FLEXIBLE INQUIRY-BASED SCIENCE TEACHING (FIBST): ACTIVITY DESIGN FOR THE ELECTRICITY MODULE AND ITS APPLICATIONS[1]

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ABSTRACT

In this study, a new model termed as “Flexible Inquiry Based Science Teaching”, which is developed using the framework of the inquiry approach is proposed. Science teachers (n=2) who participated in the study were instructed on the inquiry approach and their in-class activity applications were examined. The "electrictiy module" in the annual plans of 5th and 6th grades was chosen to be the subject of the activity designs and applications. Activities were applied in various classes in the same grade level, which allowed activity designs to be improved by performing repetitive applications based on the feedbacks. Due to the “flexible” nature of the FIBST model, teachers were able to design and apply activities according to the varying conditions of the teaching environment. At the end of the process, they gained the ability to adapt any activity into an inquiry-based activity.

Keywords: flexible inquiry-based science teaching, electricity module, secondary school students.

ESNEK SORUŞTURMA TEMELLİ FEN ÖĞRETİMİ (ESTFÖ): ELEKTRİK MODÜLÜNE İLİŞKİN ETKİNLİK TASARI VE UYGULAMALARI

ÖZ

Bu çalışmada, soruşturma yaklaşımı çerçevesinde geliştirilmiş olan “Esnek Soruşturma Temelli Fen Öğretimi” modeli sunulmuştur. Çalışmaya katılan Fen Bilimleri öğretmenleri (n=2) bu modele ilişkin aldıkları eğitimlerden sonra dersleri için etkinlik tasarlayıp uygulamışlardır. Etkinlik tasarı ve uygulamalarında konu olarak, 5. ve 6. sınıfların yıllık planlarında yer alan “elektrik modülü” seçilmiştir. Öğretmenler, hazırlanan etkinlik tasarılarını aynı sınıf seviyesinde farklı sınıflara uygulamıştır. Böylece, hazırlanan etkinlik tasarıları araştırmacıların dönütleri ve öğretmen görüşleri doğrultusunda tekrarlı uygulamalarla iyileştirilmiştir. Öğretmenler, herhangi bir etkinliği soruşturma temelli bir etkinliğe dönüştürebilme becerisine sahip olmuştur. Buna ek olarak, modelin sunduğu “esneklik” sayesinde öğretim ortamının değişken koşullarına göre etkinlik tasarlayıp uygulayabilme becerisi kazanmışlardır.

Anahtar kelimeler: esnek soruşturma temelli fen öğretimi, elektrik modülü, ortaokul öğrencileri.

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INTRODUCTION

The term "inquiry" used in science education nomenclature is semantically translated as "araştırma-sorgulama" in Turkish. This term can be literally translated into English as "research-questioning." In this study the term "soruşturma" is used to replace the traditional term "araştırma-sorgulama", not only because it covers both the concepts "research" and "questioning" which are integral elements in the research process but also is a more apt translation and would avoid confusion (Bayram, 2019). The inquiry-based approach has been included in Science Education Curriculum since 2013 (Ministry of National Education [MoNE], 2013, 2017, 2018) and in the 2023 Education Vision Document. By means of inquiry-based interdisciplinary practices, it is intended to educate people to possess 21st century skills such as critical thinking, creativity, initiative, and productivity (MoNE, 2019).

Skills defined as performing a task in accordance with its purpose transform into "competencies" when used effectively by individuals in different situations (Bayram, 2020). The curriculum is aimed at "competence in science" of students who have the knowledge and skill to use the methodology to explain the natural world in order to produce evidence-based results (MoNE, 2018). Inquiry-based approach not only raises students who are competent in science, but also contributes to students' positive attitude towards science class (Tatar & Kuru, 2009) and their motivation (Bayram, Oskay, Erdem, Özgür, & Şen, 2013).

Although studies show that the methods based on the inquiry-based approach are effective (Karamustafaoğlu & Havuz, 2016), it was observed that the practical applications based on this approach are not easily performed in the classroom environment (Usta, 2015). It was documented that teachers play a key role in the implementation of the practices based on this approach (Rocard, Csermely, Jorde, Lenzen, Walberg-Henrikson, & Hemmo, 2007). In this paper, we present practical applications in accordance with the inquiry-based approach to help teachers gain the ability to design and apply any activity according to the curriculum standards. After the teachers were trained, they designed their own initial activities based on inquiry-based approach and implemented them in the classroom environment. Following the first application, the deficiencies in the initial drafts should be detected and the activity should be revised accordingly by making the necessary corrections (Bayram, 2015). In this study, teachers went through multiple revisions and improved their activity designs by repetitive applications in different classes at the same grade level.

