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A material development study for teaching colors of light by using Algodoo*

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Abstract

Recently, technology use has gained considerable importance in both instructional activities conducted in the classroom environment and the distance education process. Accordingly, the need for teaching materials has arisen. It is thought that simulations can meet this need, especially for subjects that might cause physical material supply problems during teaching. Considering this situation, this paper introduces a material development study using the Algodoo simulation program for teaching the subject of colors of light. The material developed in this study is based on three objectives of the tenth-grade physics course-teaching program declared by the Turkish Ministry of National Education. The study details the developmental stages and experimental results of two simulations. Thus, it is expected that teachers and students can use the material introduced in this study easily with the help of the Algodoo program, which can be constructed for tablets and computers quickly and free of charge.

Keywords:

Algodoo, colors of light, physics education, simulations.

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[*] Ethics committee approval is not required as this paper is a theoretical study.

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INTRODUCTION

In the 21st century, we are in; technology is gaining more importance and becoming indispensable in our daily life. The ability of the countries to compete with each other, their economies, the development of defense systems, space exploration, and the discovery of vaccines, drugs, and treatments are directly related to technology. One of the areas where the developments in technology are reflected in education. All the improvements in technology and policies lead to dramatic changes in education (Kaya & İnci, 2021). Many factors, from teaching methods used in the instruction of students at different grade levels to teaching materials, are affected by technology. In line with those developments, new approaches are adopted in the area of education and widely used all over the world. Thus, educators can utilize technology to make students more active in the learning process by adding inquiry and problem solving aspects that are hard to achieve with the use of written materials only (Hannel & Cuevas, 2018). In addition, students must know how to use technological tools to be 21st-century learners (Ejikeme & Okpala, 2017).

The COVID-19 Pandemic, which has been effective globally since 2020, has a vital role in making the significance of technology more felt in human life and education. The global implementation of the social distance policy announced by the World Health Organization (WHO) to prevent the spread of the COVID-19 Pandemic caused schools to close their doors to students and change the usual teaching practices (Adedoyin & Soykan, 2020). In this period, learning methods such as distance, online, e-learning, mixed, blended, and flipped learning have been more popular (Yaylak, 2021). Those approaches were not new approaches to pedagogy or curriculum design, but their importance has again been recognized (Williamson, Eynon & Potter, 2020). Many countries have switched from face-to-face to distance education to reduce the adverse effects of the Pandemic (Hebebci, Bertiz & Alan, 2020). So, technology plays a critical role in the teachers and students sustaining educational activities (Evans, 2020). In educational applications such as distance education, students can access the lessons taught by their teachers by connecting over the internet through various programs from devices such as tablets and computers at home. In addition, those programs allow the recording of the lessons. Thus, students who cannot attend the lessons simultaneously listen to the lesson at any time they want. Besides, schools have enabled students to interact with each other and their teachers by using various systems that allow sharing of lesson notes. This way, students can ask their teachers questions and submit their homework, whereas the teachers can make announcements to their students.

In the online and remote learning process, mobile phones constitute one of the most effective technological tools that help students participate in online classes to do their homework and research. Especially in the last ten years, with the addition of features such as light and sound sensors and accelerometers to mobile phones, those phones have played a key role in the realization of many experiments in the home environment (Abriata, 2022). However, the quality of distance education has also been an issue of concern in terms of internet connection, teaching methods and techniques, curriculum adaptations, student participation, material development, and so on (Pürsün, Yapar, Arslantaş & Taşkesen, 2021). Besides, teachers struggle with various difficulties in this respect (Tadesse & Muluye, 2020). Nevertheless, due to the role of technology, there is a requirement for carrying out more research to improve the present quality. Therefore, the need to develop flexible, easy-to-access, collaborative, and multidisciplinary distance learning environments is highlighted to meet teachers' professional needs (Aykan & Yıldırım, 2022).

Technology also takes place in the education of students as a discipline rather than supporting the instructional activities and therefore requires technology literacy for all (Wells, 2008). The STEM approach, which has recently been widely accepted all over the world, aims to design a product in this context by associating science, technology, engineering, and mathematics disciplines with each other for the solution of a daily life problem for students at different grade levels (Kennedy & Odell, 2014). The knowledge of STEM subjects has become necessary in political, business, and educational circles to meet societies' demands since World War II (Ritz & Fan, 2015). On the other hand, the STEM approach was criticized in terms of creativity, and this deficiency was tried to be eliminated by adding an art component to the STEM approach, expressed as STEAM (Hunter-Doniger & Sydow, 2016). In the STEAM approach, with the addition of the art component to STEM, students design by considering colors and shapes (Bureekhampun & Mungmee, 2020). In both approaches, STEM or STEAM, students can benefit from technology by using various computer programs, applications, sensors, or coding while working on daily life problems according to an interdisciplinary approach.

Considering the abovementioned, the critical role of technology literacy of both teachers and students becomes clear. Technology literacy is one of the 21st-century skills defined in the literature (Aslan, 2015), and individuals need to improve their technology literacy to adapt to 21st-century conditions. However, the analysis of the research conducted on technology literacy indicates that individuals are not sufficiently equipped in this sense. Dinçer (2008) conducted research with the participation of teacher candidates from five different universities in Turkey and detected that although the participants stated that they had sufficient knowledge, skills, and attitudes toward technology, their technology literacy was low. The researcher also specified that teacher candidates did not find the technology-related course content they received sufficient. In addition, as a result of the survey conducted by Rusilowati, Kurniawati, Nugroho, and Widiyatmoko (2016) with ninth-grade students in Indonesia, the area in which students dominated at the lowest rate among all scientific literacy categories was determined as science-technology-society connections, and this situation showed that students did not have enough knowledge about science and technology.

