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Research Article

A Suggestion and Evaluation of a STEM Activity about Friction Coefficient for Pre-Service Science Teachers

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Abstract

In this study, the process of developing and evaluating a STEM activity which can be implemented during Science Teaching Laboratory Practice course in accordance with the 5E Model related to the concept of friction coefficient was addressed. The implementation of the activity was conducted in the form of a case study with the participation of 16 third year pre-service science teachers. Student journal forms and worksheets were utilized for the evaluation of the activity. As a result, it was determined that planned activity could be successfully applied to the pre-service teachers during the weekly course hours of Science Teaching Laboratory Practice course. In addition, positive feedbacks were obtained from pre-service teachers' evaluation for the activity. It is believed that such studies, which establish connections between science and different disciplines, can contribute to the training of qualified science teachers and that such studies should be given more space in science teacher education.

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Introduction

Various associations are present between the subjects within the scope of science and other disciplines. One of the fundamental aims of science education can be stated as the development of scientifically literate individuals who can manage the process of transformation of their theoretical knowledge and skills into practice and product with the combination of science and other disciplines (Güven & Sülün, 2018). Hence, science teachers should highlight the relationships between the subjects in their lessons and different disciplines clearly. This point has been reflected as a revision in the process of education of pre-service science teachers. Accordingly, the course named as "Interdisciplinary Science Education" has been placed in Science Education undergraduate program beginning from 2018-2019 academic year (YÖK, 2018).

Considering the association of science with other disciplines, the approach of "science", "technology", "engineering" and "mathematics" (STEM) in science education is quite pronounced recently (Dani, Hartman & Helfrich, 2018). It is seen that the concept of STEM is widely used in the research conducted in Turkey (Çakır, Altun Yalçın & Yalçın, 2020; Er & Acar-Başeğmez, 2020; Herdem, 2021). Besides, another use, "FeTeMM" which is constituted from the initials of the terms, "science", technology", "engineering" and "mathematics" in Turkish is encountered in Turkish literature (Çevik, Danıştay & Yağcı, 2017; Karışan & Bakırcı, 2018; Koyunlu-Ünlü & Dere, 2019). On the other hand, Yıldırım (2021) points out another form of English-Turkish translation of the term, science due to the extent of its scope. For this reason, the use of BİLTEMM is also preferred for the concept of STEM in Turkish literature as in Kulakoğlu's (2019) research. In this study, we preferred to use "STEM" due to its common use in the literature.

STEM approach is based on the integration and interconnection of different disciplines instead of the traditional understanding based on the separated disciplines (Karataş, 2018). It is specified that STEM approach provides advantages such as giving more importance to interdisciplinary studies, maintaining meaningful and in-depth learning, increasing academic achievement, making associations with daily life, improving the 21st century skills and caring occupational high schools (Yıldırım, 2021). So, it might be expressed that STEM approach means more than an educational practice. Also, STEM approach is related to changing global economy and workforce requirement (Kennedy & Odell, 2014). As a matter of the fact, in the 21st century, there exists a close relationship between the development levels of the countries and their economies. The economies of the countries depend on the qualified human power who have been trained for this reason. Barcelona (2014) emphasizes that students should have a solid STEM knowledge before starting university education and business life.

STEM approach is significant for the education of the students of all ages. It is pointed out that children's appropriate STEM experiences in their pre-school years have positive effects on supporting their academic achievements in primary school, secondary school and beyond (Tippett & Milford, 2017) in addition to their values towards STEM (Campbell, Speldewinde, Howitt, & MacDonald, 2018). The focus of this study consists of pre-service science teachers. To raise qualified individuals such as engineers, mathematicians, and scientists who will form the future of society, pre-service teachers who will take part in their education should be well-informed about STEM (Karışan & Bakırcı, 2018). Hence, the research conducted with pre-service teachers on STEM approach are of great importance.

The analysis of studies conducted with pre-service teachers on STEM approach indicates that several of them were carried out in the form of survey studies. In their study, Radloff and Guzey (2016) investigated how elementary and special education pre-service teachers visualized the concept of STEM in their drawings. As a result of the study, it was determined that pre-service teachers visualized the letters S, T, E and M as interconnected at the highest rate. When the pre-service teachers were asked to support their visuals by writing the definition of STEM, the concepts they focused on the most were found as "hands on" (practical activities), "no humanities" (a course which focuses on technical points) and "ranked" (giving more importance to engineering or technology than the other disciplines). In another study, Karışan and Bakırcı (2018) investigated STEM teaching approaches of pre-service classroom, mathematics, and science teachers. The analysis results showed that there were significant differences among STEM teaching approaches of pre-service teachers favouring pre-service science teachers. Moreover, Koyunlu-Ünlü and Dere (2019) conducted research to evaluate STEM awareness of pre-service kindergarten teachers. The research indicated no significant difference among the participants considering the gender factor. However, there were differences among them with respect to the year of study in the university. Besides, the participants who took STEM education earlier had higher STEM awareness levels than those who did not. Also, Er and Acar-Başeğmez (2020) conducted a study to determine STEM awareness and self-sufficiency beliefs of pre-service mathematics and science teachers. The study concluded a significant differentiation among participants' STEM awareness and self-sufficiency beliefs in favour of women in terms of gender. The department factor was not determined to have a significant effect on STEM awareness. However, it had a significant effect on the participants' self-sufficiency beliefs. Moreover, the year of study was identified as another significant factor which influenced participants' both STEM awareness and self-sufficiency beliefs.

Researches show that another part of the studies conducted with pre-service teachers within the subject of STEM approach considers STEM activities. In one of those studies, Anagün, Karahan and Kılıç (2020) focused on the evaluation of problem-based STEM applications within Science and Technology Teaching Course for pre-service classroom teachers. As a result of the research which lasted for four weeks, it was determined that the participants could follow the stages of design in engineering and improved their skills and affective characteristics related to STEM applications. In another study, Çakır et al. (2020) tested the effect of STEM activities based on Montessori approach on pre-service kindergarten teachers' critical thinking skills during a 14-week research and the study showed a significant improvement in participants' critical thinking skills. In the study conducted by Dani et al. (2018) with the first-year pre-school education students in the USA, the participants planned STEM activities that met the objectives in the curriculum. As a result of the study, it was determined that the ideas of pre-service teachers participating in these activities about STEM education changed from the controlling–teacher centred approach to the questioning–student centred approach. In addition to the studies mentioned, Saraç and Doğru (2021) made research in which pre-service classroom teachers developed STEM activities based on engineering design stages for 11-week period. The researchers examined the experiences of the participants during the study. The results indicated that pre-service teachers internalized general characteristics of STEM education. Also, both positive and negative opinions were obtained from the participants related to the design process of STEM activities.

When the conducted research is evaluated, it is thought that studies in the form of STEM activity implementations for pre-service teachers are very valuable in terms of both understanding the STEM approach and providing a basis for their future teaching. Considering the dimension of STEM approach to design and produce a product, physics course subjects are believed to be very convenient in terms of being handled within this framework. The subject of this research is the case of friction since it is included in the middle school science curriculum and therefore it is a subject that pre-service science teachers will teach.

