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Research Article

Effect of Algodoo Supported Periodic Table Instruction on Students' Achievements and Perceptions

Hasan ÖZCAN[1], Esra KOCA[2], Davut SARITAŞ[3], H. İlker KOŞTUR[4]

[1] Aksaray University, Faculty of Education, Türkiye, hozcan@aksaray.edu.tr, https://orcid.org/0000-0002-4210-7733

[2] Ministry of National Education, Sehit Mesut Acu Middle School, Türkiye, esra_gk@hotmail.com, https://orcid.org/0000-0001-8994-0397

[3] Nevşehir Hacı Bektaş Veli University, Faculty of Education, Türkiye, davutsaritas@gmail.com, https://orcid.org/0000-0002-5108-4801

[4] Başkent University, Faculty of Education, Türkiye, kostur@baskent.edu.tr, https://orcid.org/0000-0001-8557-4385

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Abstract–In parallel with the development of software technologies, there has been a growing use of useful and accessible simulation tools in education, enhancing the quality of simulations. This study investigates the effect of an activity designed to teach the periodic table on students' academic achievement and explore students' perceptions of the activity. The activity was based on the Algodoo tool, which is primarily used in teaching physics courses. This study employed a convergent parallel design as a mixed-methods research approach. The sample consisted of 31 students (16 males, 15 females) in grade 8, attending a central lower secondary school in a city in the Central Anatolia region of Türkiye. Both quantitative and qualitative data were collected and analyzed. The findings demonstrated that the activity supported by the Algodoo simulation software positively impacted students' academic achievement in learning the periodic table. Furthermore, qualitative data revealed that students had a positive perception of the software in terms of both educational utility and usability. Additionally, students' scientific skills were developed in the designed instructional environment. According to the findings, the Algodoo software could be incorporated into teaching not only macro-level physics but also chemistry courses.

Keywords: Science education, periodic table, Algodoo, simulation.

Corresponding author: Hasan ÖZCAN, hozcan@aksaray.edu.tr

Introduction

At the heart of technology lies its origin in "Techne", an ancient Greek term denoting the artful craft and creation of all things good. Originally, Techne embodied the essence of craft, invoking skillful artistry. It carries a rich legacy of learning, intertwined with the expertise of craftsmen who preserve and pass down the hidden values, standards, and skills that define their crafts (Hodgkin, 1990). Technology, the embodiment of systematic knowledge in creating and executing tasks, springs forth from the intersection of human interests, desires, and necessities. This pivotal aspect sets it apart from scientific knowledge. Through technology, the scientific understanding aimed at unraveling natural phenomena transforms into practical knowledge for construction and production. Gradually, it starts shaping people's lives, facilitated by advancements in technology. Today, this influence has been explicitly found in education as well, which is one of the most prominent aspects of human life. Although the importance and necessity of the use of technology in education has been emphasized for a long time (Demircioğlu & Geban, 1996; Jonassen & Reeves, 1996; Özcan & Yılmaz, 2019), the Covid-19 pandemic has intensified its importance and necessity in the past year. The published international reports (see Organization for Economic Co-operation and Development [OECD], 2020; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020; World Bank, 2020) highlight that the pandemic has provided technological opportunities to re-evaluate and re-shape the future of education. The process of the pandemic has already unveiled what existing technological opportunities provide education and enhanced the awareness of and need for innovative technologies that enable distance learning (e.g. mobile applications, web tools, communication media, augmented reality, etc.). This clearly indicates that technology will become a major component of education in the near future. In other words, technology-supported teaching (e.g. computer-assisted instruction, web-based training, etc.) are now a necessity. The use of technology in education is no longer a preference but a basic standard of education regardless of pedagogical approaches being adopted. Therefore, the incorporation of technological tools and facilities into educational settings has been increasingly sought as a standard in education.

Students' personal experiences are of primary importance in science education in particular. Many technologies currently used in education widen students' learning experiences. For instance, through simulations, students can experience events and phenomena that they cannot observe under normal or extraordinary circumstances, such as the pandemic-related restrictions. Simulations are applications that facilitate the experience of events and phenomena through representations of reality and visualizations. Simulations better facilitate the management of learning/teaching settings through not only shaping experience but also re-directing it (Özcan et al., 2020; Reynolds & Anderson, 1991). Studies have shown that simulations are effective in science education in terms of many aspects, such as conceptual learning, academic achievement, and positive attitudes (Bozkurt & Sarıkoç, 2008; Jaakkola & Nurmi, 2008; Jaakkola et al., 2011; Karamustafaoğlu et al., 2005; Rutten et al., 2012; Tanel & Önder, 2010). Simulations have long been used to teach sciences (De Jong & Van Joolingen, 1998; Hakerem et al., 1993). Yet, every day, more useful and accessible, enhanced simulations are becoming available for use in education due to rapid developments in internet and software technologies.

Algodoo

Algodoo is a simulation software used to create simulations for PCs, tablets, smartphones, and smart boards. It typically provides a digital learning platform that simulates the movements of objects that can interact with each other in accordance with Newtonian mechanics by representing the objects in 2D (Euler et al., 2020). The use of Algodoo, which is a cost-free software, is straightforward. It can produce on-screen objects that can be seen in 2D format with only the use of a mouse or touchpad. It can also design physical events (e.g. free fall) and mechanisms (e.g. simple machines). Therefore, teachers and students can easily use the Algoodo (Figure 1). Euler et al. (2020) found that students using Algodoo for the first time in physics class used three different activities: Exploration of the Software Fundamentals, Testing and Contrasting, and Engineering. They reported that students engaged in fruitful debates about physics by using software without any instructions from teachers.

