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Investigating 12th-Grade Students' Prior Knowledge of Static Electricity Concepts

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ABSTRACT

This study was aimed at describing the types of prior knowledge of the 12th-grade students of static electricity concepts. This study was done at public senior high schools in Singaraja-Bali. There were 117 students who participated in the study, they were between 16-17 years old. The data of students' prior knowledge of static electricity were collected by using Three Tier Diagnostic Static Electricity Test (TTDSET) with the index of reliability r= 0.61. The data analysis was done by descriptive technique. The result showed that the students' prior knowledge of static electricity concepts is very varied which can be categorized into four categories namely: Scientific Knowledge, Misconception, Lack Knowledge, and Error. The implication of the result in the teaching of physic is that the teacher needs to identify the student prior knowledge of static electricity concepts and design appropriate conceptual change strategies.

Keywords: prior knowledge, scientific knowledge, misconceptions, lack knowledge

INTRODUCTION

It has been long science teachers received a teaching model that was based on a hidden assumption that knowledge could be transferred directly from the teacher's mind to the student's mind (Bodner, 1986). Hence, education focused on the effort to transfer knowledge from the teacher's mind to the students' mind. According to constructivism, knowledge is constructed in the mind of learner. The scientific theory is constructed by an individual interaction in the culture that defines a discipline, in this case, physical sciences (Chambers & Andre, 1997). Studies such as R.J. Osborne &M. Wittrock (1983), R. Driver et al. (1994), R.J. Osborne et al. (1985), D.P. Maloney et al. (2001), C. Tekkaya (2002), F. Thompson &S. Logue (2006), M. Baser (2006),H. Küçüközer & S. Kocakülah (2007), A. O'Dwyer (2009), show that the students enter the classroom not with empty minds, but they bring with them prior knowledge about science which is developed from daily experiences.

Prior knowledge is given various labels such as preconception (Turgut, Gürbüz & Turgut, 2011); children science (Bell, 1993; Osborn et al., 1985); alternative conception (Peterson, 2002) and misconception (Brown & Clement, 1989). D.P. Ausubel (1968) states that prior knowledge is a single factor which is the most important in influencing learning. Similarly, D.P. Ausubel (1968), M.G. Hewson & P.W. Hewson (1983) show that one of the factors that influence student learning in science is students' prior knowledge, which can be in the form of alternative conception or also scientific conception. Prior knowledge is a knowledge that the student has before learning starts (Ediyang, 2006). Spesifically, F.J. Dochy and P.A. Alexander (1995) state that prior knowledge is all knowledge which is (1) dynamic, (2) available before learning, (3) structured, (4) can exist in various

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forms (i.e., declarative, procedural, and conditional knowledge), (5) explicit and implicit, and (6) contain component and metacognitive knowledge components.

According to constructivism, prior knowledge of the student plays an important role in developing student scientific knowledge. Prior knowledge can be viewed as naive theories that were difficult to change, as knowledge was developed base on everyday students experiences, and as system account (Esanu & Hatu, 2015). Constructivism views learning as the construction and acceptance of new ideas or the reconstruction of existing ideas (Bell, 1993). During the learning, the students develop meaning based on background, attitude, and experiences (Pinarbasi et al., 2006). Many findings show that learning outcome especially comes from prior knowledge (Roschelle, 1997). A correct prior knowledge which is consistent with new knowledge has a positive effect on the development of scientific knowledge, on the contrary, the prior knowledge which is contradicting with new information has a negative effect (Svinicki,1994). F.J. Dochy & P.A. Alexander (1995) differentiate the effect of prior knowledge into three categories 1) directly influence in facilitating learning, 2) the effect of the quality of prior knowledge (for example, incompleteness, misunderstanding, accessibility, number, availability and previous knowledge structure and 3) the interaction effect between quality and the effect facilitation.

The student prior knowledge can fit with scientific knowledge and there is also a prior knowledge that does not fit with scientific knowledge (Clement, Brown & Zeitsman, 1989). The prior knowledge which contradicts with the scientific concept is called misconception. The misconception that is brought by the student that contradicts with the scientific explanation (Broughton, Sinatra& Reynolds, 2010), is resistant to changed, is very strong and difficult to changed by traditional teaching (Sungur, Tekkaya & Geban, 2001). Misconception influences students to learn about new scientific knowledge and plays an important role in learning (Ozmen, 2007). The fact shows that misconception is the most important factor that gives a negative contribution to the students' academic success (Ozkan & Selcuk, 2012). Based on the description above, identification of the students' prior knowledge is important.