The concept of friction force is given to the seventh-grade level students in terms of middle school science course (MoNE, 2018). Theoretical knowledge related to this concept provides a basis for learning future subjects such as Law of Conservation of Energy and Newton's Laws (Kızılcık et al., 2021). Also, friction force is experienced in daily life with both its positive and negative influences.

The literature analysis shows that several studies deal with students' conceptual understandings of the case of friction (Cari, Wulandari, Aminah, Handhika & Nugraha, 2019; Corpuz & Rebello, 2011; Kurnaz & Eksi, 2015). In one of those studies conducted with high school students, Kurnaz and Eksi (2015) specified that scientific models had the least percentage among the mental models of students related to friction. In another study, Cari et al. (2019) addressed the direction of friction force in a rolling object. The researchers made an investigation with the attendance of physics education students in Indonesia and stated that students' responses in scientific understanding category had the least percentage among all categories. Also, Kızılcık et al. (2021) made a thematic analysis of the studies which focused on the understanding of the concept of friction by different age students. As a result of this study, the researchers identified students' misconceptions about friction under four categories as the effects of friction, definition and existence of friction, direction of friction and the type and magnitude of friction. The researchers concluded that most of students' misconceptions were in the category of type and magnitude of friction whereas the least of them belonged to the category of direction of friction. On the other hand, the misconception "the direction of friction is always opposite to the direction of motion." was determined as the most frequent misconception among students (Kızılcık et al., 2021).

In their study, Corpuz and Rebello (2011) handled the concept of friction in microscopic level. As a result of the interviews conducted with university students, it was determined that students believed that friction in atomic level was due to the mechanic interactions and their mental models related to the friction in atomic level were influenced from their experiences in macro level (Corpuz & Rebello, 2011). Considering those results, the researchers developed several activities (touching the surfaces of wooden block and sandpaper, moving the wooden block on sandpaper and wooden block, sliding metal gauge blocks over each other) and implemented them on students. Those implementations caused improvements in students' opinions related to friction in micro level. Moreover, Besson, Borghi, De Ambrosis and Mascheretti (2010) developed three-dimensional teaching learning sequence to improve high school students' and pre-service teachers' conceptions on friction and they obtained positive results from their study. As a result of the analyses, it is realized that studies conducted in Turkey about friction is very limited. Also, there is a need to carry out studies based on teaching which aim to improve students' understanding of this concept.

The concepts of friction force and friction coefficient can be defined with mathematical formulas. Additionally, the relationships between the variables in the formulas can be visualized with graphs. Also, several experimental set-ups can be constructed to teach those concepts and the relationships between the variables in the formulas can be tested. Moreover, all those practices can be observed with the support of technology in various ways. Simulations can be preferred at this respect.

Simulations allow testing of situations that are difficult or impossible to perform in a classroom or laboratory environment under normal conditions (Dağdalan & Taş, 2017). They are used in many different areas from military training to nursing training, from driver training to pilot training. Also, they are encountered as the most frequently preferred educational tools which are relatively easy and cheap to be utilized among other technological products (Cayvaz & Akçay, 2018). They are used in terms of science education, and they come to the fore in STEM approach (Saylan-Kırmızıgül, 2020). At this respect, one of the most popular simulation programs is Algodoo.

Algodoo is a two-dimensional physics simulation software which can be downloaded from internet freely and run-on computers and tablets (Algodoo, n.d.). So, several studies conducted by using Algodoo addressed physics subjects such as energy (Cayvaz & Akçay, 2018), force and motion (Taştan-Akdağ & Güneş, 2018), Archimedes' Principle (Çelik, Sarı & Harwanto, 2014), impulse and momentum (Çoban, 2021), Kepler's Laws (Gregorcic, 2015), optics (Özdemir & Çoramık, 2021) and the calculation of kinetic friction coefficient in an inclined plane (Coramik & Ürek, 2021). Besides, Algodoo was utilized in the teaching of a non-physics subject, diffusion (da Silva, Junior, da Silva, Viana & Leal, 2014).

The research concludes positive results from the use of simulations in science courses. In their study, Özer, Canbazoğlu Bilici and Karahan (2016) determined that students had positive opinions towards using simulations in science courses. Also, Sarı, Duygu, Şen and Kırındı (2020) identified that simulation-based STEM approach provided benefits in terms of facilitating engineering design process, facilitating experimentation, minimizing errors, and saving time. Besides, it can be stated that the importance of technology use in science education has increased even more when the conditions of the 21st century we are in, and the conditions of pandemic are considered. For these reasons, it is intended to draw attention to interdisciplinary relations by making use of technology in the STEM activity planned in the current research.

The present research considers the design of an activity based on a lesson plan according to 5E Model. 5E Model was proposed by Rodger W. Bybee in the late 1980s and it involves five stages such as engagement, exploration, explanation, elaboration, and evaluation (Bybee, 2009). 5E Model is also a model which is used in terms of STEM approach in science education (Ültay, Emeksiz & Durmuş, 2020) in addition to various other methods such as project-based learning (Özçakır-Sümen & Çalışıcı, 2019), engineering design steps (Anagün et al., 2020; Herdem, 2021), simulation-based learning (Sarı et al., 2020; Saylan-Kırmızıgül, 2020), game-based learning (Campbell et al., 2018) and Montessori Approach (Çakır et al., 2020).

The reasons of utilization of 5E model in the design of the activity in terms of the current study can be explained as it considers student centred instruction, it is a model with which teachers and pre-services teachers are familiar in terms of the teaching plans implemented in Turkey and it matches with the flow of suggested activity. Also, the elaboration stage of the model makes it possible for the students to make applications related to STEM (Yıldırım, 2021).

The aim and significance of the study

Pre-service science teachers are trained to teach physics, chemistry, and biology concepts in terms of various objectives defined in the curriculum. One of the recent approaches headed in science education is STEM approach. STEM approach allows the students to associate science subjects with the disciplines such as technology, engineering, and mathematics and to design a product. However, a survey study showed that pre-service science and mathematics teachers had "middle" level self-sufficiency beliefs about STEM whereas their attitudes were identified as "good" in this context (Er & Acar-Başeğmez, 2020). Additionally, in the study of Şahin, Göcük and Sevgi (2018) which examined the ability of pre-service physics, chemistry, biology, and science teachers to establish interdisciplinary relationships about blood pressure, it was determined that although pre-service teachers became more successful in their own field, their performance was not sufficient in the interdisciplinary questions. Moreover, the results of a meta-analysis study conducted by Becker and Park (2011) indicated that students' achievement was influenced positively from integrative approaches among STEM subjects and the researchers highlighted the need to evaluate students' learning empirically through integrative approaches among STEM subjects in the future research. For these reasons, it is believed that there is a need for successful STEM implementation studies which might be useful for the pre-service teachers and provide them insights for such applications in the future.

This study intends to present an activity suggestion based on STEM approach which can be implemented to pre-service science teachers in terms of their Science Teaching Laboratory Practice course. Also, the study aims to evaluate the opinions of pre-service teachers on the implementation of the activity suggested in the study. Thus, it is expected to contribute to the education of qualified science teachers by presenting an up-to-date teaching material in which science is associated with other disciplines, technological applications are used, and its effectiveness is tested.