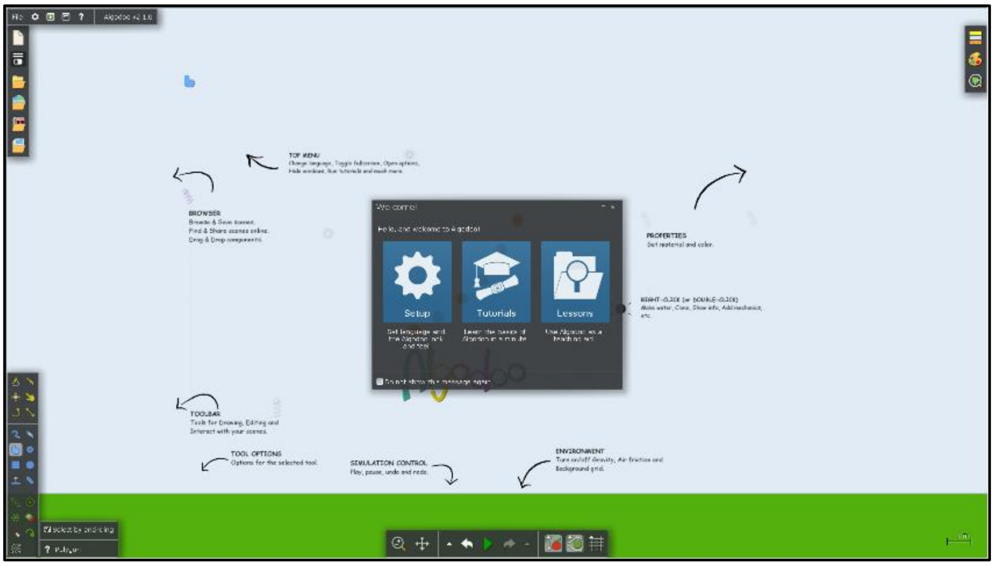

Figure 1 Software Screen and Control Panel

The existing literature proposes that the Algodoo software is primarily used to teach physics courses. Studies have demonstrated that physics education supported by Algodoo contributes to students' learning in a meaningful fashion, to develop science process skills (e.g. developing hypotheses, making inferences, identifying variables, controlling, etc.) as well as creative thinking, and to improve attitudes toward the course subject and motivation toward learning (Akdağ & Güneş, 2018; Cayvaz & Akça, 2018; da Silva et al., 2014; Gregorcic & Bodin, 2017; Hırça & Bayrak, 2013; Siregar et al., 2019).

The extant literature indicates that the Algodoo software is primarily used for teaching physics courses. Research indicates that Algodoo-based physics education enhances students' learning outcomes, fosters scientific process skills (such as hypothesis development, inference, variable identification, and control), promotes creative thinking, and improves attitudes toward the subject and motivation to learn (Akdağ & Güneş, 2018; Cayvaz & Akça, 2018; da Silva et al., 2014; Gregorcic & Bodin, 2017; Hırça & Bayrak, 2013; Siregar et al., 2019). Moreover, since the software has a design-focused approach, it contributes to making sense of the relationship between the STEM subjects of science, technology, engineering and math as required (Şahin, 2018).

Chemical Knowledge System and Periodic Table

As one of the major science subjects, chemistry comprises complex and multi-level knowledge systems. Talanquer (2011) puts forward that the chemical knowledge relevant for teaching comprises three types of knowledge: experiences, theoretical models, and visualizations. Visualizations "encompass the static and dynamic visual signs [e.g. chemical symbols and formulas, particulate drawings, mathematical equations, graphs, animations, simulations, physical models, etc.] developed to facilitate qualitative and quantitative thinking and communication about both experiences and models in chemistry" (Talanquer, 2011, p.187). In the existing literature on chemical teaching, one of the main topics has focused on students' difficulty in making sense of not-experienced, indirect levels of knowledge (e.g. atoms and molecules) and relating them to directly experienced, macro levels (Franco & Taber, 2009; Gilbert & Treagust, 2009; Taber & Coll, 2002; Tarkın Çelikkıran et al., 2019). To tackle this difficulty, it was advocated to use in chemical teaching the models, materials, and applications "illustrating" (visualizing) the micro (Jaber & Boujaoude, 2012). With newer technologies, certain technological applications (e.g. animation and simulation) are also suggested for use in chemical teaching to illustrate scientific knowledge of phenomena that people cannot directly observe through conventional materials (i.e. tangible materials, especially particle models, and analogies and drawings) (Belford & Moore, 2016).

The periodic table is a cornerstone of chemical knowledge and is considered one of the most profound discoveries in the history of chemistry. It provides a fundamental visualization of chemical elements organized according to specific rules. As an icon of chemistry (Wang & Schwarz, 2009), the periodic table is often one of the first topics taught in the discipline. Students are expected to effectively use the periodic table and to be equipped with the necessary skills to make effective predictions and test chemical elements using periodicity (Sarıtaş & Tufan, 2019). Introduction to the periodic system is a part of the 7th grade science education curriculum and falls under the lower secondary level. At this stage, students are introduced to the first 18 elements and their symbols in the periodic system. This instruction typically spans two course hours and provides students with a basic understanding without extensive exploration of the entire periodic table. Furthermore, the periodic system is revisited in the 8th grade science education curriculum (under the subject of periodic system) (MoNE, 2018, p.50). At this level, students discover periods and groups, classification of elements, history of the periodic table, and determination of metals, nonmetals, and metalloids in the periodic table over four course hours. The learning outcomes included in the science curriculum are as follows:

> F.8.4.1.1. Explains how groups and periods are structured in the periodic system. The need for periodic systems and the development of periodic systems are briefly highlighted.