Studies on preconception (prior knowledge) of students about dynamic electricity have been done by many researchers such as P.V. Engelhardt &R.J. Beichner (2004), U. Turgut, F. Gürbüz & G. Turgut (2011), I.I. Ismail et al. (2015), S. Sencar &A. Eryilmaz (2004), A. O'Dwyer (2009). On the other hand, studies on the preconception about static electricity are still very limited such as D.P. Maloney et al. (2001), E. Bilal & M. Erol (2009), V. Koudelkova & L. Dvorak (2015). Like dynamic electricity concepts, static electricity concepts is very important and is used frequently in daily life. Therefore, a correct understanding of static electricity concepts becomes urgent. Based on this rationale, meaningful teaching on static electricity concepts at school should be developed. In an effort to enhance meaningful learning about static electricity, the identification of the types of student prior knowledge about static electricity needs to be done. The question that is answered in this study was: (1) what does student prior knowledge look like concerning the concepts of static electricity?

METHOD

Participants

This descriptive study was carried out at four public senior high schools in Singaraja Bali. The number of the students involved as the sample was 117, consisting of 40 males and 77 females. They were between 16-17 years old.

Method of Data Collecting and Instrument

The data collected in this research were the types of students prior knowledge concerning static electricity concepts. The data were collected with a test technique. The instrument used was Three Tier Diagnostic Static Electricity Test (TTDSET) that is modified from D.P. Maloney et al. (2001) and E. Bilal & M. Erol (2009). This test consisted of three levels. The first level was a multiple choice that that asked the student to choose a correct answer from the alternative options answers. The second level was a multiple choice test that asked the students to choose an alternative reason that fitted with their choice at the first level. In this part, the students were also given the opportunity to write their reason if it was not found in the alternative option. The third part was the choice of the degrees of their certainty that the student has toward the answer and the reason that they have chosen. This part consisted of two alternatives, i.e., sure and not sure. This test had a reliability index of r = 0.61. There were 25 items developed to identify the student prior knowledge of static electricity concepts. **Table 1** shows the distribution of test items in static electricity subtopic.

Table 1. Distribution of test items in static electricity concepts

Static Electricity Concepts	No item
1. Electric charge	1, 2, 3, 4, and 5
2. Electrostatic Force	6, 7, 8, 9, 10, 11
3. Electric Field	12, 13, 14, 15, 16, 17
4. Energy and Electric Potential	18, 19, 20, 21, 22
5. Capacitor	23, 24, 25

Table 2. Categorization of the types of students answers

Answer level 1	Answer level 2	Answer level 3	Prior knowledge category
True	True	Sure	Scientific Knowledge (SK)
True	True	Not sure	Lack Knowledge (LK)
True	Wrong	Not sure	Lack Knowledge (LK)
Wrong	True	Not sure	Lack Knowledge (LK)
Wrong	Wrong	Not sure	Lack Knowledge (LK)
Wrong	True	Sure	Error (E)
True	Wrong	Sure	Misconception (M)
Wrong	Wrong	Sure	Misconception (M)

Adapted from D. Kaltakçi &D. Nilüfer (2007)

Method of Data Analysis

The data about the students' prior knowledge of static electricity concepts were analyzed descriptively. Qualitative analysis was used to describe the student conception categories into categories based on the result of TTDSET. Based on the result of TTDSET the students' prior knowledge was categorized into four categories: Scientific Knowledge; Misconception, Lack knowledge, and Error. The categorization was based on the combination of the student's responses in TTDSET in first, second and third levels as in **Table 2**. The student misconception types in each subconcept of electricity were described qualitatively and compared with what can be found in the literature of misconceptions.

RESULTS

Categories of Students' Prior Knowledge

Before learning about static electricity at senior high school, the students had got a prior knowledge of static electricity concepts. Based on TTDSET the students' prior knowledge about static electrical concept could be classified into four categories: Scientific Knowledge, Misconception, Lack Knowledge, and Error.

The Average Percentage of Students Who Have a Scientific Concept

Figure 1 shows the average percentage of students who have a Scientific Knowledge on electrostatic concepts.