The research questions addressed in this study are as follows:

- Can the suggested activity be used for the training of pre-service science teachers efficiently?
- What are pre-service science teachers' opinions (points learnt, STEM discipline connections, positive aspects, challenges, and suggestions) related to the implementation of the suggested activity?

Method

Research Design

The research involves two parts. The first part of the research makes a STEM activity suggestion, and the second part involves the evaluation of this suggestion. Hence, a case study was conducted for the second part of the research. Case studies are described as qualitative research design in which more than one data collection method is used and there is no generalization of the results, by creating examples and experiences to understand the results of a situation and similar situations (Yıldırım & Şimşek, 2018). Case studies can be treated as single or multiple case designs as well as holistic or embedded designs (Yin, 2009). Holistic case studies are those that investigate a unit as single global phenomenon or of a program (Yin, 2009) whereas embedded studies involve more than one unit, or object of analysis (Scholz & Tietje, 2002). In the present study, holistic single-case study was used to research the opinions of pre-services science teachers on the suggested activity.

The Participants

The participants of the study consist of 16 pre-service science teachers who study in the third year of Elementary Science Education Department in the education faculty of a governmental university in the west part of Turkey. All the participants were women. Criterion based sampling from purposive sampling methods was utilized to determine the study sample. Criterion based sampling is formed by including units which meet the specified criteria in the study sample (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz & Demirel, 2018). Considering this fact, students who took fundamental physics, chemistry and biology courses were included in the sample. In addition, the students were taking "Science Teaching Laboratory Practice 1" course which dealt with the application of their scientific knowledge at the time of the study. Besides, all the participants were taking "Interdisciplinary Science Education" course which was given in the fourth year of their program as a course from the upper term. Thus, the participants possessed knowledge about STEM approach in science education. For these reasons, those pre-service teachers were included in the sample since they were expected to make contributions to the current research in terms of the evaluation of the activity.

The Design and Implementation of the Activity

The activity which was implemented in the research was designed according to 5E Model by the researchers as mentioned earlier. The lesson plan and worksheets developed for the activity suggested in this paper are presented in the Appendix. The activity addresses the concept of friction coefficient, and it is expected to utilize this activity for the training of the third-year pre-service science teachers in terms of their Science Teaching Laboratory Practice course. The activity takes about three course hours. Although there is no situation which threatens the safety of the students in the activity, it will be beneficial to consider COVID-19 Pandemic safety conditions during face-to-face instructions.

The STEM objectives targeted at the activity are as follows:

The students will be able to

- Realize that friction coefficient is affected by the type of the surface. (S)
- Use Algodoo program at a basic level. (T)
- Examine the images of different types of wooden material under stereo microscope. (T)
- Make a design which allows changing the friction coefficient of a system by using Algodoo. (E)
- Calculate the friction coefficient of a system by using mathematical formula. (M)
- Interpret a distance-time graph which is drawn for an object beginning to move horizontally with an initial velocity under the effect of a friction force. (M)

With the activity suggested, it expected to contribute to the 21st century skills of the participants such as critical thinking, analytic thinking, decision making, innovative thinking, scientific process skills, information and media literacy and communication skills. The current research was not implemented on students working in groups due to the pandemic conditions. However, the elaboration part of the activity can be carried out with students working in groups of two people when such health considerations are eliminated from daily life. Thus, skills of the participants such as cooperative working and leadership can also be improved.

A course based on this activity considering 5E Model can be initiated by asking the following questions to the students and the responses obtained from the students can be interpreted in the engagement phase:

- Are there any doors which squeak in your dormitory or at home?
- Why does a door squeak?
- What can be done to avoid door squeak?
- What kind of differences are there between two doors which squeaks, and which does not squeak?

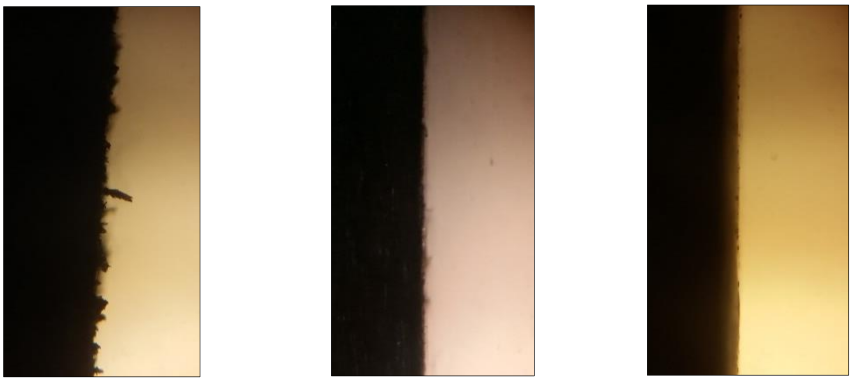
In the engagement phase, a relationship is constructed between door squeaking which is common in daily life and the concept of friction. Door squeak is associated with the friction force between the surfaces of two hinges on the door. It is highlighted that this type of force is a contact force. So, it is stated that this situation is due to the structure of the surfaces. It is explained that this squeak can be eliminated if the door hinges are lubricated or coated with liquid dish soap. From this point, exploration phase is proceeded to make further investigation of the structure of surfaces that cause friction.

One of the surfaces that are frequently used in daily life and on which an object can move, or stand is wooden surfaces. In the exploration phase, three different materials; raw wood, polished wood and sanded wood are examined under a stereo microscope with a total magnification of 40 times using 4X objective and 10X ocular. The wooden surfaces used in the activity are shown in Figure 1. After the observations, the pre-service teachers are asked to fill in the relevant parts in their worksheets. In the worksheets, the participants are asked whether the microscopic images of the surfaces are the same. Also, the participants are asked to make a comparison in terms of the roughness of the surfaces.

(i) Raw Wood **(ii) Sanded Wood** **(iii) Polished Wood**

Figure 1. Different wood surfaces used in the exploration phase of the activity

The images obtained from the microscopic examination of wooden surfaces shown in Figure 1 are demonstrated in Figure 2.



(i) Raw Wood **(ii) Sanded Wood** **(iii) Polished Wood**

Figure 2. Microscope images of different wooden materials

According to Figure 2, it is realized that polished wood is the smoothest one whereas raw wood is the roughest one. Pre-service teachers also observe this situation by touching the surfaces of those materials with their hands. Thus, it is inferred that surfaces which have different forms might have different friction coefficients and explanation phase is proceeded.

In the explanation phase, first, the question "For a frictional force to act on an object, should the object be at rest or on motion?" is posed to the participants. Afterwards, the participants are asked to make a comparison in terms of the magnitude of two forces which is applied to give an object an initial motion and which is applied to keep an object moving on constant velocity after moving it. From here, the definitions of static and kinetic friction force are made and the variation of these two forces depending on the forces applied to the object is explained on the graph shown in Figure 3 (Serway & Jewett, 2004).