When the studies focused on teachers' technology literacy were investigated, the study, which considered the professional developments of science teachers in the USA conducted by Zhang, Parker, Koehler, and Eberhardt (2015), showed that teachers needed support to adapt technology to science teaching. In addition, Pringle, Dawson, and Ritzhaupt (2015) examined science teachers' technological pedagogical content knowledge after a yearlong technology integration initiative in the USA. Although the results indicated an increase in technology-related practices, teachers were insufficient in planning to use technology to afford variety and support the development and use of higher-level skills. Besides, because of her correlation survey study with K12 teachers in Turkey, Yildiz-Durak (2021) determined the essential variable in estimating teachers' technological pedagogical content knowledge levels as teachers' self-efficacy towards technology integration. The researcher also highlighted the need to focus on the development of teachers' own beliefs in technology integration practices. Therefore, it is realized that both students and teachers lack technology literacy.

Despite the deficiencies mentioned above on technology literacy, various STEM applications can contribute to the students in this sense. The literature shows that the quasi-experimental study conducted by Anjarsari, Prasetyo, and Susanti (2020) with middle school students indicated significantly higher technology literacy skills for the students in the experimental group taught according to the STEM approach than the students in the control group taught with the traditional method. In another study, Mardiyya, Anwar, and Chandra (2020) developed an integrated STEM teaching material in the form of a book on drinking water for middle school students. The researchers described the process of development of this material in four stages and highlighted the positive effects of the study on students' technology literacy. Besides, Utami and Wilujeng (2020) showed a significant increase in the technology literacy skills in both groups due to the study they conducted with high school students in two separate groups, STEM modeling and STEM application on the simple harmonic motion. So, more research should be conducted with students in different grades to improve their technology literacy skills. In addition, research involving in-service teachers might be beneficial to eliminate the deficiencies mentioned above of the teachers.

Teachers can use many technological opportunities (augmented reality applications, animations, electronic evaluation, etc.) for teaching purposes. One of those opportunities is simulation programs. Simulations are computer programs that demonstrate an authentic system or phenomenon (Blake & Scanlon, 2007). They open the door to studying complex systems, which, because of their characteristics, cannot be covered in an exact analytic manner (Greca, Seoane & Arriassecq, 2014). In addition, they allow the users to observe the consequences of "what if" questions and to model the phenomena (Lindgren & Schwartz, 2009). Thus, simulations in science education provide several advantages for students and teachers. For example, it allows experiments that cannot be done in science laboratory due to dangerous or unethical conditions, reduces the cost of experiment materials, enables the experiments that will take a long time to be carried out faster, allows the teachers to move freely in the classroom environment instead of dealing with the experimental setup, enabling them to interact with their students more and allows the students to change and observe the variables in the experiment quickly (Blake & Scanlon, 2007). So, simulations can be used both in the classroom and in home conditions, enhancing the students' learning.

Physics course is one of the first areas in which the possibilities offered by computers are used for new teaching methods (Jimoyiannis & Komis, 2001). Simulations constitute a growing part of the scientific enterprise, and science education targets developing simulation pedagogies that maximize student learning (Lindgren & Schwartz, 2009). PhET and Interactive Physics are among the simulation programs used in physics education. One of those programs is Algodoo. Algodoo is a two-dimensional and free simulation program used in physics education worldwide. Users can easily access the program (da Silva, da Silva, Junior, Gonçalves, Viana & Wyatt, 2014). The present study focused on using Algodoo in science and physics education. The literature indicated that different grade level students have positive opinions on the use of Algodoo during the teaching process (Alan, Zengin & Kececi, 2021; Çelik, Sarı & Harwanto, 2014; Özer, Canbazoğlu-Bilici & Karahan, 2016; Taştan-Akdağ & Güneş, 2018). Also, Algodoo applications caused significant increases in the scientific process skills of high school students (Siregar, Rajagukcuk & Sinulingga, 2019) and teacher candidates (Alan et al., 2021). In addition, such applications positively affected the fifth-grade students' science achievements and motivations toward science (Saylan-Kirmizigül, 2021).

Despite its advantages, teachers might have difficulties integrating technology into instructional activities, so it is essential to ensure that teachers use technology appropriately (Voogt & McKenney, 2017). So, the teachers need better understand the Algodoo program's efficient use. In their paper, Euler, Prytz, and Gregorcic (2020) explained three types of activity to introduce the use of the Algodoo program for students and physics teachers. In this study, the first activity was related to the exploration of the software of the program. The second activity was for testing and contrasting. Moreover, the last activity was called engineering. Studies on developing teaching materials using Algodoo in detail should be increased. In this respect, da Silva et al. (2014) addressed the concept of oblique projectile motion in two stages. Firstly, they discussed a qualitative movement analysis, emphasizing the object's trajectory while controlling parameters such as the velocity magnitude and the launch angle. Secondly, they utilized Algodoo's graphical tools to make necessary calculations. Therefore, similar materials in the field can be an example for educators, and teachers can try to develop different materials based on such studies.

One of the physics subjects whose teaching should be supported with various materials is the subject of “colors of light" and "colors of pigments." When the literature is analyzed in terms of the studies on this subject, the researchers generally handle it in the form of "light and colors." Studies show that students have some misconceptions about these concepts, similar to other science concepts. In their study, Reiner, Slotta, Chi, and Resnick (2000) dealt with the misconceptions about light, heat, and electricity concepts based on the perception of attributing physical properties or behaviors to abstract physics concepts. Among these misconceptions, "Color exists only in an object." and "Different colors of the light mix as if they were liquids." are the misconceptions indicated about colors. In addition, Djanette and Fouad (2014) conducted a study in Algeria to identify university students' misconceptions about light with concept maps. In this context, they examined the effect of geometric optics teaching carried out with traditional approaches on students' misconceptions. In consequence of the study, the researchers determined that while some of the students' misconceptions disappeared, new ones emerged, and they concluded that the teaching was not successful in terms of providing conceptual change in students. Some of the misconceptions identified in the study are "Color is specific to the object.", "The object has color, or the object carries the color." and "The eyes give the color."

