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Examining the Effects of Physical Variables in Classrooms on Students' Attention via the Internet of Things

Abdulkerim AYDIN*
Engineering Faculty & Software Engineering, Ataturk University, Erzurum, Turkey
ORCID: 0000-0003-4657-3683

Yüksel GÖKTAŞ
Engineering Faculty & Software Engineering, Ataturk University, Erzurum, Turkey
ORCID: 0000-0002-7341-2466

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This study aims to examine the effects of physical variables (temperature, humidity, air quality, light, and sound) and those pertaining to the monitoring these physical variables on a group of students in terms of attention, motivation, attitudes, and perceptions of academic achievement (POA). The students were provided with a chance to monitor the physical variables through the Internet of Things (IoT) technology. This study employed a causal comparative design, which is a quantitative research method. The sample chosen by convenience sampling consisted of 262 undergraduate students from five different educational environments in the faculty of education of a large state university located in the Northeast Turkey. A prototype measuring the physical variables of the educational environments and enabling to send these to the internet was developed in the context of an IoT application, and it was ensured that the students in the five different educational environments monitored the physical variables for six weeks. Data were collected by use of the prototype created in the framework of IoT and a questionnaire. Consequently, it was concluded that the physical variables did not have significant effects on attitudes, but temperature, air quality, light, and sound had significant effects on students' attention, motivation, and perceptions of academic achievement. Furthermore, results showed that monitoring the physical variables caused a difference in the students' motivation, attention, attitudes, and POA.

Introduction

The use of technology has rapidly become widespread in education, as in many areas. An examination of the use of technology in educational environments demonstrates that it is generally used for designing teaching, increasing teacher-student interaction, and promoting students' academic achievement. In addition, there are studies demonstrating that technology is also used for regulating educational environments (Kaur et al., 2022). Thus, since a

* Correspondency: abdulkerimaydn@gmail.com

considerable part of students' learning time is spent in these environments, they need to be regulated in a style convenient for learning (Lau & Ng, 2014). The process of designing these environments can be evaluated from two aspects, namely psychological and physical (Başaran, 1996). There are certain variables in psychological environments, such as attitudes, attention, motivation, and perception, that are important in learning (Driscoll, 2000; Schunk, 2012; Solso et al., 2007). Physical environments, on the other hand, contain several physical variables, such as the size, the shape, and the internal architecture of educational environments, air quality, sound level, intensity of light, and amount of humidity and temperature (Guntha et al., 2016; Lei, 2010; Wells & Daunt, 2016).

Physical Variables

The effects of physical variables in educational environments on students have been analyzed in some studies in the literature with temperature (Alberto et al., 2021; Wargocki & Wyon, 2007), sound (Guntha et al., 2016), and air quality (Bako-Biro et al., 2012; Mazutti et al., 2020) being analyzed in more detail; however, humidity has been considered together with temperature (Orosa et al., 2014). Studies concerning physical variables claim that light (Barrett et al., 2015) or sound (Uzelac et al., 2015) is the physical variable that affects students the most. Although the physical variables affecting students in educational environments the most differ in the literature, the most commonly accepted intervals for values (Lei, 2010; Şimşek, 2009; Wargocki & Wyon, 2007) are shown in Table 1.

Table 1. Optimum Values for Physical Variables

Physical Variable	Temperature	Humidity	Air Quality	Sound	Light
Optimum Value	20-25 ^{0}C	30-60%	at least 3 m^3 oxygen per person	30-60 dB	300-500 lux

Educational environments in which the temperature is not within the best value range have an effect on students' learning performance (Alberto et al., 2021; Wargocki & Wyon, 2007), and it is claimed that temperature levels have an effect on students' attention span and emotional states (Lei, 2010). While individuals' learning performance is higher at 21-22 °C, it decreases when the temperature goes above 25 °C (Seppanen et al., 2006). Based on the above-mentioned studies, it is considered that a temperature of 20-25 °C in educational environments would be more appropriate.

Another physical variable influential on students' performance is humidity (Orosa et al., 2014), which is directly affected by temperature. The appropriate humidity in an educational environment in which the temperature ranges from 20 to 25 °C is 30-60%; however, in laboratory environments, 50% is more appropriate. Furthermore, the ratio of the amount of humidity in educational environments has an important role, since the literature suggests that sudden changes in humidity may cause asthma (Şimşek, 2009).

An insufficient amount of oxygen, poor quality of air, or inadequate ventilation (Zagatti et al., 2020) in educational environments negatively affects students' learning performance (Bako-Biro et al., 2012; Choi & Suk, 2016). In addition, failing to have the right level of oxygen in educational environments can also lead to health problems in students (Daisey et al., 2003). Therefore, appropriate air quality levels should be provided, and educational environments should be arranged in a way that each person can have at least 3 m3 of fresh air.