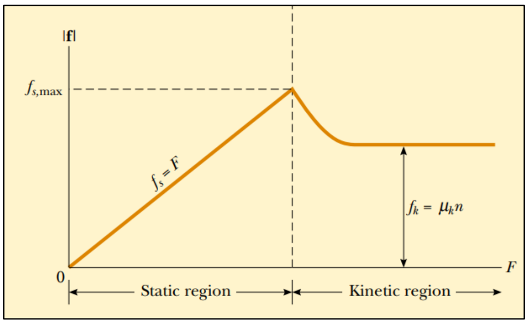


Figure 3. Variation of kinetic and static friction forces depending on the force applied

After making the definitions, the opinions of participants are taken about what the static and kinetic friction force might depend on. A possible misconception is tried to be eliminated by asking especially whether there is a relationship between the contact surface area and the friction force. Then, the formulas of static and kinetic friction force are given, and it is pointed out that they are related to the normal force (n) and friction coefficient ($f_s \leq \mu_s n$, $f_k = \mu_k n$). After defining the static (μ_s) and kinetic (μ_k) friction coefficients, the participants are asked about the variables with which those coefficients are related to. In here, it is explained that friction coefficient is related to the structure of the surfaces by referring to the observations of pre-service teachers in the exploration phase of the activity.

Kinetic friction force is clarified to the participants on Figure 4 which shows a box moving on a horizontal plane and the calculation of kinetic friction coefficient is explained as follows:

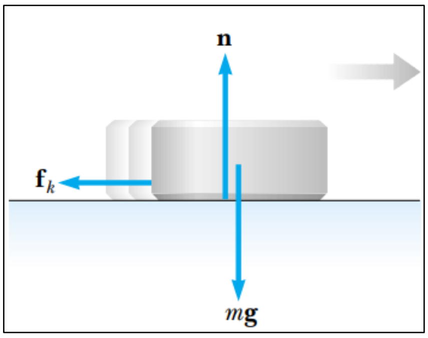


Figure 4. Forces acting on a box moving on a horizontal plane

The forces acting on a box which moves to the right direction with an initial velocity, v_i on a frictional horizontal plane are as shown in Figure 4. The box stops after taking a distance of Δx. In here, n denotes the normal force, f_k denotes kinetic friction force and mg denotes weight. Directions to the right and upwards are taken as positive. When Newton's Second Law of Motion is applied to the system,

$$\sum F_x = -f_k = ma$$

$$\sum F_y = n - mg = 0\ (a_y = 0)$$

are obtained. Also, kinetic friction force can be written as $f_k = \mu_k n$ where f_k denotes kinetic friction coefficient. By using those equations, the acceleration of the box is defined as

$$-\mu_k n = -\mu_k mg = ma_x$$
$$a_x = -\mu_k g$$

In here, the negative acceleration indicates that the box will stop after slowing down. Also, the acceleration is constant and independent of the mass of the box. For motion with constant acceleration, as $x_i = 0$ and $v_f = 0$

$$v_f{}^2 = v_i{}^2 + 2a_x(x_f - x_i)$$

By using the equation above, the friction coefficient is obtained as

$$\mu_k = \frac{v_i{}^2}{2gx_f}$$

The participants are asked to take their notes to their worksheets related to the explanation phase. After the explanations, the participants are asked to focus on the scenario presented in their worksheets. In this part, the participants are directed to use Algodoo simulation program which has been already set up in their computers. Since the participants have no information and experience related to the use of this program, a brief introduction is made about Algodoo for them. In this process, pre-service teachers carry out basic applications of the program with the presentation of the researchers. Then, the scenario situation which introduces a problem to be solved is read in the classroom and the elaboration phase is proceeded. The scenario presented in the worksheets is as follows:

A father and his little daughter stand facing each other within a certain distance on a horizontal plane. The father holds a gift box in his hands, and he tries to send this box to his daughter without going to her. The father leaves this box on the horizontal plane and pushes it to the little girl with a certain initial velocity. However, the box stops moving after a while without reaching the girl. So, the girl asks his father to do what he can to deliver the box to her.

What kind of a design can help this girl in terms of your knowledge about the friction coefficient without changing the initial velocity of the box?

In the elaboration phase of the activity, the pre-service teachers are asked to design the first case in the scenario by using Algodoo. Then, they are told to make design to carry out what is wanted in the scenario. Pre-service teachers are also asked to fill in the table given in their worksheets while making their designs. In this part, they should record several information such as the type of materials that they use, the changes that they make on the system, and the numerical values which show the distance taken by the box and the distance of the box to the girl. In here, the participants should try to design an ideal system to eliminate the problem in the scenario. After making their ideal design, they can determine the friction coefficient of the system. Also, they can compare the kinetic friction coefficient obtained from the simulation and calculated with the help of formulas by using the theoretical values. So, the participants can justify the results related to the kinetic friction coefficient. In this process, the researchers provide appropriate feedbacks to the participants when they have any questions as in the previous parts of the activity.

After the participants finish their designs, several of them are asked to present their designs to the class in terms of the evaluation phase. Students presenting their designs and sharing them with their peers is an alternative evaluation technique encountered in the literature within the scope of STEM approach (Herdem, 2021). In addition, the performance of each participant during the whole activity can be evaluated with the help of a product evaluation rubric which considers their designs. The following qualifications might be involved in such a rubric:

- Does the box in the design reach the girl?
- Does the design involve a box which looks like a gift box aesthetically?
- Is the design completed in the targeted period?
- Are the mathematical calculations carried out related to the friction coefficient of the system?
- Is the distance-time graph drawn and interpreted for the box?
- Does the participant make a successful presentation of his/her design to the peers?

Rubrics are used for evaluating student designs in STEM approach (Herdem, 2021; Özçakır-Sümen & Çalışıcı, 2019). The qualifications involved in the rubrics can be weighed as 4 points for *perfect*, 3 points for *average*, 2 points for *below average* and 1 point for *poor* performance and the total score can be obtained from the calculation of those values (Sungur-Gül, 2020).

The activity developed in this paper was implemented to the pre-service science teachers in the fall semester of 2021-2022 academic year. The implementation period took about three course hours. The research was conducted with face-to-face applications considering the COVID-19 Pandemic safety rules. According to the pandemic conditions, all the participants wore face masks, had two doses of vaccination and sticked to sitting with a definite distance with their peers. Also, the laboratories were ventilated by leaving the windows open and the hygiene was cared.

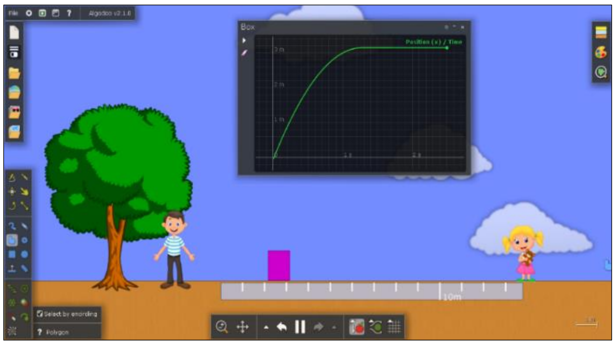
The activity began by asking questions to the participants in the engagement phase and brainstorming was made about their responses. Then, the worksheets were delivered to them, and the exploration phase was passed on. In this phase, observations of different types of surfaces were carried out with stereo microscopes. The participants involved in the current research did not have any opportunity to conduct biology laboratory courses with face-to-face practices due to the pandemic. Instead, they had to attend online teaching sessions. So, they did not have any laboratory practices at the school environment. Because the risks of the pandemic had continued, the participants were provided with microscopic images which had already been adjusted by the researchers. Thus, it was intended to eliminate close interactions of the researchers and the participants while adjusting the images in addition to ensuring effective time management. Those phases were conducted in the biology laboratory.