Inquiry-based approach is aimed at achieving the pedagogical goals such as knowledge, skills, attitudes, and values which are expected to be acquired by the student (teaching through inquiry) and teaching the nature of scientific inquiry (teaching the inquiry process), both of which depend on the conditions of the teaching environment. In order to be able to carry out inquiry-based teaching properly, the activity design and applications should be handled in a "flexible" manner considering the variable conditions of the teaching environment (student's characteristics, facilities of the teaching environment, etc.). For this reason, to achieve the pedagogical goals, all kinds of teaching methods/techniques can be used in preparing and applying the activities.

Flexible Inquiry Based Science Teaching

According to Bayram (2019), the flexible use of the inquiry process from an interdisciplinary point of view to achieve pedagogical goals is called "Flexible Inquiry-Based Science Teaching (FIBST)." Stages of FIBST are given in Table 1 (see Appendix 1 for details). In this model, when designing the activities, teachers determine the tasks including the inquiry stages, and decide on the responsibilities to be shared between the teacher and the student. On the other hand, these responsibilities can also be determined or modified during the activity application process. Thus, it can be concluded that the practices based on this model are flexible. Another indication of the flexibility of the model is that the activity design and application processes are shaped by the characteristics of the teaching environment (student's level, availability of time and material, etc.) and the competence of the teacher (knowledge, experience, etc.). Therefore, there is no strict template to follow in this model.

Table 1. Stages of FIBST

A. Formation of Groups
In-group and inter-group collaboration and role distribution within the group
B. Activity Design Rules
1. Purpose of the inquiry: Established according to the pedagogical goals determined by considering the curriculum standards. 2. Preliminary information: Prior knowledge of the students on concepts to be learned related to the pedagogical goals is determined. 3. Misconceptions: Misconceptions related to the concepts to be learned are determined. 4. Activity planning: It is decided which stages of the inquiry will be left to the responsibility of the student. 5. Material selection and procurement: Materials are determined based on the goals in the activity. 6. Safety rules: Safety precautions are determined. 7. Measurement and evaluation: Measurement tools are used to evaluate pedagogical goals.
C. Stages of Flexible Inquiry (SFI)
SFI1. Research question/instruction: The process begins with the research question/instruction. SFI2. Prediction/hypothesis: Students provide their predictions/hypotheses to answer the research question by reasoning and/or by using prior knowledge. SFI3. Presenting a proposal to verify the prediction/hypothesis: Method and approaches that can be used to determine whether the predictions/hypotheses are correct are suggested/discussed. SFI4. Realization of the proposal to verify the prediction/hypothesis: Methods, approaches and solution suggestions approved by the teacher are tested. SFI5. Acquisition of data: Data are recorded and compared with the predictions/hypotheses. SFI6. Inference: The scientificity of the information obtained by the inferences made by comparisons is discussed.

In the FIBST model, activities can be created independently or in connection with each other forming a chain of inquiry activities defined as “modules”. Modules consist of tasks termed as “sessions”. Various examples of such modules are available in the literature (Atun, 2016; La main à la pâte, n.d.). The teacher can shape the inquiry process by including additional tasks to the activities as it progresses, thereby applying the flexibility of the model in the classroom environment, which may lead to “individual education.” Inquiry-based activities can be transformed into activities conforming with Science, Technology, Engineering, and Mathematics (STEM) that allow students to engage in authentic and meaningful activities (McDonald, 2016). In other words, STEM activities that help students relate their knowledge and skills with real life (Stohlmann, Moore & Roehrig, 2012) and link disciplines in real contexts (Kelley & Knowles, 2016) can be performed based on inquiry-based approach.

ACTIVITY IMPLEMENTATION

This study was carried out in a public school in Ankara in the 2018- 2019 academic year. The activities are comprised of the practices of the fifth and sixth grade science teachers (n = 2) who were instructed on FIBST. In the study, an “electricity module” was created by taking into consideration the curriculum standards on the electricity unit, the conditions of the school and the recommended periods in the annual plan. Even though researchers and teachers constantly exchanged views and opinions throughout the entire application process, only part of the prepared module was included in this paper. Applications in the fifth and sixth grades were carried out by Teacher1 and Teacher2 respectively. All of the required ethics committee (no: 35853172-300) and legal permissions have been granted for this study.

Fifth Grade Activities

A. Formation of the groups. Teacher1 divided the students into groups before starting the sessions in each class and formed the student groups to be heterogeneous within the group and homogeneous among the groups considering the characteristics of the students. She asked the students to name their groups and wrote the names on the board. However, when she found out that it was difficult to remember the group names, she decided to change the strategy and used the names of the spokespersons as the group name.

B. Activity design. The activity was designed according to the seven stages in the theoretical framework.

1. Purpose of the inquiry. The pedagogical goals, in which the goals specified in the curriculum and the goals expected during the activity are listed as follows.
Curriculum standards:
F.5.7.1.1. To show the elements of an electrical

circuit with symbols.
F.5.7.1.2. To be able to construct the electrical circuit drawn.
Other learning outcomes:
- Complying with safety rules.
- Participating in in-group/intergroup studies.
- Sharing own materials with friends.
- Sharing own results within the group and with the class and peer teaching.
- Knowing which circuit element to use to light a bulb on in an electrical circuit.
- Knowing that both conducting ends of the circuit element (the light bulb) must be in contact with the electrical circuit.

