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# Misconceptions on Gravitation among Class IX Students of CBSE

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***Abstract***

*Misconceptions are the wrong ideas/ imaginations developed in the schema of the student. These ideas of any phenomena certainly differ from the commonly accepted ideas/ conceptions by the scientists of global science communities. Misconceptions may occur in many ways like naïve beliefs, peer group discussion, through wrong interpretation by teacher, by multimedia etc. In the modern era, online learning is playing a vital role in science. In this study the misconceptions were identified by the administration of a self-made two-tier diagnostic test based on the gravitation chapter of class IX of the NCERT. This study prevails many misconceptions that exist in the schema among the students of CBSE schools of Varanasi district.*

***Key Words****: Misconceptions, Gravitation*

## Introduction:

Education is a social endeavour to initiate individuals into the diverse forms of human knowledge enabling and ennobling them into the culture of learning to learn and innovate. Scientific knowledge constitutes a major chunk of the organized curriculum for the school going students and a sound understanding of this organized body of knowledge has been and will continue to be a central concern for all concerned.

Comprehension of the structure of knowledge in any discipline is a function of the understanding of the constituent concepts, often referred to as the structural unit of the discipline, with clarity. The fact explains the focus of the instructional efforts on enabling students to develop an understanding of the concepts with clarity (Siddharth, 2020). Any error in understanding of the concept by the student has a long-lasting effect leading to faulty organization of knowledge in the cognitive structure (Dhindsa & Anderson, 2011) as well as future learning at all stages in future. It is recommended strongly that the errors or faults in the students' conceptions need to be identified as early as possible to prevent further cognitive



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loss (Halim et.al., 2018). Consequently, identification and remediation of the misconceptions has been a popular, relevant and significant area of research among science education researchers (Isabelle, 2008; Resbiantoro & Setiani, 2022; Yip, 1998; Ariyani & Rusilowati, 2023).

The present paper communicates the research work carried out in the field of science education and centred around misconceptions related to two important concepts represented in the science textbook for Class IX published by NCERT and followed by the schools affiliated with CBSE.

**Origin of the Study**

Concept is an abstract idea that presents a summary of some complex idea making it convenient for communication. Concepts are formed as mental images which assist students in classifying his/her experiences and help them communicate accurately in science (Vinner, 1983). However, the misconception is also a common occurrence among the students at all levels manifested as inability to relate different concepts or incorrect classification of examples into relevant concepts, or over- generalization of the concepts (Bau-Jaoude,1991) and making it markedly different deviant from the standard view acknowledged by the scientific community (National Academy of Sciences, 1997) with quite a longer half-life.

Misconceptions have been a significant area of research in the field of science education (Vosniadou, 2020). Studies are reported in different subjects at school level such as biology (Yates & Marek, 2014; Kumandaş etal., 2019; Simpson & Marek,1988; Fisher et.al, 2002), physics (Chang et.al.,2007; Kuczmann, 2017; Resbiantoro & Setiani, 2022) and chemistry ( Chu & Hong, 2010; Adesoji & Babatunde, 2009; Al-Balushi et.al., 2012). Studies have also been reported at higher education levels in subjects such as in biology (Coley & Tanner, 2015; Stern et.al., 2018), in physics (Jacobs, 1989; Daud, 2015; Bozzi, et.al., 2019) and in chemistry (Zoller, 1990; Pérez et.al., 2017; Tümay, 2016;).

