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Let's Ask Students for the Most Fruitful Context of Charging Phenomenon

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Abstract

This study aimed to determine the most fruitful context of the electrical charging phenomenon. For this aim, semi-structured interviews were conducted with 15 tenth-grade high school students in the 2016-2017 academic years. 12 open-ended questions were asked to students and students' answers were analyzed by using content analysis. The examples (event/experiment/product/etc.) given by students as answers were accepted as cases examined in this case study. When the students were asked which example (event/experiment/product/etc.) they would like to be used to express themselves better, they generally preferred to give laboratory-based experiments mentioned in school textbooks or lessons, their life-based experiences, or some analogies. For example, 67% of the student chose an event they experienced in their daily lives (e.g., combing hair with a plastic comb) and 67% of the student chose a laboratory experiment (e.g., an experiment of rubbing two insulating objects such as an ebonite rod rubbed with a wool piece as the closest context to them to explain charging phenomena. When we look at the reason why they gave these examples, we found that many students find these examples easy (f=17), known (f=17), and understandable (f=15), that these examples are given in the lessons (f=11), and they are frequently experienced in daily life (f=10). In addition, an unexpected result was obtained in this study.

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Introduction

Students frequently complain that the knowledge taught at schools is not relevant to their daily lives. Thus, they are often confused about the reasons for learning science. In addition, they have difficulty transferring knowledge to a situation other than the one in which it was learned (Laugksch, 2000). These are some of the major challenges currently faced in science education. To overcome these challenges, Gilbert et al. (2011) suggested learning within a context in context-based courses. Embedding science in context gives an opportunity to learners real and meaningful learning (Fensham, 2009). The "context" is defined as the phenomenon surrounding, the focal event, and providing its appropriate interpretation (Duranti & Goodwin, 1992, p.3). According to Gilbert (2006, p.960), an educational context (or focal event) has four attributes as the following:

i. The focus event should be on the characteristics of the environment (social, spatial, and temporal) in which the event takes place: The focus event, where, when, and how does it occur under what conditions?
ii. Individuals related to the focus event should exhibit some behaviors: What can individuals do behaviorally in the focus event?
iii. The focus event requires the use of a specific language.
iv. A relationship should be established between the background information of the individuals about the focus event.

Among these attributes, the fourth attribute of the context especially includes the interests that students are familiar with. Thus, determining the most fruitful contexts that students are interested in is very important for many researchers (e.g., Kaltakci 2012; Kutluay, 2005; Pesman, 2005; Turker, 2005) who used these contexts to identify students' perceptions of a specific topic. Since the students may explain themselves better with one context than another one, selecting the most suitable context that students are more familiar with than the others can allow researchers to take more efficient information. Furthermore, many researchers (e.g., Bao & Redish 2006; Fischbein et al., 1989; Hrepic 2002, 2004; Palmer, 1993; Ozcan, 2015; Saglam et al., 2012; Whitelock, 1991) presented that students' mental models might be context-dependent. In other words, students can use different mental models while discussing the same event in different contexts. For this reason, a misconception that cannot be observed in any context may arise in a different context (Saglam et al., 2012). For example, the test, Force Concept Inventory (FCI) (Hestenes et al., 1992), one of the most widely used concept diagnostic tests in the world, was adopted in some studies to investigate the dependency of context. Griffin (2004) and Stewart et al. (2007) re-adapted the FCI by making six different changes to the contexts. Similarly, McCullough (2004) rearranged FCI by using contexts that are closer to male, such as hockey, rocket, and shotgun, etc., or contexts that are closer to female, such as shopping, cooking, jewelry, etc. In all three studies, the effect of contexts on the FCI results was investigated. According to the results of these studies, it was determined that while the change in context did not affect the general test results, there was a significant difference in context in some questions. In another study, it is found that in the context of force in sports, the misconception that "every movement requires force" depends on context variables such as what is the moving system (ball or human), movement direction (vertical or horizontal), or movement speed (fast or slow) (Palmer, 1993, p.232).

One of the most effective ways to identify the contexts that students are interested in is to interview them. Interviewing is one of the useful techniques used frequently for obtaining information from students (Bar et al., 1994; Guo-Li, 2009; Loughran & Derry, 1997; Watts, 1983). A major advantage of interviewing was that it offered an opportunity to probe students' views in more depth than was possible through the questionnaire (Loughran & Derry, 1997). Wandersee et al., (1994) revealed that 46 percent of 103 misconception studies used interview techniques while identifying misconceptions. It will be suggested to determine the contexts that are appropriate to students' interests and understanding levels with a preliminary study (Elmas et al., 2011). As a result, whatever the contexts are used for, choosing the most suitable contexts is extremely important. Thus, this study aims to determine the most fruitful context of the charging phenomenon based on students' daily life experiences by interviewing them.

Method

This study is an example of a case study, which is one of the qualitative research designs. The examples (event/experiment/product/etc.) that students would like to be used to express themselves better were considered as the cases examined in this study.

Sample

The sample of the study consisted of fifteen tenth-grade high school students from two different Anatolian high schools in the 2016-2017 academic years. Seven of them are girls and eight of them are boys. In the selection of individuals for the interviews, the convenience sampling method was used. Then, the students who volunteered to participate in the study were selected.