2. Preliminary information. According to the curriculum, the third and fourth grade students learn how to set up a simple electric circuit, the circuit elements and their functions in the circuit to light a bulb. During the inquiry process, the teacher gathered information about the prior knowledge of her students on electrical circuits. She found out that they had difficulty in understanding that a circuit element has two conductor ends (Engelhardt & Beichner, 2004) and each of these conductor ends should be connected to the circuit in order to obtain a closed circuit and light the bulb.

3. Misconceptions. Learning the concept of electricity requires comprehending physical phenomena that is neither perceived nor observed. It is especially important to understand such phenomena in order to grasp the main activity (Yürümezoğlu & Çökelez, 2010, p. 148). Therefore, it is essential to reveal students' misconceptions in such an abstract concept. During the activity, it was found out that the students thought that the light bulb would be on when the switch was “open” and perceived the term "open circuit" as "the circuit in which the light bulb was on." By making the working mechanisms of the materials “visible” by the students, it was aimed to prevent such misunderstandings. It was further observed that some students perceived the light bulb itself as an essential circuit element and thought that "an electric circuit cannot be installed without a light bulb" (Bayram, 2019) and "the light bulb will not light up without a switch, battery holder, socket and cable" without regard to the actual functioning principles of these elements in the electrical circuit. To this end, the teacher emphasized the working mechanisms of the materials by showing the internal structure of circuit elements as shown in Figure 1 and Photograph 1. Teachers should follow the literature to find out about such possible misconceptions beforehand.

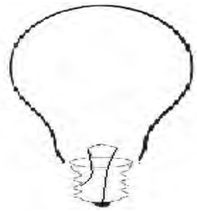


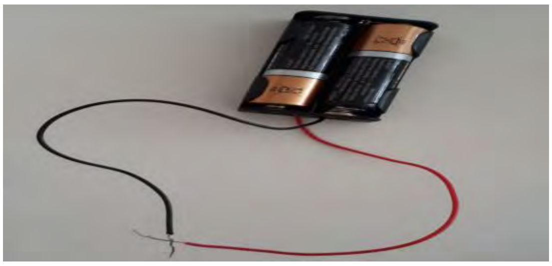
Figure 1. Internal Structure of the Bulb


Photograph 1. An Open Switch

4. Activity planning. The teacher was well aware that the student should be active in the process and made the students responsible for the inquiry process.

5. Material selection and procurement. The teacher did not plan on the procurement of materials but asked the students to procure materials based on the previous years' activities. Accordingly, she only asked the students to "provide the necessary materials to install a simple electrical circuit." The teacher supplemented the students' materials with the materials in the laboratory. Required materials are bulb (0.2A-3.5V), bulb holder, battery (1.5V), cable, switch, and battery holder.

6. Safety precautions. The teacher noticed safety issues during the inquiry process. When the batteries are in the battery holder (Photograph 2), touching the ends of the cables together causes a short circuit causing an excessive current flowing through the circuit and the cables would overheat and may burn.


Photograph 2. A Short Circuit

7. Assessment and evaluation. The teacher expected students to learn about the circuit elements, to be able to show the elements of an electrical circuit with symbols and construct the electrical circuit they have drawn, to comply with the safety rules, participate in in-group/inter-group discussions, communicate effectively, gather the necessary materials and share own materials with friends.

C. Activity application. Activities prepared for the learning outcomes of the fifth-grade electrical unit were carried out at each class level for 2 hours (1 session). The teacher applied the activity designs in classes 5/B, 5/C and 5/A in that order and was observed by the researchers for a total of 6 hours. As the implementations progress, the activity drafts were modified based on the feedbacks. The applications in class 5/A (last class the activity was implemented) are presented in detail in this paper. Activities in class 5/A are also compared with the ones in classes 5/B and 5/C.

SFI1. Research question/instructions. The teacher entered the classroom 5/A holding an electrical circuit in her hand and asked her students what circuit elements they can identify in the circuit. After an in-group discussion, each group shared their ideas with the class. Afterwards, the teacher wrote the instruction "Light the bulb using the least number of circuit elements." on the board and asked the students to express the instruction in their own words to make sure they understood the instruction.

SFI2. Prediction/hypothesis. The teacher-initiated in-group discussions and received initial opinions from each group on how to fulfill the instruction. Some groups stated that at least three elements (bulb, cable, battery) were required while some argued that at least four elements (bulb, cable, battery, switch) were required. The teacher initiated an inter-group discussion on whether the circuit switch was indeed necessary. After this discussion, due to the nature of the flexible inquiry-based teaching, the initial instruction was "re-expressed" as "light the bulb using 3 circuit elements."