F.8.4.1.2. Classifies chemical elements in periodic systems as metallic, semi-metallic, and non-metallic.

The structuring of periods and, relatedly, the concept of period and certain periodic trends, are taught in relation to the topic of the electron distribution of the atom within the course subject of 'Particulate Structure of Matter' delivered in 7th grade. Hereinafter, the periodic table is structured within indirect phenomena such as the electron distribution of the atom. Hence, it is plausible to employ simulations in the teaching of the subject.

The current body of research on the use of the periodic table in chemical education suggests that conventional tangible materials are mainly employed in curriculum design for experiential studies, particularly in secondary education. These materials comprise either the periodic table itself or its enriched version with other tangible materials (e.g. drawings, natural samples of element compounds, etc.), or parts of the periodic table (e.g. chemical elements purposefully-prepared for gaming and information cards) (Alexander et al., 2008; Bayır, 2014; Bernardo & González, 2021; Erdoğan, 2018; Joaquín et al., 2015; Kavak, 2012; Woelk, 2009). These studies found that such tangible materials contribute to chemical education in terms of permanent learning, motivation, and participation. In addition, Wiediger (2009) investigated the use of technology in the teaching of the periodic table, for which image-editing software was developed and introduced to imitate a periodic table activity supported by a paper-based card sorting game.

The use of instructional technologies in science education has become prevalent in recent years. Simulation offers numerous advantages over traditional materials, especially in chemistry education (Krüger et al., 2022). Simulations provide students with the opportunity to conduct unlimited experiments in a safe environment and receive rapid feedback. Additionally, they can prepare students for laboratory experiments, reinforce concepts in the classroom, and provide experience using instrumental methods that may not be available in the laboratory. However, the periodic system was not investigated in the studies conducted. Studies are generally conducted at the undergraduate level and relate to chemistry laboratory subjects (Li et al., 2022; Wang et al., 2023)

Currently, experiential and applied studies exploring the effectiveness of teaching materials in simulation-based instruction of the periodic table.

Research Aims

Previous studies have suggested that the Algodoo software was used in relation to STEM activities, mostly to physics subjects at the macro level, to develop students’ design skills. Studies have shown that it positively affects not only students’ academic achievement but also their perceptions and attitudes toward the use of education technologies in science education. However, among them, no studies have focused on chemical teaching. Given that the periodic table is defined within the electron structure of the atom in lower secondary science education, the use of simulations supported by Algodoo could facilitate the teaching of this course subject. Therefore, this study aimed to investigate the effect of an activity, which was designed with Algodoo to teach the periodic table, on students’ academic achievement and explore students’ perceptions of the activity. The activity design was based on Algodoo, which is predominantly used in the teaching of physics courses.

Method

The study used a convergent parallel design as the mixed-methods research design. Mixed-methods design aims to elicit in-depth information on both quantitative and qualitative aspects of the research topic. The convergent parallel design allows simultaneous collection of both quantitative and qualitative data and allows interpretation of such data following analysis using appropriate methods (Creswell & Plano-Clark, 2018). The quantitative component of the study was conducted through a quasi-experimental design with a pretest–posttest control group. A quasi-experimental design was used to find, if any, significant differences in the relationship between the experimental group (EG) and the control group (CG) in terms of academic achievement. The qualitative component of the study was conducted using the phenomenological design to explore students’ perceptions of the Algodoo application.

Sample/Study Group

The sample for the quantitative component of the study consisted of 31 students (16 males, 15 females) from 8th grade, attending one of the central lower secondary schools located in a city in the Central Anatolia region of Türkiye during the fall semester of 2019-2020. Due to pandemic-related limitations, a convenience sampling method was chosen over purposive sampling. Specifically, the groups were two sections of the 8th grade level within the same school. The experimental and control groups consisted of 15 and 16 students. In order to elaborate on the outcomes of the quantitative data and explore the perspectives of the participants, semi-structured interviews were conducted in the experimental group. The sample of the qualitative component of the study consisted of five students (three males and two females) from the experimental group who volunteered to be involved in this component of the research. The design of the study emphasized the participants' experiences and their interpretation of those experiences (Dodgson, 2023). A small sample size was used, as is common in qualitative research, to ensure adequate representation of the participants' experiences (Young, 2018). Data saturation, which provides detailed insights, was also considered. The researchers used purposive or convenience sampling to select participants with specific characteristics or experiences related to the research topic (Gill, 2020). The sample for this study consisted of five volunteer students from the experimental group: three boys and two girls. According to Çokluk, Yılmaz, and Oğuz (2011), the number of participants selected for the interviews depends on the richness and sufficiency of the data. In this case, when the first five interviews were carried out, researchers noticed that the qualitative data collected was sufficient for the analysis. This sample size was sufficient for data collection and analysis.