Another factor affecting students in educational environments is the excessive amount of sound (Guntha et al., 2016), and Uzelac et al. (2015) stressed that sound was the physical

variable affecting students the most. When the level of sound in educational environments is too high, the teacher raises her/his voice, and s/he is obliged to spend more energy for classroom management. This results in wasting time in lessons, which is undesirable in educational environments (Palau & Mogas, 2019). In addition, too much sound in educational environments also causes students to have difficulty in focusing on the subject being taught and creates misunderstandings (Johnson, 2001). In noisy situations, students have to make more effort to understand the teacher, and this decreases their attention span (Palau & Mogas, 2019). For all these reasons, sound is one of the physical variables that need attention in educational environments (Recalde et al., 2020).

Barrett et al. (2015) performed multi-statistical analyses to determine the physical variables which affected students in educational environments the most. The results showed that the effect of light was 12% while the effect of air quality was 16% and that of temperature was 12%. The literature also reports that an inappropriate level of light affects students' academic achievement (Tanner, 2009) and their learning performance in class (Lei, 2010; Cech, 2016); thus, it is important to analyze the effects of light on students. A summary of the literature examining the effects of the five physical variables referred to in this study is given in Table 2.

Table 2. The Effects of the Physical Variables on Students

	Temperature	Humidity	Air Quality	Light	Sound
Reading Velocity	√	0	0	0	0
Performance	√	0	√	√	√
Academic Achievement	√	0	0	√	√
Psychology	√	0	0	√	0
Health	0	√	√	0	0
Focus	0	0	√	0	0
Attention	√	√	0	0	0
Motivation	0	0	0	0	0
Attitude	0	0	0	0	0
Perception of Academic Achievement	0	0	0	0	0

As shown in Table 2, physical variables have various effects on students, and the purpose of the current study is to analyze the effects of these variables on students. The study used the Internet of Things (IoT) to monitor the physical variables.

Internet of Things – IoT

IoT refers to the communication of devices that perceive and activate each other via a connection (Gubbi et al., 2013). IoT is used in many areas, such as health, smart homes, urban planning, and education (Aztori et al., 2010). As some research claims that 50 billion objects (devices) may connect to the internet in 2025 (Evans, 2011), the use of IoT in education becomes increasingly important with the strengthening of infrastructure and increase in investment. This paper examines the effects of physical variables on students using IoT technology, which ensures that students monitor the physical variables synchronically. The current study is considered important because of its use of IoT technology in education (Aydın et al., 2021). IoT technology enables information received from one object to be stored/observed in another and allows objects to send information to each other and interact (Moreira et al., 2017). In this study, the physical variable data taken from classroom

environments were stored and observed on a server. IoT technology is composed of the following components: internet, semantics, and things (Figure 1) (Atzori et al., 2010).

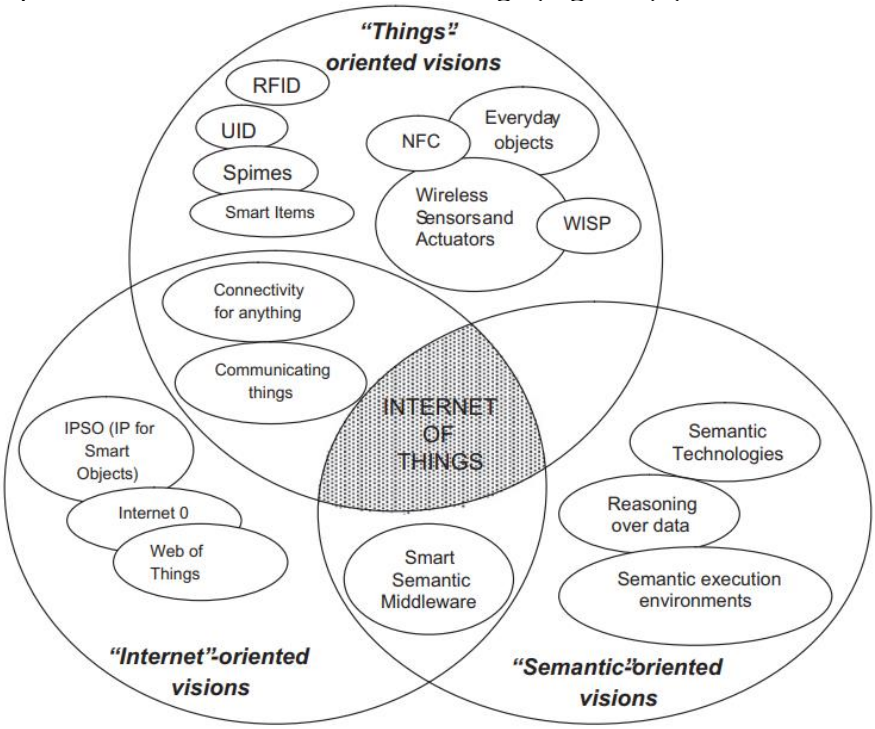


Figure 1. ‘‘Internet of Things” paradigm (Atzori et al., 2010).