SFI3. Presenting a proposal to verify the prediction/hypothesis. According to the specified instruction, students stated that they could verify their predictions by experimenting.

SFI4. Realization of the proposal to verify the prediction/hypothesis**.** The teacher approved the students' proposals and the students performed experiments to light the bulbs by using the allotted materials. Each group was given enough time to light their bulbs on. The teacher realized that some groups were having difficulties in following the instructions, and from time to time she helped them construct the circuit. She explicitly stated that each circuit element has two conductor ends and each of these ends should be in contact with an end of another element.

SFI5. Data acquisition. The students recognized that the minimum number of elements needed to light the bulb was 3. They compared their initial opinions at the prediction/hypothesis stage with the empirical data they have obtained during the experiments. Some student groups stated that the data they obtained was consistent with their predictions (as they had predicted, they were able to light the bulbs using three elements), while other groups realized that their prediction and the data they obtained were inconsistent (three instead of four elements were sufficient to light the bulb).

SFI6. Inference. After comparing their predictions and the data they collected, the groups who realized the inconsistencies structured their knowledge by changing their initial opinions. The inferences made by the groups as a result of the experiments had become the "class knowledge." Accordingly, the class concluded that three elements were enough to light the bulb. At this point, the teacher may restart the inquiry process by stating that it would be possible to light the bulb using only two elements (a flat battery and a bulb).

Instructions following the initial instruction. The groups were asked to light the bulb by using higher number of circuit elements. The groups were able to follow the instruction "Let's build a circuit using bulbs, batteries and cables." going through a similar process as described above. After informing the class about the symbols of some circuit elements (stating that there are no symbols for elements such as light holders and battery holders) and how to draw circuit diagrams using these symbols, the teacher provided the new instruction "Draw the diagram of the circuit you can build with the materials you have."

The groups drew various circuit diagrams according to their materials and constructed their circuits according to the diagrams drawn.

Repetitive applications and comparison of instructions. The teacher entered the classroom 5/B holding an electrical circuit consisting of a battery holder, multiple batteries, a light bulb and bulb holders. She started the lesson by giving the instruction "What does a simple electrical circuit consist of?" and asked students to recall what they had learned in grades 3 and 4. The groups did not understand what was meant by the word "simple" in the instruction. The circuit shown by the teacher was complicated for the students and they were not able to analyze it. Due to this experience, the teacher used a circuit containing only a single circuit element in other classes (5/C and 5/A) and modified the instructions accordingly as shown in Table 2.

Table 2. Instructions for the Fifth Grade

Instructions for Class 5/B
Instruction 1: What does a simple electrical circuit consist of?   *Instruction 2:* Draw the diagram of the circuit you created.   *Instruction 3:* Draw the circuit you created using symbols. (How many batteries and bulbs have you used? Draw accordingly.)
Instructions for Class 5/C
Instruction 1: How can I light the bulb using the least number of circuit elements?   *Instruction 2:* Create circuit with battery, bulb and connecting cable.   *Instruction 3:* Draw the diagram of a circuit that you will create using the circuit elements you have.
Instructions for Class 5/A
Instruction 1: I want you to light the bulb using the least number of elements.   *Instruction 2:* Let's build a circuit using a lamp holder, bulb, battery, and cable.   *Instruction 3:* Draw the diagram of a circuit that you can create using the circuit elements you have.

The teacher stated that the instructions varied from class to class because students' levels and reactions were different, and she was willing to use the time as effectively as possible. She also stated that in her opinion the most efficient instruction to start the lesson was the one she used in class 5/C.

Teacher's assessments. The teacher realized that students' prior knowledge should be carefully taken into consideration and their skills need to be improved. She observed that students had difficulty in drawing + and – poles of two batteries connected in series or drawing a circuit with two bulbs and drawing conductive cables. In drawing circuit diagrams, she observed that they tend to draw curved lines rather than straight lines. At the end of the process, the teacher stated that, the students help each other within the group working environment and cooperate by participating in in-group/inter-group discussions. The mainstreamed students were also more willing to participate in the activities. Students have described building an electrical circuit as "challenging." The teacher commented that this was due to the students being physically and mentally active during the entire session. The students were asked what they had learned and how they could use this new knowledge in practical scenarios at the end of the activity. The students stated that in case of a power outage they can light their bulbs so that they would not fear the darkness and they can use the circuits to illuminate inside of their wardrobe. The students were involved in the inquiry process and associated what they have learned with daily life situations. They were convinced that they could solve their daily life problems by using the newly acquired knowledge. This shows that STEM activities can be easily applied based on the inquiry approach. The teacher can extend the inquiry process by providing a new instruction such as "Design a product to illuminate an environment you deem necessary."