Instrument

Semi-structured interviews were conducted with the students individually in the 2016-2017 academic year. They were conducted immediately after the students had completed the related unit. All interviews were carried out face-to-face and one-to-one. Each interview lasted about half an hour. In addition, they consist of two parts (Annex 1). The first part consists of introductory questions prepared to reduce the excitement of the participants and to create a friendly conversation environment. The second part, it was aimed to determine the contexts in which more detailed information can be obtained from the participants when talking about charging. For this aim, twelve open-ended questions were asked to the students in this part. The interview tool was developed by the researchers. Before developing it, researchers gather information about the "interviewing" process from the well-known book written by Frenkel & Wallen (2006). Then, opinions were received from two experts working as professors in the physics education department of a university to ensure that the questions were suitable for the research purpose of the study and grammatical rules as well. Furthermore, all kinds of drawings, expressions, etc. used by the participants in the interviews have been taken into consideration as a data source.

Data Collection & Analysis

Each interview was audio-taped with students' permission and then all of them were transcribed. In the interviews, the note-taking technique was used by using follow-up tables prepared by the researcher previously. After the answers to the questions were transcribed, content analysis was performed. During the content analysis, firstly the frequencies of the similar answers given to each question were determined. Then, similar answers were grouped under the same sub-category (if possible). The answers that could not be placed in the appropriate category were named in the other category. The answers in the other category were generally unsuitable for the questions since the students do not know how to explain the related concept or event through the examples they gave. Finally, sub-categories were gathered under a main category. The suitability of the nomenclature of the determined categories was evaluated by three experts. The consistency between the opinions of the experts is over 90 percent. Moreover, while giving the results, direct quotations from the students were included for each possible sub-category. Finally, the high-frequency answers were accepted as the most effective context for the concept stated in the question. Furthermore, with a large sample, the effect of the gender of students in selecting the context can be also considered in the other studies. In this case, the context that is closer to males and the context that is closer to females can be determined efficiently.

Results

The data that was taken from the interviews were used to determine the most fruitful contexts of charging based on the student's daily life experiences. The questions asked in the interviews and the results of the analysis of the interview transcripts are summarized below. While entering the data into the tables, the abbreviations were used for female (F) and male (M) students respectively.

Analysis of Question 1

Question 1: Which example (event/experiment/product/etc.) would you like to be used in explaining the charging phenomenon to express yourself better? Why did you choose this example?

Table 1

Students' Answers to Question 1

Category	Category Content	Students	f	Reason for Choosing Example
Life-Based Experience	Making a 'popping' (a crackling) sound while taking off the wool sweater (or the dress etc.)	F6, M4, M6	3	Being frequently experienced in daily life (F6, M4, M6), allowing learning by touching, hearing, and seeing (M6)

	Separating the hair strands or sticking to the comb while combing hair	F3, F4	2	Being explained with these examples in books, lessons, etc. (F3)
	Lifting of the hair strands and hearing crackling sounds while sliding from the (plastic) slide	F3, F7	2	Being an easy example (F5)
	Hearing a crack when covering with a blanket (includes a high rate of nylon)	F4	1	Being a simple example (F4)
	Feeling distortion when touching a metal object (e.g. a metal part of a car)	F7	1	Being frequently experienced in daily life (F7)
	A spark jumping from the screen of the television (worked for a long time)	M7	1	Being frequently experienced in daily life (M7)
Laboratory Experiment	Pulling the small pieces of paper with an ebonite stick (or a plastic comb, a balloon, etc.) rubbed with the wool fabric (or the hair, the sweater, etc.)	F1, F2, F3, F5, M1, M2, M5, M7, M8	9	Being an explanatory (F1), a known (F2), an easy (F2, F5, M1, M5) example, allowing detailed explanation (M2)
	Pulling the hair strands with a plastic balloon rubbed with the wool fabric	M8	1	Showing that the balloon can be used outside of the purpose of the game (M8)
Other	The electrical force required for the current to continue between the plates of the capacitors	M3	1	The capacitors provide more obvious observation (M3)

Table 1 shows that most of the students tend to give an event they experienced in their daily lives (e.g., combing hair with a plastic comb) or a laboratory experiment (e.g., an experiment of rubbing two insulating objects such as an ebonite rod rubbed with a wool piece) as the closest context to them to explain charging. In addition, although one student (M3) indicated the electric force between the plates of the capacitors as an example, he could not explain how to use this example to explain the phenomenon of charging.

Analysis of Questions 2 and 3

Question 2-3: Give some examples of insulating and conducting objects.

The three most common examples for insulators are plastic - a plastic pen, balloon, ball, stick, or comb, etc. (f=10), wood - a wood plate or pen, etc. (f=9), and wool - the wool fabric examples respectively. Porcelain, nylon, paper, glass, insulators, marble, foam, eraser, and rubber are also mentioned by only one student.

The three most common examples for conductors are iron - an iron ball or stick, etc. (f=9), gold – the gold jewelry, necklaces, rings, or earrings, etc. (f=8), and copper – a copper wire, etc. (f=8) examples respectively. Silver, salt water, metals – a metal key (or chain, fork, nail, door handle, etc.) is also mentioned by two students. In addition, alloys, humans, acids-bases, electroscopes, and lightning rods are also mentioned by only one student.

