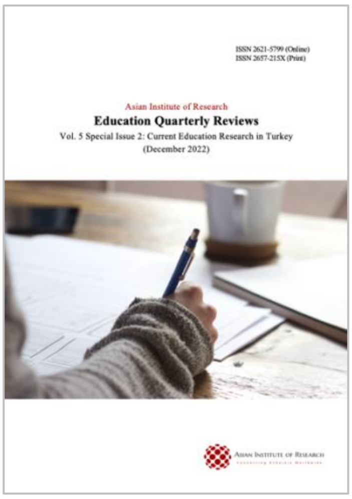

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Examining the Effect of Using Mobile Technologies in Chemistry Laboratory on Self-Directed Learning Readiness: An Action Research

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Abstract
The aim of the present research is to determine the current situation in the readiness levels of 11th grade high school students for self-directed learning, to examine the effectiveness of laboratory activities developed with with mobile technology integrated into the 5E learning model in various chemistry subjects on students' self-directed learning levels, and to contribute to improving the quality of teaching by taking student opinions about the activities developed at the end of the study. The research was designed as action research from qualitative research designs. The related laboratory activities developed within the scope of the research were carried out with thirty-three 11th grade students. The Self-Directed Learning Readiness Scale (SDLRS) was used to determine the readiness levels of high school students for self-directed learning and a semi-structured interview form was used to determine the students' views on the activities. The data obtained from the interviews were analyzed by content analysis. During the applications, students performed the activities with mobile technology in a much shorter time compared to the classical laboratory activities and they had the opportunity for self-directed learning thanks to the mobile technology support they used in the applications. In the study, it was observed that students improved their ability to display the data obtained from the necessary calculations in various chemistry subjects, especially at the end of the activities, in the form of graphs without the help of a teacher.

Keywords: Chemistry Laboratory, High School Chemistry Teaching, Mobile Technology, Readiness for Self-Directed Learning

1. Introduction

1.1 Introduce the Problem

Today, technology plays the most important role in making life easier and more efficient (Siwawetkul & Koraneekij, 2020). The availability of smartphones at affordable prices has led to an increase in the use of applications for various aspects of life such as communication, travel, entertainment, productivity and learning (Kearney, Burden & Rai, 2015). Technology is widely used in every aspect of our daily lives as well as in teaching and learning environments. The mobile devices used in mobile learning in our modern life are summarized as follows (Göksu & Atıcı, 2013): Laptop, tablet PC, personal digital assistant, smartphone. Four different communication or connection technologies are used to enable mobile devices to communicate online or with other mobile devices: GPRS, Wireless (Wi-Fi), Bluetooth and Infrared. These communication technologies are available on some mobile devices. With the advent of mobile technologies, students learn how to better learn scientific knowledge through these mobile devices, and in the process, students become inquisitive and inquisitive individuals. Mobile learning provides new possibilities for the learner, such as learning that is personalized, contextualized and unhindered by temporal or environmental constraints and self-directed / independent (Crompton, 2013).

The definitions made in terms of the amount of responsibility that learners accept for their own learning are used in the literature for self-directed learning. The self-directed learner takes control of his/her own learning and is free to learn the information that he/she thinks is important to him/her (Fisher, King & Tague, 2001). The willingness of the learner to undertake his/her own learning varies depending on attitude, ability and personality traits. Knowles (1975, 1990) mentions two continuous situations in educational environments: Teacher-directed (pedagogical) learning and self-directed (andragogic) learning. According to Knowles (1990), the pedagogical learner is completely dependent on the teacher in identifying learning needs, formulating goals, planning and implementing learning activities, and assessing learning. Andragogic learners, on the other hand, prefer to take responsibility for meeting their own learning needs (Fisher, King & Tague, 2001). Therefore, the self-directed learning continuum can be defined as follows: The amount of control the learner has over his/her own learning, the amount of freedom given to learners to assess learning needs and apply strategies to achieve learning goals (Fisher, King & Tague, 2001).