Sixth Grade Activities

A. Formation of groups. The application was first performed in class 6/D. Teacher2 had each group in the class elect a group spokesperson and encouraged students to engage in group work. She wrote the group names on the board but during the activity process she addressed the groups with the name of the spokesperson instead of the group names initially assigned. The teacher did not assign any other duties within groups and held the spokesperson responsible for handling and managing the materials. In class 6/C, where repetitive applications were held, the teacher wrote the names of the student groups on the board and this time continued to address them with their initially assigned names throughout the entire process. She also asked groups to elect a spokesperson as well as a group secretary, a group leader and a materials supervisor within the group, ensuring that each student in the group takes responsibility. The teacher encouraged collaboration among groups by ensuring that all groups act simultaneously, and by urging those groups that have completed their activities help other groups.

B. Activity design. The activity was designed according to the seven stages in the theoretical framework.

1. Purpose of the inquiry. The pedagogical goals of the activity are listed as follows.
Curriculum standard:
F.6.7.1.1. The student classifies the substances according to their conductivity by using the designed electrical circuit.
Other learning outcomes:

- Complying with safety rules
- Participating in in-group/inter-group studies
- Sharing own materials with friends
- Sharing own results within the group and with the class and peer teaching
- Knowing that both conducting ends of the circuit element (the light bulb) must be in contact with the electrical circuit.

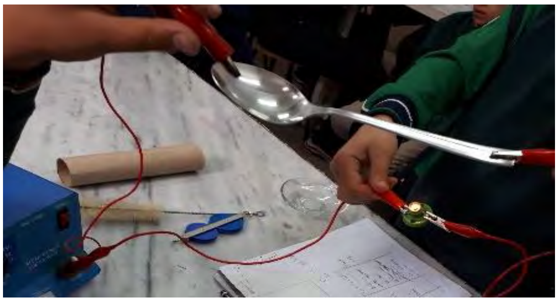
2. Preliminary information. According to the science curriculum, it is assumed that the students in the fifth grade know how to set up a simple electric circuit, the circuit elements and their functions in the circuit to light a bulb as well as symbols of these elements. The teacher is familiar with the students from the previous year and has already covered the electricity unit in the class. However, she does not precisely know about the students' prior knowledge on conductivity/insulation and makes guesses based on her experience with the students. During the inquiry process, the teacher was able to assess the prior knowledge of the students on the subject and she noticed that they had difficulty in understanding that a circuit element has two conductor ends and each of these conducter ends should be connected to the circuit in order to obtain a closed circuit and light the bulb.

3. Misconceptions. It was found out that the students thought that the light bulb would be on when the switch was "open" and perceived the term "open circuit" as "the circuit in which the light bulb was on." The teacher was advised to read the literature about the misconceptions of students on the subject of conductivity/insulation.

4. Activity planning. The teacher was aware of the fact that the student should be active in the process. She gained an understanding on how to share responsibilities and which inquiry stages will be left to the responsibility of the students during the application of the inquiry process.

5. Material selection and procurement. The students were asked to supply the materials and the teacher supplemented the students' materials with the materials in the laboratory. In this activity, students were required to test the electrical conductivity of solids. They were asked to choose any object and encouraged to be as creative as possible. Required materials are bulb (0.2A-3.5V), bulb holder, battery (1.5V), cable, switch, and battery holder.

6. Safety rules. Students were cautioned not to hold conductive materials they had connected into the circuit with bare hands. They were informed to hold the circuit elements by their insulating parts as shown in Photograph 3. They have also been warned not to operate the power supply at high voltage levels to prevent electric shocks. The teacher realized during the activities that such safety rules should be specified.



Photograph 3. Testing the Conductivity of a Spoon

7. Assessment and evaluation. In this activity, the teacher expected students to learn about the functions of circuit elements and to be able to classify solid objects as conductors or insulators as well as complying with the safety rules, participating in in-group/inter-group discussions, communicating effectively, and sharing own materials with friends.

C. Activity application. The teacher applied a 2-hour session in class 6/D and a 1-hour session in class 6/C in that order. The researchers observed both sessions entirely (total of 3 lesson hours). Since class 6/D was observed for a longer period and the activities were fully completed, the applications carried out in this class are presented in detail in this paper. Class 6/C was observed until the data acquisition stage.

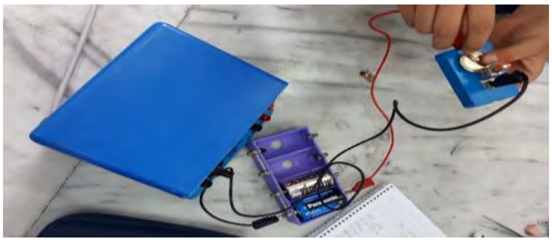
SFI1. Research question/instruction. The teacher started the lesson by asking students to recall the elements in a simple electric circuit and what is needed to set up a circuit. She asked them to write down the necessary materials on a piece of paper immediately and initiated an in-group discussion. Then she asked each group to delegate a student to gather the necessary materials and laboratory equipment. Student groups acquired materials such as battery holder, switch, bulb, cable, battery, and bulb holder. They were then asked to share the list of materials they have chosen with the class. Afterwards, the teacher asked students to write down the functions of these materials (switch, lightbulb and holder, etc.) in an electric circuit after an in-group discussion. She then initiated an inter-group discussion on functions of the individual circuit elements during which the students made statements such as “A light bulb provides brightness, provides heat and light.”, “The cable is used for transferring the current like a bridge.” and “Bulb holder is for placing the bulb.” The teacher tested students' preliminary knowledge by asking what kind of symbols were used in drawing a simple electric circuit. She asked groups to show draw the individual symbols of the bulb, battery, cable, and the switch. During this process, she noticed that the students could not recall the symbols they had learned last year. For example, the teacher suggested to the students who had difficulty drawing the symbol of the battery to refer to the textbook.

