,37	11,01
IoT	19	100	31,58	33,17	100	57,89	32,33
Total	19	67,74	33,45	20,09	80,65	59,76	14,08

In the evaluation process, firstly, in order to decide on the statistical tests to be used in the pre-test - post-test comparisons, it was checked whether the data exhibited normal distribution, and it was seen that Skewness and Kurtosis values were between -1.5 and +1.5 for all data. After it was determined that the data exhibited normal distribution, t test, one of the parametric comparison tests, was used in the comparison process.

The results of the paired sample t test for the pre-test - post-test comparison of the total scores of the Physical Programming Achievement Test and the findings related to the hardware, programming and IoT sub-dimensions are given in Table 5.

Table 5

Physical Programming Achievement Test Total Scores and Pre-test Post-test Paired Sample T Test Results for Hardware, Programming, IoT Sub-dimensions

	Measure	**N**	**Mean**	**Standard Deviation**	**t**	**df**	**p**
Total	Pre test	19	33,45	20,08	-5,52	18	0,00
	Post test	19	59,76	14,07			
Hardware	Pre test	19	28,61	16,71	-4,53	18	0,00
	Post test	19	48,02	14,44			
Programming	Pre test	19	25,14	16,29	-5,18	18	0,00
	Post test	19	47,37	11,01			
IoT	Pre test	19	31,58	33,17	-3,11	18	0,01
	Post test	19	57,89	32,33			

As can be seen in Table 5, there is a significant difference in favour of the post-test in the comparison of pre-test and post-test total scores ($p<.05$). In addition, a significant difference was found in favour of the post-test in the scores obtained from the questions related to the acquisitions related to hardware, programming and IoT ($p<.05$).

Fiedman test, which is one of the dependent non-parametric comparison tests, was used in order to compare the effect of the training given in terms of sub-factors. When the test results given in Table 6 are analysed, it is seen that there is no significant difference in terms of sub-dimensions and the training given is equally effective in terms of sub-dimensions.

Table 6

Friedman Comparison Test Results for Post-test Pre-test Difference Scores of Achievement Test Sub-dimensions

Sub-dimensions	N	Rank Mean	Chi Square	df	p
Hardware difference score	19	2,03			
Programming difference score	19	1,92	0,19	2	0,9
IoT difference score	19	2,05			

Comparison results for the questions in the teacher candidates' achievement test

In order to evaluate the success of the students in the context of each question, column graphs were used. The column graph of the frequencies of the students who were able to solve each question in the Achievement Test correctly in the pre-test measurement is given in Figure 4. When the figure is analysed; it was determined that all questions (1,7,10,21,22,29) that were above average (8.5) were questions that did not require circuit installation on the breadboard.