Studies on misconceptions in Indian context span over several decades even though with a lower frequency (Oberoi, 2017; Patil, et.al.,2019; Ramesh, et.al., 2020; Roy & Mohapatra, 2022). Further, the methodical advancements in assessment of misconceptions are even rare. Majority of the studies used the conventional methods of diagnosis viz. multiple-choice questionnaire (Rollnick and Mahooana, 1999; Oberoi, 2017; Kaur, 2013) and a few countable studies reported the use of two tier or three tier instruments for diagnosis (Gurel, et.al.,2015; Oberoi, 2017). Further, a majority of the studies had a wide domain

covering the entire content at a given class level. The researchers assumed that the diagnostic tests need to be developed and misconceptions need to be diagnosed specifically in individual topics. Such specificity helps in identifying the most significant misconceptions in the particular topic in an organized way. a need was thus felt to map the major misconceptions in a focussed way and using the more advanced technique of assessing misconceptions. The literature suggests the development and use of a two-tiered diagnostic tool to assess the existing misconceptions among the students (Mutlu & Sesen, 2015) as an effective way to diagnose the misconceptions (Treagust, 1988; Odom & Barrow, 1995). specificity of the study was attained by focussing on the physical science concepts or themes included in the science text book for class IX. Further a pilot study was conducted using the Physics Achievement Test (PAT) on a sample of 227 students from randomly selected eleven schools affiliated to CBSE in the city of Varanasi. The achievement test sampled items from five chapters (Motion, Force and Laws of Motion, Gravitation, Work and Energy and Sound) of class IX science textbook of NCERT. The test was developed and standardized following the ideal procedures including blue print preparation, item analysis and split-half reliability computation. The set of items related to the chapter on Gravitation had the highest percent students scoring below the z-score of -1σ. As such the diagnosis of misconception was focussed on the theme of Gravitation.

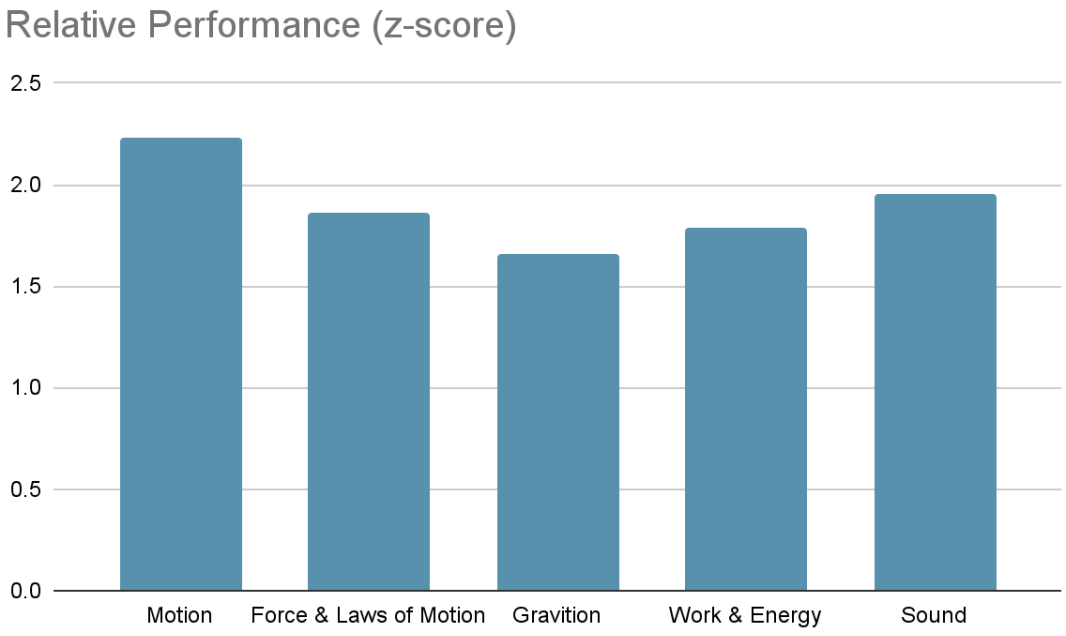



Figure 1: Percent Students Scoring Below -1σ.

The data from the pilot study was used to justify the selection of diagnostic test related to the theme. The study was thus conceptualized with the following guiding questions:

- What are the major misconceptions related to Gravitation among the secondary level students following the science textbooks from NCERT in general science?

**Purposes of the Study**

The study aimed to identify the major misconceptions related to Gravitation among the school-going students (Class IX) to create a rich database on the popular misconceptions for the teachers. The study also aimed, corollary to the primary purpose, to develop a two-tier diagnostic test related to the major concept *Gravitation* that can be used by the teachers to identify the students' misconceptions in their class.

**Method of the research**

The present study followed the descriptive survey method in accordance to the purposes of the study. The study was conducted on a sample of 423 Class IX students from different schools affiliated with CBSE in the city of Varanasi. CBSE schools are the most widely spread schools in the city as well as across the country. Further, CBSE keeps itself revising and updating with the latest government-initiated policies through MoE and issuing guidelines for the schools affiliated with it.

The sample was selected in multiple stages. Initially, a list of 9 (approximately 10%) schools were randomly selected from the list of 83 schools (sampling frame) in the city available at the official website of the Central Board of Secondary Education (https://www.cbse.gov.in/). The student sample was finally selected following an incidental random sampling technique.

*Instrument*:

A self-made two-tiered diagnostic test fashioned after Treagust (1988) with items written in accordance to a blueprint based on the content flowchart for the topics related to Gravitation (Figure-1) was used to collect the data. The two-tier diagnostic test was used because the most popular technique has been the use of two-tiered diagnostic tests used in several past studies (Aikenhead, 1987; Chen, Lin & Lin, 2002; Fetherstonaugh &Treagust,1992; Chau, Treagust & Chandrasegaran, 2009; Chu, & Chang, 2014; Odom & Barrow, 1995).

Tier-I of the test included 15 items with four alternatives including the correct alternative. Tier-II of the test included 4-6 short phrases representing a reason for the choices made at Tier-I. The phrases were empirically derived through analysis of open-ended responses obtained from students (n= 479) during the tool development phase. Two criteria were used to qualify the students' response in the open-ended section for inclusion as a reason in Tier-II for their choice viz. a) the response needs to have meaningful sentences that together present a reason for the choice made in Tier-I of the test and b) each such response needs to have a frequency count of at least ten percent of the sample. Those responses that had a frequency count of less than ten percent of the sample were considered as random error without any systematic reasoning framework. The qualified responses were further reworded to create a precise and concise phrase representing a misconception. Additional phrases (Reason) were identified through a review of literature on misconceptions related to Gravitation (Liu, Fang. 2016; Anggoro et.al., 2017; Khandagale and Chavan, 2017; Syuhendri ;2019).

The content validity of the tool was established through the expert opinion from three Physics teachers, one teacher-educator and one college-level physics teacher. The use of blueprint further added to the content validity of the test. The Cronbach-α coefficient for the two-tier Diagnostic Test was found to be 0.72 that was consistent with the reliability index reported in another study (Tsui & Treagust, 2010) and hence the tool was considered to be reliable.

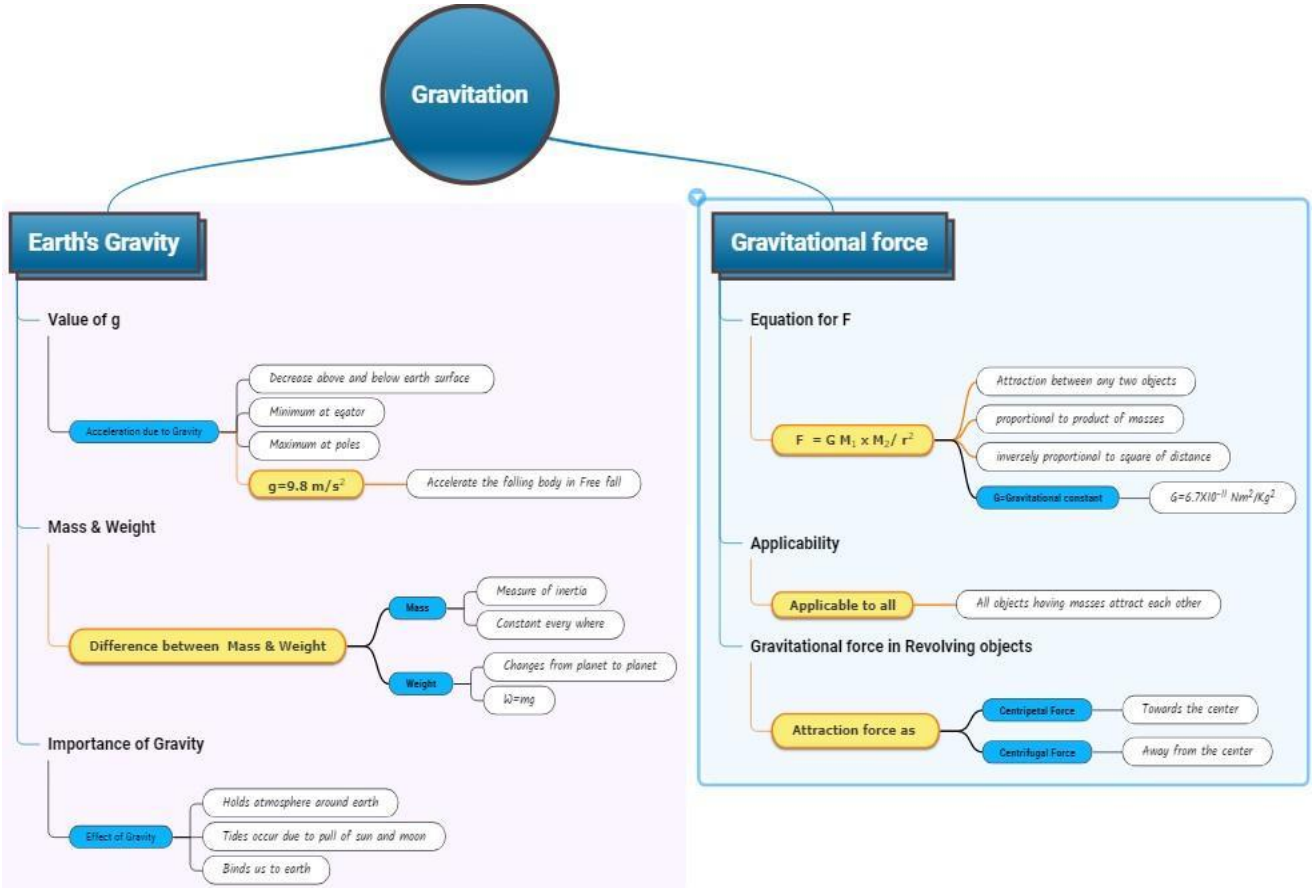



*Fig-2: Flowchart for Content Analysis (Gravity and Gravitational Force).*

**Data Collection and Data Screening**

The students' responses on Tier-I & Tier-II were scored as 01 for correct reasoning and 0 for incorrect reasoning provided respectively. The overall score for a student was thus as follows:

- 02 for correct responses on both Tier-I and Tier-II that represented correct conception.
- 01 for those with correct responses on Tier-I but incorrect on Tier-II representing the presence of misconception.
- 00 for those responding incorrectly on both Tier-I and Tier-II representing a lack of knowledge. (Baweja, 2008).

**Findings**

The data was analyzed in two steps. The first step analysis presents the students' performance on Tier-I of the Diagnostic Test and step-two analysis presents the prevalent misconceptions held by the students as revealed from the diagnostic test.

*A. Students Performance on Tier-I Diagnostic Test*

The analysis pertaining to students' performance on Tier-I is presented in Table 1 below:

The major concept for assessment of the misconception was Gravitation which was further analyzed into three concepts viz. *Gravitational Force*, *Gravity & g* and *Mass,weight &g*. Each concept was further analyzed into its sub-concepts. The student's performance with respect to the concepts is presented in Table-1.

Table 1**: Students' Performance on DTG-Tier-I (Concept-wise)**

| **Concept** | **Item No.** | **Correct Response** | **Incorrect Response** |
|---|---|---|---|
| Gravitational Force | 2,4,5,7,9 | 61.56 | 38.44 |
| Gravity & g | 3,6,11,12,14 | 67.88 | 32.12 |
| Mass, weight &g | 1,8,10,13,15 | 66.66 | 33.34 |

**Interpretation**

Table-1 shows that approximately **38 %** of students scored incorrectly on the concept of Gravitational Force, approximately **32 %** of students scored incorrectly on the concept of **Gravity and g**, and approximately **33%** of students scored incorrectly on the concept of **Mass and Weight**.

More than **60 %**of students responded correctly across the concepts as is evident from Table-1 and **over one-third** of the students responded **incorrectly** across all the concepts. The performances on different concepts are also presented in Figure-3.

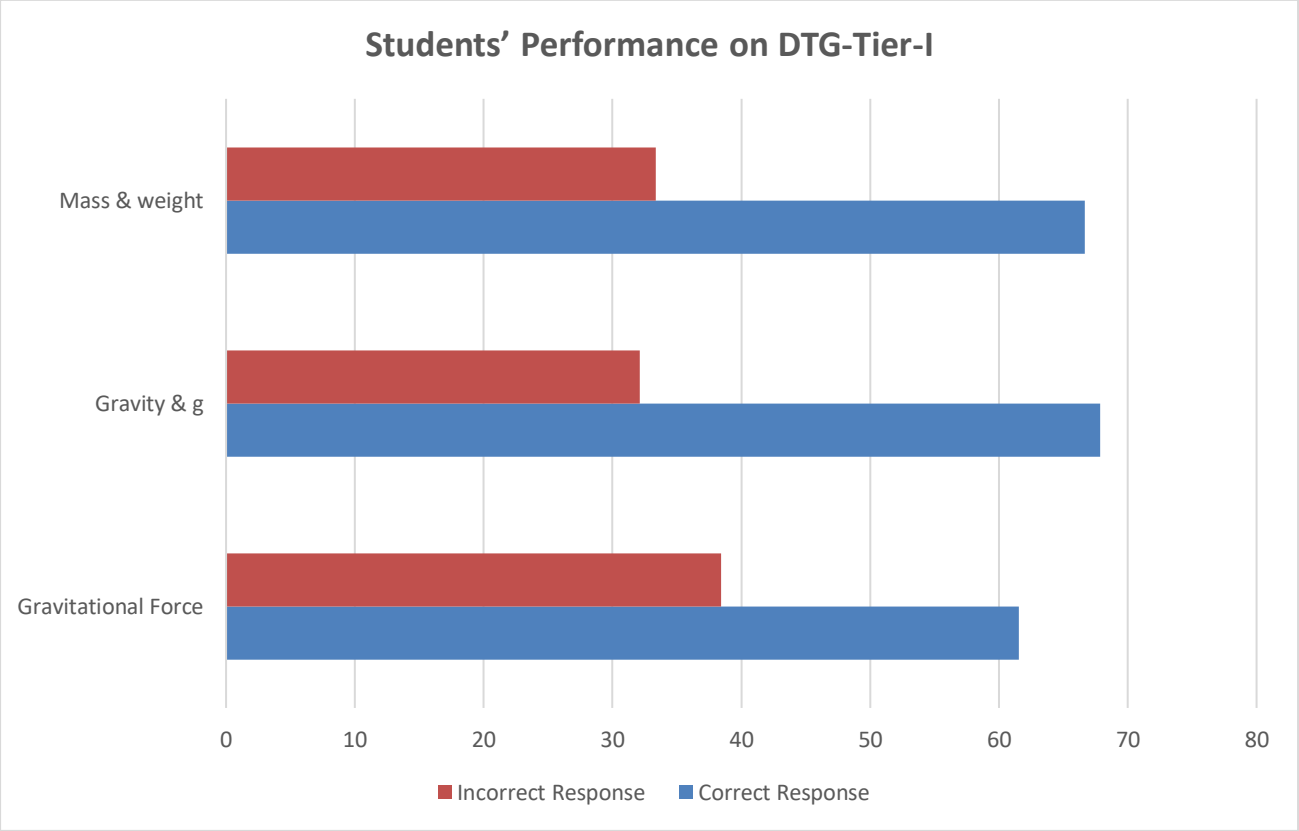



*Figure 3: Performance on DTG-Tier-I (Concept-wise)*

*B. Student's Misconceptions related to Gravity and Gravitational Force*

The list of major misconceptions related to Gravitational Force and Gravity among class IX students of CBSE schools as evident from the analysis of the students' response on Tier-II of the DTG is presented in Table 1. The misconceptions were analyzed and categorized into three broad concepts viz. '*Gravitational Force*', '*Gravity and g*' and '*Mass, Weight and g*' within the broad theme of Gravitational Force and Gravity. Major misconceptions are presented concept-wise in the following sections.

**1. Gravitational Force**

The misconceptions related to Gravitational force is summarized in Table 2 below.

Table 2**: Misconceptions related to Gravitational Force (n= 423)**

| S.No. | Misconceptions | n | % |
|---|---|---|---|
| 1 | *Gravitational force is seen only in case of massive* | 116 | 27.42 |

| | | | |
|---|---|---|---|
| | *objects.* | | |
| 2 | *Gravitational force is not applicable for all objects.* | 50 | 11.82 |
| 3 | *Gravitation force and gravity are the same.* | 45 | 10.64 |
| 4 | *There is no gravitational force in space where no medium exists.* | 94 | 22.22 |
| 5 | *Gravity exists only on the Earth.* | 58 | 13.71 |
| 6 | *The living things do not have gravitational force acting between them.* | 95 | 22.46 |
| 7 | *Inertia nullifies gravitational force among the bodies.* | 74 | 17.49 |

Gravitational force is universal in nature. The NCERT textbook describes it as force of attraction that applies between two bodies is directly proportional to the product of masses and inversely proportional to the square of the distance between them. (NCERT, p. 101). However, a large number of students (~27%, a third of the sample) failed to grasp the essence of gravitational force and believed that Gravitational force is seen only in the case of massive objects and further misconceived that Gravitational force is not applicable for all objects (~12%).

Gravitational force exists between any two bodies (NCERT, p.102). However, students held the misconception that the gravitational force is applicable only between the objects on earth (13 % approx.) and that space has no medium and hence no force exists (~22%). Further several students misconceived that Gravitational Force is applicable in context of only non-living objects and it could not exist between living organisms (~22%).

Gravitational force and gravity are two different concepts. Gravitational force exists between any two bodies of universe Whereas gravitational force is termed as gravity in case of earth (NCERT, p, 103). A considerable size of the sample misconceived that the two concepts are one and the same (~17%) revealing that they missed to grasp the difference between the two at a subtle level.

**Gravity and 'g'**

A total of nine misconceptions identified related to the concepts of Gravity and 'g' and their interrelationship. The misconceptions and their frequency of occurrence is presented in Table 3 below.

Gravity is defined as the attraction force between earth and object under the influence of acceleration due to gravity (NCERT, p.103). The value of 'g' is given to be 9.8 $m/s^2$ near the surface of earth. Further 'g' is a variable while 'G' is a constant. The student missed out in identifying this important difference and considered both as constants (~10%). Another important misconception was that 'G' and 'g' as one and the same term with identical numerical value (~26%).