After recording the results of their observations on worksheets, the participants were transferred to the computer laboratory. In here, the concepts of friction force and friction coefficient were explained to them considering their observations and daily life experiences. In addition, a short training on the basic usage information about Algodoo was given to the participants. Then, the elaboration phase was started. In this phase, the participants were asked to make a system design which met the conditions given to them. Figure 5 shows photos from the implementation of the activity in the biology and computer laboratory.

Figure 5. Photos taken in biology and computer laboratory during the implementation of the activity

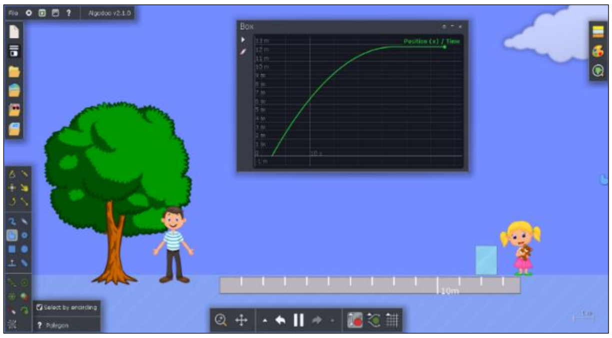
In the elaboration phase, the participants were asked to save the final version of their designs on their computers. In Figure 6.a and Figure 6.b, screenshots of a participant's sample design of the problem situation and the obtained simulation result for this situation are given respectively. Figure 6.c and Figure 6.d demonstrate the screenshots of this participant's ideal system design and the simulation result for the solution of the problem situation respectively.

(a) A sample pre-service teacher design of the problem situation



(b) The simulation of the design related to the problem situation

(c) An ideal system design for the solution of the problem situation



(d) The simulation of ideal system design related to the solution of the problem situation

Figure 6. A sample from the screenshots of the designs made by the same participant in the implementation process

In the evaluation phase of the activity, the participants made presentations to introduce their designs to their peers. Figure 7 demonstrates a photo related to this phase.

Figure 7. An example of the presentations made by the participants

Data Collection Instruments

Data of the research were collected with the help of student journal forms (SJFs) and worksheets. Thus, qualitative data in line with the nature of the study were obtained.

SJFs were taken from Herdem's (2021) study. Herdem (2021) utilized those forms to investigate the opinions of middle school students on STEM activities which she implemented. In the current study, opinions were taken from three experts in the science education field to use those forms for university students. In this context, the questions numbered 1, 2, 3 and 5 were taken as in their original forms whereas a modification was made for the question numbered 4. In question 4, the students were asked to indicate the connections of science with other STEM disciplines as a result of the activity. The participants were not asked about science connections of the activity as in the original form since they were expected to give detailed answer for this point while indicating their learning from the activity for question 1. For question 4, the titles such as mathematics, technology and engineering connections were given to the students expressly and they were asked to list those connections. So, it was aimed to determine pre-service teachers' opinions clearly. SJFs were implemented in the end of the activity.

Worksheets developed by the researchers were delivered to the participants to record and interpret their observations during the activity. Data obtained from worksheets were used to support data obtained from SJFs.

Data Analysis

Collected data were analysed by content analysis from qualitative approach. In content analysis, data which are similar to each other are gathered under definite concepts and themes, they are arranged in an understandable manner and interpreted (Yıldırım & Şimşek, 2018). Thus, the opinions of the participants related to the activity were detected and the results were tabulated. Also, abbreviations in the form of PT1, PT2… were used to indicate each *p*re-service *t*eacher who gave a response for the mentioned category.

In data analyses, responses given to the questions were examined one by one by each researcher and they were gathered under categories (themes) by determining the concepts and codes in their responses. This process was carried out for five questions (points learnt, connections of science with other STEM disciplines, positive aspects, challenges, and suggestions) as suggested in Herdem's (2021) research. The categories and codes determined in the present study are demonstrated in Figure 8. The categories were highlighted in bold, and the codes were written in normal colour for the analysis of each question.

Questions	• **Analysis Categories** • Codes
Q1: The points learnt	• **Concepts related to friction** • **Algodoo** • **Formulas** • **Microscope**
Q2: Connection of science with other STEM disciplines	• **Mathematics connections** • In calculations • In using formulas • In the interpretation of the graphs • **Technology connections** • In using Algodoo simulation • In using microscope • In the examples given during the instruction • **Engineering connections** • In making designs by using the simulation program • In the details related to the design • In making drawings
Q3: Positive aspects of the activity	• **Conceptual** • Comprehension/reinforcement of the subject • Durability of learning • Intelligibility of learning • Concreteness of learning • **Affective** • Learning with fun • A nice experience for future • **Skills** • Using Algodoo in a general manner • Designing systems which are impossible to create under normal conditions • Making observations with microscope • Establishing relationships between STEM disciplines • Using time efficiently • Improving design skills
Q4: Challenges of the activity	• **Getting the box to its destination** • **Making mathematical calculations** • **Figuring out Algodoo** • **Observing microscope image**
Q5: Suggestions	• **Similar activities should be implemented more frequently** • **The use of such simulation programs should be used more often** • **Related data interval should be presented to the students for their designs**

Figure 8. Analysis categories and codes for each question in SJF

In data analysis process, inter-consistency coefficient which considers the agreements and disagreements in the analyses of two researchers was calculated by using the formula defined by Miles and Huberman (1994). Thus, inter-consistency coefficient was calculated to be 96% and indicated the reliability of data analysis (Yıldırım & Şimşek, 2018).

In the present study, various data were also obtained from worksheets that participants filled during the implementation process. This data provided triangulation for the study by making direct quotations from participants' sentences. In qualitative studies, triangulation can be used in terms of data sources, methods and researchers and it is reported to increase the cogency of the study (Yıldırım & Şimşek, 2018). Thus, the use of two different data sources was expected to increase the cogency of the study results.

Validity and Reliability of the Research

In terms of ensuring the internal reliability of the current research, multiple researchers were involved in the coding process of data and comparisons were made for their coding. In terms of external reliability of the research, the method and stages of the study were explained step by step clearly. The results of the research were associated with study data clearly. When the validity of the research is considered, consistency of the findings with the conceptual framework was checked to ensure internal validity. To confirm the findings of the study, the designs made by the participants on the computers, screenshots related to those designs and their worksheets were used. In terms of external validity of the research, it was considered to make detailed explanations of the research to allow comparing this process on other samples. Testing of same research in similar settings is made possible by presenting the lesson plan and worksheet used in the research in the Appendix.

Findings

The Points Learnt as a Result of the Activity

The analyses results showed that the points learnt by the participants as a result of the activity were collected under four main categories as indicated in Table 1.