Furthermore, five students prefer to give examples such as electric cables (the inside of the cable is conductive like copper, and the outside is an insulator) (f=2), an iron teapot with an insulating handle (f=1), a control rod (f=1), a metal knife, a spoon, or a fork, etc. with plastic handle (f=1) that has both conductive and insulating bodies.

Analysis of Question 4

Question 4: Which example (event/experiment/product/etc.) would you like to be used in explaining the charging of insulating objects to express yourself better? Why did you choose this example?

Table 2

Students' Answers to Question 4

Category	Subcategory	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Laboratory Experiment	Electrostatic Experiments	Pulling the small pieces of the paper with an ebonite stick (or a plastic comb, a balloon, a pen, etc.) rubbed with the wool fabric (or the hair, the sweater, etc.)	F1, F2, F4, F5, F6, F7, M1, M2, M7, M8	10	Being an understandable (F1, F4), explanatory (F2), known (F5, F7, M8) example, the insulators can be electrified only by the friction (M1), easy availability of the materials (M7)
		Sticking of the balloon rubbed with the hair to the wall	F6, M4	2	
	Other	Pure water: ▪ "A certain potential difference occurs when a potential difference is applied to both sides of pure water." (M3) ▪ "Since the pure water is not ionic, it does not conduct the electricity." (M4)	M3, M4	2	Allowing the subject to be more understandable (M3), thought that pure water conducts electricity (M4)
Life-Based Experience		A jumping spark when taking off a sweater due to charging	F3	1	Being frequently experienced in daily life (F3)
Using an Analogy		Holding the plastic handle of the iron teapot ▪ "Charging occurs only in a certain area of insulating bodies. The teapot on the stove will be hot, but only the area of the handles that touches the teapot will be hot. The other parts of the handles are not hot. Like charging of insulators." (M6)	M6	1	The similarity of the heat conduction and the electrical charge transfers of the materials (M6)

Table 2 shows that many students (80%) prefer the experiment of rubbing two insulating objects together to explain the charging of insulating objects. In addition, a student gave an analogy of a plastic-handled hot iron teapot to indicate the similarity of the heat conduction and the electrical charge transfers of the materials, and two students gave an unsuitable answer. One student (M5) did not give any answer to this question.

Analysis of Question 5

Question 5: Which example (event/experiment/product/etc.) would you like to be used in explaining the charging of conductive objects to express yourself better? Why did you choose this example?

Table 3

Students' Answers to Question 5

Category	Subcategory	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Laboratory Experiments	Electrostatic experiments	Bringing two electrically charged conductive objects (or spheres, balls, etc.) to contact. /Touching the conductive object to the electroscope ▪ "When touching a charged metal body to an uncharged electroscope, the electroscope's leaves open." (M1)	F1, F2, F4, M1, M2, M8	6	Being an understandable (F1, M2), a known (F4), an easy (M8) example, the conductors can be only electrified by touching (M1)
		Bringing two electrically charged conductive objects (or spheres, balls, etc.) closer together.	F5, F7	2	
Laboratory Experiments	Other	Applying a potential difference to the saltwater: When we apply a potential difference to both sides of salt water, a certain potential difference will occur. Here, we will use saltwater as a conductor (M3).	M3	1	Being an experiment that takes place in a short time (M3)
		Lighting a bulb when touching two copper wires in a circuit: ▪ "The passing of the electricity through the conductor proves that the conductor is electrified. Thus, the bulb lights." (F3)	F3	1	Being an experiment experienced by the participant (F3)
		Using a copper wire in electrical circuits: ▪ "The use of a copper wire in electrical circuits can explain this situation." (M5)	M5	1	The first example that comes to mind (M5)
	Charging Capacitor Experiment	Using the capacitors: ▪ "We can describe charging of the conductive objects both experimentally and visually by using charging capacitors and drawing them schematically." (M7)	M7	1	The capacitors can be given as the most obvious example for charging of conductor (M7).
Life - Bas		Feeling a distortion when touching a metal door handle. (F5)	F5	1	

		Creating a spark (or a crack): ▪ "When connecting two cables to the positive and negative poles of the battery and touching the other ends of the cables to each other, a spark (or a crack) appears." (M4)	M4	1	Being an experienced event (M4)
Using an Analogy		An iron teapot on the stove: ▪ "Charging in the conductor's spreads to every region. Although only one part of the teapot is on the fire, the heat spreads all over it. Even if we rub it with our hands, it gets hot." (M6)	M6	1	The similarity of heat conduction and electrical charge transfer of the materials (M6)

Table 3 shows that many students (%40) prefer the experiment of touching two conductive objects, as the closest context to them to explain the charging of conducting objects. One student (F6) did not give any answer to this question.

Analysis of Question 6

Question 6: Which example (event/experiment/product/etc.) would you like to be used in comparing the types of charging to express yourself better? Why did you choose this example?