IoT is used in various fields today and has positive effects (HaddadPajouh et al., 2021). It is mainly used in the fields of health (Qadri et al., 2020), logistics (Günay et al., 2021), smart cities (Huang et al., 2022), agriculture (Al-Garadi et al., 2020), and industry (Manavalan & Jayakrishna, 2019). Another field where IoT technology is used is education (Zeeshan et al., 2022). With the network infrastructure developed with IoT in educational environments, it has become more possible to access information from anywhere, to teach the concepts of computer science using IoT, to interact with materials remotely, and to collect data in educational environments through sensors (Aydın et al., 2021). Furthermore, using ICT technology, smart classroom, campus, and laboratory studies are conducted, and simultaneous feedback systems are created (Gul et al., 2017).

Significance and Purpose

The literature contains analyses on a number of physical variables in educational environments, in particular those that have an impact on students’ attitudes, attention, and motivation (Driscoll, 2000; Schunk, 2012; Solso et al., 2007). In general, students are expected to have positive attitudes towards their classes, focus their attention on lessons, be motivated, and have positive perceptions of academic achievement (POA) (Illeris, 2009). Therefore, physical variables that can affect students in educational environments should be revealed so that students can meet such expectations.

Previous research on physical variables has mostly addressed similar educational environments and similar students. Therefore, it is recommended that research also be conducted in different educational environments with students of different characteristics (Barrett et al., 2015). Thus, this study was conducted with students in five different educational environments. As shown in Table 2, there are only a limited number of studies

investigating the effects of physical variables (temperature, humidity, air quality, light, and sound) on students' attention, motivation, attitudes, and POA. Hence, the research questions focused on the following items:

(1) Which physical variable has the largest effect on students in educational environments?
(2) Which physical variables affect students' motivation, attention, attitude, and POA the most?
(3) Do temperature, humidity, air quality, sound, and light in educational environments cause a difference in students'
    (a) motivation towards the course?
    (b) levels of attention?
    (c) levels of attitudes?
    (d) POA?
(4) Does monitoring the physical variables in educational environments cause a difference in students'
    (a) motivation?
    (b) levels of attention?
    (c) levels of attitudes?
    (d) POA?

Method

This study adopted a causal comparative research design, which is a quantitative research method. Although the cause-and-effect relationships set up in causal comparative studies can be inadequate (McMillan & Schumacher, 2010), the study still employed a causal comparative design because studies using this design give ideas about the real causes of the subject studied even though they may not determine them (Gay & Airasian, 2000). Furthermore, such studies play important roles in conducting research in which it is not possible to intervene in independent variables (Fraenkel et al., 2011). This method was chosen in the current study since intervening in the physical variables of educational environments and changing them would be difficult to apply and would cause ethical problems. Thus, in this study, no interventions were made in the physical conditions of educational environments. Instead, they were monitored via a prototype created in the context of IoT, and the educational environments with good and bad physical conditions were distinguished.

Sample

The sample was formed through convenience sampling and composed of 262 undergraduate students from five different educational environments of the faculty of education of a state university located in the Northeast Turkey. The sample was chosen from the said faculty because it incorporated various types of classes and was easy to reach for the researcher. The sample group took part in the research on a voluntary basis. Since physical variables were analyzed, the features of the educational environments where the experiments were performed were important. Table 3 gives the data pertaining to the environments. The study was started in 2017, updated in the following three years, and ended in 2020.

Table 3. The Educational Environments in the Study

Type	Number of participants	Computer capacity	Experimental equipment	Field (m^2)	Volume (m^3)	Table	Interactive board
Graduate School classroom	18	-	-	37	148	15 (single)	1
Computer labs 1-2	78	48	-	115	460	49 (single)	1
Chemistry lab.	38	-	+	180	720	48 (single)	-
Regular classroom	23	-	-	59	236	10 (triple)	1
Lecture hall	105	-	-	177	885	40 (triple)	-
TOTAL	262	48	1	568	2449	152	3

Data Collection

Data were collected through a questionnaire and the prototype created within the framework of IoT. First, the physical variables of the five educational environments were monitored for six weeks, and the values were stored. In the second stage, the stored data were monitored, and the questionnaire was applied to the students both when the physical variables were appropriate and when they were not. In the third stage, the questionnaires were divided into two according to situations in which the physical variables were appropriate and inappropriate. In the final stage, the groups' questionnaires were compared, and any significant differences between them were determined. The data collection process is shown in Figure 2.

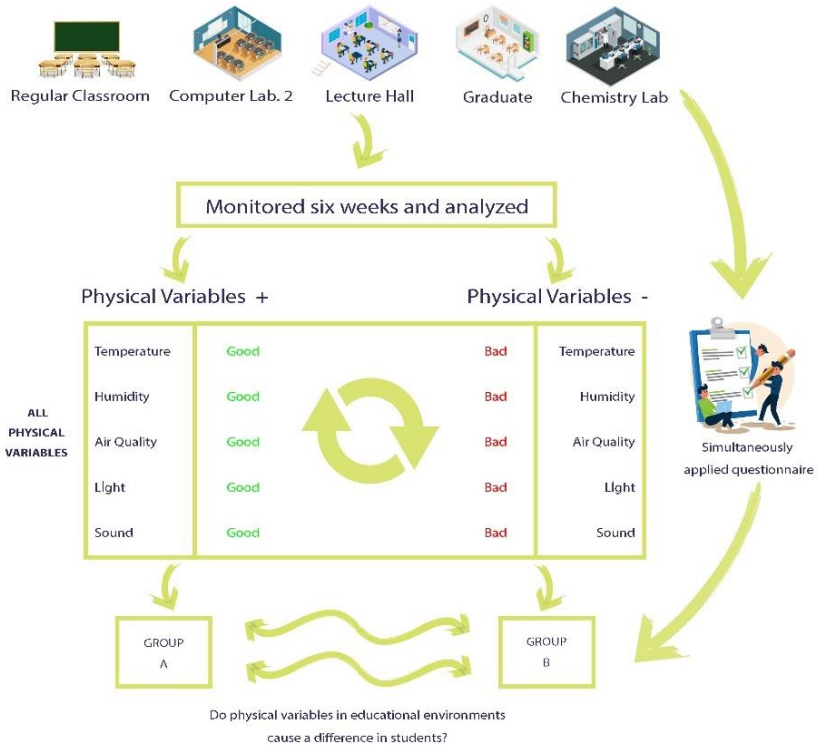


Figure 2. Data Collection Process

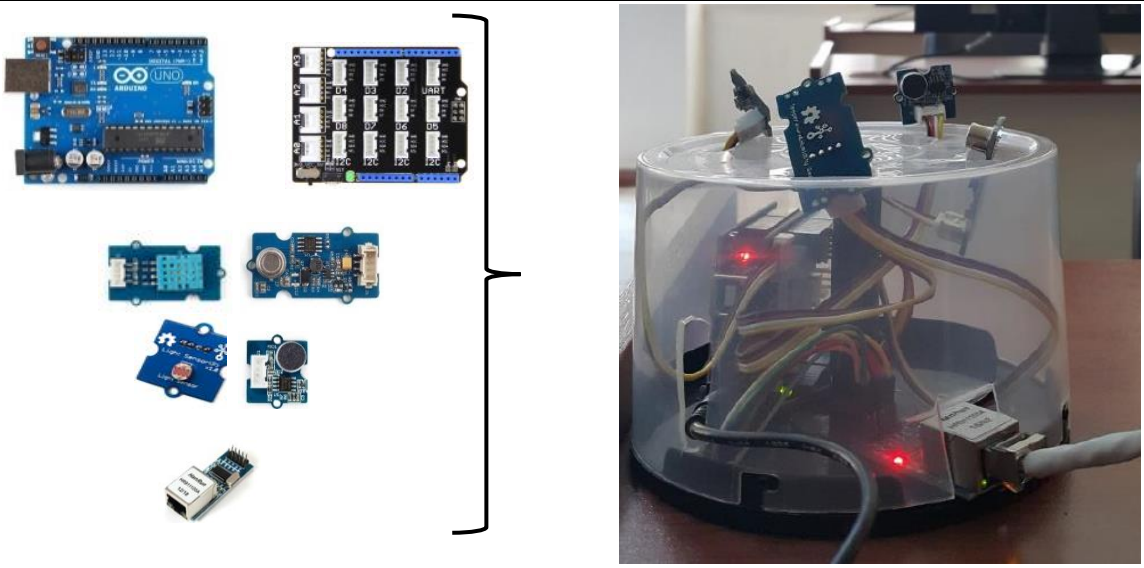
Questionnaire

As stated by Airasian and Gay (2003), it is necessary to take maximum care in relation to the validity and reliability measures in the process of developing a questionnaire. The reliability of the 30 items developed based on the five-point Likert-type measurement with the data collected in the study was found to be $\alpha = 0.805$. The questionnaire developed was given to the students at the end of each lesson, and they were asked whether their attention, motivation, attitudes, and POA were affected by the physical variables in the lesson that day. In this way, data were collected from the students for situations in which the physical variables were optimum and for situations in which the physical variables were not optimum. The data for the level of the physical variables were obtained from the prototypes which made instant measurements in the educational environments.

Prototype

A prototype was developed within the scope of IoT in this study. Arduino Uno R3 card, Grove module, Grove sensors (temperature, humidity, air quality, light, and sound), and an ethernet module were used to measure the physical conditions of the educational environments and to send the results to the internet. Card, module, and sensors used are shown in Table 4.

Table 4. The Products Used in the Prototype



The current version of the prototype consisted of the items described in Table 4. After the final testing, the prototype was ready. The places where prototypes would be put in the educational environments were chosen considering that they would be close to the classroom environment, would not ruin the ergonomics, would not distract students' attention, would be in the appropriate location for the measurements, and would supply the average values in the educational environments. In consideration of these factors, five prototypes were placed in different educational environments as described in Table 5.

Table 5. The Location of the Prototypes in the Educational Environments

Classroom	Location	Description
Graduate school classroom	In the middle of the room	A small classroom which can hold 15 students and contains a round table. The prototype was placed in the middle of that table where it was close to students and measured the average physical conditions in the educational environment.
Regular classroom	At the top left-hand side of the blackboard	A 30-student classroom with a traditional desk arrangement. Measurements were made by placing the prototype in different locations in the classroom, and no significant differences were found between them. Since the light on the ceiling did not yield fruitful values, the prototype was then placed at the top left-hand side of the blackboard, a location which would not distract students and in which accurate measurements would be made.
Chemistry lab.	On the column in the middle of the classroom	A room in which chemistry classes are held and experiments are undertaken. Placing the prototype on the ceiling would not work, since the ceiling was too high. Thus, it was installed on the column in the middle of the classroom where students did experiments. This location allowed the physical values of the environment to be measured accurately and the data about the average physical conditions of the classroom to be obtained.
Computer labs 1-2	On one of the computer desks students use	This room contains 48 computers in a traditional classroom layout. Initially, it was considered that the average physical values could be obtained from the middle of the ceiling in the classroom, but the values for the light were not appropriate. In the pilot studies, the measurements made according to the desks the students used provided fruitful results, and thus a computer desk used by the students was the right location in which the average classroom physical conditions could be measured. Thus, that location was chosen.
Lecture hall	At the top left-hand side of the blackboard	The 90-people lecture hall was the largest space in the study. The middle of the ceiling was too high, and the measurements made from that point did not reflect the classroom atmosphere directly. The light values obtained at the back of the classroom were too low compared to the average values. Therefore, the prototype was placed at the top left-hand side of the blackboard, a location close to the students and from which the average classroom values could be measured.

The prototype produced in IoT technology contributed to the study as follows: 1) The data concerning the educational environments in the study could be instantly monitored. 2) The data related to the physical variables could be sent to the internet. Then, the students were able to immediately monitor the physical variables in the educational environments.

The data sheet of the sensors (Grove base shield module, temperature-humidity, air quality, light and sound sensors) indicated that the sensors used in the prototype could make valid measurements even in the long term (Grove, 2019). After determining their validity, the five prototypes were produced and exposed to evaluation by placing them in the same environment. The average measurement results obtained at the end of the one-week evaluation are shown in Table 6, revealing that the data had over 99% similarity. Thus, it can be stated that the prototypes made valid and reliable measurements.

Table 6. Relative Evaluation of the Prototypes

Prototype No	Temperature (^{0}C)	Humidity (%)	Air quality (3)	Light (Lux)	Sound (Db)
1	27.70	32.49%	2.12	376	47.50
2	27.57	33.10%	2.12	377	47.16
3	27.48	32.70%	2.13	379	47.18
4	27.80	32.92%	2.12	380	47.39
5	28.10	32.24%	2.11	378	47.70

Data Analysis

The data in the groups studied did not have normal distribution. In such cases, the Mann-Whitney U test, the non-parametric equivalent of the t-test, should be used, and the findings should be obtained accordingly (Airasian & Gay, 2003). The analysis methods used for the research questions in this study are shown in Table 7.

Table 7. Data Analysis

Research questions	Data collection tools	Data analysis techniques
1	Questionnaire	Descriptive
2	Questionnaire	Descriptive
3	Questionnaire	Descriptive /Mann-Whitney U
	Prototype	Descriptive /Mann-Whitney U
4	Questionnaire	Descriptive /Mann-Whitney U
	Prototype	Descriptive

Results

Physical Variable Most Affecting the Students in the Educational Environments

The questionnaire asked the students which physical variable most affected them. The results indicated that the students had been most affected by temperature ($\overline{X}$= 4.20), which was followed by air quality ($\overline{X}$ = 4.13), sound ($\overline{X}$= 4.02), and light ($\overline{X}$= 3.86), and they were least affected by humidity ($\overline{X}$= 3.75).

The Ways in which the Physical Variables Most Affected the Students

The averages for the questions about the effects of physical variables on the students' attention, motivation, and POA were examined in this study. Accordingly, the physical variables had the greatest effect on the students' attention ($\overline{X}$= 4.17), which was followed by motivation ($\overline{X}$ = 4.15) and attitudes ($\overline{X}$= 4.06), respectively, and they had the least effect on their POA ($\overline{X}$= 3.82).

The Effects of the Physical Variables

The effects of the physical variables on the students were examined. The students were asked to complete a questionnaire concerning whether the physical variables were within the range of optimum values. In Table 8, Group A shows the situation in which the physical variables were within the range of optimum values, and Group B shows the situation in which they were not within the range of optimum values.

Table 8. The Effects of Physical Variables on the Students

		Motivation		Attention		Attitude		POA	
		A	B	A	B	A	B	A	B
Temperature	n	143	119	143	119	143	119	143	119
	Mean Rank	142.74	118	140.40	120,.0	138.08	123.59	144.42	115.8
	$\overline{X}$	4.58	4.29	4.44	4.23	4.28	4.15	4.07	3.70
	SD	0.706	0,.14	0.698	0.799	0.812	0.852	1.028	0.935
	Z		3.013		2.320		1.687		3.232
	p		*0.003**		*0.020**		*0.092*		*0.001**
Humidity	n	114	148	114	148	114	148	114	148
	Mean Rank	136.52	127.64	136.59	127.58	132.75	130.54	127.74	134.39
	$\overline{X}$	4.01	3.89	3.96	3.83	3.73	3.72	3.60	3.75
	SD	0.902	0.938	0.985	0.901	1.002	1.056	1.110	0.953
	Z		1.012		1.013		0.246		0.738
	p		*0.311*		*0.311*		*0.806*		*0.461*
Air Quality	n	181	81	181	81	181	81	181	81
	Mean Rank	142.49	94.50	141.01	99.47	135.51	118	137.98	109.68
	$\overline{X}$	4.39	3.90	4.40	4.06	4.30	4.25	4.01	3.66
	SD	0.898	0.877	0.842	0.634	0.801	0.436	1.071	1.019
	Z		4.745		4,121		1.771		2.686
	p		*0.000**		*0.000**		*0.077*		*0.007**
Light	n	182	80	182	80	182	80	182	80
	Mean Rank	143.79	120.28	145.50	118.73	139.55	124.16	146.75	117.58
	$\overline{X}$	4.09	3.78	4.19	3.90	4,08	3.90	3.98	3.51
	SD	0.919	1.017	0.839	0.839	0.898	0.866	1.213	1.023
	Z		2.724		3.126		1.796		3.265
	p		*0.006**		*0.002**		*0.073*		*0.001**
Sound	n	101	161	101	161	101	161	101	161
	Mean Rank	145.76	122.56	150.97	119.29	140.89	125.61	145.88	122.48
	$\overline{X}$	4.32	4.04	4.45	4.09	4.22	4.00	4.07	3.75
	SD	0.849	0.964	0.714	0.860	0.823	0.993	0.986	1.065
	Z		2.632		3.598		1.722		2.575
	p		*0.008**		*0.000**		*0.085*		*0.010**

It is clear from Table 8 that the variables of temperature, air quality, light, and sound had significant effects on the students' attention, motivation, and POA. However, humidity did not have significant effects on the students. In addition, the physical variables did not have significant effects on the students' attitudes.

The Effects of Being Able to Monitor the Physical Variables

Of the students addressed in the five educational environments in this study, those in the computer lab, regular classroom, and chemistry lab monitored the physical variables while the students in the graduate school class and the lecture hall did not monitor the physical variables. Thus, whether there were any significant differences in attention, motivation, attitudes, and POA between the groups who monitored and who did not monitor the physical variables was examined. The results (Table 9) showed that monitoring the physical variables caused a difference in the students' motivation, attention, attitudes, and POA.

Table 9. The Effects of Monitoring the Physical Variables on the Students

	Motivation		Attention		Attitude		POA	
	A	B	A	B	A	B	A	B
n	139	123	139	123	139	123	139	123
Mean Rank	145.64	115.52	146.46	114.59	140.91	120.87	142.57	118.99
$\overline{X}$	3.89	3.43	3.87	3.41	3.87	3.56	3.75	3.39
SD	0.953	1.102	0.899	1.047	0.838	1.064	0.984	1.076
Z		3.374		3.592		2.266		2.631
p		*0.001**		*0.000**		*0.023**		*0.009**

Discussion

Temperature was found to be the physical variable most affecting the students, which could be attributed to the climate of the city in which the study was conducted. The average temperature of this city during the six weeks when the study was performed was 7 °C, and the average temperature in the educational environments was 23 °C. Apparently, the temperature was too low outside but too high inside the educational environments. Thus, the difference in temperature may have affected the students. The study also found that unsuitable temperatures reduced the students' motivation, distracted their attention in class, and reduced their POA, which is consistent with the literature (Lei, 2010; Wells & Daunt, 2016). On the other hand, the study determined that temperature did not have a significant effect on attitude, although in the questionnaire, some students commented that temperature could affect their attitude when the levels were not appropriate over a long time.

Emmons and Wilkinson (2001) argue that humidity at inappropriately high levels distracts students' attention and can even cause health problems. In the current study, 38% of the students said that raised humidity made breathing difficult. The variable of humidity is generally considered together with temperature (Barrett et al., 2015; Orosa et al., 2014). In the current study, humidity and temperature were considered as variables to be analyzed separately. Although indirect interpretations on humidity were presented, it was concluded that humidity did not have significant effects on the students, which could be attributed to the humidity being approximately 24% in one group and 36% in the other. In addition, the rate of humidity in the city in which the study was conducted was 32% on average during the six weeks of the experiment process, confirming that humidity did not have significant effects on students. However, the researchers believe that conducting the study in a city with a higher percentage of humidity may change the results.

Since it is considered that there should be at least 3 m^3 of fresh air per person in educational environments (Şimşek, 2009), students are reported to be unable to focus on lessons when there is not sufficient fresh air in educational environments (Uzelac et al., 2015). This study also revealed that the students' motivation decreased, their attention was distracted, and their POA was negatively affected when the air quality was poor. Yet, no significant effects were found on attitudes when the air quality was poor, although the students stated that their attitudes would be affected if they were exposed to poor air quality (Zagatti et al., 2020) for a long time. Therefore, it would be more meaningful to analyze the effects of air quality on students' attitudes through a study which would take longer than six weeks.

The sound level in educational environments is a variable likely to affect students' academic achievement and psychological states (Palau & Mogas, 2019). Some of the studies examining the effects of physical variables claim that sound is the physical variable most affecting

students (Uzelac et al., 2015). This paper examined the effects of sound on students and found that having an inappropriate level of sound affected the students' attention, motivation, and POA in negative ways. However, it was also found that the level of sound did not have significant effects on the students' attitudes. The students stated that having inappropriate levels of sound in the educational environments for a long time would affect their attitudes.

The last physical variable of this study was light. Some studies consider light as the physical variable most affecting students (Barrett et al., 2015; Emmons & Wilkinson, 2001). Barrett et al. (2015) detected that having light at inappropriate levels in educational environments had a negative effect on students physically and mentally. Moreover, the level of light also affects students' academic achievement (Tanner, 2009) and their performance in classes (Lei, 2010; Cech, 2016). The current study analyzed the effects of light on students' motivation, attitudes, and POA. The students stated that they were more alert and more motivated in educational environments with an appropriate level of light and that they would be more successful in that situation; however, the level of light was found to have no significant effects on attitudes, although the students commented that being in conditions of inappropriate light for a long time might affect their attitudes.

Given the literature in the related field and the results of the current study, it is concluded that it is necessary to design experiment which can reduce the negative effects of physical variables on students (Barrett et al., 2015; Recalde et al., 2020; Lei, 2010; Wargocki & Wyon, 2007). The current study used IoT to reduce the effects of physical variables on students, and thus enabling students to continuously monitor the physical variables on the internet. In this way, the students were informed about the conditions of the educational environments in which they would be taught, and they attended the classes that were more suited to the conditions of the educational environments. Thus, the students were provided with a safer environment. The students who monitored the physical variables via IoT stated that their attention, attitudes, motivation, and POA were affected in positive ways, since they felt more comfortable.

Limitations of the Study

This study aims to examine the effects of physical variables and monitoring these physical variables on a group of students in terms of attention, motivation, attitudes, and POA. The study has some limitations. First, among physical variables, only temperature, humidity, air quality, light, and sound were examined in the study. Other physical variables were not considered. Second, data were collected from 262 undergraduate students at a university in Northeast Turkey. In future studies, data can be collected from students from different climates and cultures. The third limitation is about the physical variables. During the study period, the physical variables may have changed in a way that students could not notice. The fourth and last limitation is that just two data collection tool was used in the study. More data collection tools can be used in future studies.

Conclusion and Suggestions

This study analyzed the effects of physical variables on students and demonstrated the results by applying IoT through which students could monitor those variables. The results obtained about the effects of physical variables are summarized in Table 10. It was found that the physical variable most affecting the students was temperature and that the physical variables most affected their motivation and attention.

Table 10. Summary of the study results

	Temperature	Humidity	Air Quality	Light	Sound	Monitoring
Attention	+	-	+	+	+	+
Motivation	+	-	+	+	+	+
Attitude	-	-	-	-	-	+
POA	+	-	+	+	+	+

The findings of the study were compiled to determine the effects of physical variables on students. In the light of the findings obtained from this study, the following recommendations for improvements to educational environments can be made to future researchers and practitioners:

(1) Windows allowing enough sunlight in could be designed.
(2) Lights could be arranged in a way that brightness can be automatically adjusted according to the level of sunlight in the room.
(3) Active smart heating and cooling systems could be used in order to maintain temperature at ideal level.
(4) Humidifiers could be used to balance the humidity.
(5) New learning institutions could be built in quieter areas of cities, or sound insulation could be applied to existing buildings.
(6) To raise the air quality, trees could be planted in the neighborhood of schools, universities, and other learning institutions.
(7) Studies conducted on the effects of physical variables on attitudes could be analyzed over longer periods of time.
(8) Tools should be used for preventing excessive heating and for maintaining air quality at the optimum level in schools and other learning institutions.
(9) In situations where the rate of humidity differs, the effects of humidity on students could be studied comparatively.
(10) Studies to reduce the negative effects of physical variables on students could be undertaken.
(11) Prototypes produced through IoT technology could be used for data collection purposes.