Data Collection Tools

Quantitative data of this study was collected with the academic achievement test (AAT), and qualitative data was collected with semi-structured interviews (SSI). With the data collection from multiple data sets, it was aimed to enrich the data to be analyzed in this study.

The AAT was developed to analyze learning outcomes of the course subject of the periodic table delivered in 8th grade science education. To design the AAT, a large pool of multiple-choice questions was developed by initially compiling questions on the periodic table that were asked in certain exams prepared by the Turkish Ministry of National Education (MoNE). These examinations included the Public Boarding School Scholarship Exam (PYBS), Placement Test (SBS), Examination for Transition from Primary to Secondary Education (TEOG), and High School Entrance Examination (LGS). Then, the weights of questions to assess the learning outcomes were determined by preparing a table of specifications (see Table 1). In the first version of the test, there were 25 multiple-choice questions used. Three academics specializing in science education and a teacher of science were consulted to assess the scope and convenience of the test for each grade level. Following the expert opinions, the prepared questions were endorsed and found appropriate in terms of both scope and convenience for students of all grade levels. The AAT, which comprises 25 questions, was then tested on a student group of 31 from 9th grade, who had already been taught the course subject. The initial data gathered in this preliminary study were analyzed using SPSS 24.0. Five items were removed from the AAT because item analysis showed that item difficulty indexes and item discrimination coefficients of those five items were at the unacceptable level. Therefore, the final version of the test included 20 items. Examples of the items used in the achievement test are presented in Figure 2.

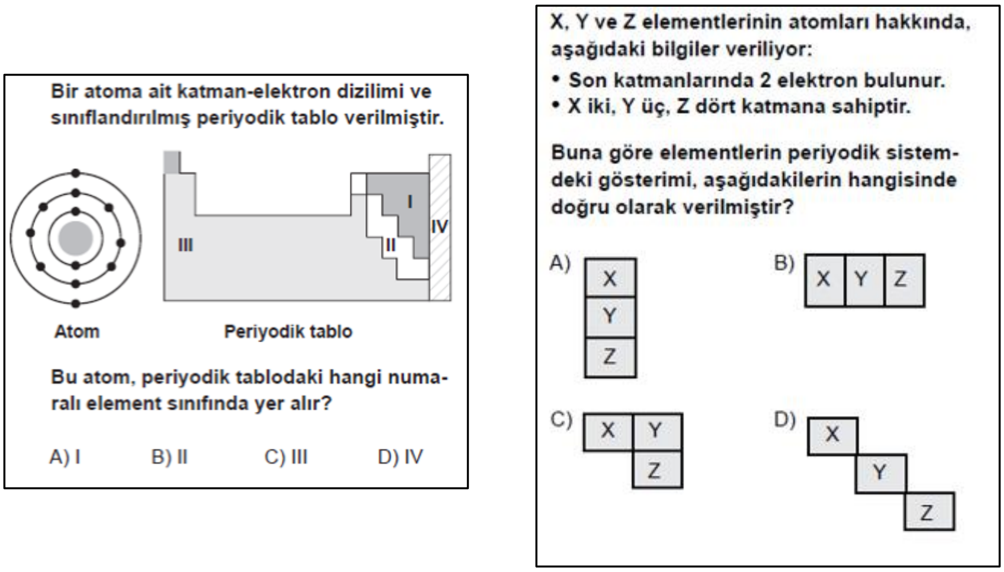

Figure 2 Examples of Items in AAT

Table 1 explains the content of the multiple-choice test used for data collection.

Table 1 Contents of the Academic Achievement Test

Questions	Content
1, 9, 11, 14, and 15	Properties based on the positions of elements in the periodic table
2, 4	The arrangement of elements in the periodic table according to their atomic numbers
3, 5, and 16	Placement of non-metallic and metallic properties in the periodic table
6, 7, and 8	Locating the position of element with and atomic number in the periodic table
10, 12, 17, and 20	Relationship between an element's electron structure and its position on the periodic table
13, 18, and 19	Classifying daily life samples into metals and non-metals according to their properties

Item difficulty and item discrimination indexes were re-calculated after the 20-item AAT was re-tested in the sampling group. Test items had an average difficulty with an item difficulty index between .30 and .675. The items of the test also had an item discrimination index between .375 and .695. To prove the validity and reliability of the final version of the 20-item AAT, the coefficient of internal consistency of KR-20 was calculated for the test. KR-20 was found to be.81, which proves the test was valid and reliable as it exceeds the minimum value of .70 to be considered so.

The SSI schedule explored students' perceptions of Algodoo after they were taught the periodic table supported with Algodoo applications. The SSI consisted of 12 open-ended questions (Appendix 1) and allowed further questions to be added to the interview schedule during the interview (Yıldırım & Şimşek, 2013). Interview questions were prepared in consultation with two academics who specialized in science education. Next, an academic in science was consulted regarding the interview schedule. Following their suggestions, alternative questions were developed, probes were revised, and the interview schedule was finalized.

Implementation

The study was conducted with an experimental group and a control group, and no significant difference was found between the two groups based on the AAT pretest. The teaching of the periodic table was delivered along with an algodoo simulation in the experimental group, whereas curriculum-based suggested activities were followed in the control group through a 5E lesson plan. While both groups were provided with general information about the study, the experimental group was also introduced to the Algodoo software. The operator of the Algodoo simulations was prepared in advance for the simulations to be used in the experimental group and consulted an academic of science for their convenience. The simulations included applications that allow students to create their own atoms, periods, and arrangements while also enabling them to place elements on the periodic table themselves (Appendix 2). After simulations were found convenient, classes were delivered to students in the experimental group by following the phases of the 5E instructional model (i.e. Engage, Explore, Explain, Elaborate, and Evaluate).