Undoubtedly, constructivist learning approach is one of the educational environments in science education that enables students to increase their responsibility for their own learning, to have more control over the teaching of targeted concepts, facts and events, and to be active and active in accessing information inductively. At each stage of the learning models in this learning approach, students are active and take more responsibility for their self-learning in accessing information (Güngör Seyhan & Morgil, 2007). In this study, the 5E learning model based on the constructivist learning approach was used. The activities developed to be applied at various stages of the related learning model were supported by sensors integrated with mobile technology. Experimental sets consisting of sensors integrated with mobile technology consist of a PC tablet and a wide variety of sensor kits. The experiment set can be used for teaching-learning purposes in both in-class and out-of-class environments. In case some of the variables targeted to be investigated change during the experimental process, the relevant experimental set can provide opportunities to record data instantaneously in a synchronized manner and display them in the form of tables/graphs. Therefore, it is seen that laboratory applications at the high school level in the Turkish education system are not carried out very often, and the related activities are carried out with closed-ended (confirmatory) laboratory approaches and therefore are examples of pedagogical learning as stated by Knowles (1990) (Güngör Seyhan & Okur, 2020). In the light of this information, this study aims to develop laboratory activities through sensors integrated with mobile technology integrated into various stages of the 5E learning model in teaching various chemistry topics. In this way, it is thought that laboratory activities carried out through sensors integrated with mobile technology will provide an andragogic learning environment for high school students. The opinions of the volunteer students selected for the effectiveness of the related activities on the students' readiness levels for self-directed learning were also consulted at the end of the study.

1.2 Research Objectives

For improving education at all levels in schools and in the field of learning, improving teacher quality and productivity, competencies need to be developed and the teaching environment needs to be reorganized and strengthened in accordance with the student-centered approach. Based on all this information, the aim of this study is to examine the effect of laboratory applications carried out through sensors integrated with mobile technology integrated into the 5E learning model for high school 11th grade students on students' self-directed learning readiness levels. At the end of the study, student opinions about the activities were also investigated.

2. Conceptual Framework

2.1 Self-Directed Learning

Nowadays, thanks to the developing technology, accessing information and following new developments has become easier and easier, and the need for learning and therefore questioning new information has also increased. In this process of rapid change, the environments in which students receive ready-made information and passively participate in learning-teaching environments have been replaced by an education system in which students actively participate in the learning process, are more critical and inquisitive, and are more responsible for their own learning. The main purpose of the science course is to raise individuals who can use 21st century skills such as questioning, research, analytical and critical thinking skills, and being a good problem solver. Bloom states that there are different components of learning and that these components should take place in learning processes in certain steps. These components include curiosity, need, motivation, questioning, doubt, research, experimentation, adaptation and reinforcement. It is emphasized that learning can be complete and useful when these components are present. All these developments bring along the importance of the concepts of readiness for self-directed learning in the literature.

The earliest sources of self-directed learning date back to Greek philosophers. According to Socrates, it was defined as the self-directed learning of individuals by taking advantage of the opportunities in the environment, while Plato emphasized that the most important goal in students' learning was to give them the ability to learn by self-direction. While Aristotle emphasized the importance of self-awareness, Kulich (1970) gave many examples of self-directed learning in history. Newsom (1977), on the other hand, worked on the importance of "Lifelong Self-Directed Learning" in 1558-1640 and argued that andragogic learning in classes, schools and libraries has many benefits. This learning has been defined as "the degree to which an individual possesses the attitudes, abilities and personality traits necessary for self-directed learning" (Wiley 1983, p.182). If the content of this definition is examined, there are several assumptions about readiness for self-directed learning: Adults are naturally self-directed, so readiness for self-directed learning exists along a continuum and is present to some degree in individuals. Second, the competencies necessary for self-direction can be developed to some extent and the best way to learn autonomous behavior is to act autonomously. Finally, the ability to learn independently in one situation or context can be generalized to other settings (Candy 1991; Fisher et al., 2001; Guglielmino 1989).