In her study, Haagen-Schützenhöfer (2017) specified that students in the 13-15 age group had misconceptions about light, white light, daylight, and sunlight. The researcher also stated that white light was perceived as "colorless" by students; the concept of light-evoked "colorlessness and brightness" in most students, and that the students could make no connection between the "light concept" and the "color effect." In another study, Martini, Tombolato and D'Ugo (2019) researched fifth-grade students and primary school teachers to detect possible misconceptions about color. Their findings indicated that teachers and students carried misconceptions and naïve ideas about color vision due to the lack of explicit distinction between physics, physiology of the visual system, and painters' practice standpoint. Some of the students' misconceptions were as follows; "It is possible to get black light by mixing colored lights.", "The primary colors are the most used colors." and "The primary colors are red, yellow, and blue." Besides, teachers recognized black and white as non-colors but provided incorrect justifications. In addition, they were unaware of the difference between the colors of light and pigment.

To eliminate students' misconceptions and improve their understanding, some studies in the literature are based on developing physical materials for students to understand the subject of light and colors better. In one of these studies, Yurumezoglu, Isik, Arikan and Kabay (2015) developed an experimental activity based on the absorption of light colors by pigments. The researchers aimed to make it easier for all students from preschool to university level to understand the relationship between colors of light and pigment with this activity, in which they created an artificial rainbow. In another study, Yurumezoglu, Karabey and Yigit-Koyunkaya (2017) explained the concept of shadow within the framework of the STEM approach by associating the concepts of colors of light and pigment with the concept of sets in mathematics. This study demonstrated the concepts of full, partial, and multi-layered shadow using red, blue, and green LEDs. In addition, these concepts were defined by mathematical expressions related to sets. In another study, Haagen-Schützenhöfer (2017) investigated the opinions of high school students in Austria about what color the objects illuminated with different colors would appear by using the "Color Vision Tube" and provided the opportunity to observe the answers to the questions asked by the students using this tube. The researcher stated that this tube, which could be done quickly, made teaching the subject effective and straightforward.

Today, technology-supported approaches are also fundamental in teaching science concepts besides physical materials. In this context, in a study conducted by Carr, Gardner, Odell, Munsch and Wilson (2003) with university-level students in the USA, the effect of asynchronous online education on students' understanding of light and color concepts was examined. Researchers investigated whether the messaging board, which allowed students to interact with each other, affected their conceptual understanding. The study depicted that student interactions in the asynchronous online education process positively affected conceptual understanding. In another research, Olympiou and Zacharia (2011) studied the effects of three different approaches on university students' understanding of light and color in Cyprus. The approaches used in this research were teaching in physical conditions, teaching in a virtual environment, and teaching by blending both. According to the research results, the teaching approach in which students' conceptual understanding was at the highest level was the blended teaching approach. Also, Olympiou, Zacharia and de Jong (2013) investigated whether university students' conceptual understanding of light and color was affected by using simulations and representations of abstract objects. Consequently, the researchers pointed out that students with a high prior knowledge could construct abstract concepts about simple physical phenomena in their minds. In contrast, they needed explicit representations of abstract objects in the learning environment to understand more phenomena that are complex. Besides, Karabey, Yigit-Koyunkaya, Enginoglu and Yurumezoglu (2018) introduced an activity that could be used within the framework of the STEAM approach on complementary colors in their work. In this activity, the researchers discussed the subject of complementary colors within the scope of physics, mathematics, and art disciplines, and they stated that this activity could be used for students of different age groups by using technology support. As can be seen, different uses of technology can contribute to students' understanding of the concepts of light and colors.

The colors of light and pigment can be taught to students easily with the help of physical materials in the classroom. However, in cases where access to physical materials is difficult, there is a need for alternative materials. In addition, with the transition from face-to-face education applications to distance education due to the COVID-19 Pandemic that emerged at the beginning of 2020, the importance and necessity of materials that can be used within the framework of distance education have been better understood (Şahin & Kabasakal, 2021). For these reasons, there is a need for specially developed materials for some subjects, such as colors of light.

On the subject of colors of pigment, which are discussed together with colors of light in the tenth-grade curriculum applied in Turkey, each student can quickly examine the primary colors of pigment, the secondary colors of pigment that emerge as a result of the mixture of primary colors of pigment, and the relations between these colors by using the crayons found in their homes. The primary colors of pigments are Cyan, Magenta and Yellow (CMY). Blue (Cyan+Magenta), Green (Cyan+Yellow), and Red (Magenta+Yellow) are secondary colors of pigments. When the primary colors of pigments are added, one on top of the other, they form black. For colors of pigment, complementary colors are the colors that complete the mixture to create black (for example, Magenta is complementary to Green) (Karabey et al., 2018).

Contrary to pigment colors, specific materials (such as lasers, lenses, and prisms) are necessary to examine primary and secondary colors of light. The primary colors of light are Red, Green, and Blue (RGB). Cyan (Blue+Green), Magenta (Red+Blue), and Yellow (Red+Green) are secondary colors of light. When the primary colors of light are added one on top of another, they form white light (Karabey et al., 2018). Complementary colors for light colors are the colors that complete the mixture to create white. On the other hand, this process can be made easier with technology support. According to the literature, there are studies on material development on the subjects of oblique projectile motion (da Silva et al., 2014), Kepler's Laws (Gregorcic, 2015), impulse and momentum (Çoban, 2021), optics (Özdemir & Çoramık, 2021), kinetic friction coefficient (Coramik & Ürek, 2021) using the Algodoo program. However, it has been noticed that there is no material developed using the Algodoo simulation program in teaching the subject of primary, secondary, and complementary colors of light.