The teacher tested whether the students could distinguish between the on/off states of a switch by asking what the position of the switch was when the lamp in the classroom was on. Then she wrote the instruction “Install a simple electrical circuit.” on the board. The groups were given sufficient time to carry out this preparatory instruction and then shared their experiences with the class. After the instruction was carried out by all groups, the teacher took the circuit built by one of the groups and when the switch was closed, brought the plastic parts of the cables together, noting that the light bulb did not turn on and asked the reason for this. One of the students replied "Plastic!" and the teacher stated that the plastic part of the cable is an insulator. She then asked what a conductor/insulator is. One of the students responded that “Heat conductors are heat conducting materials and heat insulators do not conduct heat." The teacher directed the student by stating that the subject of the unit was related to "electricity" and asked groups to perform an in-group discussion on the concepts of "conductor" and "insulator." After this discussion, the teacher drew the shape of the conductor cable on the board and explained that the outer part of the cable was made of insulating material that does not conduct electricity, and the inner part was made of conductive material that conducts electricity. She also showed that the bulb lights up by "touching" the conducting parts of the cables to one another. The teacher then asked students to remove the switch from their circuits and complete circuit with various objects of their choosing from their surroundings. She asked them to determine whether the material is a conductor or an insulator and to tabulate their data. Finally, she wrote the instruction “Create a circuit using various materials instead of the switch.” on the board.

SFI2. Prediction/Hypothesis. The teacher skipped this stage. If the prediction/hypothesis stage was carried out, the teacher would have the opportunity to re-express the instruction to make sure that it was fully grasped by the students. It was observed that the students had difficulty understanding the instruction because the term "circuit" in teacher’s instruction meant "closed circuit.” Realizing this, the teacher had to give explanatory information on how the instruction would be carried out by visiting individual groups during the next stages.

SFI3. Presenting a proposal to verify the prediction/hypothesis. Since research question/instruction stage already directed students to perform experiments, this step was skipped.

SFI4. Realization of the proposal to verify the prediction/hypothesis. The teacher enabled the students to conduct experiments. Visiting the groups one by one, the teacher tried to observe whether the students were able to create a closed circuit by using the everyday materials. Students were given sufficient time and provided with clues whenever they had difficulties. The teacher observed that some of the groups were very successful in their experiments and assigned them "sub-instructions" to ensure that these groups could act simultaneously with the others. Accordingly, the teacher asked these groups to test the conductivity of at least 10 objects. The groups were very creative when using the everyday objects. One of the groups realized that they could use any point in a closed circuit to test the conductivity of the object. As shown in Photograph 4, they placed the test object in between the conductive part of the holder and the conductive part of the cable.



Photograph 4. Conductivity Test of a Coin

SFI5. Data acquisition. Students tested materials such as nails, pencil tips, metal spoons, sponges and hooks, and recorded the data they obtained according to the conducting/insulating features of the items. The groups shared their experiments with the with the class. Since the students' prediction/hypotheses were not received, they were not able to compare their initial ideas with the data they obtained.

SFI6. Inference. As a result of the experiments, the test objects have been the classified as conductors and insulators, a "common idea of the whole class" had been achieved. It was concluded by the class that the conductive materials complete the circuit.

Instructions following the initial instruction. In the previous stages, students built an electrical circuit and tested whether an object is a conductor or an insulator. Based on the recommendation of the researchers to turn this activity into a STEM application, the teacher instructed students to "Create a device that determines whether an object is a conductor." In the upcoming classes this activity could be extended to include testing conduction /insulation properties of liquids and gaseous substances. Furthermore, a new STEM activity can be planned to "design a device that tests the conductivity of liquids."

Repetitive applications and comparison of instructions. It was observed that the students had difficulty recalling the symbols of basic circuit elements such as batteries. Consequently, they were not able to draw a circuit diagram. Students confused electrical conductivity with the thermal conductivity. The teacher realized that the students were familiar with the concept of "conductor" but they had difficulty in understanding the concept of "insulator." Since the concept of "closed circuit" was not well understood in class 6/D, the instruction given to class 6/C was modified accordingly as shown in Table 3. In class 6/C, inter-group discussions were more frequent, and students' prediction/hypotheses were received before proceeding to the stage of presenting a proposal to verify the prediction/hypothesis.