2.2 Self-Directed Learning and Technology

With the rapid development and change in the technology sector in recent years, laptop computers, smart phones and tablets have replaced the desktop personal computer, which has been used as the only technology product in the classroom until now, as they are more ergonomic and offer access at less cost. The integration of more widespread internet access into these technologies and their use in educational environments provide teachers with more flexibility for their role as a guide. As the place of technology in the learning-teaching environment becomes more important, researchers have started to give more importance to studies on this subject (Meyer, Rose & Gordon 2014). However, it is also among the opinions stated that access to technology alone will not be sufficient for students' self-directed learning (Rose & Meyer, 2002). For this reason, all knowledge, skills and tendencies that may be necessary for students and/or teachers to develop self-directed learning should be investigated first (Shotlekov & Charkova, 2014). Afterwards, it is necessary to investigate the knowledge, skills and tendencies required for technology literacy and technology integration of students and teachers (Reinders & White, 2016; Jiménez, Lamb & Vieira, 2017). How students' technology literacy should be measured and evaluated is one of the issues that should be investigated. Based on all this, it has become a common goal for educators to incorporate technology into learning-teacher environments to support more self-directed and autonomous learning in the classroom. However, it is reported that teachers have difficulties in integrating more self-directed learning approaches, methods and/or techniques into their educational environments. Self-directed learning differences in students and/or various competency differences in students, language backgrounds and/or socioeconomic backgrounds are shown as the reason for this situation (Francis, 2017).

2.3 Mobile Technology in Turkish Science Education

The use of information technologies such as computers in science teaching is one of the most promising developments in recent years. However, very little research is known about the use of such information technologies within the framework of applied learning-teaching environments such as laboratories. Using computers integrated into laboratory work is one of the special opportunities that this technology provides.

Computers can serve as tools for measurement, graphing, simulation and modelling, to list just a few of the rich possibilities. Many related studies have claimed that one of the main problems posed by the "classical" laboratory work in science education is that students can perform experiments without being able to successfully follow the steps described in the laboratory worksheet and without understanding the physical model that validates their activity (Lunetta 1998; Pernot, 1993). The new technologies can complement and further support student collaboration and participation in school laboratory experiences (Lunetta 1998) emphasize that computer-aided modeling can be more effective in enabling students to be more active during laboratory work (Schecker 1990; Niedderer, Schecker & Bethge 1991) and in strengthening the link between theory and practice (Sander, Hucke & Fischer, 2002).

An education project has been developed in Turkey in order to use technology effectively in the classroom, to eliminate the inequality of opportunity between schools in terms of technological equipment and to enable teachers to integrate technology into their classrooms more easily. The FATIH Project, carried out in cooperation with the Ministry of National Education and the Ministry of Transport, aims to provide technological equipment to schools, professional development programs for teachers on the use of this equipment and training of users. In addition, this project has many specific objectives such as developing lifelong learning, enabling individuals to improve themselves through e-learning, ensuring that every student graduating from high school has the skills and basic knowledge to use information technologies, ensuring that one out of every three people benefit from e-education services through the effective use of the Internet, providing individual opportunities for the use and learning of information and communication technologies, and making the Internet a safe environment for the whole society. In this context, the Ministry of National Education has demonstrated that it is not remaining silent about technological applications by purchasing experiment sets with sensors (NOVA 5000-Tablet PC) integrated with mobile technological devices in parallel with the developments in technology to the science laboratories in the schools within the scope of this project, which was put into practice in 2009.

2. Method

2.1. Research Design

This research was designed as action research, one of the qualitative research methods. Action research involves the researchers' handling of the implementation process in order to understand and solve the problems that arise in practice (Yıldırım & Şimşek, 2013, p.74). Action research begins with reflections on the practices by the researcher. The plan created to solve the problem must be compatible with the research methods and appropriate tools should be used in this process. Even if the plan is well designed, it can be revised throughout the process. When the relevant action is completed, reflection is made on this action and the action is evaluated (Collins & Spiegel, 1995).

2.1 Study Group

The study group of the presents research consists of 33 high school 11th grade students studying in a branch of one of the qualified public high schools in the center of Sivas province. The sample of study group was determined according to the purposeful sampling method, which is one of the non-probability sampling methods. In this sampling method, the researcher determines the units to be included in the sample with the researcher's own judgment in accordance with the purpose of the researcher based on previous knowledge, experience and observations (Ural, 2011:45). In this study, sensors integrated with mobile technology were used in the applications in the guidance materials developed by the researchers. Therefore, students in schools that have mobile technological devices used within the scope of the study were included in the study. Students carried out the applications in the developed guidance materials in groups of 4-5 students. The implementation process was carried out as group work. Simple random sampling method was used to form student groups (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz & Demirel, 2008: 89).