Table 1. The points learnt as a result of the activity

Categories	Participants
Concepts related to friction	PT1, PT2, PT4, PT5, PT6, PT7, PT8, PT9, PT10, PT11, PT12, PT13, PT14, PT15, PT16
Algodoo	PT1, PT3, PT4, PT5, PT13, PT16
Formulas	PT8, PT9, PT12
Microscope	PT3, PT4, PT16

According to Table 1, most of the participants asserted that they learnt concepts related to the friction as a result of the activity. Those can be listed as *the factors which affect friction force, the relationship between the type of the surface and the friction force, calculation of the friction force, the effect of friction force on the motion of an object, variation of the friction coefficient* *according to the type of the surface, the factors affecting friction coefficient* in addition to the fact that *the friction force is not related to the contact surface area,* and *the static friction coefficient is greater than the kinetic friction coefficient.* Moreover, the participants indicated their knowledge and skills related to the use of *Algodoo*. Besides, several participants mentioned formulas such as $x_f = v_i^2/2g\mu_k$, $f_k = \mu_k mg$ and $a_x = -\mu_k g$. Finally, they mentioned their learning related to the *use of microscope* as gaining microscope experience and the differentiation of the images of raw, sanded, and polished wood under microscope.

The abovementioned points were also reflected in the participants' notes on their worksheets. The notes about the concepts related to friction written by PT14 on her worksheet are given as follows:

$x_f = v_i^2/2g\mu_k$, $f_k = \mu_k n \rightarrow f_k = \mu_k mg$,

The friction coefficient is affected by the type of the object and the type of the surface.

$\mu_s > \mu_k$

$\sum F_x = -f_k = ma$

$\sum F_y = n - mg = 0 \ \rightarrow n = mg$

$a_x = -\mu_k g$

PT3's expressions taken from her worksheet are as follows: "The surfaces that we observed under microscope were not the same. The polished surface was the smoothest one under microscope. Then, the sanded wood came. The roughest one was the raw wood."

Connection of science with other STEM disciplines established at the activity

Participants' connections of science with other STEM disciplines established at the activity within the scope of mathematics, technology and engineering contexts are presented in Table 2.

Table 2. Participants' connection of science with other STEM disciplines

Mathematics Connections	Participants
In calculations	PT1, PT2, PT3, PT4, PT6, PT7, PT10, PT11, PT12, PT13, PT15, PT16
In using formulas	
When calculating the distance taken by the box	PT5, PT8, PT9, PT12
When calculating the magnitude of friction force	PT7, PT14
When calculating the friction coefficients	PT5
In the interpretation of the graphs	PT12, PT16
Technology Connections	
In using Algodoo simulation	PT2, PT5, PT6, PT7, PT8, PT9, PT10, PT11, PT12, K13, PT14, PT15, PT16
In using microscope	PT2

In the examples given during the instruction	PT1
Engineering Connections	
In making designs by using the simulation program	PT2, PT3, PT4, PT6, PT9, PT10, PT14, PT15, PT16
In the details related to the design	
Design of the box	PT8, PT11, PT12, PT13
Design of the surface	PT12, PT13
Sending the box in different angles	PT12
In making drawings	PT1, PT5, PT7

Participants' connections established within the scope of mathematics were collected under three headings which were general calculations, using formulas and the interpretation of the graphs. Within the scope of technology, the most mentioned connection was the use of Algodoo simulation program. The use of microscope and examples given during the instruction were also mentioned in this context. When the connections within the scope of engineering relationships were considered, the participants' opinions were gathered under three headings. Those were making design by using the simulation program, details of the designs and making drawings.

Table 3 which was taken from PT2's worksheet shows her design process illustrating the participant's connections of science with other STEM disciplines:

Table 3. PT2's design process taken from her worksheet

	The things I did	Distance taken by the box	Distance of the box to the girl
Design 1	- At first, the surface was wooden. - The box was made of wood. - The box was 1 kg. - Initial velocity was 5 m/s. - There was no air friction.	3.147 m	9.853 m
Design 2	- At first, I changed the type of the surface to ice, and it took 8.978 m distance. - Next, I changed the type of the box, and I made the box reach to the girl by placing the box made of glass on ice. - The box was still 1 kg in mass. - Initial velocity was still 5 m/s. - Again, there was no air friction in the system.	12.714 m	0.286 m

Positive Aspects of the Activity

The analyses showed that the participants' views related to the positive aspects of the activity were collected under three main categories as can be seen in Table 4.

Table 4. Positive aspects of the activity

Categories	Codes	Participants
Conceptual	Comprehension/reinforcement of the subject	PT1, PT6, PT9, PT10, PT12, PT15
	Durability of learning	PT4, PT11, PT14
	Intelligibility of learning	PT5, PT12, PT13
	Concreteness of learning	PT13, PT15
Affective	Learning with fun	PT8, PT10
	A nice experience for future	PT5
Skills	Using Algodoo in a general manner	PT1, PT2, PT6, PT12, PT16
	Designing systems which are impossible to create under normal conditions	PT2, PT3, PT6, PT7, PT9, PT16
	Making observations with microscope	PT2, PT4, PT16
	Establishing relationships between STEM disciplines	PT9, PT12, PT13
	Using time efficiently	PT14
	Improving design skills	PT2

When Table 4 is examined, it is realized that the participants mostly mentioned various skills in terms of the positive aspects of the activity. This category was followed by the conceptual gains. In another words, the participants expressed that the activity mostly contributed to their various skills and conceptual understandings. Additionally, the activity was determined to be beneficial in terms of affective domain. In this context, PT5's statements in her SJF are as follows: "Using Algodoo program provided a nice experience for my future teaching career. The subject became more intelligible for me after we learnt it with the help of the activity. Besides in her SJF, PT9 expresses that "We cannot make such a design under normal conditions. We achieved it with the help of the simulation program. In addition, we used STEM efficiently. We understood the connection of STEM disciplines with each other. And we made a revision of the subject of friction."

Challenging Parts of the Activity

Examination of the participants' responses related to the challenging parts of the activity indicated that three participants (PT2, PT12 and PT16) did not have any difficulties in the activity. The views obtained from the rest of the participants are shown in Table 5.

Table 5. Challenging parts of the activity

Themes	Participants
Getting the box to its destination	PT3, PT4, PT5, PT6, PT8, PT9, PT11
Making mathematical calculations	PT4, PT7, PT9, PT10, PT13, PT14
Figuring out Algodoo	PT1, PT7
Observing microscope image	PT15

According to Table 5, the most challenging part of the activity was related to the design process. Besides, mathematical calculations were important factor which caused difficulty for the participants. This finding can be supported by the participants' expressions on their worksheets. For example, PT4 indicated that her design did not meet the little girl's expectation. PT4 calculated that the box was 1.086 m away despite the improvements in her design. Besides, PT6 and PT11 provided no response whether they achieved the goal of their designs. Additionally, PT10 and PT14 made no justification for the calculation of friction coefficient on their worksheets.

Suggestions of Pre-service Teachers Related to the Activity

Analyses of the final question indicated that five participants (PT5, PT6, PT13, PT14, PT15) did not provide any suggestions about the activity due to the fact that the activity is appropriate in its current form. The suggestions obtained from the rest of the participants were collected under three main categories as shown in Table 6.