Table 4

Students' Answers to Question 6

Category	Subcategory	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Contact Type1 (Rubbing)	Laboratory Experiment	Pulling the small pieces of paper with an ebonite stick (or a plastic comb, a balloon, or a pen, etc.) rubbed with the wool fabric (or the hair, the sweater, etc.)	F1, F2, F3, F4, F5, F6, M1, M2, M5, M6, M7, M8	12	Being explained with these examples in the textbooks or lessons (F1, F2, F3, F6), being a known (M1), a memorable (F4), an explanatory (M7, M8) example
	Life-Based Experience	Hearing a crack when sliding off the slide	M4	1	Being frequently experienced in daily life (M4)
Contact Type 2 (Touching)	Laboratory Experiment	Touching two electrically charged conductive objects (or spheres, balls, etc.)	F1, F2, M1, M2, M3, M5, M8	7	Being explained with these examples in textbooks or lessons (F1), being a known (M1), a simple (M3), an explanatory (M8) example
Contact Type 2 (Touching)	Laboratory Experiment	Touching an electrically charged conductive body to the electroscope	F3, F5	2	Being explained with these examples in books or lessons (F3), being frequently

					experienced in daily life (M4)
		Touching an electrically charged conductive body to the ground	M7	1	Being an explanatory example (M7)
		Touching a (spherical) charge to the paper (or aluminum strips, etc.)	M6	1	Being an example that appeals to more sense organs (M6)
	Life-Based Experiment	Feeling a distortion when putting our hands in the electrical outlet	M4	1	Being frequently experienced in daily life (M4)
		Approaching a conductive object to another electrically charged object	F1	1	Being explained with these examples in books or lessons (F1)
Approach Without Contact	Laboratory Experiments	Bringing two objects (or balls, iron pieces, etc.) closer together	F2, F4, M1, M2, M5, M8	6	Being explained with these examples in books or lessons (F2), being a memorable (F4), a known (M1) example
		Approaching an electrically charged object to an electroscope	F3, F5	2	Being frequently experienced in daily life (M4)
		Approaching a (spherical) charged object to a piece of paper (or aluminum strips)	M6	1	Being an example that appeals to more sense organs (M6)

Table 4 shows that many students preferred to use a laboratory experiment to explain and compare the types of charging. An example of rubbing two insulating objects against each other (80%), touching two conductive objects to each other (73%), and bringing an electrically charged object closer to another object (67%) are the common laboratory examples indicated by students. None of the students stated that they could explain the phenomenon of charging with examples of rubbing two objects, at least one of which is conductive, or touching two objects, at least one of which is insulating to compare the types of charging. One student (F7) did not give any answer to this question.

Analysis of Question 7

Question 7: Which example (event/experiment/product/etc.) would you like to be used in explaining what electric charge is to express yourself better? Why did you choose this example?

Table 5

Students' Answers to Question 7

Category	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example

Category	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
An Explanation of Subatomic Particles	An electron: ▪ "They are electrons providing charging with a negative charge. Thus, electrons can be represented on a balloon." (F1)	F1	1	Being an understandable example (F1)
	A proton, a neutron, and an electron: ▪ "Electric charge can be described by explaining properties of the proton, the neutron, and the electron." (M2)	M2	1	
Looking at the Absence of Coulomb Interaction Between Bodies	The interaction of two electrically charged ebonite sticks: ▪ "We can explain the reactions of two ebonite sticks rubbed with a woolen fabric. Same charges repel each other while opposite charges attract." (M8)	M8	1	Easy availability of the materials (M8)
	The interaction of the electrically charged object and a neutral object with the electroscope: ▪ "I would bring the plus, minus, and neutral objects closer to the electroscope, then touch it, and look at their interactions." (M5)	M5	1	Being taught in this way in lessons (M5)
	The interaction between the electrically charged balls: ▪ "The same charged balls repel each other; opposite charges attract." (F4)	F4	1	The first example that comes to mind (F4)
Using Analogy	The magnet model: ▪ "The magnet poles are just like the electric charges. I can explain from the magnets." (F3, F5)	F3, F5	2	The magnet poles are like the electric charges (F5)
	The ball (or marble) model: ▪ "Large balls fixed to the board and rotating a small ball attached to them by a rope: The positively charged proton moves slower than the negatively charged electron. Since it is larger and heavier." (M6) ▪ "We can think of electric charge as a marble. We can explain its quantum state with 3 marbles and 5 marbles, etc." (F7)	M6, F7	2	Enabling analogy (M6)
Category	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Explaining Directly	Explaining directly: ▪ "There are two types of charges, positive and negative. Charging occurs with the change or the movement of charges. Charging occurs with the movement of negative charges. Positive charges are constant and do not move." (M1). ▪ "The positive charge does not move but the negative charge moves." (M4) ▪ "After explaining the concepts of the electron, proton, and quark with the help of a video, I explain why the negative charges move." (M7)	M1, M4, M7	3	Being easy, accessible, visual, and helping to explain the basic characteristics of electrical charge (M7)
Unrelated	The unrelated statement: ▪ "We can obtain an observable result without any particular intermediary: like a charged particle placed inside a hollow sphere forming a charge outside the sphere." (M3) ▪ "Circuit current goes from plus to minus." (F3)	F2, F3, M3	3	Transferring charge without any connection is interesting (M3)

Table 5 shows that 2 students stated that they could explain by explaining the electron, proton, and neutron from subatomic particles, 3 students stated that they could explain by using electrical interactions between objects, 4 students stated that they could explain by using an analogy, and 3 students stated that they could explain by directly explaining the properties of electric charge to explain what a charge is. One student (F6) did not give any answer to this question.

Analysis of Question 8

Question 8: Which example (event/experiment/product/etc.) would you like to be used in comparing the properties of neutral and electrically charged objects to express yourself better? Why did you choose this example?