2.2 Data Collection Tools

In order to determine the self-directed learning readiness of high school students, the "Self-Directed Learning Readiness Scale (SDLRS)" developed by Fisher, King and Tague (2001) was used as a data collection tool in this study. In the original version of the scale, Fischer et al. (2001) created an item pool of 93 items after reviewing the literature, and then these items were presented to expert opinion using 2 rounds of Delphi technique, and a 52-item draft form was created. After the draft form, it was applied to 201 students studying in the Nursing Undergraduate Program. A 40-item 3-dimensional (self-management, desire for learning and self-control) scale was obtained from the application, whose Kaiser-Meyer-Olkin (KMO) value was calculated as 0.88. The total internal consistency reliability coefficient of the scale was 0.92; the internal consistency reliability coefficients of the three subscales were calculated as 0.86, 0.85 and 0.83 respectively. The adaptation of the scale to Turkish for use with prospective teachers was carried out by Şahin & Erden (2009) and Salas (2010). The scale was used by Ulusoy & Karakuş (2018) for the study conducted for high school students. In the study by Salas (2010), first of all, linguistic equivalence of the scale items was made and factor analyzes were performed by applying the form to pre-service teachers in order to determine the construct validity of the Turkish form. As a result of the factor analysis, the KMO value of which was calculated as 0.90, 7 out of 40 items in the original scale were removed from the scale. Consisting of 33 items and 3 dimensions (self-management, desire for learning, and self-control), the scale explains 41.02% of the variance and item loads vary between 0.35 and 0.76. In comparisons between 27% upper and 27% lower group averages, t values were found to be significant at the level of 0.00 ($p=0.00<0.05$). While scoring the items in the scale, the individual who marks the "Strongly Agree" section is given 5 points, and the individual who ticks the "Strongly Disagree" section is given 1 point. Since items 25 and 33 contain negative statements, they are scored in reverse while scoring. Other than these items, 31 items are scored normally. The lowest score that can be obtained from the scale is 33, and the highest score is 165. It is accepted that the higher the score obtained from the scale, the higher the individual's SDLR level (Salas, 2010).

Cronbach's Alpha coefficient was used to determine the internal consistency of the scale. The Cronbach's Alpha value, which is the internal consistency coefficient of the scale, was 0.91; The internal consistency coefficients of the three factors were calculated as 0.89, 0.82 and 0.77, respectively. In addition, the total item correlations were checked for reliability. The correlation between the main scale and subscales was significant at $p<0.01$ ($p=0.00<0.01$). In the light of these data, it is seen that the scale is a valid and reliable valid measurement tool that can be used to measure pre-service teachers' self-learning readiness. A pilot study was conducted with 178 high school students before using SDRLS in this study, which was adapted into Turkish for use with pre-service teachers. After the validity and reliability analysis, the Cronbach's alpha reliability coefficients of the scale were calculated as 0.84 for the total scale and 0.81, 0.80 and 0.82 for the sub-dimensions, respectively.

Another data collection tool used in the study was semi-structured interview forms consisting of 4 open-ended questions. This form included students' opinions about the laboratory applications carried out with mobile technology, which were thought to have an impact on students' readiness for self-directed learning. Expert opinion was utilized to ensure the content and face validity of the semi-structured interview questions. The interviews were conducted with a total of 6 volunteer students who participated in the activities. It is very important to ensure ethical rules in research, therefore, the students were coded as VS1, VS2, ..., VS6 in order to keep their identities confidential. The interview with each student lasted approximately 15-20 minutes.

2.3 Mobile Technology-Supported Laboratory Activity

The study started with a literature review on laboratory applications with sensors integrated with mobile technology. As a result of the reviews, it was determined that applications supported by mobile technological devices are not used in science laboratory environments in the Turkish education system (Güngör Seyhan & Okur, 2020). Experimental sets consisting of sensors integrated with mobile technology were used in the study. The related experiment sets are Windows CE-based NOVA5000 experiment systems distributed to schools by MoNE in 2009 for use in primary and secondary education levels. NOVA5000 experiment systems are portable systems that can work with Windows operating system and allow data to be transferred to other devices using technology. In this context, it was decided to prepare laboratory activities realized with the help of sensors integrated with mobile technology in teaching various chemistry subjects at high school level. After the pilot studies of the developed activities, the necessary arrangements were made by the researchers and the actual applications were started.