Table 6. Suggestions related to the activity

Themes	Participants
Similar activities should be implemented more frequently	PT1, PT2, PT4, PT9, PT10, PT11, PT12, PT16
The use of such simulation programs should be used more often	PT3, PT7, PT8, PT9
Related data interval should be presented to the students for their designs	PT11

Although the participants mentioned several challenging points about the activity in Table 5, most of them insisted on using similar activities or Algodoo simulation program in their courses more frequently as can be seen in Table 6. In this context, her SJF, PT1 expresses that "Taking place in such kind of studies gives me so much pleasure. I suggest more studies like this be done." In addition, PT8 states that "I think we should learn to use Algodoo for various other subjects." Also, PT16 indicates that "Such kind of implementations should increase in physics, chemistry, and biology. This implementation has been so efficient although I knew the subject of friction coefficient." Those suggestions support the positive aspects of the activity. On the other hand, only one participant, PT11 expresses that "Possible data intervals can be presented to the students for their designs."

Discussion and Conclusion

As a result of the research, it can be stated that the activity suggested in this paper might contribute to the education of pre-service science teachers. In their study, Dani et al. (2018) assert that STEM activities can provide effective clinical settings to develop science teachers. The general result of the study is in parallel with the positive consequences of the research which were carried out with pre-service teachers in the literature (Anagün et al., 2020; Çakır et al., 2020; Dani et al., 2018; Saraç & Doğru, 2021). In line with this result, another study indicates that pre-service science teachers constitute the group who believes the requirement of interdisciplinary education at most among other groups (such as physics, chemistry, and biology pre-service teachers) and there is no one who possesses negative views at this point (Şahin et al., 2018).

When the participants of the study were asked to evaluate their learning from the activity, almost all the participants highlighted various concepts about friction. In this context, it is realized that the participants developed scientific views contrary to the misconceptions stated in the literature. For example, the participants asserted that there was no relation between the friction force and contact surface area which are in contact contrary to the misconception "Friction is depended on the magnitude of the surfaces which are in contact." defined in the literature (Kızılcık et al., 2021). Besides, the participants asserted that "Friction force depends on the type of the surface.", and "Static friction coefficient is greater than the kinetic friction coefficient."

As well as the mentioned conceptions, the participants also indicated that they learnt Algodoo simulation program, several formulas, and the use of microscope as a result of the activity. It can be said that these concepts and skills, stated by the pre-service teachers within the scope of the activity, overlap with the STEM disciplines. Similarly, Herdem (2021) as a result of her research with middle school students within the scope of science teaching based on STEM approach determined that several learning of students was related to the disciplines of science, technology, mathematics and engineering. The current research also addressed participants' STEM connections of the activity. In this context, the participants expressed that Algodoo use was related to technology and engineering, microscope use was related to technology, and the formulas used were related to mathematics. Thus, several responses of pre-service teachers related to their learning from the activity supported their STEM connections.

The skills and information to use Algodoo in terms of the addressed subject in this paper might also be used to improve students' scientifically unacceptable views. Besson et al. (2010) state that in a system in which a body is placed below another, students tend to think that there is only one single friction force, and there is no force applied to a body below another body. To eliminate this tendency, "view forces" property of Algodoo program might be used. Thus, it will be easier to determine the direction of friction force and to draw free object diagrams in the analysis and teaching of moving systems placed one on another.

Making microscope observations within the current STEM activity was another gain for the participants. Also, in their study, Huang, Wood and Demos (2018) explain that microscopy with ultraviolet surface excitation can provide cross-disciplinary experiences in STEM and undergraduate education. The researchers emphasize a rapid and safe methodology promises for future scientists and medical professionals. With the suggested activity, it is possible for the teachers to explain the differences between structures of surfaces observed under microscope and observed with naked eye. Thus, the students can examine appearing and detailed images of the surface instead of referring to the drawings of the textbooks. In this way, the fact that friction coefficient is almost independent of the surface areas of the contacting surfaces (Serway & Jewett, 2004) can be more easily explained to the students.

When the participants were asked to explain the positive aspects of the activity, it was realized that the activity was beneficial both in terms of conceptual, affective and skills, supporting the above-mentioned results. Also, in another study based on conduction of STEM activities with pre-service classroom teachers, affective benefits of the study were determined as well as the benefits on science process skills and life skills (Anagün et al., 2020). Besides, in terms of conceptual aspects, the participants talked about the benefits of the activity on the comprehension and reinforcement of the subject as well as the intelligibility, and concreteness of the learning. Similarly, previous research indicates that STEM implementations increase academic achievement (Özdemir & Cappellaro, 2020) and ensure durability of learning (Özdemir & Cappellaro, 2020; Saraç & Doğru, 2021).

In the current research participants mentioned several affective aspects of the activity such as being enjoyable and providing a nice experience for their future career. Likewise, STEM activities were determined to be entertaining in the previous studies conducted with elementary school students (Ültay et al., 2020), middle school students (Herdem, 2021) and pre-service teachers (Çakır et al., 2020; Saraç & Doğru, 2021). Also, it was determined that STEM implementations provided an entertaining and effective learning environment by in-service teachers (Özdemir & Cappellaro, 2020).

In addition to the positive aspects of the activity, it was determined that the participants experienced several challenges in several parts. The most important one of these challenges was making a design which would make the box reach the target. This case can be associated to the engineering connections. Hence, it can be stated that the participants had difficulty in terms of engineering skills (f=7) at most. This difficulty was followed by the challenges experienced in mathematical calculations (f=6). Besides, very few participants had difficulties in the comprehension of Algodoo (f=2) and microscopy examination (f=1). As can be seen, the least challenging skills are related to technology. These results are in line with a study conducted with teachers. In their study, Özdemir and Cappellaro (2020) identified that mathematics (6.6%) and engineering (3.3%) were the disciplines which evoked in the minds of teachers at least within STEM whereas technology (20.0%) was the discipline which evoked in their minds at most. Therefore, in line with the ratios of teachers' associations of STEM disciplines, it can be stated that while pre-service teachers had more difficulties in mathematics and engineering skills, they had less difficulties in technology. Besides, various students were also determined to have several difficulties in different STEM implementations (Herdem, 2021; Ültay et al., 2020).

Considering the final part of the research which dealt with the suggestions made by the participants, it is recognized that the participants were satisfied with the activity. In their responses, they mentioned utilization of such activities and Algodoo simulation program within their education more often. Previous research also indicated positive attitudes of the participants towards the use of Algodoo (Cayvaz & Akçay, 2018; Çelik et al., 2014; Dağdalan & Taş, 2017; Taştan-Akdağ & Güneş, 2018). By teaching the use of a simulation program such as Algodoo to the pre-service teachers, it is expected to contribute to the characteristics of those individuals such as being technology literate, being innovative, and being open to the developments as stated in the literature within the scope of STEM (Özdemir & Cappellaro, 2020). On the other hand, as a result of their study conducted with the ninth-grade students, Taştan-Akdağ and Güneş (2018) detected that students' insufficient level of English caused problems in their use of Algodoo. For this reason, it is required to know basic English which is necessary to learn and use most of the programs such as for Algodoo. No such difficulty was encountered in the current research since the study group consisted of university students. However, the development of English language skills of high school students might be recommended since technology will be even more prominent in the future.