Table 6

Students' Answers to Question 8

Category	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Looking at the Absence of Coulomb Interaction Between Bodies	Using an electroscope: ▪ "I would touch the charged and neutral objects to the electroscope and also, bring them closer together to it look at the motion of the leaves of the electroscope (M5)." ▪ "I would look at the effect of an uncharged electroscope and a charged electroscope exerts on a metal object. If it is charged, it acts an effect on the metal object." (F3)	F3, F5, M5, M8	4	Observable of the repulsive-attractive forces (F3), being an understandable example (M5)
	Pulling the small pieces of paper by the charged objects ▪ "When bringing the neutral objects closer to each other, they do not attract each other. When bringing a plastic comb close to the pieces of paper without rubbing our hair, the comb does not pull the paper. But when we rub it with our hair, it pulls." (F6)	F1, F4, F6	3	Being an understandable example (F1), being the first example that comes to the mind (F4)
Looking at the Absence of Coulomb Interaction Between Bodies	The lighting: ▪ "If I observe an effect, it is charged. For instance, lightning between the clouds is an indication of the charge transition. That is, they are charged. Normally, clouds are neutral; we do not observe the lightning." (F6)	F6	1	
	The interaction of the electrically charged bodies: ▪ "We can observe the repulsive and attractive forces using fixed and moving balls tied on the rope. The same charge repels, the opposite attracts. Neutral is not affected." (F2) ▪ "I put two uncharged bodies and two charged bodies at certain distances and discuss their effects so that the properties can be explained." (M7)	F2	1	Being an understandabl e example (F2, M7)
Use of Analogy	The human model: ▪ "I would liken the neutral and charged bodies to humans. People rush to help someone who is seeking help. The person seeking help represents the positive charge, the neutral that does not do anything, and the helping person represents the negative charge." (M4)	M4	1	There are too many people waiting to help those who seek help (M4)

	The safety pin model: ▪ "A neutral is the closed safety pin, electrically charged is an open safety pin, and a wardrobe is as the outside of the world: The neutral objects do not show any electrical interactions. The charged objects tend to either repel or attract. If we throw a closed safety pin into the wardrobe, it will not get caught in anything. If we throw the open safety pin, it will be stuck if there is something that it can attract." (M6)	M6	1	Being an understandable analogy to teach neutral and charged bodies (M6)
	The radiometer model: "The radiometer is black and white. One is negative and the other is positive. The two become neutral together." (F7)	F7	1	A radiometer is like neutral and charged bodies (F7)
	The clusters model: ▪ "I explain the neutral and charged objects with the clusters containing the positive and negative integers: I can draw a cluster, for example. It contains positive and negative numbers. If the total is zero, I say neutral. If not, I say charged." (F5)	F5	1	
Explaining	Describing the properties of the neutral and charged objects: ▪ "The properties of the neutral and the electrically charged bodies are explained and the charge transitions can be observed …. We cannot say that there is no charge in the neutral bodies. In neutral objects, the positive and negative charges are equal. In charged bodies, one side is dominant, so they can be positively or negatively charged. (M2)	M1, M2	2	
Other	A positively charged body: ▪ "I would tell with a positively charged object. The positively charged object has a certain and does not change in number in any way. There is a continuous transition to negatively charged bodies." (M3)	M3	1	Protons are stationary and electrons spin around them (M3)

Table 6 shows that experiments looking for any electrical interaction between the objects, or an analogy (e.g., a human, a pin) were indicated respectively by 9 and 4 students as the closest context to them. 2 students stated that they can explain whether the objects are electrically charged or not, based on the definitions of neutral objects and electrically net charged objects in the book to compare the properties of neutral objects with electrically charged objects. One student (M7) did not give any answer to this question.

Analysis of Question 9

Question 9: Which example (event/experiment/product/etc.) would you like to be used in investigating whether an object is electrically charged, and if so, what kind of charge is it to express yourself better? Why did you choose this example?

Table 7

Students' Answers to Question 9

Category	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Laboratory Experiment	Looking at the electrical interactions of multiple objects: ▪ "I observe the interactions of positively and negatively charged objects by bringing them closer to another object. I would move one object closer to another object with a positive charge. If it attracts it is minus, if it repels it is plus, if it's not reacting it is neutral." (M5)	F3, F4, F6, F7, M2, M5, M6, M7, M8	9	Being a reasonable (M5), simple, and understandable (M7) example, being easy to apply (M6)
	Using an electroscope: ▪ "I would observe the movement of the leaves of an electroscope by bringing the other charged objects closer to the charged or the neutral electroscope." (M1, M4)	F1, F5, M1, M2, M3, M4	6	Being an understandable (F1, M2), an easy (M2, M3) example, the electroscope serves its purpose (M1), the electroscope is the only known object that can be used to find charge (M4)
	Bringing objects closer to the small pieces of paper: ▪ "When we bring an object close to the paper pieces without rubbing it with wool fabric, we see that it cannot be attracted. Because it is neutral. But it pulls when rubbed. Because it is charged. I have no example of separating the positive or negative. A neutral body does not attract anything. Charged bodies attract or repel." (F2)	F2	1	Being a memorable example (F2)
Unrelated	The unrelated statement: ▪ Bringing positive and negatively charged objects closer to the poles of the magnets (F3).	F3	1	

Table 7 shows that an experiment in which they could look at the electrical interactions between them using more than one object, and an experiment in which they could use an electroscope were indicated respectively by 11 and 6 students as the closest context to them to investigate whether an object is electrically charged or not, and if so, what kind of charge it is.