2.4 Application Process

In this study, it was determined that high school students' readiness for self-directed learning was at a low level with the pre-test of the SDLRS applied before the interventions. The reason for this result may be that there are limited laboratory applications for the subjects that are theorized in the classroom in science courses, the use of classical experimental tools and the experiments are carried out with closed-ended laboratory approaches in cookbook format. Therefore, the researcher(s) aimed to solve this problem with a study based on the technical skills laboratory approach. In the study, it is thought that the contents of laboratory applications supporting the theoretical teaching of various chemistry topics given in high school chemistry course should be revised and with this revision process, students' readiness for self-directed learning can be improved. For this purpose, four guidance materials were designed for various chemistry topics (Gas Laws, Colligative Properties, Solubility, Chemical Equilibrium: Let's Find the Equilibrium Constant) within the framework of the 5E learning model, including laboratory activities supported by sensors integrated with mobile technology. The related materials consist of student worksheets in which the introduction, exploration and evaluation steps of the 5E learning model are discussed and a teacher guide material in which all steps of the learning model are explained. The study was conducted in a total of 10 weeks during the academic year in which the related chemistry topics were included.

3. Results

3.1 Findings from the self-directed learning readiness scale

SDLRS was applied as pre and post-test in order to determine the students' readiness levels for self-directed learning before the applications and the change in these levels after the 10-week applications. The results obtained from the dependent variable t-test analysis to determine whether there is a significant difference between the pre and post test scores of the related scale are given in Table 1.

Table 1: Dependent variable t-test results regarding SDLRS pre- and post-test scale scores

SDLRS	N	X	SD	df	t	*p*
Pre-test	33	83.5758	5.08693	32	- 17.094	0.000
Post-test	33	106.4848	7.32343			

According to the analyses, there was a significant increase in students' readiness for self-directed learning as a result of sensor-supported laboratory applications integrated with mobile technology ($t(33)= -17.094$, $p<0,005$). Before the applications, the mean of the pre-test results of the students' SDLRS was $X_{pre}= 83.58$, while this value was $X_{post}= 106.48$ after the applications. This finding shows that sensor support integrated with mobile technology in laboratory applications is effective in increasing students' readiness for self-directed learning.

3.2 Results from the semi-structured interview form

Sensor-supported laboratory applications integrated with mobile technology for various chemistry subjects were carried out in the study. In this context, student and teacher guidance materials were developed for various chemistry subjects. At the end of each related activity and then at the end of all the applications, 6 volunteer students were interviewed about the effectiveness of the applications.

In the first question of the semi-structured interview questions, pre-service teachers were asked "Considering the experimental process steps of the laboratory applications with sensors integrated with mobile technology (separately for each of the related activities), what do you think about the advantages and disadvantages? Explain" question was asked. The answers given by the students to this question of the interview were transcribed and codes were created. As a result of the answers given, the codes extracted as the advantages and disadvantages of the applications and the sample answers given by the students are presented in Table 2

Table 2: The students' responses and frequencies to the first question of the interviews as "Advantages (A) and Disadvantages (D)"