Percentage of male and female students who have scientific knowledge on the electric charge, electrostatic force, energy and electric potential relatively the same. Meanwhile, on the capacitor concept the percentage of female students who have scientific concept higher than male students. The higher average percentage of students who have scientific knowledge occurs on the concept of electric charge and the lowest occur on the concept of energy and electric potential.

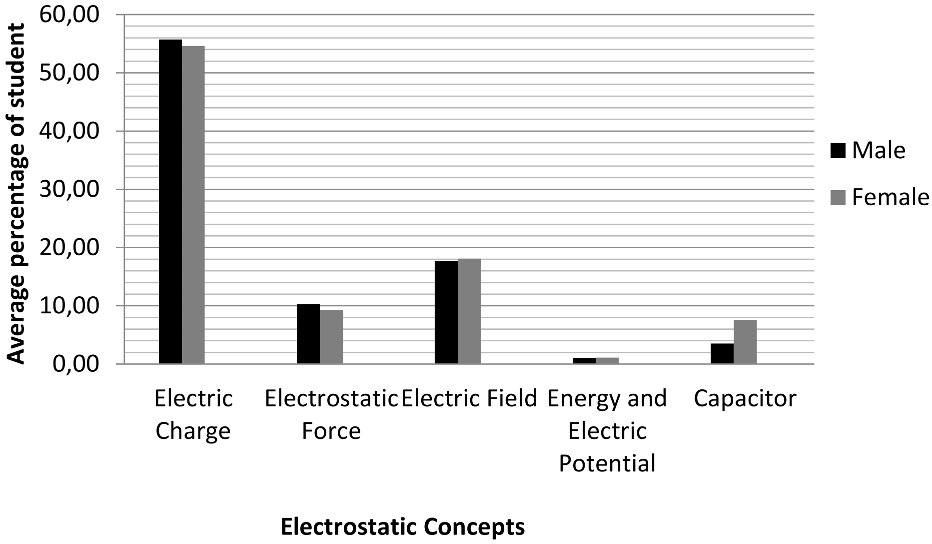

Figure 1. The average percentage of students who have a Scientific Knowledge

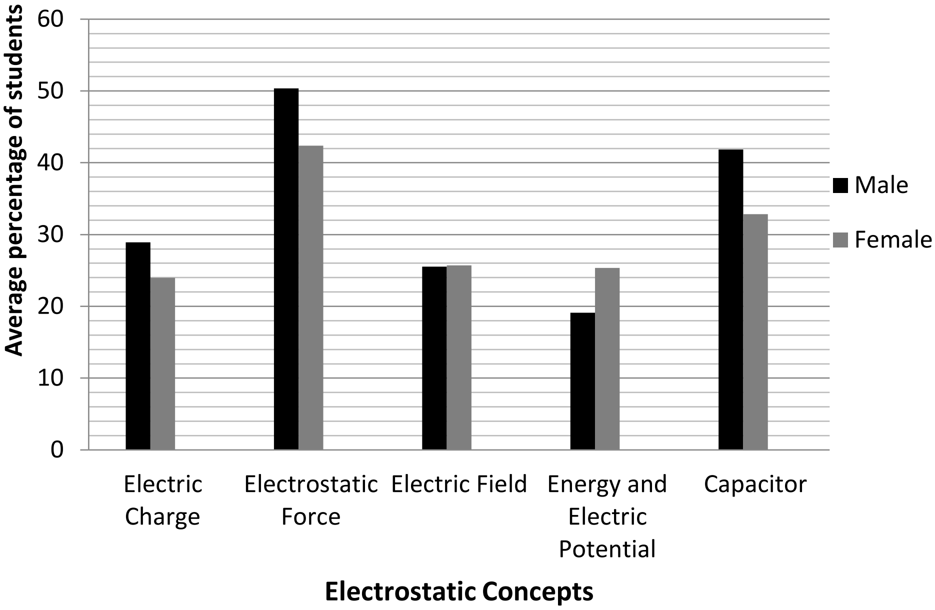

Figure 2. Average percentage of students experiencing misconceptions

The Average Percentage of Students Experiencing Misconception

Figure 2 shows the percentage of students experiencing misconceptions in electrostatic concepts. In the electric charge, electrostatic force, and capacitor concepts, the average percentage of male students experiencing misconceptions is higher than female students. In contrast to the concept of energy and electric potential, the average percentage of female students experiencing misconceptions is higher than that of male students.