Analysis of Question 10

Question 10: Which example (event/experiment/product etc.) would you like to be used in explaining the importance of the shape of the object in the charge distribution of an electrically charged body to express yourself better? Why did you choose this experiment?

Table 8

Students' Answers to Question 10

Category	Subcategory	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Laboratory Experiment	Size	Using spheres with different sizes	F1, F2, F3, F4, M2, M3, M5, M8	8	Being an understandable example (F1)
	Hollow - Solid	Using hollow and filled spheres like iron balls and plastic balls, etc.	F5, M4	1	
	Symmetry	Using sharp objects like knives, funnels, etc.	F5, F6, F7, M6	4	
Use of Analogy	Symmetry	Filling the flour with the funnel: "Charge density is higher at the sharp parts. When filling flour with a funnel, although there is flour all over the funnel, there is more flour in the sharp part and it is poured from the sharp part when pouring." (M6)	M6	1	Having a good explanation of the charge distribution in sharp objects (M6)
		Using a pin on the water ▪ "First, I make a small compass by slowly dropping a pin on the water. Using the difference between the sharp and the blunt end (explaining its deviation in the magnetic field) I can explain that it is the same in electricity." (M7)	M7	1	Being a visual example (M7)
Direct Description		Independence from shape: ▪ "It does not depend on the shape. The charges are homogeneously distributed throughout the conductor. For example, wherever you touch metals in a conductive object if the tissue has electricity, you will be hit. Its distribution is evenly distributed everywhere." (M1)	M1	1	

Table 8 shows that spheres have different sizes (or radii), hollow and solid spheres (e.g., plastic ball, iron ball), sharp objects (e.g., knife, funnel), and a charged conductor was indicated respectively by 8, 2, 4, and 1 student as the closest context to them to explain the importance of the shape of the object in the charge distribution of an electrically charged body.

Analysis of Question 11

Question 11: Which example (event/experiment/product/etc.) would you like to be used in explaining the factors on which the electrical force (Coulomb force) depends to express yourself better? Why did you choose this example?

Table 9

Students' Answers to Question 11

Category	Subcategory	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Laboratory Experiment	Distance	Looking at the change in electrical interactions when changing the distance between the charged objects	F1, F2, F3, F4, F5, F6, F7, M1, M2, M3, M4, M5, M6, M7	14	Being an understandable example (F1), being easy to apple (M8), being at the force formula (M2, M3)
	Magnitude of Charge	Looking at the electrical interactions when changing the amount of the charge of the charged objects ▪ "We can increase the magnitude of the charge by increasing the friction time." (F6)	F4, F6, F7, M2, M5, M6	6	
	Size of Object	Using some spheres with different sizes (or radii): "I would see if their interactions were affected by the size by using different-sized spheres." (F3)	F3, M2, M8	3	
Use of Analogy	Size of Object	The electric motor: ▪ "As low-engine cars speed less, the sphere with a smaller radius will have less charge." (F3)	F3	1	

Table 9 shows that an experiment by changing the distance between electrically charged objects, an experiment by changing the charge magnitudes of electrically charged objects, and an experiment using spheres with different sizes (or radii) was indicated respectively by 14, 6, and 5 students as the closest context to them to investigate the factors on which electrical force depends.

Analysis of Question 12

Question 12: Which example (event/experiment/product/etc.) would you like to be used in explaining the concept of electrical grounding to express yourself better? Why did you choose this example?

Table 10

Students' Answers to Question 12

Category	Subcategory	Category Content with (if Necessary) Students' Expressions	Students	f	Reason for Choosing Example
Laboratory Experiment	Connecting a Charged Body to Ground with a Conductor	Connecting a charged object to the ground with a conductor	F2, F5, M1, M5	4	Being taught in lessons (M1)
		Connecting the charged electroscope to the ground with a conductor	F1, F3	2	
		Connecting the Van de Graaff generator's Sphere to the ground with a conductor	M8	1	Being watched by the participant (M8)
Life-Based Experience	Lightning rods	Lightning rods on the buildings	F3, F6	2	
	Contact of a Human to the Ground	Walking electrically charged people on the ground with the bare feet	M1, F4	2	Being known to the public (F4)
		Touching of an electrically charged person to the ground	M4	1	
		Touching the ground after sliding off the slide	M2	1	Being experienced (M2)
	Grounded Socket	Grounded sockets	M3, F6	2	Being daily life example (F6)
Use of Analogy		Anthill: ▪ "When grounding is done, the potential is the same everywhere. In an ant colony lined up side by side, there are ants everywhere between the nest and the endpoint. They do not bite each other as the potential is the same." (M6)	M6	1	
		Water drainage: ▪ "I would compare the electron to water flowing through water drainage." (F7)	F7	1	
Explaining in Wiring Diagram		Using an electrical wiring diagram: ▪ "I would explain the grounding part from the electrical wiring diagrams." (M7).	M7	1	

Table 10 shows that the event of connecting an electrically charged object to the earth with a conductor, the event of an electrically charged person touching the ground, a sample of the earthling socket, and an analogy such as a water drain was indicated respectively by 9, 4, 2, and 2 students as the closest context to them to explain the electrical grounding phenomenon.