Table 3. Instructions for the Sixth Grade

Instructions for Class 6/D
Instruction 1: Set up a simple electric circuit. *Instruction 2:* Create a circuit using various materials instead of a switch. *Instruction 3:* Create a device that determines the conductivity of materials.
Instructions for Class 6/C
Instruction 1: Set up a simple electric circuit. *Instruction 2:* Draw a simple electric circuit diagram. *Instruction 3:* Identify the materials that complete the circuit (closed circuit) and the materials that does not (open circuit).

Teacher's assessments. The teacher encouraged students to recall what they had learnt in the previous grade about the elements of a simple electric circuit and their functions. However, she observed that they could not recall most of the concepts they had learnt a year before. The teacher also realized that the students had difficulty in following the instructions as a result of not being able to fully understand the concepts of closed and open circuit and she tried to explain these concepts by giving simple clues. She felt the need to “re-express” the instructions for students to understand. It was revealed that it was important to emphasize that all the elements forming a closed circuit are conductors. The teacher commented that it would have been much easier for students to understand the concepts of open and closed circuits if the definition of “electrical circuit” (which is a closed circuit that provides a complete loop of the current passing through it) was established at the very beginning of the process. The teacher also stated that the students asked for the names of the materials they did not know about and that they expected her approval before using any material. During the experiments, students initially classified the materials as the ones that "light the bulb” and those that “do not light the bulb.” These expressions were then changed into scientific language as “conductors” and “insulators."

CONCLUSIONS and SUGGESTIONS

In this study, two inservice science teachers were offered to use the "Flexible Inquiry-Based Science Teaching-FIBST" model in their classes. They were asked to design activities on any subject of their choice. Teachers, who work at the same school, decided to design activities for the same subject (electricity unit) at different grade levels (grades 5 and 6). It was observed that even though teachers knew about FIBST, they had difficulties in designing their first activities and the researchers provided guidance throughout the preparation of the first draft of the flexible inquiry process.

The teachers noticed that the instructions given in the activities are prone to change instantly based on the teaching environment, and that the students could be reincluded in the inquiry process by means of new instructions. During the activities, Teacher1 realized that students change their ideas as a result of comparing their initial ideas with the data they collected. This constitutes the basis of constructivism. In some situations, it would be possible to omit some stages of the activity. For instance, the teacher may choose not to take proposals to verify the prediction/hypothesis when it is obvious that experiments should be performed. In such cases, this stage can be embedded into the realization stage. However, during the activities in the sixth-grade class, Teacher2 skipped the stages of taking prediction/hypothesis and the presentation of a proposal to verify the prediction/hypothesis. Consequently, students were not able to compare the data acquired with the prediction/hypothesis and the teacher could not observe how the students structured the information in the next stages.

Depending on the availability of time, resources and material, or due to the nature of the activity, the teacher may choose to take the responsibility of carrying out all the inquiry phases or share the responsibility of a few or all of the phases with students. The instructions based on the inquiry process may be provided to perform STEM activities, through which the expectation of "gaining an interdisciplinary perspective" in the curriculum can be satisfied. These are indications of the flexibility of the FIBST model.

Teachers' verbal assessments regarding their students were converted into rubrics (see Appendix 2, Appendix 3). In addition to the standard learning outcomes mentioned in these rubrics, it was observed that the students' attitudes towards science lesson (Tatar & Kuru, 2009) also improved considerably. It was noted that students took responsibility starting from the stage of determining a research question and teachers acted as a guide. The teachers stated that they were able to understand and appreciate the stages of the inquiry only when they had experienced repetitive applications in the classroom. After this process, it was observed that the teachers gained the ability to adapt any activity as an inquiry-based lesson.

This process can contribute to the goals set forth by the 2023 Education Vision Document and the curriculum. The teachers stated that the preparation of modules on various other subjects in the science curriculum would be essential in terms of gaining a holistic perspective. Teachers were advised to collaborate with their colleagues to develop modules based on school conditions in the upcoming years. This cooperation can contribute to the School Improvement Model, which envisions the improvement of each school within its own conditions, as stated in the 2023 Education Vision Document (MoNE, 2019).

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Appendix 1

Flexible Inquiry Based Science Teaching (FIBST)

According to Bayram (2019), the flexible use of the inquiry process from an interdisciplinary point of view to achieve pedagogical goals is called "Flexible Inquiry-Based Science Teaching (FIBST)."

A. Formation of Groups and Role Distribution Among Students in FIBST
Activities based on FIBST are carried out in groups in cooperation within and among groups. The teacher encourages students to collaborate, and if necessary, intervenes in group work and ensures that the procedure is carried out effectively. Before the commencement of the activities, it is essential for the teacher to ensure that students distribute roles (such as group spokesperson, group leader, group secretary, materials supervisor etc.), and inform them about the responsibilities of each role. This makes it easier for the teacher to maintain the order of the class during the in-group and inter-group interactions. Various strategies can be used to create student groups. It is recommended that the groups to be heterogeneous within itself (consisting of students of various levels). On the other hand, each group should include the same number of students of the same level to create a homogeneous group structure.