Algodoo simulations were used by the operator in the explain phase and by students in the elaborate and evaluate phases (Figure 3). In the control group, the contemporary methods suggested in the science curriculum were followed, and constructivist activities were carried out as the instructional procedure through the 5E strategy. Efforts were made to make the only difference between the groups be the use of the Algodoo simulation. In both groups, the same person as the operator delivered the teaching. Teaching is delivered over eight contact hours . At the end of the delivery, the AAT posttest was administered to the students. In addition, five students from the experimental group were interviewed to understand their perception of Algodoo.

Figure 3 Pictures of the Use of Algodoo Simulations

Data Analysis

The quantitative data gathered from the AAT in this study were transferred to the SPSS 24.0 package. The pre- and post-test score distributions of the experimental and control groups were examined before the data analysis. distribution (Table 2). The Shapiro-Wilk test for distributions indicated that the distribution of pretest scores was normal, whereas the distribution of posttest scores was not normal (Table 2).

Table 2 Data about Distribution Normality

	Shapiro-Wilk		
	X^2	Sd	p
Pretest	.939	31	.078
Posttest	.566	31	.000

The Mann–Whitney U test was used to examine the significance of mean differences between pretest and posttest. Moreover, the Wilcoxon signed-rank test was used to identify the significance of differences by examining the changes between the means of the pretest and posttest of both the experimental group and control group.

The data collected from the semi-structured interviews were first transcribed. Then, they were analyzed through content analysis (Yıldırım & Şimşek, 2013), with which codes and themes, representing the data at best, could be accessed. These themes were then presented in support of direct quotations from interviewees' responses. The students interviewed were anonymized with pseudo-names in those quotations as P1, P2,…,P5.

Findings

Findings regarding the effect of the Algodoo applications used in periodic table instruction on student achievements

Before the study, a pretest was administered to examine the significance of the mean differences between the experimental and control groups. As shown in Table 3, in accordance with the results of the Mann–Whitney U test [U (29) =72.500, p>.05], there was no significant difference between the means of pretest scores of the experimental group ($\bar{X}$=58) and of the control group ($\bar{X}$=66,88).

Table 3 Mann-Whitney U Test Results Regarding the AAT Pretest Scores of the EG and the CG

Group	N	Mean Rank	Rank Sum	U	P
Experimental	15	12.83	192.50	72.500	.057
Control	16	18.97	303.50		

The Mann–Whitney U test was used to examine the significance of mean differences between the posttest means of the experimental group ($\bar{X}$=93) and the posttest means of the control group ($\bar{X}$=83.44). Table 4 shows that there was a significant difference in between, which is in the advantage of the experimental group, and it was found meaningful as a result of the Mann–Whitney U test [U (29) =70.50, p<.05]. The Cohen d value was examined with the posttest means to investigate the influence of the quantity of Algodoo applications and was found to be .70. This value indicates that the quantity of influence is at a medium level (Cohen, 1992).

Table 4 Mann Whitney U Test's Results Regarding the AAT Posttest Scores of the EG and the CG

Group	N	Mean Rank	Rank Sum	U	P	d
Experimental	15	19.30	289.50	70.500	.037	.70
Control	16	12.91	206.50			

The Wilcoxon signed-rank test was used to examine the significance of mean differences between both groups' pretest and posttest means. Table 5 demonstrates that the difference between pretest and posttest means of the experimental group was significant, as shown in the results of Wilcoxon signed-rank test [Z (14) =3.414, p<.01]. Similarly, the difference between pretest means and posttest means of the control group was significant, as shown in the results of Wilcoxon signed-rank test [Z (15) =3.473, p<.01].

Table 5 Wilcoxon Signed-Rank Test Results for the AAT Pretest and Posttest Scores of the EG and CG

Group	Survey	N	$\overline{X}$	SS	Z	p
Experimental	Pretest	15	58.0000	15.90148	3.414	.001
	Posttest	15	93.0000	4.55129		
Control	Pretest	16	66.8750	16.11159	3.473	.001
	Posttest	16	83.4375	18.68321		

Findings regarding students' perceptions of the Algodoo applications used in the teaching of the Periodic Table

Upon content analysis of the SSI data, 2 themes and 9 codes were identified, as shown in Table 6. The theme of educational utility revealed students' perceptions of the Algodoo application during their learning process. The theme of positive features unearthed students' perceptions of the features of an algodoo simulation. The content analysis subsumed codes under two main categories: Educational Utility and Use (Figure 4).

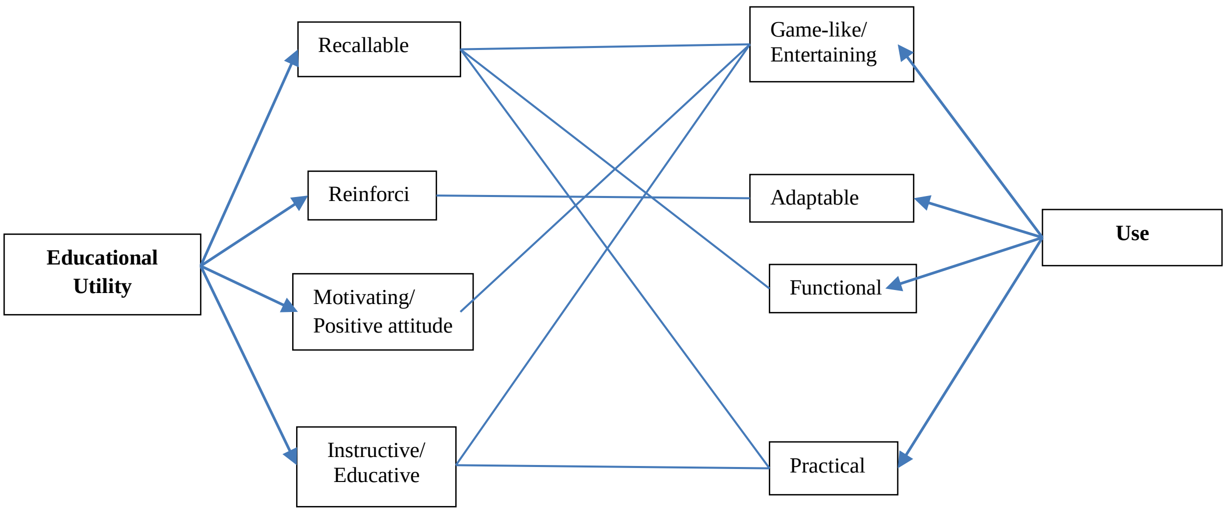

Figure 4 Codes and Categories Identified Through Content Analysis

Figure 4 demonstrates that the participants positively perceived both categories. There seems to be no negative perception regarding the instructional activity supported using the Algodoo software. The relationships the participants made between educational utility and the use of the activity were as follows (Table 6):

Table 6 Themes and Exemplary Quotations

Themes	Exemplary Quotations
Relationship between the instructive/educative aspect of the activity and its practical and entertaining nature	P4: *"I really like that it can be recalled, it is educative, and it is very practical, I mean, you can recall the [necessary] information in a glimpse."* P3: *"The activity was very entertaining. In fact, I have not been able to distinguish the chemical elements so far, but I am much better at it now. The training was really nice; it was good, instructive."*
Relationship between the recallability of the information and the functional, entertaining, and practical use of the activity	P1: *"It was quite educative and recallable. It was designed in a very useful way. I really like it."* P5: "The *application is really good. It stuck in my mind. It was really fun and educative."*
Relationship between reinforcing capacity and re-adaptive capacity of the activity for given information	P2: *"I do not understand some topics in electrical circuits. [Within this activity], electrical circuits can be designed, and I can use them for revisions."* P4: *"It helps us better understand the subject*-matter *through visualizing it. I wish I had such an activity in an English class as well so that I could understand English words better."*
Relationship between motivating capacity/positive attitude-generating capacity and entertaining capacity of the activity	P1: *"The subject matter has been quite troublesome for me. When I started to use the material and learn about it, I started to grasp the subject matter [better]. We first thought it was boring, but the more we learned about it, the more fun we had."* P3: *"It was entertaining and educative'. First, I thought about not paying attention to the lesson, but then, I realized how nice it was to learn once we progressed."*

Conclusion and Discussion

The research findings of this study evidently demonstrated that an instructional activity supported with Algodoo simulation software was relatively more effective in students' academic achievement in learning the periodic table than contemporary curricular activities. In addition, considering the qualitative research findings, it was found that students have a quite positive perception toward the software in terms of its educational utility and use.

However, although the generalizability of the results of the study conducted using convenience sampling was low, the choice of convenience sampling was deemed necessary for the study. As a matter of fact, this study was conducted with students who had never experienced Algodoo software before. In this context, the findings can be evaluated from different perspectives.

First, it has long been argued that simulations have a positive impact on science education (De Jong & Van Joolingen, 1998; Rutten et al., 2012). Specific to the Algodoo software, the findings of this research support the findings of many other studies with similar samples that used the same software. In fact, Şahin's (2018) recent study carried out with the participation of students in Years 7 and 8 demonstrated that students have positive perceptions of the use of Algodoo for STEM activities to teach simple machines and energy. Similarly, Cayvaz and Akçay (2018) suggested that 7th grade students perceive the Algodoo-supported learning activity as entertaining and that it facilitates the learning process for students during the teaching of work and energy. Moreover, Gül (2019) conducted a similar and experimental study with 7th graders, being taught about light in an activity prepared with the 5E instructional model. Gül found that there is a significant effect of this Algodoo-supported activity on students' academic achievement. Likewise, Özer's (2019) experimental study with Year 6 students learning about power and motion demonstrates that Algodoo-supported activities have a positive effect on students' academic achievement.

Second, the findings of this research were original in terms of the use of the Algodoo software in the teaching of the periodic table. Indeed, in parallel to the rationale for the development of this software, it is used in activities to teach subjects in macrophysics. However, it is not possible to make a sound comparison between the findings of this study and others since there are not any studies focusing on the use of this software in chemical education in general or in the teaching of the periodic table. On the other hand, it is widely discussed in the existing literature that gaming and game-based tangible materials in the teaching of the periodic table have positive effects on students' academic achievement and their attitudes toward the subject (Bayır, 2014; Bernardo & González, 2021; Erdoğan, 2018; Joaquín et al., 2015; Kavak, 2012; Woelk, 2009). Therefore, given that students perceive the software as 'entertaining/game-like', it can be argued that the software has the effect of a game. This argument indirectly supports the existing literature on the teaching of the periodic table through games and gaming. Third, considering that the software is a simulation and enables chemical visualization at the micro and macro levels, such applications as animation and augmented reality seem to be effective for chemical education (Belford & Moore, 2016; Cai et al., 2014). Therefore, the simulation features of the software are conducive to subject-specific teaching. This suggestion similarly supports studies on chemistry and simulations, although indirectly.