The Aim and Significance of the Study

This study aims to present a material that can be used within the scope of physics education for high school students with the help of the Algodoo simulation program for teaching the subject of light colors. Therefore, this paper considers the developmental stages of the material in addition to the experimental results related to the application of the material. Hence, the paper is structured as a theoretical study.

Teachers in classroom teaching can use the developed material. In addition, students can easily use the developed material for the studies carried out at home. Besides, they can use the material during distance education. Moreover, this subject provides interdisciplinary learning content (Martini et al., 2019). Therefore, teachers and researchers can use this material in the STEM-based science teaching of students. Thus, technology support might be provided for students to learn primary, secondary, and complementary light colors.

METHOD

The target of the Material Developed in the Study

The material developed in this study is for 10th-grade students. In addition, the developed material might allow students at different grade levels interested in this subject, such as gifted students, to work in this context.

This study focuses on three objectives in the 10th-grade physics curriculum declared by the Turkish Ministry of Education (Ministry of National Education [MoNE], 2018). These three objectives, which are related to each other, are the primary objectives in teaching light colors. The first two of these objectives are under the subject of "prisms," and the third one is under the "color" issue and are as follows:

- **i.** With the help of experiments or simulations, the students are provided to draw the path of monochromatic light in prisms.
- **ii.** The students can observe the separation of white light into colors in a prism through experiments or simulations.
- **iii.** It is provided to classify colors of light and pigment as primary, secondary, and complementary. It is emphasized that the primary colors in the light are the secondary colors in the pigment, and the secondary colors in the light are the primary colors in the pigment.

In line with the objectives mentioned above, the researchers developed two different simulations within the scope of this study. The first developed simulation uses a prism and a monochrome light source to visualize light paths. Besides, this simulation visually presents white light's separation into its constituent colors. The second simulation aims to teach the concepts of primary, secondary, and complementary colors in a virtual environment using light sources of different colors. The details of the developmental stages of the simulation are as follows:

Development of Simulation 1

The first simulation developed includes a light source whose color can be changed and six prisms with different interior angles whose refractive index can be changed (Figure 1).

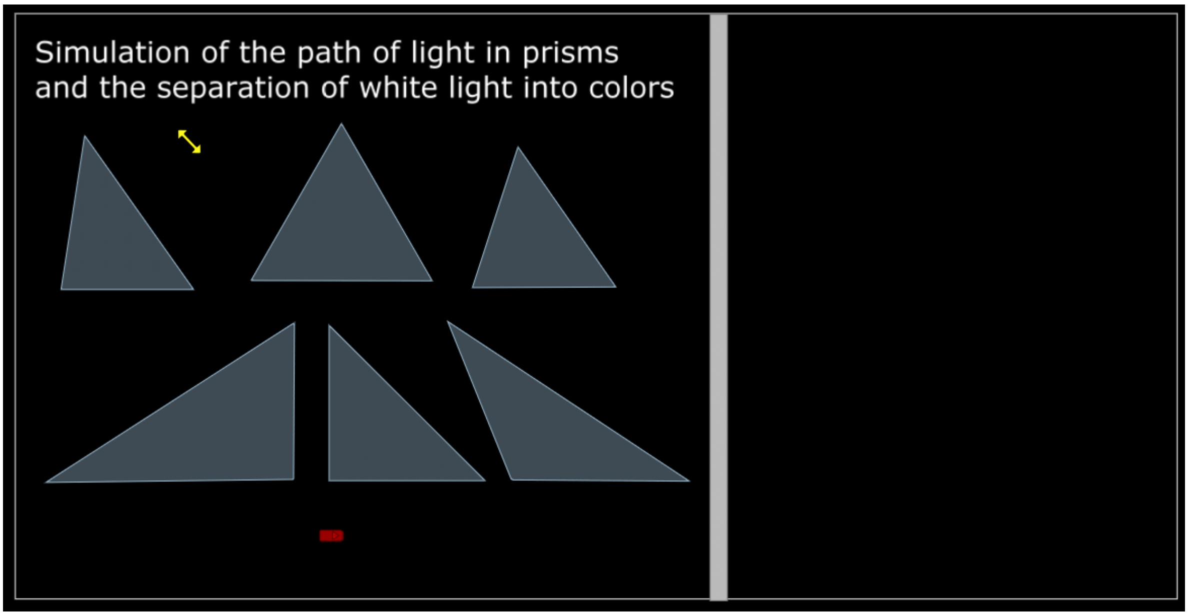


Figure 1. Screenshot of the simulation developed for teaching the path of light in prisms and separating white light into colors.

In the simulation, the "laser pen" plug-in in the Algodoo simulation program is used as the light source, the "fade distance" value is set to 300 m, and the "size" value is set to 7.0 m. Prisms with different interior angles, isosceles right triangles and equilateral triangle prisms are frequently used in traditional optics laboratories.

Development of Simulation 2

The screenshot of simulation 2, which aims to teach the concepts of primary, secondary, and complementary colors using light sources of different colors, is given in Figure 2.