Figure 4

Question Based Achievement Graph for the Pre-test

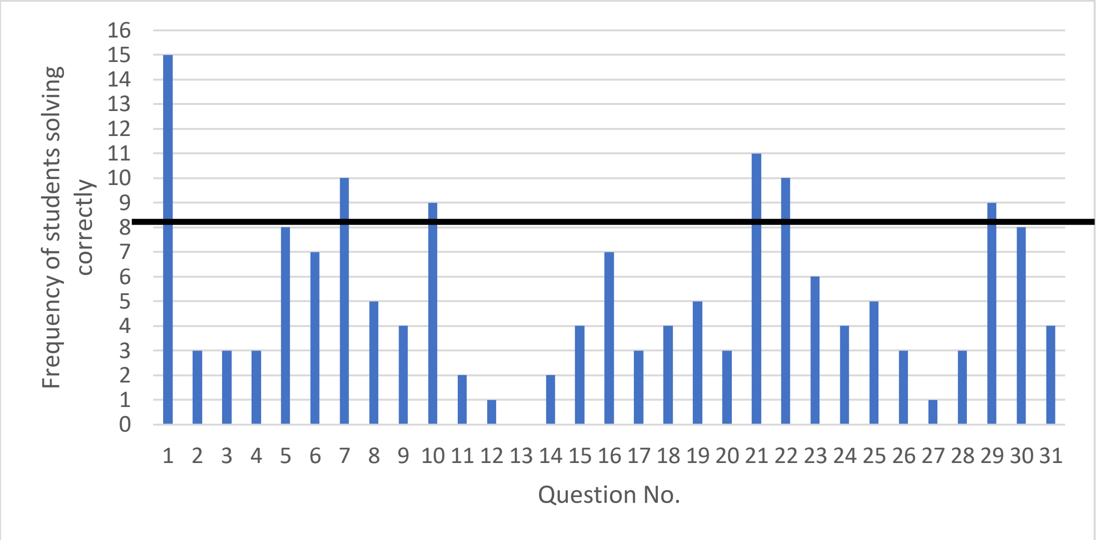
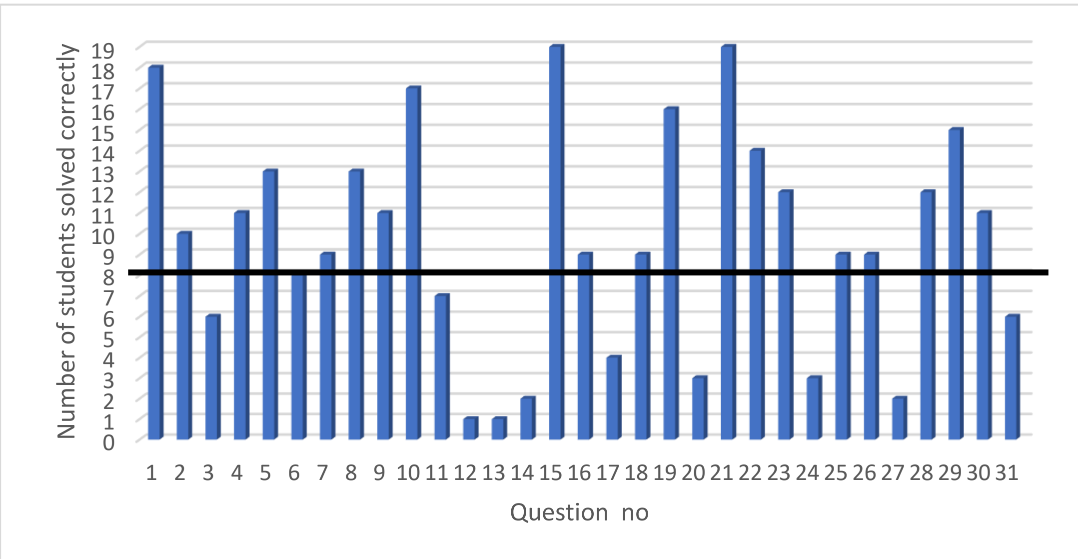


Figure 5 shows the post-test results of the students. Although it is seen that the number of questions above the pre-test average has increased in the evaluation, it was determined that the students' success in the questions that did not require the use of breadboard was relatively higher. It is seen that the participants showed success below the average in questions numbered 11,12,13,14, which require the use of breadboard.

Figure 5

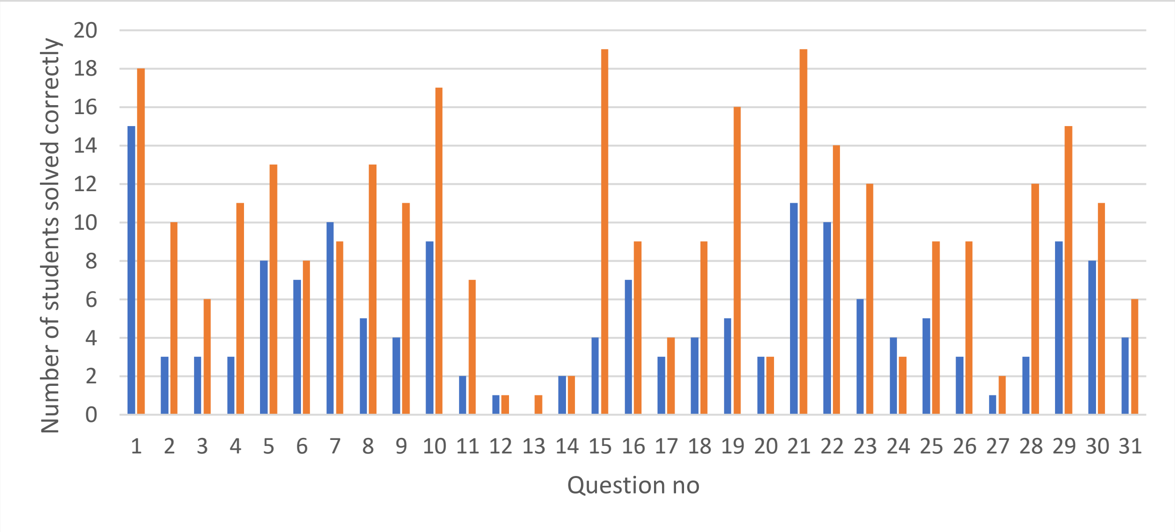
Question Based Achievement Graph for the Final Test



When the graph given in Figure 6, where the pre-test and post-test results of the students can be seen together, it is seen that the students improved in almost all questions and the number of students who could solve the questions correctly increased partially.