Although the Algodoo software is designed for macro phenomena in compliance with Newtonian mechanics, the findings of this study demonstrate that it can also be used in the teaching of other subjects, such as the periodic table. This suitability can be discussed from different perspectives. First, it can be suggested that Algodoo software as a simulation tool is effective in the teaching of the periodic table because it is related to micro-level phenomena such as atomic structure and electron configuration and abstract concepts. Second, the software supports various skills, namely designing, making hypotheses, and testing. (Siregar et al., 2019). Hence, the software is likely to be more effective at upper year-levels, considering that the periodic table, which can be regarded as 'big data' within chemical education, requires skills such as hypothetical thinking and designing newer tables (Sarıtaş & Tufan, 2019). Furthermore, conventional technologies in the teaching of the periodic table are based on games and tangible 3D materials. Thus, various advantages of educational technologies used at upper year levels can also be used in Algodoo and similar similar software programs.

In science education, simulations are suggested for promoting meaningful learning. However, certain hazardous situations may require particular attention. Specifically, the epistemological quality of the information and visualization provided by simulations require particular attention from students (Greca, 2014). Otherwise, chemical illustrations in these types of technological applications can cause conceptual misunderstandings and instructional challenges (Yılmaz & Sarıtaş, 2020). Lastly, considering that Algodoo software enables teachers to organically initiate classroom discussions with minimal intervention on scientific phenomena, laws, and principles (Euler et al., 2020), this software can be quite compliant with pedagogical approaches such as argumentation based on debating in the teaching of other chemistry and science subjects.

In this study, due to pandemic conditions, the sample was limited to 31 individuals. Although the small size of the classes in the sample allowed students to engage in longer Algodoo simulations, it may be considered limited in terms of generalizability. In future studies, new research should be conducted with a larger sample size.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

There is no conflict of interest to declare.

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This study was conducted without external funding support.

CRediT author statement

All authors contributed equally to this work, and therefore, no specific roles are assigned. The order of authorship is as agreed upon by all contributors.

Research involving Human Participants and/or Animals

This study involving human participants has received approval from the [Aksaray University, Social and Human Sciences Research Ethics Committee] and all procedures performed in this study are in accordance with the ethical standards outline.

Algodoo Destekli Periyodik Tablo Öğretiminin Öğrencilerin Başarılarına ve Algılarına Etkisi

Özet:

Yazılım teknolojilerinin gelişimine paralel olarak eğitimde kullanışlı ve erişilebilir simülasyon araçlarının kullanımı daartmıştır. Bu çalışma, periyodik tabloyu öğretmeye yönelik tasarlanmış bir etkinliğin öğrencilerin başarılarına etkisini araştırmayı ve etkinliklerine dair algılarını keşfetmeyi amaçlamaktadır. Çalışmada kullanılan etkinlik, genellikle fizik konularının öğretiminde kullanılan Algodoo'ya dayanmaktadır. Çalışma, bir karma yöntem araştırma yaklaşımı olarak yakınsak paralel deseni kullanmaktadır. Türkiye'nin İç Anadolu bölgesinde bir şehirde bulunan merkezi bir ortaokuldaki 8. sınıf öğrencilerinden oluşan örneklem, 31 öğrenciyi (16 erkek, 15 kız) içermektedir. Bu çalışmanın desenine uygun olarak hem nicel hem de nitel veriler eş zamanlı toplanıp analiz edilmektedir. Bulgular, Algodoo simülasyon yazılımı tarafından desteklenen etkinliğin periyodik tabloyu öğrenmede öğrencilerin akademik başarısını olumlu yönde etkilediğini göstermektedir. Nitel veri bulguları da, öğrencilerin yazılımı eğitimsel fayda ve kullanılabilirlik açısından olumlu bir şekilde algıladıklarını ortaya koymaktadır. Ayrıca tasarlanan öğretim ortamında öğrencilerin bir takım bilimsel becerilerinin de geliştiği gözlemlenmiştir. Bulgular, Algodoo yazılımının sadece makro düzeyde fizik konuları için değil, aynı zamanda kimya konuları için de öğretimde kullanılabileceğini önermektedir.

Anahtar kelimeler: Fen eğitimi, periyodik tablo, algodoo, simülasyon.

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APPENDIX 1

Semi-Structured Interview (SSI) Questions

1. Do you like science courses?
2. How do you feel when takingin a science course?
3. What do you think aboutof the course we covered inon the periodic table?
4. What do you think about materialsthe material related to the periodic table?
5. When you first saw this material related to the periodic table, what did you thinkcame to your mind? Can you explain the material by relating it to the periodic table?
6. What are the positive aspects of this material related to the periodic table?
7. What are the negative aspects of this material related to the periodic table?
8. Can you use this material related to periodic tablesthe periodic table without any help?
9. Would you like to use this material related to the periodic table outsideoutside of class?
10. If you were to design a material related to the periodic table, what typekind of material would you design?
11. Would you like science courses taught usingthe science courses to be taught with other similar materials?
12. Would you like other courses taught usingto be taught with other similar materials like this one??