The current research indicated only one student who suggested presentation of data interval which was necessary to make an appropriate design for them. However, STEM practices carry several advantages for students such as improving in-depth thinking skills as well as improving themselves and comprehension of what to do (Saraç & Doğru, 2021). So, it is thought that presenting data interval directly to the students may prevent them from being fully involved in the process by limiting their creativity and inquiry skills. Accordingly, this was not considered as an acceptable and reasonable suggestion. The literature depicts students' recommendations such as "giving extra time" and "using a variety of materials" considering the STEM practices in which they involve (Herdem, 2021).

Finally, the activity suggested in this paper is expected to contribute pre-service science teachers' views on STEM approach by the implementation of it to the similar samples. Thus, future science teachers can be provided with a kind of STEM experience and the background to carry out similar implementations in their own carriers.

Ethical Committee Permission Information

Name of the board that carries out ethical assessment: Balıkesir University Science and Engineering Ethical Committee

The date and number of the ethical assessment decision: 14.01.2022 – 2022/1

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Author Contribution Statement

Handan ÜREK: *Conceptualization, literature review, methodology, implementation, data analysis, translation, and writing.*

Mustafa ÇORAMIK: *Conceptualization, literature review, methodology, implementation, data analysis, writing.*

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Appendix A. The lesson plan based on 5E Model developed for the activity by the researchers

Engagement

The following questions are posed to the students to take their attention to the lesson:

- Are there any doors which squeak in your dormitory or at home?
- Why does a door squeak?
- What can be done to avoid door squeak?
- What kind of differences are there between two doors which squeaks, and which does not squeak?

The responses are commented. In this phase, a relationship is constructed between door squeaking which is a frequently encountered situation in daily life and the concept of friction. Door squeak is associated with the friction force between the surfaces of two hinges on the door. So, it is stated that this situation is due to the structure of the surfaces. It is explained that this squeak can be eliminated if the door hinges are lubricated or coated with liquid dish soap. From this point, exploration phase is proceeded to make further investigation of different surfaces in micro level to examine the structure of different forms of wood which are often used in daily life.

Exploration

In this phase, the students settle down in biology laboratory to make microscope observations with a magnification of 40X under stereo microscopes. Raw, polished, and sanded wood blocks are delivered to the students in addition to the worksheets. The questions stated in the worksheets related to this phase are as follows:

Considering each form of the wooden surfaces (raw, polished, and sanded wood),

1. Are the microscope images same for different forms of wood? Please explain.
2. What can you say if you make a comparison among the appearances of those surfaces?

The students are expected to take notes. Also, they are expected to make an inference, "The friction force to be applied by surfaces with different characteristics may vary". And the explanation phase is proceeded.

Explanation

In the explanation phase, first, the question "For a frictional force to act on an object, should the object be at rest or on motion?" is posed to the participants. Afterwards, the participants are asked to make a comparison in terms of the magnitude of two forces which is applied to give an object an initial motion and which is applied to keep an object moving on constant velocity after moving it. From here, the definitions of static and kinetic friction force are made and the variation of these two forces depending on the forces applied to the object is explained.

After the definitions are made, the opinions of participants are taken about what the static and kinetic friction force might depend on. A possible misconception is tried to be eliminated by asking especially whether there is a relationship between the contact surface area and the friction force. Then, the formulas of static and kinetic friction force are given, and it is pointed out that they are related to the normal force (n) and friction coefficient ($f_s \leq \mu_s n$, $f_k = \mu_k n$). After defining the static (μ_s) and kinetic (μ_k) friction coefficients, the participants are asked about the variables with which friction coefficients are related to. In here, it is explained that friction coefficients are related to the structure of the surfaces by referring to the observations of pre-service teachers in the exploration phase of the activity.

Kinetic friction force is explained to the participants on a figure which shows a box moving on a horizontal plane and the calculation of kinetic friction coefficient is provided. The students are asked to take notes on their worksheets. Before proceeding to the elaboration phase, a brief introduction is given to the students related to Algodoo simulation program.

Elaboration

In this phase, the participants are asked to make design to solve the problem which is given in their worksheets considering their knowledge and experiences obtained from the first three phases of the course. The following scenario is presented to the participants in the worksheets:

> A father and his little daughter stand facing each other within a certain distance on a horizontal plane. The father holds a gift box in his hands, and he tries to send this box to his daughter without going to her. The father leaves this box on the horizontal plane and pushes it to the little girl with a certain initial velocity. However, the box stops moving after a while without reaching the girl. So, the girl asks his father to do what he can to deliver the box to her.
>
> What kind of a design can help this girl in terms of your knowledge about the friction coefficient without changing the initial velocity of the box?

Design 1: Make a design for the case in the first part of the abovementioned scenario by using Algodoo.
Design 2: Make a design for the case in the second part of the abovementioned scenario by using Algodoo.

The participants are asked to design the first case in the scenario by using Algodoo. Then, they are told to make another design to solve the problem in the scenario. In this process, they are asked to fill in the table in their worksheets such as recording the types of materials that they use, the changes that they make on the system etc. and accordingly determine the distance taken by the box and distance of the box to the girl. In this phase, the participants should try to design an ideal system to eliminate the problem in the scenario.

After this process, the participants determine the kinetic friction coefficient of the ideal system. Also, they can compare and interpret the kinetic friction coefficient obtained from the interpretation of the graph in the program and calculated with the help of formulas by using the theoretical values. Finally, they respond to the question given in the worksheets about whether they met the little girl's expectation with their designs.

Evaluation

After the participants finish their designs and fill in their worksheets, several of them are asked to present their designs to the class. In this phase, designs are transferred to the teachers' desk with the help of a flash disk. Thus, different designs and results are shared with whole class. Also, differentiation of the values obtained from theoretical calculations and experimental results related to the friction coefficient is discussed.

Students' performance and their designs might be evaluated with the help of a rubric. The following qualifications might be considered in such a rubric:

- ✓ Does the box in the design reach the girl?
- ✓ Does the design involve a box which looks like a gift box aesthetically?
- ✓ Is the design completed in the targeted period?
- ✓ Are the mathematical calculations related to the friction coefficient of the system carried out?
- ✓ Is the distance-time graph drawn and interpreted for the box?
- ✓ Does the participant make a successful presentation of his/her design to the peers?

Appendix B. The worksheets used in the activity developed by the researchers

The worksheet used in the exploration phase:

Answer the following questions considering each of the wooden surfaces (raw, polished, and sanded wood) which you have observed under the microscope:

1. Are the microscope images of those surfaces same? Please explain.

2. When you make a comparison among the images of those surfaces, what would you conclude?

The worksheet used in the explanation phase:

My notes related to the explanation phase:

The worksheets used in the elaboration phase:

A father and his little daughter stand facing each other within a certain distance on a horizontal plane. The father holds a gift box in his hands, and he tries to send this box to his daughter without going to her. The father leaves this box on the horizontal plane and pushes it to his daughter with a certain initial velocity. However, the box stops moving after a while without reaching the little girl. So, the little girl asks his father to do what he can to deliver the box to her.

What kind of a design can help this girl in terms of your knowledge about the friction coefficient without changing the initial velocity of the box?

Design 1: Make a design for the case in the first part of the abovementioned scenario by using Algodoo.
Design 2: Make a design for the case in the second part of the abovementioned scenario by using Algodoo.

	The things I did	**Distance taken by the box**	**Distance of the box to the girl**
Design 1			
Design 2			

Justification of the kinetic friction coefficient: