Diagnosing elementary teacher’s misconceptions of gravity

A Desstya¹,*, Z K Prasetyo² and Suyanta³

¹Elementary Teacher Education, Muhammadiyah University of Surakarta, Jalan A Yani Tromol Pos 1, Pabelan, Sukoharjo Indonesia, Indonesia
²Department of Sciences Education, Universitas Negeri Yogyakarta, Jalan Colombo No 1 55281, Indonesia
³Department of Chemistry Education, Universitas Negeri Yogyakarta, Jalan Colombo No 1 55281, Indonesia

Corresponding email: ad121@ums.ac.id

Abstract. Gravity is one of the important concepts in elementary school. The teachers must understand it well without misconceptions. Furthermore, it is obvious that research on elementary teacher misconceptions of this concept is rarely done. The goal of this study was to describe the elementary school teacher's misconceptions of gravity. This was a qualitative research. The study was conducted on 30 public and private elementary school teachers in Surakarta. The test was used as data collection instrument consist of 3 true false questions with reasons. The teacher was to be a misconception if the justification of a statement was true, the discussion was wrong. The result indicated that 30% of teachers experienced misconceptions. They stated that objects on earth were not thrown into space due to the earth's magnetic force. Tides were caused by the rotation of the moon around the earth and the evaporation of water. Parachutists with closed parachutes fall faster because the earth's gravity was not obstructed. These indicated the need for efforts to improve teacher professionalism so that the quality of learning was better.

1. Introduction
Science is knowledge that contains many concepts. The concept is spread in several topic areas such as energy and the change (force, sound, heat, magnetism, electricity, light and simple aircraft), living things and life processes (including humans, animals, plants, and their interactions with the environment, and health), objects and their properties and uses (including liquid, solid, and gas), and earth and the universe (including earth, earth, solar system, and other celestial bodies). The concept in the scope of energy and the change material can be said to be more abstract and difficult to understand [1][2] than the concepts contained in other scopes. As with the concepts contained in the style. In a more detailed study, the force is divided into several materials, such as the magnetic force, the spring force, the gravity, and the electric force. Gravity is a material whose concept is often understood as a misconception [3], [4], [5], [6] for students. Misconception is a condition that is marked when the understanding of a student / learner is different from the generally accepted scientific consensus [7]. Misconception is a situation that shows the difference between conceptual ideas and generally accepted scientific consensus [8].

Misconceptions have a negative impact on the learning process in students [9]. Misconception is a big obstacle for students in learning science [10]. Misconceptions that are left continuously and are not immediately dealt with will have fatal consequences, ie students will have difficulty [11] students build
new knowledge based on their misconceptions [12] academic achievement will decrease [13], [14]. These adverse effects will continue to emerge if the misconception is left alone. So there needs to be an effort to reduce or find out the source of the cause of misconception.

[15] states that the main sources of misconceptions among students are students themselves, teachers, books, contexts, and ways of teaching teachers. Suparno also stated that teachers who lack knowledge of the material being taught are the cause of natural science misconceptions in elementary school students. This is reinforced by the statement [16]; [17]; [18] that teachers who do not understand the material or know the material incorrectly will cause misconceptions on their students. [19] also states that teachers who lack understanding of material can cause uncertainty in conveying it to students, which in turn leads to misconceptions. The review states that the teacher can be the main cause of misconceptions among students, with specific causes not mastering the content.

In elementary schools, science teachers have positions as classroom teachers. There is no special emphasis that class teachers must have an educational background in science (physics, chemistry, biology). This sometimes gives an assessment that classroom teachers who are not from an educational background to science will not master the concepts of science well. As stated by [20] that elementary school teachers who are not educated in natural sciences will tend to avoid teaching difficult science contents, especially physics, and prefer to teach biology material that is considered easier. If this becomes a habit and is left alone, over time the concepts taught will not be completely correct, and a misconception arises in the teacher himself. Thus, the explanation above is an urgency to carry out the process of diagnosing elementary school teacher's understanding of science material, one of which is the gravity.

Several studies have revealed the existence of students' misconceptions on the gravity, including [21] who have examined the misconceptions of force and gravity in high school students. [22] revealed a misconception in students who revealed that gravity is not a force, because it physically does not touch the object acting on it. Students also assume that objects fall down because they occur naturally. Gravity is an object and not a force. [23] also revealed the existence of misconceptions in junior high school students. They claim that the gravity only occurs in heavy objects [24]. Misconceptions on student teacher candidates. Their understanding states that heavier objects always fall faster. The above research shows that misconceptions have been conducted on students and students at various levels of the school, both from elementary school, junior high school, and senior high school. This shows that there is still no diagnosis of gravity material misconceptions in elementary school teachers. Thus, this study aims to diagnose misconceptions about gravity in elementary school teachers.

2. Methodology Research
This is a qualitative research with descriptive type. The population was all grade 4 elementary school teachers in Surakarta (as many as 120), with 30 teachers from public and private elementary schools, with accreditation A and B as a sample. The sampling technique was purposive random sampling technique. The sample consisted of teachers with an age range of 30 to 60 years, and 50% of them were certified educators. Data collection techniques are done by tests. The instrument used was a misconception detection test on gravity topic in the form of True or False with reason. This instrument has previously been through the validation process by two experts in the field of Natural Sciences, and has been declared valid and reliable, so it is ready to be used to collect data. The data is analyzed by referring to indicators of concept understanding formulated by [25], namely "understanding", if "correct" in determining the truth of a statement and its reasons; "Misconceptions" if determining statements is true, but the reasons are wrong; "Do not understand" if in determining the truth of a statement along with the reasons it is considered wrong; and "guess" if in determining the truth of the statement is considered wrong, but the reason is correct. The data validity is seen by observing and synchronizing the answers from the respondents several times).
3. Result and Discussion
Understanding the concept of gravity from elementary school teachers is presented in Table 1.

Table 1. Categories of Understanding the Concept of Gravity

| Question | Categories of Understanding the Concept (%) | Sum (%) |
|----------|--------------------------------------------|---------|
|          | Understand | Misconception | Not Understanding | Guess |         |
| A        | 60.00     | 20.00         | 6.67            | 13.33 | 100     |
| B        | 70.00     | 10.00         | 16.67           | 3.33  | 100     |
| C        | 16.67     | 60.00         | 20.00           | 3.33  | 100     |
| Average  | 48.89     | 30.00         | 14.44           | 6.66  | 100.00  |

Based on Table 1 it can be seen that 48.89% of teachers understand the concept of gravity well. As many as 30% of teachers experienced misconceptions, 14.44% of teachers did not understand the concept, and 6.66% of teachers guessed the concept.

Some level of understanding of the concept of gravity can be explained through the teacher's answers to the following questions.

3.1. Question A (True - False) Objects on earth are not thrown out of space because of the magnetic force between one object and another.
In this question, 60% of teachers have understood the concept well. They have stated that objects on earth were not thrown out of space not because of the magnetic force between one object and another, but because of the earth's gravity. As many as 20% of teachers experience misconceptions, which are marked by statements that objects on earth are not thrown out of space not because of the magnetic force between one object and another, but because of the earth's gravity. However, there are several reasons for incorrect details including: a) because earth objects are still in the scope of the atmosphere, and are influenced by the speed of rotation of the earth, b) due to the magnetic attraction on earth, c) there are gravity or magnetic forces of the earth that are cause objects on earth are not thrown out of space, d) the attraction of the earth is stronger than the force of gravity outside the earth except the sun. The reason is not in accordance with scientific conceptions.

According to scientific conceptions, objects on earth are not thrown out of space because of the gravity. Gravity is the force of attraction between mass objects. Objects referred to in the context of the matter are objects on the face of the earth and the earth. Objects on earth have a mass of m1 and the earth has a mass of M2.
The two objects are separated by \( r \). Gravity is a symptom of the appearance of interactions in the form of attraction between objects that exist in nature. Every object in nature experiences a gravity. According to Newton, if there are two objects with mass in close proximity between the two there will be gravity or forces of attraction between masses, as presented in Figure 1.

The magnitude of this gravity force corresponds to Newton's Law:

"All objects in nature will attract other objects with a force whose magnitude is proportional to the product of the mass of the particle and inversely proportional to the square of its distance", then the magnitude of the gravity between the two objects can be calculated by the formula:

\[
F = G \frac{m_1 M_2}{R^2}
\]  

with : \( F = \) gravity (Newton); \( m_1 = \) mass of objects on earth (kg); \( M_2 = \) earth mass (kg); \( R = \) distance between objects (m); \( G = \) gravitational constant \((6.67 \times 10^{-11} \text{Nm}^2\text{kg}^{-2})\). From the above equation it can be seen that the magnitude of the attractive force between objects that exist on earth and the earth will be even greater if the two bodies are also large. In this case, the mass of the earth (\( M_2 \)) is greater than the mass of objects on earth (\( m_1 \)). Earth with a larger period will be more powerful to attract other objects with smaller times. This is why all objects on earth always fall toward the center of the earth, which turned out to be pulled by the earth which has a greater time. The gravity will be greater if the distance between the two objects that pull each other to pull smaller (getting closer).

The teacher assumes that the gravity is the same as the magnetic force of the earth, thus causing objects on earth not to be thrown out of space. Another understanding why objects on earth are not thrown into space is due to the magnetic attraction that exists on earth. The scientific concept states that the earth is a large magnet. The earth’s magnetic north pole is at the south pole of the earth, and vice versa the earth’s magnetic pole is at the south pole of the earth. But unfortunately, the teacher has not explained to detail in accordance with this scientific concept. The teacher states that "the pull of the earth is stronger than the force of gravity outside the earth except the sun". From this statement it can be concluded that the teacher understands that the earth has a stronger attraction when compared to the attraction of objects outside the earth. But the pull force of the earth itself is smaller than the sun. There is no further explanation for this statement.
The teacher argues that objects on earth are not thrown because objects on earth are still in the sphere of the atmosphere, and are influenced by the speed of rotation of the earth. Another reason is the attraction of the earth is stronger than the force of gravity outside the earth except the sun. The choice of words from the earth's gravity and the gravity is inconsistent, and this also raises a doubt whether they have different or the same meaning.

3.2. Question A (True - False) The cause of sea water can experience ups and downs is the attraction of the earth.

In this question, 70% of teachers have understood the concept well. They have stated that sea water can experience ups and downs not because of the attraction of the earth, but because of the attraction of the moon and the attraction of the sun. Tidal water is an event of high and low sea level changes due to the attraction of objects in the sky, especially the sun and moon against the mass of sea water on earth. Tide means rising sea levels, while low tide is an event of falling sea levels. Because the distance of the moon to the earth is closer when compared to the distance of the sun to the sun, then the pull force of the moon against the earth is what has a greater influence on the ebb and flow of sea water compared to the pull of the sun. The magnitude of the attraction of the moon and the sun towards the earth depends on the mass of the object and the distance between the two objects that attract each other. The moon gives a greater pull than the sun. Although the mass of the moon is smaller than the sun, but the moon is closer to earth. This event can be explained through the Figure 2.

Figure 2. The scheme of attraction in tidal events
The biggest tides occur in phases 1 and 2 (new moon and full moon), which is when the sun, moon and earth are in a straight line. This highest tide occurs because there are two objects namely earth (object 1) and the moon and sun (object 2) which attract each other. At the time of the new moon, the position of the moon and the sun will attract the earth. Although the mass of the moon is smaller than the sun, but the moon has a closer distance than the sun. So that the two objects (the moon and the sun) will pull together the earth together, and the easily drawn part of the earth is the compressible part, which is sea water. Thus, there was a maximum tide of sea water. In the full moon phase, the position of the moon is closer to the earth, when compared to the sun, so the more dominant is the mass of the moon, not the mass of the sun. But when the position of the sun, earth, and moon is in 90° position (figure 2), the lowest tide will occur. This is because the force of the moon and the force of the sun will weaken to one another, so that as a result objects on the earth that are drawn are also weak (a little). The part of the earth that is spread by sea water will be greatly influenced by the gravity of the moon. As a result, the area facing the moon will experience a high tide, while the area that is perpendicular to the moon's position will experience low tide.

10% of teachers experience misconceptions in this section. They claim that sea water can experience ups and downs not because of the pull of the earth, but the pull of the moon. Another reason for the tides is the moon's revolution against the earth. This reason can actually be deepened by respondents in explaining how sea water can experience tides. But this was not done. The explanation is only limited to the reason for the existence of a moon revolution against the earth. The moon revolution against the earth is a lunar event circulating around the earth. The circulation of the moon to the earth gives rise to the appearance of different phases of the moon. While others claim that the cause is water evaporation. Evaporation or evaporation of water is the event of a change in the form of a liquid into a gas. There is no connection whatsoever between evaporation and tides. It can be understood that the teacher has a factual understanding related to events, namely tides and evaporation of water. Abstract factual knowledge from tidal events is still considered difficult for teachers to understand correctly. Likewise, factual knowledge of water evaporation events. Each has a different concept, but the teacher understands it as something that is interrelated. It can be seen that the teacher likens the event of rising sea water because seawater evaporates. It can also be said that the conceptual and procedural understanding of teachers still needs to be improved. Conceptual knowledge includes principles (rules), laws, theorems or formulas that are interrelated and well-structured [26] Conceptual knowledge includes classification and category knowledge, basic and general knowledge, theoretical knowledge, models and structures. Tidal water is related to the theorem of gravity with the magnitude of the force which can be calculated using Newton's Law formula. Whereas in the event of evaporation of water there is basic and general knowledge about the form of objects and their properties. Microscopically, this water evaporation event is also related to the molecular structure of liquid objects and gas objects. As explained through the figure 3 and 4.

![Figure 3 Molecule structure of liquid](image1.png)  ![Figure 4. Molecule Structure of gas](image2.png)
When viewed from its molecular structure, liquids have medium density, while gases have a very small density. This is the reason why gaseous substances can evaporate in the air, which is none other than because its density is very small.

Based on the analysis of answers, the teacher does not have the expected conceptual knowledge. Conceptual knowledge is a type of cognitive domain, where understanding involves cognitive processes. According to Bloom, the dimensions of the process of cognition consist of remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). Understanding of conceptual and procedural knowledge involves cognitive processes at the C4, C5 and C6 levels, or what is often referred to as high-level thinking (HOTS).

3.3. (B - S) Based on the picture above, picture B reflects that the parachutist jumps more easily than picture A.

| Figure | Position |
|--------|----------|
| A.     | When free falling just after the jump and before the umbrella opens |
| B.     | Fall to the ground after the umbrella opens |

In this question, 16.67% of teachers have understood the concept well. They have stated that parachutist B is no easier to jump down than parachutist A. 60% of teachers experience misconceptions in this section. They claim that "the parachutist B reflects that the parachutist is easier to jump down than picture A" is wrong. The comments given are also not in accordance with scientific conceptions. The reason given by the teacher has not described the detailed concept related to Newton's Law II. The teacher points out the reason that parachute B is slower to the ground because the parachute has opened; parachute A is not open so that it does not prevent falling down, parachute A's gravity is stronger, parachute B has a barrier, and parachute B is slowed by parachute.

Based on scientific conceptions, the phenomenon applies Newton's Law II, which states that the magnitude of acceleration depends on the resultant force and is inversely proportional to mass [27]. The teacher is only able to explain concepts that are observed concretely, which only lead to factual knowledge. Conceptually, the working principle of skydiving can be described with Newton's Law II:

"The acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and it inversely proportional to the mass of the object".
This is summarized in the equation:

\[ a = \frac{\sum F}{m} \]  

(2)

\( a \) = the acceleration of an object \((\text{m} / \text{s}^2)\); \( F \) = force acting on an object (Newton); \( m \) = mass of an object (kg)

Figure 5 describes the types that work on both parachutes.

**Figure 5.** Descriptions of force type that work on parachute

Figures 5A and 5B show two parachutes with the same mass. Figure A uses an open parachute, and B is not open. In figure A, the parachutist has a mass of \( m \), because it is pulled by the acceleration of gravity \((g = 9.8 \text{ m} / \text{s}^2)\), then the parachutist has a gravity of \( W = m \cdot g \). When the parachute opens with a certain surface area, there is an air-friction force against the parachute to descend down. So based on the Newton II Law equation, the amount of force \((\sum F)\) is equal to the gravity \((W)\) minus the compressive force of air \((F_u)\). The resulting acceleration is calculated by equation:

\[ a = \frac{(W - F_u)}{m} \]  

(3)

From figure 4 showed that the air friction in Figure A is greater (because the parachute has been opened), and the air friction in Figure B is smaller and even close to zero (none). From the equation it can be seen that with the equal mass \((m)\), the equal weight \((W)\), and different air friction forces, the acceleration \((a)\) produced in both events is shown to be greater when the parachute has not yet opened. The acceleration in parachute B is proportional to the magnitude of the earth's gravity \((g = 9.8 \text{ m} / \text{s}^2)\). It can be concluded that parachute A will be longer in the air and will not quickly fall, while parachute B will quickly go down.
Based on an analysis of respondents' answers, it showed that only cognitive processes at the level below HOTS are used by teachers to answer given problems. They only proceed at the level of knowing, understanding, and applying to the factual knowledge they see. The lack of high-level thinking in teachers is still very entrenched. Research [28] also proved that high-level thinking is positively correlated with the mastery of a learner's concept, but does not correlate with misconceptions. And this is in line with the results of this study. The lack of high-level thinking in this study does not affect the condition of teacher misconceptions. This is indicated by 48.78% of teachers who have understood the concept well. This number indicates more teachers who understand the concept than those who experience misconceptions. This showed that teachers who have high-level thinking skills will master the concept better.

The strong reason that caused the misconception in the matter of gravity experienced by 30% of elementary school teachers was that they did not master the material. In this study, elementary school teachers in Surakarta who had an educational background in science were only about 15%, i.e., there were 5 teachers. Many teachers who have no educational background to science, even though they have been educated in elementary school teachers who teach all subjects including science, still have differences in mastery of concepts.

4. Conclusion
The result indicated that 30% of teachers experienced misconceptions. They stated that objects on earth were not thrown into space due to the earth's magnetic force. Tides were caused by the rotation of the moon around the earth and the evaporation of water. Parachutists with closed parachutes fall faster because the earth's gravity was not obstructed. These indicated the need for efforts to improve teacher professionalism so that the quality of learning was better. In addition, the need for the detection of misconceptions on other topics.

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