The Average Percentage of Students with Lack of Knowledge

The average percentage of students who experience lack of knowledge is shown in **Figure 3**.

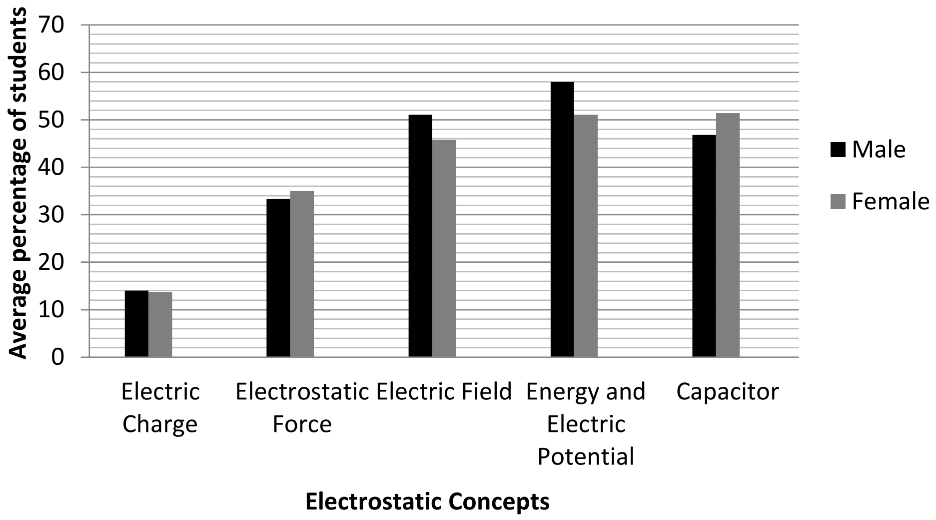

Figure 3. Average percentage of students with Lack Knowledge

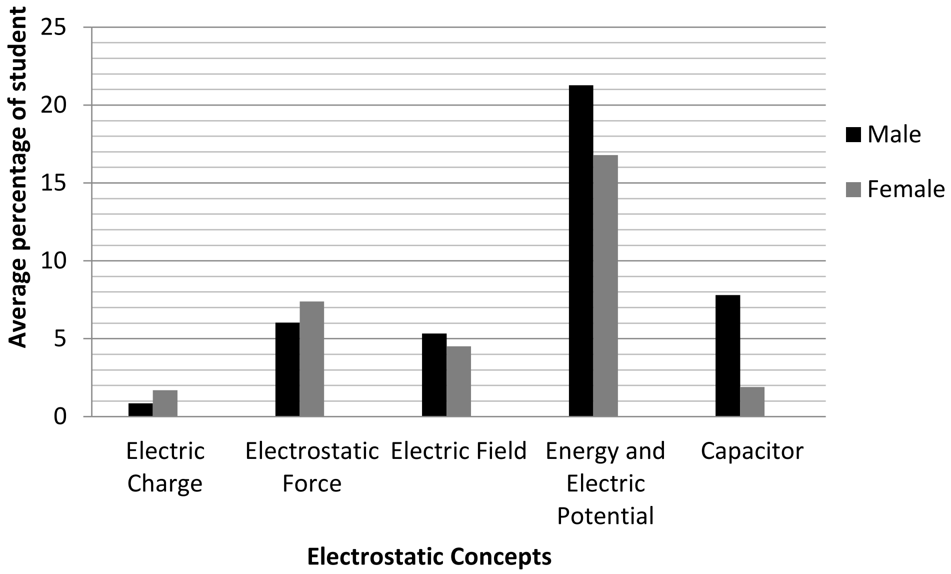

Figure 4. Average percentage of student who experience error

It appears that on the concept of electric charge and electrostatic force the average percentage of students who experience lack of knowledge between male and female students is relatively the same. In the concept of electric field and energy and electric potential, the average percentage of male students who experience lack of knowledge is greater than female students. Meanwhile, on the capacitor concept, the average percentage of female students who experience lack knowledge higher than male student. The highest average percentage of students with lack knowledge occurred in the concept of energy and electric potential and the lowest on the electric charge concept.

The Average Percentage of Students Who Experiencing Error

The average percentage of students who experiencing errors is shown in **Figure 4**. The percentage of students who were experienced the highest error occurred in the concept of energy and electric potential, and the lowest occurred in the concept of electric charge.