APPENDIX 2

Experimental Group Sample Lesson Plan

Engage:

After welcoming the students, the teacher reminds them of the elements and their uses they saw in previous years by asking:

Which elements did we observe?

Where were we using them?

What do you know about the characteristics of these elements?

This prompts students to recall their previous knowledge. Then, the teacher presents the periodic table brought to the class and asks why and based on what it was created:

Why and based on what criteria were this periodic table created?

This captures the attention of students. Afterwards, the teacher continued by saying, "Today, we will learn about the periodic table and the classification of elements."

Explore:

After identifying which subject will be learned, the students are asked to perform Activity-1. According to the activity, students are divided into three groups. Each group is given 20 small square papers and a piece of cardboard. Students are asked to create their own periodic tables with the first 20 elements they have learned thus far. It is expected that students will discover that elements are arranged according to their atomic numbers, considering the properties and atomic numbers of the elements.

When students create their own periodic tables, they are asked how they created them. Each student created their own according to different properties. Students are told, "As budding scientists, you have created your own periodic table and classified the elements based on their different properties.

Explain:

Activities in Activity 1 were evaluated. The teacher will explain academic information related to the subject.

Regarding the Periodic Table; In ancient times, people believed that there were four elements: air, water, earth, and fire. Additionally, materials such as gold, silver, tin, copper, lead, and mercury were known, but were not considered elements. However, these elements are now accepted as elements.

Up to 1869, 63 elements had been discovered. Today, there are more than 110 elements, and new elements will be discovered in the future.

The first periodic table was created in 1829 by Johann Dobereiner, who formed triads of elements with similar properties.

In 1862, French scientist Beyuger de Chancourtis arranged elements with similar physical properties in spiral rows.

De Chancourtis placed the known elements around the perimeter of a cylinder in 16 mass units.

Newlands classified elements into 11 groups based on similar physical properties. Elements with atomic weight of eight have similar properties.

Newlands defined this as the LAW OF OCTAVES.

According to this law, any element has properties that are similar to those of the eighth element in the table.

The first to present the periodic table in its current form was German scientist Lothar Meyer and Russian scientist Dmitri Mendeleev.

Mendeleev noticed that when atoms were arranged by increasing their atomic weights, certain properties were repeated.

He arranged elements in rows based on their repeated properties, creating a periodic table with the first two periods having seven elements each and the next three periods having seventeen elements each.

He left some places blank in the periodic table because he believed that there were undiscovered elements.

In subsequent years, a modern periodic table, which we accept it to now, was prepared. In 1911, Ernest Rutherford determined the nuclear charge. Henry Moseley showed that elements were arranged according to their atomic numbers in his studies. Today's periodic table is different from Mendeleev's and others in that it arranges elements not by atomic weights but by atomic number. The most significant change in the periodic table was made by Glenn Seaborg, who added two rows below the periodic table.

Mistakes made in the previous stage are corrected, and the truths are reinforced. Students are asked if they know any other examples, and discussions will take place on these examples.

Sample practices related to the subject in the Algodoo program are shown.

Elaboration:

In this section, the periodic table material prepared in the Algodoo program is presented to the students to help them better understand the information they have learned. Students are allowed to perform activities on Algodoo to reinforce the subject.

Evaluate:

Daily journals are assigned to students regarding the subject.

What did I learn from this activity?

What did I do well? Why?

Which area did I struggle in? Why?

Where did I need help?

In which area should I improve myself?

What strengths and weaknesses do I have?

Acquisition assessment is performed by creating an application on Algodoo.

Engage:

After welcoming the students, the teacher reminds them of the elements and their uses they saw in previous years by asking:

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What do you know about the characteristics of these elements?

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This captures the attention of students. Afterwards, the teacher continued by saying, "Today, we will learn about the periodic table and the classification of elements."

Explore:

After identifying which subject will be learned, the students are asked to perform Activity-1. According to the activity, students are divided into three groups. Each group is given 20 small square papers and a piece of cardboard. Students are asked to create their own periodic tables with the first 20 elements they have learned thus far. It is expected that students will discover that elements are arranged according to their atomic numbers, considering the properties and atomic numbers of the elements.

When students create their own periodic tables, they are asked how they created them. Each student created their own according to different properties. Students are told, "As budding scientists, you have created your own periodic table and classified the elements based on their different properties.

Explain:

Activities in Activity 1 were evaluated. The teacher will explain academic information related to the subject.

Regarding the Periodic Table; In ancient times, people believed that there were four elements: air, water, earth, and fire. Additionally, materials such as gold, silver, tin, copper, lead, and mercury were known, but were not considered elements. However, these elements are now accepted as elements.

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Mistakes made in the previous stage are corrected, and the truths are reinforced. Students are asked if they know any other examples, and discussions will take place on these examples.

Elaboration:

In this section, to help students better grasp the information they have learned, a matching activity is conducted on the interactive whiteboard, reflecting different periodic table shapes created by various scientists on the history of the periodic table. The activity includes information on the scientist to which it belongs and according to which rule it was created.

Evaluate:

Daily journals are assigned to students regarding the subject.

What did I learn from this activity?

What did I do well? Why?

Which area did I struggle in? Why?

Where did I need help?

In which area should I improve myself?

What strengths and weaknesses do I have?