Code No	Code	Participants	f	Excerpts from student responses
A1	Effective and economical time management	VS1,VS2, VS3, VS4, VS5, VS6	6	*"...By performing our experiments much faster, we had the opportunity to do the experiment over and over again and to notice the variables in the experimental setup..." (VS6).* *When we did the "chemical equilibrium" experiment with classical tools, we were reaching the equilibrium constant from the height calculation by looking at the color intensity of 4-5 solutions that we created by diluting from the standard solution. Sometimes this high value could be very different from the values found by other groupmates and this took a lot of time. But with these experiment sets, we finished this experiment on our own in a very short time" (VS3).* *"...We can reach the results of the experiment in a very short time. We were able to spend more time on graphing these results and interpreting the graphs when we wanted to..."(VS1).*
A2	Faster access to more reliable data sources	VS2, VS3, VS4, VS6	4	*"...These sensor kits allowed us to reach the results of the experiment in a shorter time. In this way, we had the opportunity to discuss more with our groupmates about the results of the experiment. Since we easily understood how to use these sensor kits in the process steps of the sample experiments, we needed our teacher in very few stages in real activities." (VS2).*
A3	Providing synchronized visual data	VS1, VS4, VS5, M6	4	*"..... For example, in the experiment "Finding the chemical equilibrium constant", we were able to see the data we received with the help of the colorimeter sensor for the color intensity values corresponding to each solution concentration on the PC tablet in both table and graph form" (VS6).* *"In the experiment about the equilibrium constant, our teacher asked us to draw the results in the form of a graph using the values obtained at the end of the experiment. Many of my groupmates had difficulty in drawing. With the instant display of the graphs on the PC tablet, we had the opportunity to compare ourselves." (VS3)*
A4	Preservation of written and visual data in digital environment	VS1, VS2, VS3, VS4, VS5, VS6	6	*"...Maybe this is the best part of these applications. In the previous semester, we had a notebook in which we recorded all the data in the laboratory. In these applications, we were able to record all the data of each activity on the PC tablet, we did not have to worry about losing the data."(VS2).*
A5	Being portable (mobile) of experimental tools and equipment	VS1, VS2, VS3, VS4, VS5, VS6	6	*"One of our activities was about colligative properties. In the freezing point depression experiment, we had the opportunity to take the temperature sensor and watch the change in the freezing point of water in the school garden." (VS1)*
D1	Requires experience in installation and use	VS1, VS4, VS5, VS6	4	*In the experiment "...Finding the equilibrium constant" we used the colorimeter sensor and it was the first time we had seen it. Although our teacher had explained the colorimeter analysis beforehand, it was a bit tiring to put the solutions into the relevant tubes and place them on the sensor and access the*

				desired information on the PC tablet and understand what it meant, so we relied more on our teacher's help" (VS4).
D2	Blunting the ability to record and visually present data from BSBs	VS1, VS4, VS6	3	*"...We had experiments that required both graphical and tabular representation of the data at the end of the experiment. Especially in the experiment "Let's find the equilibrium constant", we had to reach the equilibrium constant by interpreting the graphs to be drawn with the help of the data. As in this experiment, some of our groupmates used the graphs drawn instantly on the PC tablet instead of drawing them themselves in advance." (VS6)*
D3	Sensitivity and high cost of sensors	VS1, VS2, VS3, VS4, VS5, VS6	6	*"At the beginning of the lesson, our teacher told us that experiment sets with sensors are quite costly. Since the new version of the sets had just been released, he mentioned that it would be difficult to find spare parts for these sets and told us to use them carefully. This worried us" (VS6).*

The second question of the interviews was "On the PC tablet screen, one of the mobile technological devices, there were synchronized table and/or graphical displays for your related experiments. Do you think that the instantaneous nature of these displays provided any benefit for you to draw graphs independently? Explain with your justification". The answers given by the students to this question of the interview were analyzed and codes were created. The codes extracted as a result of the answers given and the sample answers given by the students are presented in Table 3.

Table 3: Student responses and frequencies to the second question of the interviews

Code No	Code	Participants	f	Excerpts from student responses
*DIGBS1	The instantaneous nature of table/graphic representations facilitates learning	VS2, VS3, VS5, VS6	4	*"...For example, in the gas laws experiment, it was very nice to see and interpret the instant graphs with the other variable affected by this change as soon as we changed a variable for each law" (VS2)*
DIGBS2	To teach drawing and interpreting tables/graphs independently	VS2, VS3, VS5	3	*"Since we had to reach conclusions about the graphs we drew in the activities, we were able to draw more accurate graphs with the help of the tables shown instantly. And the conclusions we reached could be more accurate" (VS3)*
DIGBS3	Passivating table/chart drawing	VS1, VS4, VS6	3	*"In some experiments, some of my groupmates were trying to conclude the experiments directly from the ready-made graphs instead of drawing independent graphs and comparing them with the graph on the PC tablet." (VS6)*

*DIGBS: Drawing and Interpreting Graphs by Self

In the third question of the interviews, the students were asked "In this study, you used sensors integrated with mobile technology in applications related to various chemistry subjects. So, in which other science subjects other than chemistry would you consider using these mobile technological devices and why? Explain your reasons with your examples". The answers given by the students to this question of the interview were analyzed and codes were created. The codes extracted as a result of the answers given and the sample answers given by the students are presented in Table 4.