In the concept of energy and electric potential and capacitor the average percentage of male students who were experienced errors higher than female students. Meanwhile on the concept of electric charge, electrostatic force, and electric field the average percentage of male and female students who were experienced error relatively the same.

Types of Students' Misconception in Static Electricity Concepts

The qualitative analysis of the students' responses in TTDSET item shows the types of the students' misconceptions about static electricity concept as follows.

(1) A balloon rubbed by silk will have the static electric charge that it can attract paper torn pieces. The term static electricity is identical to a static charge.

(2) Plastic rubbed by cloth will get additional electrons from the cloth, that the plastic charge becomes positive; the cloth will have the negative charge so that the cloth and the plastic will attract each other.

(3) A neutral object has more neutrons then electrons and protons.

(4) An object is called neutral if it has the same number of protons neutrons and electrons.

(5) In an interaction between two objects with different charges, the object with a greater charge obtains a smaller force.

(6) In an interaction between two charged particles, the particle with a greater charge exerts a greater force. This is similar to the finding of E. Bilal & M. Erol (2009).

(7) In the interaction between two particles with the charges of +2 unit and +1 unit, particles with a +1 unit charge experience force twice from particles of +2 unit charge The students drew the attractive force vector in the +1 unit charge twice as long as in the -2 unit charge.

(8) In the interaction between two particles with the charges of +2 unit and +1 unit, particles with a +2 unit charge experience force twice from particles of +1 unit charge. The students drew the vector of repulsive force in the -2 unit charge twice as long as the +1 unit charge.

(9) In the interaction between two objects with the same sign but with different number of charges (for example +Q and +4Q), the objects with the smaller number charge obtains a greater acceleration. In this case the students equate charge with mass in Newton's second law.

(10) The students do not do vector addition to obtain total force in the interaction between two charges or more.

(11) A charge in a uniform electric field does not have acceleration. A similar misconception is also found in E. Bilal & M. Erol (2009), i.e., the particle charged in a uniform electric field moves at a constant speed.

(12) A charged object that lies in a more densely electric filed lines obtains as smaller acceleration than if it is placed in less densely electric field line because of the denser the electric field line, the smaller its field strength.

(13) In the parallel plate capacitor the wider the surface of the plate the greater its capacity to store charge because the parallel plate capacitor capacity meets the equation $C = \varepsilon d/A$, with C= capacitor capacity, d=distance between parallel plates, and A=the area of the surface of the parallel plate.

(14) In the parallel plate capacitor the greater the distance between the surfaces of plates the greater its capacity to store charge because the parallel plate capacitor capacity meets the equation $C = \varepsilon d/A$, with C= capacitor capacity, d=distance between parallel plates, and A=the area of the surface of the parallel plate.

(15) Some capacitors in series circuit, the capacity of the equivalent capacitor is greater than the capacity of each component.

(16) In some capacitor with different capacity connected in series, the potential difference of each capacitor is the same.

(17) Some capacitors with the same capacity that connected in series, the capacity of the substitutes are greater when they connected in parallel.

(18) Energy stored by some capacitors with the same capacity connected in series is greater than the energy stored by some capacitors with the same capacity connected in parallel because the capacity

of the substitutes connected in series is greater than the parallel circuit. Energy stored in capacitor $E= ½CV^2$.

(19) The electric field strength in the center of a ball cell whose inner part radius r and outer part radius R charged +Q distributed evenly in the ball cell is kQ/r^2, because the electric field strength in a point inversely proportional with the square of the distance of the point to the source charge. Here the students apply electric field formula of the point charge in the continuous charge distribution.

(20) A positive charge if placed in an electric field, its potential energy increases because it moves in the opposite direction to the electric field.

(21) Electron will move from high potential to low potential.

(22) If a positive charge that is released from rest in the uniform electric field, its potential energy will decrease because the charge moves in an opposite direction to the electric field.

(23) A positive charge in uniform electric field moves toward low potential, the work done by the negative electrostatic force changes in negative potential energy which means its potential energy becomes lower.

(24) The greater the distance between two equipotential surfaces with the same potential difference, the work exerted by the electrostatic force to move the charge from one surface to another becomes greater.

(25) The greater the distance between two equipotential surfaces with the same potential, the work exerted by electric field becomes greater, because E =V.d, with E = electric field, V =potential different between two equipotential surfaces and d =distances between equipotential surfaces.