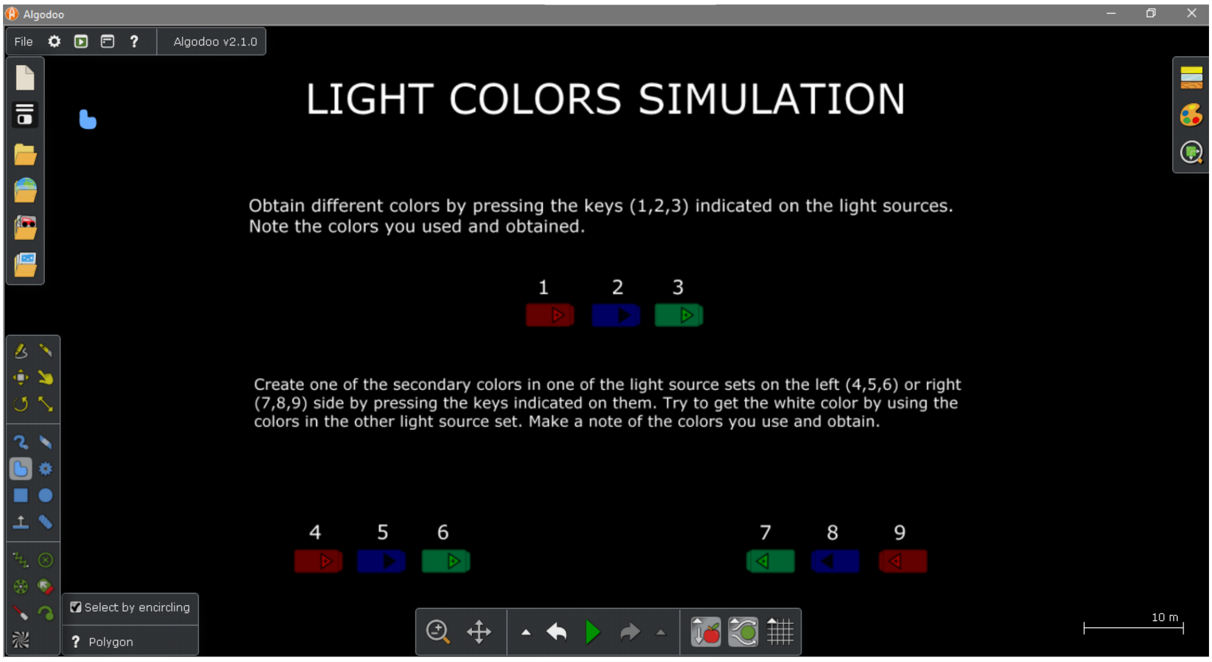


Figure 2. Screenshot of the simulation developed for teaching light colors.

In simulation 2, the "fade distance" value for each "laser pen" is set to 1000 m, and the "size" value is set to 5.0 m by using the "laser pen" plug-in in the Algodoo program as a light source. In this way, students can see the light sources more clearly. In the simulation using nine lasers in total, HSVA values defining colors for red were 0°, 100%, 80%, 80%; for blue, 240°, 100%, 80%, 80%; and for green, 150°, 100%, 80%, 80%. Each key from 1 to 9 on the keyboard activates a different light source. In order to add this feature, each light source is activated with a different key by entering the essential information (from 1 to 9) in the "activation button" tab under the "laser pens" window from the "edit" interface. Each light source's "toggle" feature is selected, so the activated light source does not turn off again after the relevant button is released. In this way, students are prevented from pressing more than one key simultaneously while using the simulation, thus providing ease of use.

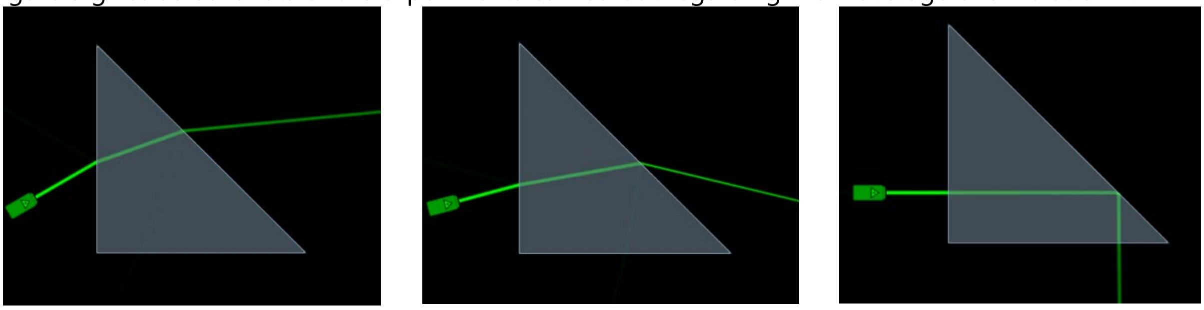
Applications of the Simulations

In this section, the experimental results, which can be obtained from two different simulations developed within the scope of the study, are given.

The Application of Simulation 1

The application of simulation 1, which can be used in teaching the objectives related to the subject of "prisms," consists of two stages. The first stage of the simulation aims for the students visually observe the paths followed by the light in the virtual environment by using the light source and prism they chose. In addition, students can repeat the experiment for different angles of incidence and prism positions. Prisms made of glass (n=1.52) or acrylic (n=1.49) materials are generally used in the traditional laboratory environment. With the help of the simulation, experiments can be performed with prisms with different refractive indices apart from these prisms with a specific refractive index. In addition, prisms with isosceles right triangles, or equilateral triangles, are generally used in optical experiments in the laboratory. In addition to presenting six prisms with different interior angles to the students ready in the simulation, it is also possible for the students to create the prisms with the interior angles they want. This way, the traditional laboratory environment's two limitations (refractive index and standard prisms) are eliminated. In addition, a red laser is generally preferred as a light source in the laboratory environment. This is because it is accessible and easy to observe in experiments. The developed simulation removes this limitation, ensuring that the student can adjust the light color to the desired color.

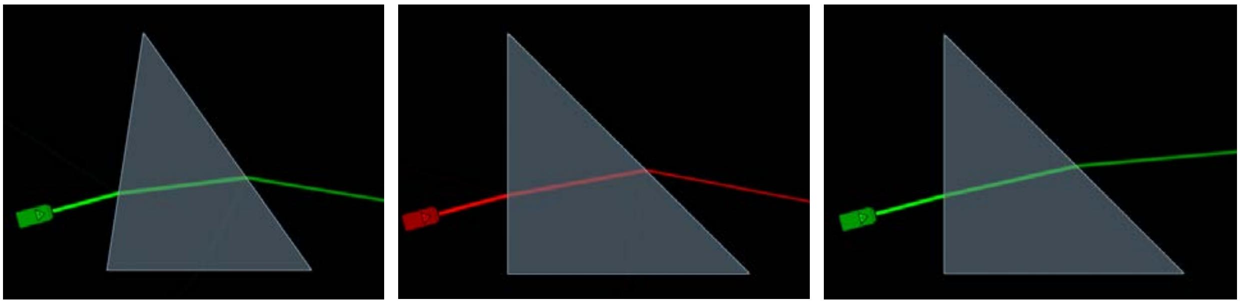
Figure 3 gives screenshots of the experiments carried out regarding the first stage of simulation 1.



(a) **(b)** **(c)**

Figure 3. Experiments Using A Green Laser and An Isosceles Right-Angled Glass Prism.

In Figure 3, the angle of incidence of a light source in the same position is changed, allowing the light to fall on the prism. In this way, students can observe the path of the light in the prism. The same experiment can be carried out with prisms with different interior angles in the simulation (Figure 4.a.), using different colored light sources (Figure 4.b) or with an isosceles right triangular prism with different refractive index (Figure 4.c).



(a) **(b)** **(c)**

Figure 4. Experimenting with Figure 3.b with a) a glass prism with different interior angles, b) a different color light source (red), and c) a prism with different refractive index (n=1,20).

The second stage of the developed simulation aims for the students to observe the separation of white light into colors. For this purpose, we use a white light source and a prism made of glass material. Figure 5 gives the screenshot of the experiment performed.

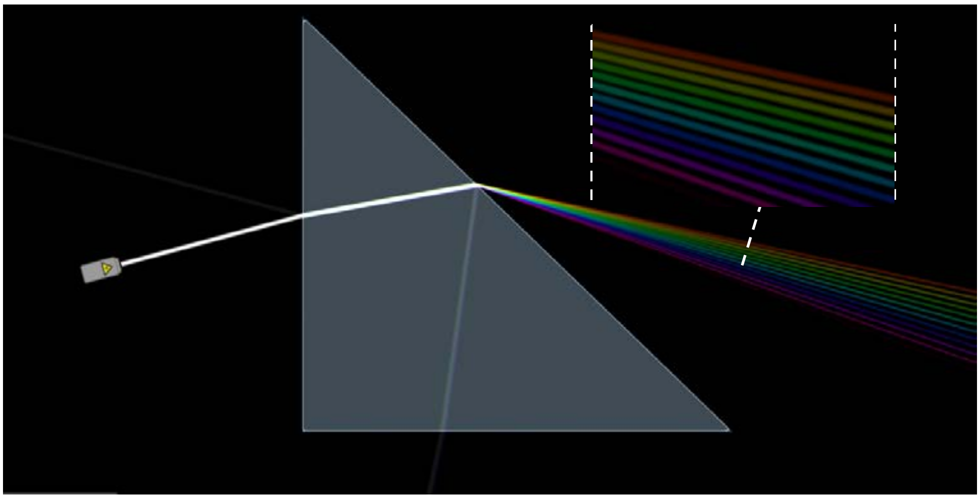
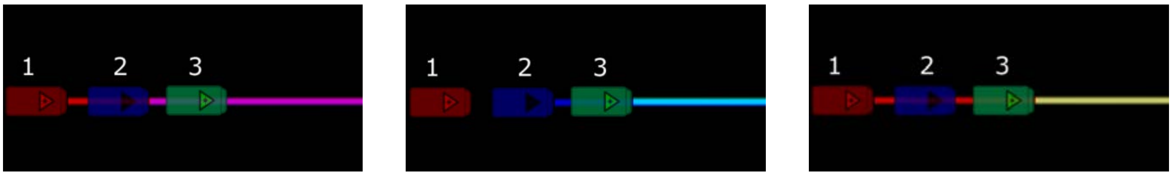


Figure 5. Simulation Representation of The Separation of White Light into Colors Passing Through A Glass Prism.

As seen in Figure 5, when white light enters a glass prism, it passes through the prism and separates into its constituent colors. Students can easily approach the image obtained in this simulation and see the results more clearly. Figure 5 also gives a closer view of the obtained colors. In this second stage of the simulation, it is also shown that the size of the medium's refractive index depends on the light's wavelength. In parallel with our actual observations, the simulation displays that the red light with the longer wavelength is refracted the least, while the violet light with the shorter wavelength is refracted the most.

The Application of Simulation 2

Simulation 2 consists of two parts. In the first part, the student is asked to create the secondary colors of light using the primary colors of light (red, blue, and green) and to note the colors used and obtained. In this way, it is aimed that students determine the primary colors of light that create secondary colors of light. Figure 6 gives the creation of magenta, cyan, and yellow colors, which are the secondary colors of light, respectively, using primary colors in simulation.