Table 4: Student responses and frequencies to the third question of the interviews

Code No	Code	Participants	f	Excerpts from student responses

Physics	Presenting examples of physics topics	VS1, VS2, VS3, VS4, VS6	5	*“For example, among the sensors, we can use current and voltage sensors in experiments related to the subject of “transformer” from physics” (VS2)* *"We can use the magnetic field sensor in the "Magnetism" unit” (VS4)*
Biology	Presenting examples of biology topics	VS3, VS5, VS6	3	*“I think oxygen or pulse sensors are super sensors, I think they are often used in the "Respiratory systems" unit” (VS3)* *“Our teacher mentioned the pulse sensor, it can be used in the unit "Circulatory systems” (VS5)*

In the fourth question of the interviews, the students were asked “What are your thoughts and suggestions about the contributions of laboratory applications with the help of sensors integrated with mobile technology to science education?”. The answers given by the students to this question were analyzed and codes were created. The codes extracted as a result of the answers given and the sample answers given by the students are presented in Table 5.

Table 5: Student responses and frequencies to the fourth question of the interviews

Code No	Code	Participants	f	Excerpts from student responses
S1	Increasing self-confidence and motivation	VS1, VS2, VS3, VS4, VS5, VS6	6	*“As we used the equipment in the experiment sets more often, we were able to set them up more easily and perform experiments more easily. Our enthusiasm for laboratory practices increased.” (VS6)* *“We looked forward to the lab class throughout the semester, we felt like we were the real owners of the lab” (VS2)*
S2	Increasing the ability to use technical tools	VS2, VS4, VS5, VS6	4	*“We are not unfamiliar with sensors, especially in the field of robotics and coding, we often heard about them, such as distance sensors or light sensors. In these sets, we learned much more types of sensors. We had experiences about how instantaneous changes are realized and visually given through a sensor.” (VS4)*
S3	Enabling self-learning	VS1, VS3, VS4, VS6	4	*“I think it is enough for our teacher to teach the installation and use of the sensor kits, and then we can reach the results on our own by trial and error” (VS6)* *“These were the applications where we developed the ability to draw graphs on our own. At least we reached the correct drawings on our own by comparing them with the graphs on the PC tablet without asking our teacher” (VS4)*
S4	Ability to continue learning in out-of-school environments	VS1, VS2, VS6	3	*“As I mentioned before, we can use the sensors in the experiment set not only in the classroom but also outside the classroom. Because all the tools used in the whole set are portable.” (VS1)*
S5	Time savings	VS1, VS2, VS3, VS4, VS5, VS6	6	*“We do not carry out laboratory applications very often, but in some of the applications we did, since the experimental process took a lot of time, the conclusion and/or discussion of the data obtained from the experiment was given as homework. In these applications, we were able to complete all of them in the same class period” (VS6)* *“I think the biggest contribution of these apps is that they save time. But I think these applications should be built in. In this way, we can do laboratory practice more often.” (VS4)*