(26) The wider the surface of the plate of parallel plate capacitor, the greater is the capability to store a charge because C = εAd, where C = capacitor capacity, A= area of the surface of the parallel plate and the d= distance between two parallel plates.

(27) If some capacitor is connected in series, the capacity of the equivalent capacitor equals the sum of the capacity of each capacitor. The student regards capacitor series circuit with is the same as electric resistance series circuit.

(28) The capacity of the equivalent capacitor of some capacitors that are connected in parallel is smaller than the capacity of the capacitor of each component. The students regard capacitor of the parallel circuit that is the same as are resistance in the parallel circuit.

DISCUSSION

The high average percentage of students who had a scientific knowledge about electric current can be assumed to be caused by the fact that before studying at senior high school the students have got a lesson about electric current in their previous education. At junior high school, the students learned the basics of electric charge which included how to make an object become charged, types of charge, and the characteristics of electric charge.

The average percentage of the students who had misconceptions and lack knowledge was still high enough. Student misconceptions about electric charge are widely contributed by the students' misconception on the concept of a neutral object. Many students interpret neutral objects as an object having more number of neutrons than the number of protons and electrons. In this case, the student equates the word neutron with neutral words. In addition, students' misconceptions on electric charges also come from students' understanding that a neutral object is an object with no charge. Students' understanding of moving charge also contributes to students' misconceptions about electric charge. Students think that an object is positively charged not because its electrons move to another object but rather because it gets a positive charge from another object.

Students misconception about electrostatic force was caused by many factors. First, the students did not know that in the electrostatic interaction between two objects with different charges, the two charges experienced the same electrostatic force. On the contrary, the students understood that a greater charge obtains a greater force, even there were also students who understood that a greater charge exerts a greater work toward other objects. This agrees with the finding in D.P. Maloney et al. (2001) and E. Bilal & M. Erol (2009). It seems that the failure of the students in understanding Newton's third law affects to their understanding to concepts of the electrostatic force (Meloney, 2001). Second, the students' misconceptions in electrostatic force were also seen from their ignorance of the relation between the distance between two charges, the students did not understand qualitatively that electrostatic force is inversely proportional to the square of the distance between the two charges that interact. A similar misconception is also found by V. Koudelkova & L. Dvorak (2015), that the students did not know qualitatively about electrostatic force (Coulomb force). In representing attractive force or repulsive force between two charges in a vector diagram, many students could not differentiate vector length for different attractive force or repulsive force. Third, the students tried to use Newton's second law in electrostatic force but they thought that an object charge was the same as its mass. When they were asked to determine the acceleration experienced as the result of an interaction of two objects with the same masses but with different charges, many students said that an object with a smaller charge had a greater acceleration.

For the concept of the capacitor, the students had not learned it at junior high school. The students' misconception about the concept of the capacitor was largely coming from the misinterpretation of series or parallel circuits of some capacitors. At junior high school, the students had learned electric resistance series and parallel circuits. When they were asked about capacitor series and parallel circuits they interpreted them similar to their interpretation of electric resistance series or parallel circuits.

For the concepts that have not been taught at junior high schools such as electric field, electric potential, and the capacitor, many students did not have any knowledge about them (lack knowledge). Electrostatic concepts in general, and electric field, electric potential, and the capacitor, in particular, were less familiar to them in their daily life. Concepts such as electric field, electric line force, the motion of charge in the electric field, an electric field of continuous charge, potential difference, electric potential energy, equipotential surface, the motion of charge in the equipotential surface are abstract concepts that are remote from the students daily life. The students acquire prior knowledge through interactions with their environment. The students' less familiarity with static electricity concepts caused their very low level of interaction with the concepts, this caused a relatively high percentage of the students with lake knowledge about the electric field, electric potential, and capacitor.

CONCLUSION

Before entering formal lessons students have had prior knowledge of static electricity concepts. Their prior knowledge can be categorized into four categories: scientific knowledge, misconceptions, lack of concepts, and errors. There are thirty types of misconceptions identified in this study, some of which are alike to those found in misconception literature. Students' prior knowledge of static electricity concepts is very useful in designing appropriate conceptual change strategies. Therefore it is very important for the teacher to identify the variety of student's prior knowledge about static electricity before starting the lesson.

Disclosure statement

No potential conflict of interest was reported by the authors.

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