Note

This study was created from the master's thesis titled " Examining the influence of physical variables in classrooms on students via internet of things application (Thesis Number:463100)

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APPENDIX 1. QUESTIONNAIRE

THE EFFECTS OF PHYSICAL VARIABLES ON STUDENTS

Respond to the following statements by choosing the option that you think is most suitable for you (based on today's class)	I absolutely disagree	I disagree	I am undecided	I disagree	I absolutely agree
1) When it is too hot or too cold in the classroom, it reduces my motivation towards the class.	*1*	*2*	*3*	*4*	*5*
2) When it is too hot or too cold in the classroom, it distracts my attention.	*1*	*2*	*3*	*4*	*5*
3) When it is too hot or too cold in the classroom, it affects my attitudes towards the class in a negative way.	*1*	*2*	*3*	*4*	*5*
4) When it is too hot or too cold in the classroom, it affects my achievement in the class in a negative way.	*1*	*2*	*3*	*4*	*5*
5) When it is too hot or too cold in the classroom, it does not affect me much.	*1*	*2*	*3*	*4*	*5*
6) Too much or too little humidity in the classroom affects my motivation in the class in a negative way	*1*	*2*	*3*	*4*	*5*
7) Too much or too little humidity in the classroom distracts my attention.	*1*	*2*	*3*	*4*	*5*
8) Too much or too little humidity in the classroom affects my attitude towards the class in a negative way.	*1*	*2*	*3*	*4*	*5*
9) Too much or too little humidity in the classroom affects my achievement in the class in a negative way.	*1*	*2*	*3*	*4*	*5*
10) Too much or too little humidity in the classroom is not important for me.	*1*	*2*	*3*	*4*	*5*
11) Having a classroom sufficiently ventilated affects my motivation in a positive way.	*1*	*2*	*3*	*4*	*5*
12) Having a classroom sufficiently ventilated helps me focus in the class better.	*1*	*2*	*3*	*4*	*5*
13) Having a classroom sufficiently ventilated affects my attitude towards the class in a positive way.	*1*	*2*	*3*	*4*	*5*
14) Having a classroom sufficiently ventilated helps me succeed more in the class.	*1*	*2*	*3*	*4*	*5*
15) I do not mind the amount of ventilation in the classroom.	*1*	*2*	*3*	*4*	*5*
16) Not having sufficient light in the classroom affects my motivation in the class in a negative way.	*1*	*2*	*3*	*4*	*5*
17) Not having sufficient light in the classroom distracts my attention.	*1*	*2*	*3*	*4*	*5*
18) Not having sufficient light in the classroom affects my attitude towards the class in a negative way.	*1*	*2*	*3*	*4*	*5*
19) Not having sufficient light in the classroom affects my achievement in the class in a negative way.	*1*	*2*	*3*	*4*	*5*

20) Having too much or too little light in the classroom is not very important for me.	*1*	*2*	*3*	*4*	*5*
21) When the sound level in the classroom is too high, it reduces my motivation towards the class.	*1*	*2*	*3*	*4*	*5*
22) When the sound level in the classroom is too high, it distracts my attention.	*1*	*2*	*3*	*4*	*5*
23) When the sound level in the classroom is too high, it affects my attitude towards the class in a negative way.	*1*	*2*	*3*	*4*	*5*
24) When the sound level in the classroom is too high, it affects my achievement in the class in a negative way.	*1*	*2*	*3*	*4*	*5*
25) The sound level in the classroom does not affect me much.	*1*	*2*	*3*	*4*	*5*
26) Being informed about the measurements of the physical variables (temperature, light, air quality, sound, and humidity) in the classroom increases my motivation.	*1*	*2*	*3*	*4*	*5*
27) Being informed about the measurements of the physical variables (temperature, light, air quality, sound, and humidity) in the classroom increases my attention.	*1*	*2*	*3*	*4*	*5*
28) Being informed about the measurements of the physical variables (temperature, light, air quality, sound, and humidity) in the classroom helps me to develop a positive attitude towards the class.	*1*	*2*	*3*	*4*	*5*
29) I think I will be more successful when I am informed about the measurements of the physical variables (temperature, light, air quality, sound, and humidity) in the classroom.	*1*	*2*	*3*	*4*	*5*
30) Knowing about the measurements/conditions of the physical variables in the classroom is not important for me.	*1*	*2*	*3*	*4*	*5*