(a) **(b)** **(c)**

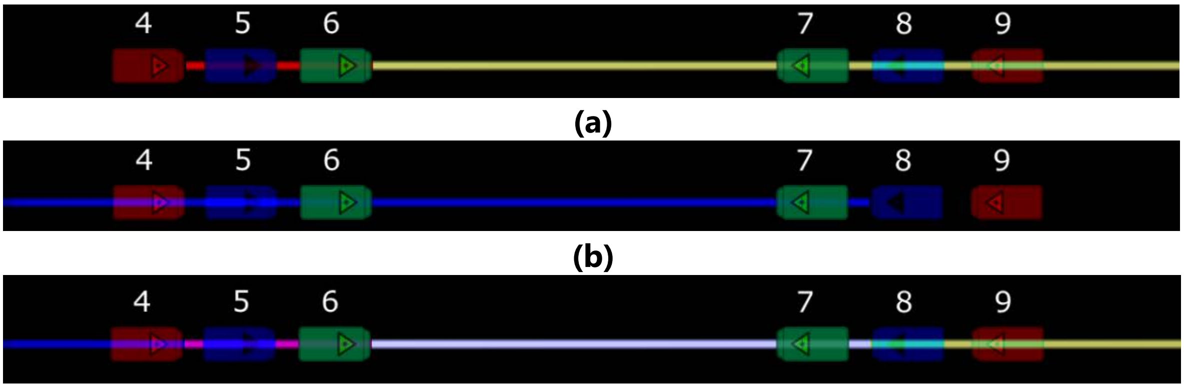
Figure 6. Overlapping a) red and blue light to form magenta b) blue and green light to form cyan c) red and green light to form the yellow color of light in the Algodoo simulation program.

In the simulation shown in Figure 6, students press the keys 1 and 2 to obtain magenta, whereas they press the keys 2 and 3 to obtain cyan. Besides, they press keys 1 and 3 to obtain yellow. The following equations also summarize the formation of magenta, cyan, and yellow color of light:

(a) Red Light (key 1) + Blue Light (key 2) = Magenta
(b) Blue Light (key 2) + Green Light (key 3) = Cyan
(c) Red Light (key 1) + Green Light (key 3) = Yellow

The second part of simulation 2 aims to teach complementary colors of light. For this purpose, six light sources consisting of primary colors placed opposite each other in two sets are used. At this stage, students are asked to adjust one of the light source sets from the keyboard to create one of the secondary colors of light (magenta, cyan, or yellow) they learned in the first part of the application of this simulation. Then, the students are expected to try to obtain the white color by using the light sources in the second light source set. Students, who are asked to note down the color combinations they have obtained, will thus be able to learn the complementary colors of light.

Figure 7 gives the formation of white color with the help of the developed simulation of yellow and blue colors, which are called complementary colors of light.

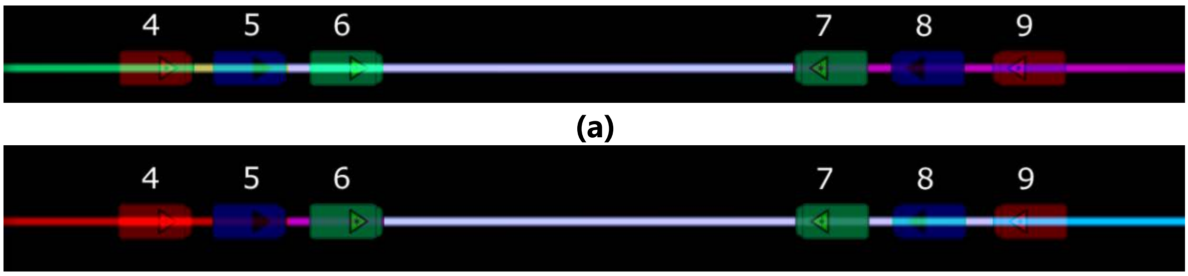


(c)

Figure 7. Formation of white color from yellow (4, 6) and blue color (8).

In the simulation shown in Figure 7, students press the related keys to form the white color of light. To obtain the yellow color, students press keys 4 and 6. (a). To obtain the blue color, they press key 8. (b). To obtain white color, they press the keys 4, 6, and 8 on the keyboard. (c). Alternatively, students can press the keys 7 and 9 to get the yellow color (a) and press the key 5 to get the blue color (b). Thus, they press the keys 5, 7, and 9 on the keyboard to get white color (c).

Similar to the simulation shown in Figure 7, Figure 8 gives the formation of white color from magenta and green, in addition to cyan and red color of light.



(b)

Figure 8. Formation of white color a) from magenta (4, 5) and green color of light (7) b) from cyan (5, 6) and red color of the light (9).

There is an alternative way to obtain the colors of light shown in Figure 8. The students can press keys 8 and 9 to get magenta and press key 6 to get the green color. Thus, they press the keys 6, 8, and 9 to get white color (Figure 8.a). For part b of Figure 8, they press keys 7 and 8 to get cyan and press key 4 to get red color. Therefore, the students obtain the white color of light by pressing the keys 4, 7, and 8 on the keyboard.

Figure 7 and Figure 8 show that the second stage of simulation 2 yields results following the experimental observations about complementary colors. In simulation 2, during teaching, students can note the colors they use and obtain, as indicated in Figure 2.

DISCUSSION AND CONCLUSION

In this study, the researchers explain the developmental stages of Algodoo simulations that can be used in the teaching of three different objectives related to the subject of colors of light in the tenth-grade Turkish physics-teaching program in detail, in addition to the experimental findings that can be obtained with the application of the simulations. The goal of simulations is not to replace laboratory practice; on the contrary, by allowing students to interact with the variables tested in an actual experiment, to provide them with an active role in the teaching process, to make them apply more of the learned principles and to achieve their learning goals (Huppert, Lomask & Lazarowitz, 2002). For this reason, the literature introduces the concept of virtual laboratories, which also involve using simulations in science learning to improve the quality of education (Maulidah & Prima, 2018; Potkonjak et al., 2016). Nevertheless, there are ongoing discussions on using virtual versus traditional laboratories for physics learning.