In addition, when the students are asked why they gave these examples, the most common reasons are that the examples are easy (f=17), known (f=17), and understandable (f=15), that these examples are given in the lessons (f=11), and they are frequently experienced in daily life (f=10).

The main categories and their distributions regarding questions asked to interviewers were given in Table 11.

Table 11

Main Categories and Their Distributions Regarding Questions

Question Number / Category	1	4	5	6	7	8	9	10	11	12	f	%
Laboratory Experiments	10	14	12	33	3	9	16	13	23	7	**140**	**70,4**
Life-Based Experiments	10	1	2	2	-	-	-	-	-	8	**23**	**11,6**
Analogies	-	1	1	-	4	4	-	2	1	2	**15**	**7,5**
Direct Definition	-	-	-	-	5	2	-	1	-	2	**10**	**5,0**
Unrelated Examples	1	-	-	-	3	1	1	-	-	-	**6**	**3,0**
Unanswered	-	1	1	1	1	1	-	-	-	-	**5**	**2,5**
f	**21**	**17**	**16**	**36**	**16**	**17**	**17**	**16**	**24**	**19**	**199**	**100,0**
%	**10,6**	**8,5**	**8,0**	**18,1**	**8,0**	**8,5**	**8,5**	**8,0**	**12,1**	**9,5**	**100,0**	

Table 11 showed that 199 answers were coded under five main categories. 70,4%, 11,6%, and 7,5% of the answers were in the category of laboratory experiments, life-based experiments, and analogies respectively. This result implies that students prefer to talk about the more concrete context for the charging phenomenon. This result also showed that in-school experimental activities and out-of-school individual experiences have an important place in learning.

Conclusion and Discussion

In this study, the most fruitful context of electrical charging was determined. Thus, which example (event/experiment/product/etc.) 15 tenth-grade high school students would like to be used in explaining the specific “events” to express themselves better were asked by using some semi-structured interviews. The “events” are

- charging phenomenon,
- charging of insulating objects,
- charging of conductive objects,
- the types of charging, what electric charge is,
- what electric charge is,
- the properties of neutral and electrical charged objects,

- investigating whether an object is electrically charged, and if so, what kind of charge,
- the importance of the shape of the object in the charge distribution of an electrically charged body
- the factors on which the electrical force (Coulomb force) depends
- the concept of electrical grounding

Moreover, instead of giving a suitable example, 10 times direct definitions were used, 6 times unrelated examples were given, and 5 times no answers were given by students (see Table 11). This was an unexpected result of this study. Although they determined the examples themselves, a small number of students do not know how to explain the related concept or event through the examples they gave. In addition, some students gave incomprehensible answers to the questions. This may be because they are not familiar with the context-based lessons. Like these students, the knowledge of preservice science teachers in context-based teaching is inadequate and they need training to be able to develop a context-based lesson plan (Aydin-Ceran & Ergul, 2022; Gungor et al., 2023).

Furthermore, the result of this study showed that the students may have some misconceptions about charging. For example, students especially have difficulty with the types of charging and what a charge is. Since none of the students were aware that charging with friction is also charging with contact. That is, they are not different types. Thus, they should be talked about under the same type of charging. Considering the misconceptions in the literature about charge, it is seen that charge is considered the same as an electron (Başer & Geban, 2007; Gunes, 2005; Goris, 2012), is thought to be a material (Goris, 2012), and continuous (Gunes, 2005). Moreover, unfortunately, none of the students stated that they could explain the phenomenon of charging with examples of rubbing two objects, at least one of which is conductive, or touching two objects, at least one of which is insulating to compare the types of charging. They often express the charge term instead of the charged particle. They frequently use the plus and the minus terms instead of the positive and the negative respectively. In addition, one of the male students (M1) said that "neutral objects can be electrified by rubbing against each other, but not by touch."

In addition, when asked to students to give examples of insulators and conductors, they tend to give an example of the types of materials such as plastic or iron instead of giving an example of a real object such as a plastic pen or an iron ball, from which insulating objects are made. The reason for this may be that the word plastic is often preferred over real objects such as plastic rods in lessons and textbooks. Simsek Cetin (2014) also had high school students prepare posters and tried to reach which physics subjects the students were interested in and the contexts they wanted to see in the physics lesson. According to the results of this research, the contexts that students want to see about electricity were conductors and plastics.

Finally, when the students are asked why they gave these examples, the most common reasons are that the examples are easy (f=17), known (f=17), and understandable (f=15), that these examples are given in the lessons (f=11), and they are frequently experienced in daily life (f=10).

Limitation & Suggestion

Selecting the most fruitful context plays a key role to achieve success since the effectiveness of context-based learning or educational activities is generally related to the most fruitful context used. In this study, laboratory experiments mentioned in school textbooks or lessons, life-based experiments, and analogies were chosen by high school students to express some events related to charging phenomena.