B. Activity Design Rules in FIBST
Science Curriculum (MoNE, 2018) expects science teachers to prepare and apply their in-school and out of-school activities in accordance with the inquiry approach. To accomplish this, teachers can design their activities by using the following guidelines (Bayram, 2019):

1. Purpose of the inquiry: By reviewing the standard learning outcomes in the annual plan, pedagogical goals (knowledge, skills, attitudes and values) are determined according to the standards in the Science Curriculum, and "the purpose of the inquiry" is created. Based on the purpose of the inquiry, learning outcomes of the inquiry process should be clearly specified.
2. Preliminary information: Prior knowledge of the students regarding the targeted pedagogical goals is determined.
3. Misconceptions (Misconceptions): Possible misconceptions the students may have on the subject should be identified by reviewing the relevant literature.
4. Activity planning (FIBST stages and students' responsibilities): It is determined which stages of the inquiry process will be left to the student's responsibility and which stages should be managed by the teacher in the designed activity.
5. Material selection and procurement:
• The selection of the materials required for the activity is entirely left to the responsibility of the students and students are asked to perform their activities using the materials they have chosen.
• The teacher provides more materials than needed for the activity, and students are asked to choose from the provided materials to perform the activities.
• The teacher provides the materials needed for the activity and the students are asked to perform the activities only by using these materials.
6. Safety rules: Safety precautions must be taken before and during the activity. Possible safety hazards should be identified before the activity by careful examination of the physical environment and the activity process.
7. Assessment and evaluation: Considering the purpose of FIBST, measurement tools should be developed for the evaluation of the pedagogical goals determined for the activity. During the course of the process, students' skills can be evaluated using rubrics or other measurement tools.

C. Stages of Flexible Inquiry (SFI)
SFI1. Research question/Instruction: The process is initiated by a question from the students or the teacher regarding an unexpected phenomenon, or the teacher may simply give an instruction.
SFI2. Prediction/Hypothesis: The teacher allows students to provide possible explanations, answers or suggestions by reasoning and/or prior knowledge. The predictions/hypotheses should be expressed verbally or in writing by the students in their own words.

SFI3. Presenting a proposal to verify the prediction/hypothesis (Experiment, Observation, Expert Opinion, Document Research, Survey etc.): The teacher asks students to devise a method to verify their predictions/hypotheses. Students propose methods for the "verification" or the "falsification" of the predicted hypotheses. The teacher may decide to follow up on a single proposal or may let each group devise its own proposal. Proposals are approved by the teacher before being realized by the students.
SFI4. Realization of the proposal to verify the prediction/hypothesis: Proposals approved by the teacher are realized by the teacher or students.
SFI5. Data acquisition: Data obtained by performing the proposed methods (experiment, observation data, document information, expert opinions, etc.) are documented in worksheets/notebooks. The students are asked to compare the recorded data with their initial predictions. This activity can be performed by means of in-group or inter-group discussions. As a result of these discussions, students are asked to identify the consistencies and inconsistencies between their estimations/hypotheses and the data they acquired.
SFI6. Inference: The teacher creates an environment where the “acceptability” of the conclusions reached by the student groups is discussed and may elevate these conclusions to attain “knowledge value” or support these conclusions with scientifically accepted “scientific knowledge.”

Appendix 2

The Fifth Class Electricity Unit Inquiry Process Rubric

1.Unsatisfactory, 2. Satisfactory, 3. Good

	Student or group name	Student or group name	Student or group name	Student or group name	Student or group name
Learning Outcomes					
Complying with safety rules					
Participating in in-group/inter-group studies					
Acquiring the required materials					
Sharing own materials with friends					
Sharing own results within the group and with the class					
Peer teaching					
Effective communication					
Identifying basic circuit elements					
Drawing the symbols of the elements of basic circuit					
Constructing the electrical circuit drawn					
Knowing which circuit element to use to light a bulb on in an electrical circuit					
Knowing that both conducting ends of the circuit element (the light bulb) must be in contact with the electrical circuit					

Appendix 3

The Sixth Class Electricity Unit Inquiry Process Rubric

1.Unsatisfactory, 2. Satisfactory, 3. Good

	Student or group name	Student or group name	Student or group name	Student or group name	Student or group name
Learning Outcomes					
Complying with safety rules					
Participating in in-group/inter-group studies					
Acquiring the required materials					
Sharing own materials with friends					
Sharing own results within the group and with the class					
Peer teaching					
Communicate effectively					
Knowing that both conducting ends of the circuit element (the light bulb) must be in contact with the electrical circuit					
Knowing the functions of the circuit elements					
Classifying substances according to their conductivity by using the designed electrical circuit					