Figure 6

Question Based Achievement Graph for Pre-Test and Post-Test



Comparison Results According To Pre-Test Levels Of Teacher Candidates

In Table 7, the participants were divided into two different groups with pre-test results below and above the average (27,5). Thus, the effect of the training on students with different pre-test results was tried to be determined.

Table 7

Comparison Of The Study Group With The Overall Average

	Below average	**Above average**
Number of students	9	10
Average	12,5	41,0
Overall average	27,5	

Since the number of students in each participant group was not sufficient for normal distribution, this time group comparison was carried out using Mann-Whitney Test and the results are given in Table 8.

Table 8

Mann-Whitney U Test Results of Below Average and Above Average Groups

Groups	N	Mean Rank	Rank Sum	Mann Whitney U	z	p
Below average	9	8,11	73,00	28,00	-1,39	0,18
Above average	10	11,70	117,00			

When Table 8 is analysed, it is seen that there is no statistically significant difference between the groups, and the training provided brought the two groups with different levels of knowledge before the training to the same level of success.

Assessment Results For Students at K12 Level

The descriptive statistics results of the evaluation made out of 100 for the test results carried out with K12 level students before and after the application are given in Table 9.

Table 9

Descriptive Statistics for Achievement Test Results

		Pre Test			Post Test		
	N	Max	Mean	Standard Deviation	Max	Mean	Standard Deviation
Hardware	20	40	24,00	7,54	50	37,00	7,33
Programming	20	35	20,25	7,86	40	30,75	5,91
IoT	20	15	5,75	4,37	15	11,75	4,67

Total	20	80	48,50	15,31	95	76,00	13,24

Pre-test - post-test comparisons were carried out in order to determine the effects of the application with the MIDEP card in K12 level students. After it was determined that the data exhibited normal distribution in the normality test, t test was used in the comparisons.

The findings obtained as a result of the pre-test-post-test comparison to determine the extent to which the application carried out with K12 students affected the total score and the students' status regarding the hardware, programming and Internet of Things sub-dimensions can be seen in Table 10.

Table 10

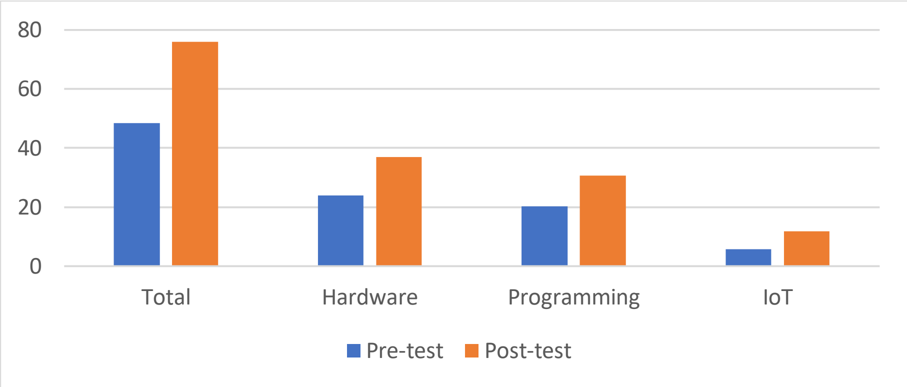
Pre-test Post-test Paired Sample T Test Results for Total Score, Hardware, Programming and IoT Sub-dimensions of Physical Programming Achievement Test

	Measure	**N**	**Mean**	**Standard Deviation**	**t**	**df**	**p**
Total	Pre test	20	48,50	15,31	-7,45	19	0,00
	Post test	20	76,00	13,24			
Hardware	Pre test	20	24,00	7,54	-6,3	19	0,00
	Post test	20	37,00	7,33			
Programming	Pre test	20	20,25	7,86	-5,20	19	0,00
	Post test	20	30,75	5,91			
IoT	Pre test	20	5,75	4,37	-4,86	19	0,00
	Post test	20	11,75	4,67			

As seen in Table 10, there is a significant difference in favour of the post-test in the comparison of pre-test and post-test total scores ($p<.05$). In addition, a significant difference was found in favour of the post-test in the scores obtained from the questions related to hardware, programming and IoT sub-dimensions ($p<.05$).

Figure 7

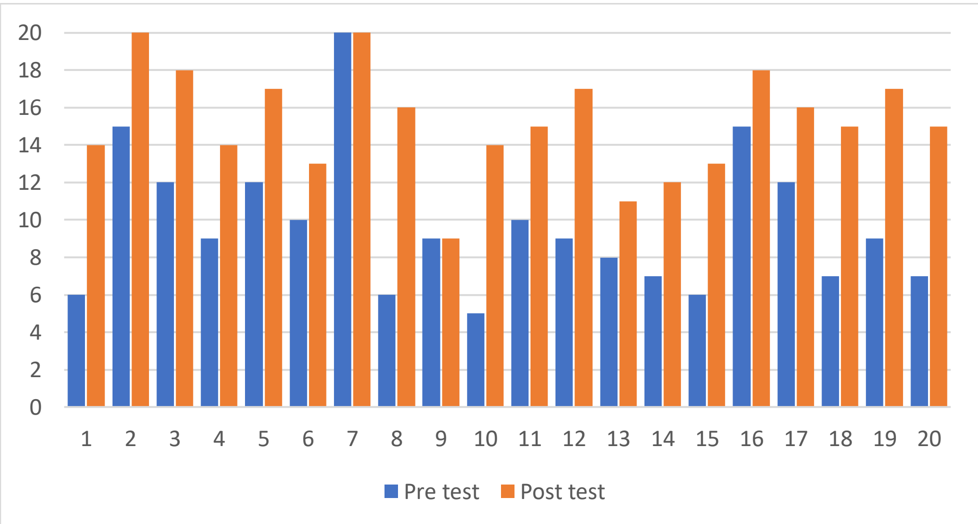
Comparison of Pre-Test Post-Test Score Averages According to Sub-Dimensions



The graph shows the comparison of pre-test and post-test mean scores according to sub-dimensions (Figure 7). As seen in the graph, it is seen that the average scores in all sub-dimensions increased in the post-test. The graph in Figure 8 shows the comparison of pre-test and post-test correct numbers according to the questions. According to the graph, it is seen that the number of correct answers increased in the post-test.

Figure 8

Comparison of Pre-Test Post-Test Correct Numbers According to the Questions

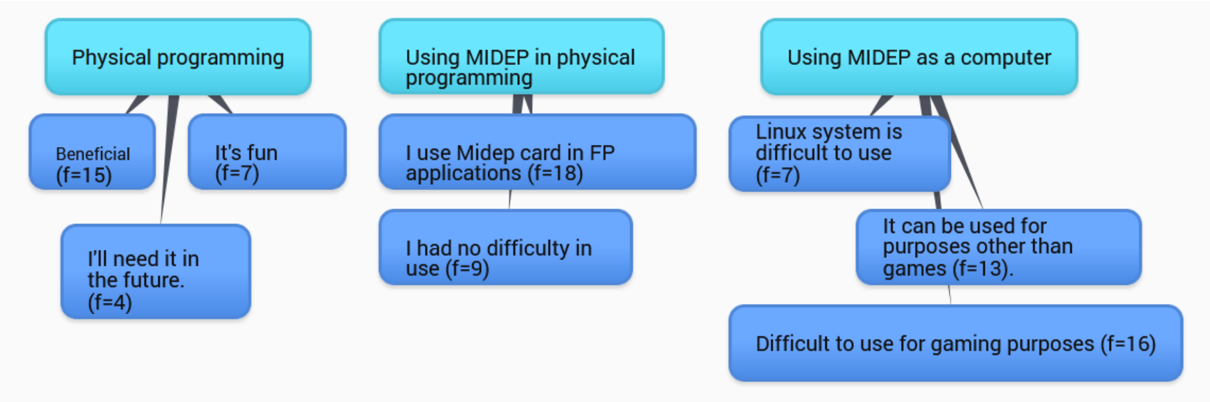


Findings Related To K12 Focus Group Interview

In the focus group interview, the answers given to the questions of physical programming, the use of MIDEP in physical programming and the use of MDAP as a computer were coded and presented under these three themes (Figure 9).

Figure 9

Responses to the Focus Group Interview



As seen in Figure 8, under the physical programming theme, the majority of the students found the physical programming applications useful (N=15). Most of the students stated that they could use the MIDEP card in physical programming applications (N=18). In the use of MIDEP as a computer, most of the students stated that it was difficult to use the MIDEP card for game purposes and that it worked slowly (N=16).

Discussion and Conclusion

According to the evaluation findings, there was a significant difference in favour of the post-test in the pre-test - post-test comparisons made in terms of both the total scores obtained from the achievement test and the scores obtained from the sub-factors (Hardware, Programming and Internet of Things) in pre-service teachers and K12 students. This finding agrees with similar studies conducted using physical programming cards (Bogdanovic et al., 2014; Charlton & Avramides, 2016; Osipov & Riliskis, 2013). However, considering that the training time given in the study was limited to four hours, it can be thought that this success will increase even more with longer trainings. This result needs to be tested with evaluations to be made after longer training.

When the comparison was made in terms of the sub-dimensions of the achievement test applied to the pre-service teachers, it was seen that it did not create a significant difference and was equally effective in terms of sub-dimensions. This result indicates that the projects included in the booklet target the achievements in the sub-dimensions and exhibit a balanced distribution. On the other hand, the fact that the pre-service teachers had taken a basic electronics course before the education given to them did not have a positive effect is a very thought-provoking result showing that the quality of the basic electronics course taken by the students should be questioned.

According to another result determined after the analyses, it was observed that the training given to the pre-service teachers using the MIDEP card and booklet reflected more positively on the achievement level of the disadvantaged group in terms of the pre-test results, that is, the students with pre-test scores below the average increased their achievement level as much as the students with above average scores. This result is an expected result and can be interpreted as the fact that the tools and materials used allowed students, especially those who had no experience in the subject, to learn gradually from easy to difficult. Because in the first projects, students had the opportunity to implement projects with block-based programming without the need for circuit installation with breadboard, and the fact that the cognitive load on the students was reduced in this process reflected positively especially on inexperienced students. This situation coincides with the results of studies that emphasise that block-based programming education has a positive effect and is an effective tool for beginners (Ozoran et al., 2012; Sırakaya, 2018; Talan, 2020; Tamer, 2021).

According to another evaluation result, it is seen that almost all of the questions in which the students showed above-average success in the question-based comparisons made to the pre-service teachers consisted of questions that did not require the use of breadboard. This is an important clue that although they are university students and have taken a basic electronics course before education, they may still have problems using a breadboard, and this result emphasises the importance and necessity of the tools and materials used in education.

The findings obtained from the interviews with K12 students indicate that students have a positive attitude towards physical programming applications. In addition, the students stated that they did not encounter any difficulties in performing physical programming applications with the MIDEP card. A significant portion of the students also stated that they did not experience any difficulty in using the MIDEP card as a computer. However, it is possible to say that the fact that the students experienced the Linux operating system for the first time had a negative effect on their use. The inclusion of a section on the use of Linux at a basic level in the MIDEP booklet, especially for K12 students, may reduce this difficulty. The fact that the MIDEP card does not have the hardware of an advanced desktop computer, especially in image processing, was also emphasised by the students and it was stated that it would not be possible to use the MIDEP card for gaming purposes. It can be said that the image processing capability of the MIDEP card should be improved as much as the price performance balance allows.

Recommendations

Although it was observed in the study that the physical programming training given with the MIDEP card and the experiment booklet had positive results, it is thought that there is a need to test the MIDEP card with longer-term trainings. On the other hand, the effectiveness of the MIDEP card can be tested in trainings such as Internet of Things, robotics, artificial intelligence, etc. The fact that the teacher candidates who took basic electronics course in the study could not make any difference against the teachers who did not take basic electronics course and that they still have problems in using breadboard type materials can be analysed in depth.

It is thought that the MIDEP card and booklet should be updated in parallel with the developing technology and contents, it should be able to offer different operating system options to the students, and the image processing capability should be increased as much as the price/performance ratio allows.

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