The result of a meta-analysis of 23 research conducted between 2008 and 2022 showed that context-based learning (CBL) has a significant effect on Turkish students' science academic achievement (Karasubasi et al., 2023). The success of context-based courses is directly related to the context used in the courses. An educational context should be selected by considering students' interests rather than teachers or other sources. Teachers and their students should be part of the choice of contexts process. For example, according to a useful dictum of Salters' curricula developers, based at York University in England, science concepts should not be introduced until they understand some familiar context in the lives of their students outside school (Smith, 1988, p.891). As Yarosh & Guzdial (2007) stated that assignments and course material designed with a context can improve students' performance and motivation if they are meaningful to students. On the other hand, even in the programs that adopt context-based curricula, teachers are not generally free for the choice of contexts since the contexts are generally prescribed in the context-based curriculum. Similarly, in studies using the context-based approach (e.g. Aydin-Ceran & Ergul, 2022), the contexts are usually determined by the researchers who prepared the lesson plan. Similarly, Lindell et al. (2006) revealed that out of 12 misconception tests that are widely used in physics education literature, only four of them use student perceptions in the test development process, and only two of them consider alternative models of students while creating answer options.

The laboratory experiments mentioned in school textbooks or lessons are the most chosen context by high school students. This result reveals the importance of the content information in the textbooks or lessons. Since the textbooks (Abimbola & Baba, 1996; Barrass, 1984; King, 2010, Unsal & Gunes, 2002) and the teachers (Barrass, 1984) are the common sources of misconception, non-scientific information should be avoided while preparing their content of them. In addition, teachers should be very careful while choosing examples while explaining the content.

Furthermore, since choices of context vary according to students' various individual variables such as interest and success in the course (Habig et al., 2018; Güth & van Vorst, 2021; van Vorst & Aydogmus, 2021) or gender (van Vorst & Aydogmus, 2021) the effect of these variables on students' context selection should also be investigated in future research. For example, learners with high performance and high interest in chemistry are more likely to choose non-contextualized tasks, students who are interested in chemistry and show an intermediate level of performance choose the uncommon context, and learners with the lowest performance, interest and self-concept choose an everyday context (Güth & van Vorst, 2021). Thus, the effect of these individual variables on students' context selection should also be investigated in future research.

Thus, the result of the analysis of the data obtained from the interviews can be used to determine the most suitable contexts as the focus event in the other interviews to indicate possible misconceptions of the students about charging. Kaltakci (2012), Kutluay (2005), Pesman (2005), and Turker (2005) are some researchers who used students' most fruitful contexts to identify students' perceptions of a specific topic.

Finally, the accuracy of the students' statements was excluded from the scope of this study. Thus, they can also be analyzed according to the degree of accuracy.

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Annex 1. Interview Form

Dear participant,
This interview is being held to determine the most suitable context to obtain detailed answers from you when talking about charging. Your participation is on a voluntary basis.

Your answers to the questions will be used in my doctoral thesis that I am conducting at Gazi University, Department of Physics Education. For this reason, your sincere answers to the questions without worrying about getting points will greatly contribute to my thesis. Thank you for your participation and contribution to my thesis.

Date	:	/ 2018
Starting Time	:	
End Time	:	
Participant	:	
Gender	:	☐ Male ☐ Female
Class	:	
Physics Course Exam Grade	:	

I. Introduction Questions

1) How is your relationship with physics courses?

2) How is your relationship with the subject of Electricity in Physics?

3) Do you have experience in electricity? Please explain.

4) What are the most difficult subjects in electrical lessons? Why do you think these topics are difficult?

II. Main Questions

Explanation:

While answering the questions in this section, you are requested to give at least one example of charging. This example can be an event you have experienced or observed, an experiment you had done, or a product you have used. For this reason, when answering the questions, clearly indicate where, by which people, by which objects and how the example or examples you will give in the questions were realized. In other words, when answering the questions, describe your example in the best way by specifying all the features related to the example you will give. Then explain why you chose this example.

	Question	Example	Explanati	Reason
1	Which example (event/experiment/product/etc.) would you like to be used in explaining the charging phenomenon to express yourself better? Why did you choose this example?			
2	Give some examples for insulating objects.			
3	Give some examples for conductive objects.			
4	Which example (event/experiment/product/etc.) would you like to be used in explaining charging of insulating objects to express yourself better? Why did you choose this example?			
5	Which example (event/experiment/product/etc.) would you like to be used in explaining charging of conductive objects to express yourself better? Why did you choose this example?			
6	Which example (event/experiment/product/etc.) would you like to be used in comparing the types of charging to express yourself better? Why did you choose this example?			
7	Which example (event/experiment/product/etc.) would you like to be used in explaining what electric charge is to express yourself better? Why did you choose this example?			
8	Which example (event/experiment/product/etc.) would you like to be used in comparing the properties of neutral and electrically charged objects to express yourself better? Why did you choose this example?			
9	Which example (event/experiment/product/etc.) would you like to be used in investigating whether an object is electrically charged, and if so, what kind of charge is it to express yourself better? Why did you choose this example?			
10	Which example (event/experiment/product/etc.) would you like to be used in explaining the importance of the shape of the object in the charge distribution of an electrically charged body to express yourself better? Why did you choose this experiment?			
11	Which example (event/experiment/product/etc.) would you like to be used in explaining the factors on which the electrical force (Coulomb force) depends to express yourself better? Why did you choose this example?			
12	Which example (event/experiment/product/etc.) would you like to be used in explaining the concept of electrical grounding to express yourself better? Why did you choose this example?			