According to a study that intended to compare the effect of actual experiments and PhET simulations on high school students' conceptual understanding in Macedonia, students in both groups had a similar understanding of the subject of electrostatic charging (Ajredini, Izairi & Zajkov, 2013). The researchers also highlighted the importance of the teacher factor in the implementation of different approaches effectively. In another study, Chen, Chang, Lai, and Tsai (2014) investigated the effects of virtual versus physical manipulation using a simulation-based laboratory activity and a microcomputer-based laboratory activity on eleventh-grade level students in terms of the Boyle's law experiment in China. Their results showed no significant differences between the two groups considering learning achievement. Besides, Hannel and Cuevas (2018) conducted a study to compare the effect of the traditional laboratory with the computer-based simulation method on sixth-grade students in the USA. The researchers concluded that the two groups had no significant difference in the students' science achievement. Those findings imply that both hands-on and virtual laboratories result in students performing equally well in learning the concepts.

Along with the Pandemic, when distance education had to be used widely, the importance of such applications has been understood more. The results of qualitative research conducted with the parents of sixth-grade students in Turkey showed that science teaching with distance education was insufficient and needed improvement (Tanık-Önal & Önal, 2020). In addition, a survey study with secondary school students in Indonesia indicated that about 70% of the students did not find online learning motivating compared to conventional learning (Bestiantono, Agustina & Cheng, 2020). Distance education of science, technology, and engineering subjects carries problems due to their nature since they require hands-on experience, such as laboratory experience (Potkonjak et al., 2016). Hence, as mentioned in this study, teachers can use such simulations in both classroom and distance education, and the material will contribute to physics learning.

The use of Algodoo simulations brings various advantages to science learning. Firstly, simulations are reported to increase teaching success with traditional methods (Rutten, van Joolingen & van der Veen, 2012). Also, simulations help in learning new concepts (Fadzli et al., 2020) and improve conceptual understanding (Fraser, Pillay, Tjatindi & Case, 2007; Fratiwi, Samsudin & Costu, 2018; Jimoyiannis & Komis, 2001) and increase academic achievement (Huppert et al., 2002; Saylan-Kirmizigül, 2021). They help students visualize abstract concepts (Fraser et al., 2007). Therefore, the Algodoo simulations developed in this study can enhance student achievement in traditional teaching and student-centered approaches. In addition, the simulations created with Algodoo can be transferred to the smart board in the classroom environment, and active participation of the students in the learning process is ensured (Gregorcic, 2015; Gregorcic, Etkina & Planinsic, 2018). Such use is also possible with the present material. Apart from the classroom environment, students can have the opportunity to reinforce the subject by working in their own homes with the Algodoo simulations during extracurricular times. Besides, Algodoo simulations allow students to modify the variables and observe the data on the graphs (da Silva et al., 2014).

Another benefit of simulations, which is directly related to technological applications, is that it increases motivation toward science (Saylan Kirmizigül, 2021) and STEM motivation (Fadzli et al., 2020; Ng & Chu, 2021). For instance, Ürek and Çoramık (2022) utilized Algodoo simulations for preservice science teachers in the elaboration phase of a lesson structured according to the STEM approach and 5E Model. Thus, Algodoo can be productive for the physics classroom when the students can freely explore the software (Euler et al., 2020). In addition, flight simulations are used for primary school students in terms of out-of-school STEM activities (Ng & Chu, 2021). So, with the use of simulations, students can be motivated toward STEM fields and encouraged to pursue careers in STEM fields in the future. In this way, students whose knowledge base is more than a superficial understanding of isolated facts can be developed to make tomorrow's workforce (Wells, 2008). Thus, an important step can be taken to solve one of the problems regarding the future of science education.

The literature also includes STEM studies that establish a relationship between teaching colors of light and the STEM approach (Yurumezoglu et al., 2017) and the STEAM approach (Karabey et al., 2018) for the students. Therefore, as this study focuses on, materials that develop students' conceptual understanding of colors will reflect on their designing skills and contribute to their interdisciplinary studies. Also, researchers use STEM-based instructional resources to develop pre-service primary school teachers' knowledge and self-efficiency for teaching the optics concepts (Martínez-Borreguero, Naranjo-Correa & Mateos-Núñez, 2022).

As well as their advantages, the simulations have several limitations to consider when using them in teaching and learning. The simulations do not run independently without making the necessary adjustments, and the successful use of technology in science education is closely related to the teacher's capacity in this sense (Blake & Scanlon, 2007). As in the case of the Pandemic, teachers might be unprepared to use technology due to their lack of training or have concerns about their technological knowledge (Kelly, Bradley, Gratch & Maninger, 2007). The utilization of Algodoo simulations requires the technological literacy of both teachers and students. This point can be asserted as a challenge and barrier facing the use of the program when the present deficiencies of teachers (Pringle et al., 2015; Yildiz-Durak, 2021; Zhang et al., 2015), teacher candidates (Dinçer, 2008) and students (Rusilowati et al., 2016).

Nevertheless, the pandemic period allowed students and teachers to spend more time in front of their computers, use various computer programs and develop their skills (Abriata, 2022). For this reason, the Algodoo simulation program, which is free to use, relatively easy, and widespread, was preferred to minimize the problems encountered when different researchers or teachers want to apply it in the study. Another limitation of the simulations is that there is no physical manipulation of the real-world variables and no tactile or kinesthetic facet (Kelly et al., 2007). Hence, it is essential to use such materials appropriately, such as when there is no laboratory equipment to experiment physically or in the case of distance education when there is no alternative to virtual experiences. In addition, it is possible to utilize simulations to support hands-on activities in the classroom or laboratory environment. For instance, the connection of a traditional laboratory to digital tools such as simulations was reported to yield an increased impact on student outcomes (Uwamahoro, Ndihokubwayo, Ralph & Ndayambaje, 2021).

Considering the material presented in this paper, it is recommended to conduct future research to test the efficiency of the Algodoo simulations developed for teaching colors of light by applying them to high school students and investigating the effect of those simulations on students' learning. In addition, students' opinions toward using those simulations can be examined. Besides, physics teachers' opinions towards using such material during an optics subject can be investigated by considering such an application's positive and negative aspects.

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