4. Discussion

Prior to the applications, it was determined that the 11th grade students participating in this study had a low level of readiness for self-directed learning ($X=83.58$). This situation is considered to be originated from the fact that in addition to in-class theoretical teaching of the subjects in high school level science courses, limited activities of laboratory applications are carried out with classical experimental instruments and closed-ended laboratory approaches in cookbook format. Based on this basic problem situation, students' and teachers' guidance materials suitable for laboratory applications with sensors integrated with mobile technology were developed in the present study to be used in teaching various chemistry topics (Gas Laws, Colligative Properties, Solubility, Chemical Equilibrium: Let’s Find the Equilibrium Constant). It is thought that these guide materials will support the development of students' self-directed learning skills. At the same time, it is aimed to contribute to improving the quality of teaching by taking student opinions about the activities at the end of the study. Following the chemistry laboratory applications carried out with the help of sensors integrated with mobile technology, it was determined that there was a significant increase in students' readiness levels for self-directed learning and the scores obtained were in the average category ($X=106.48$, $p<0.005$). Today, self-directed learning has attracted great attention at all levels of education, especially in the field of adult education. In recent years, educators have begun to pay more attention to the idea that learning does not have to be connected to school (Keeton, 1976; Fisher et al., 2001). Even when learning takes place in connection with an educational institution, some individuals may respond better when given more opportunities for self-direction in the learning process (Guglielmino, 1977). The term "self-directed learning" has been used to describe behaviors ranging from participation in programmed learning (Campbell, 1963) to the self-initiated, self-planned activities of self-directed learners such as Maslow's self-actualizing individuals (Maslow, 1969; 1970).

Self-directed learning is defined as the ability of students to identify their own learning needs and goals without the help of others, to identify the necessary human and material resources, to identify appropriate learning strategies and to evaluate the results of learning (Fisher et al, 2001). Constructivist learning approach, which integrates laboratory environments that require the use of mobile technological tools, is one of the most effective learning approaches that can develop this ability. In the study, it was observed that the mobile technology supported 5E learning model led to an increase in students’ readiness for self-directed learning. These results support the results of Okur (2014; 2021), Okur & Güngör Seyhan (2022) and Güngör Seyhan & Okur (2022) studies using strategies, methods and techniques within the constructivist learning approach in which technology is integrated.

At the end of the study, the students stated that the necessary data in their experimental applications was obtained in a short time through the sensors in the related mobile technological devices and this was a great advantage. The students also stated that they think that the "learning" process can happen by itself and independent of the teacher, as mobile technological devices such as these experimental sets are independent of time and space. It is observed that learning activities that will take place outside of school, when applied in a planned and systematic way together with the science curriculum used in in-school learning, make significant contributions to science learning and teaching in students (Luehmann, 2009; Tatar & Bağrıyanık, 2012; Güngör Seyhan & Çelik, 2021). The students stated that the activities carried out with mobile technological devices have advantages such as "it facilitates data recording and helps in graphic drawing". It is thought that the feature of recording data, as in these computerized systems, provides an important advantage for students to return to related data and graphics when they feel the need, even in the future, to increase their learning in related subjects (Güngör Seyhan & Okur, 2020; 2022). Students with personal mobile devices, from phones to laptops, can quickly access internet resources to support self-study. The increasing importance of information in the information age has led institutions to seek new methods to access information. At home and on the go, students value the opportunity to get quick access to learning resources and engage in non-formal learning. Some experts define devices, especially the Internet, as a technology that plays an important role in the process of knowledge transfer in order to apply different approaches in education. This process is done through familiar tools and interfaces without intrusion into their online social space. These technologies have an important role in education in terms of efficiency and making learning an enjoyable activity (Güngör Seyhan & Okur, 2022).

5. Conclusions

In recent years, it has become important to prefer an andragogic learning environment in which students prefer to take their own responsibility in meeting their own learning needs, unlike pedagogical learning, which is more dependent on the teacher in determining learning needs, formulating goals, planning and implementing learning activities, and evaluating learning. Undoubtedly, constructivist learning approach is one of the educational environments in science education that enables students to increase their responsibility for their own learning, to have more control over the teaching of targeted concepts, facts and events, and to be active and active in accessing information inductively. At each stage of the learning models in this learning approach, students are active and take more responsibility for their own learning in accessing information. Furthermore, students are encouraged to use tools and technology to conduct scientific research. Learning using mobile devices such as tablet computers facilitates teaching. Since wireless technology can be used anywhere, it also creates learning opportunities in out-of-school environments. This learning model is learner-centered in nature and supported by technology. Learning environments in which mobile technological devices are integrated provide the opportunity to access information anytime and anywhere. In this way, researcher-inquisitive learning-teaching in both classroom and laboratory environments will continue to function in realistic environments. Therefore, as in science education, mobile technological devices have been included in learning-teaching environments more and more in recent years. While preparing plans and programs, adopting mobile technologies as a tool rather than a target will provide a more effective use.

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