*Table 3:* **Misconceptions related to Gravity and 'g' (n= 423) (Item Nos.** 3,6,11,12,14 **)**

| S. No. | Misconceptions | n | % |
|---|---|---|---|
| 1 | *G and g are the same variable and have the same value.* | 112 | 26.48 |
| 2 | *Acceleration due to gravity (g) has a constant value.* | 44 | 10.40 |
| 3 | *Heavy objects fall faster in all conditions.* | 84 | 19.86 |

The concept of 'g' has a significant implication in the explanation of free-falling bodies. However, a chunk of the sampled students believed that the heavier objects will always fall faster than the lighter objects irrespective of whether they are falling in the air or in vacuum (~19%). These students failed to grasp the role of mass in determining the pace of free-falling bodies.

**Weight, Mass & 'g'**

One of the significant ideas in the chapters one related to the interrelationship between mass, weight and "g". The students' misconceptions related to this relationship are presented in Table 4 below.

| Table 4**: Misconceptions related to Weight, Mass and 'g' (n= 423)** | | | |
|---|---|---|---|
| **S. No.** | **Misconceptions** | **n** | **%** |
| 1 | *Weight is inversely proportional to gravity.* | 64 | 15.13 |
| 2 | *Value of g depends on the object's mass falling near the earth's surface.* | 60 | 14.18 |
| 3 | *Mass changes and depends upon the gravitational force.* | 58 | 13.71 |
| 4 | *Weight does not depend upon acceleration due to gravity.* | 107 | 25.30 |
| 5 | *Mass and weight are the same physical variables.* | 70 | 16.54 |

One of the applications of the concept of 'g' in relation to weight is seen in explanation for free fall of bodies in air and in vacuum. Weight is defined as a product of mass of object and acceleration due to gravity g (NCERT, p.103). However, many students held the misconception that weight and 'g' are inversely proportional to each other. (~15%). Another important misconception related to this relationship was that near the surface of the earth there is a direct relationship between 'g' and mass of the body (~14%).

Further students have misconceptions that mass changes and depends upon gravitational force (~13%) and they also think that weight does not depend upon acceleration due to gravity (~25%). The students also expressed the reasoning and have misconception that they cannot differentiate mass and weight (~16%).

## Conclusion

Gravitational Force and gravity are a problematic topic for the secondary level students (Yılmaz, 2001; Khandagale & Chavan, 2017; Syuhendri, 2019;). The study found several misconceptions related to the topic among the students of Class IX in Varanasi city of Uttar Pradesh in India. However, several of the misconceptions identified in the present study are universally reported across several studies. For example, the misconception that *Mass and weight are the same physical variables* was reported in earlier studies as well (Métioui & Trudel, 2021). Similarly, the misconception *Heavy objects fall faster in all conditions* was also reported in previous studies (Syuhendri, 2019). However certain misconceptions were

also reported in the present study that was not located in any study included in the review of literature. The occurrence of such misconception reveals that the misconceptions can be context specific as well depending upon the instructional approach (Qian & Lehman, 2017) in different contexts.

The study is a rare study since very few studies on misconceptions are conducted at the school level and is even a rarer occurrence in the Indian context. The study was also unique in its methodical approach using the two-tiered Diagnostic Assessment (Chen, Lin & Lin, 2002; Treagust, 1986) adding more validity to the findings (Gurel et.al., 2015). Most of the studies, particularly in the Indian context, employed one step diagnostic instruments (Chakraborty & Mondal, 2012; Jain, 2014; Khandagale, et.al., 2017; Deshmukh, & Deshmukh, 2007) with only countable studies employed two-tiered diagnostic test (Baweja, 2008).

The findings of the study are a rich resource that presents an empirically established list of misconceptions related to an important topic in the science curriculum of secondary level students. The findings are useful for the future researchers to design specific instructional strategies to remedy the misconceptions. Second, it serves as a resource for the teachers to make informed decisions while planning their lessons in light of the misconceptions that exist among a sizable number of students at the secondary level.

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