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Remediating misconceptions related to particulate nature of matter using video animation: An action research

Yonten Chophel
Daga Central School, Dagana, Bhutan
yanphel7@gmail.com

ABSTRACT

Misconception sabotages the meaningful learning. Young learners can have misconceptions about the science concepts with which they interpret their new experiences, hampering the development of canonical scientific knowledge. Identifying and remediating the misconceptions of the learners is an important task as an educator. Therefore, this study aimed to explore the misconceptions of the 9^{th} grade students on particulate nature of matter (PNM) concept and effectiveness of the use of video animations in remediating those misconceptions. The study adopted a mixed method approach. The sample consisted of 20 students studying in 9^{th} grade of Daga Central School in Bhutan. The misconception was identified using the certainty of response index (CRI) diagnostic technique. The study revealed 10 kinds of misconceptions held by students related to PNM, under the four themes, i.e., All matter is made of discrete particles, Space between the particles is empty, Particles are in constant random motion, and Bonds or forces exist between particles, the number of students' having misconception on the particulate nature of matter concept reduced considerably in the post-test after the use of video animations as the intervention. The study also revealed that most of the misconceptions that student possesses were rooted in their inability to understand the chemical concepts from macroscopic, sub microscopic, and symbolic perspective. The study contributed in two aspects: first, the study identified four themes in which students had misconceptions, alerting educators to be cognizant when involving in discourse of PNM concepts. Second, the study suggests that use of video animations as a potent strategy to teach PNM concepts to help students develop the canonical scientific knowledge on PNM concepts, as demonstrated by this study.

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INTRODUCTION

Science education in Bhutan started with borrowed curriculum from India in the 1960s (Dema & Tshering, 2020). Over the few decades, there was gradual change in the curriculum, most notable are: new approach to primary education (NAPE) in 1986 for classes IV to VI mainly to promote science based on Bhutanese natural and social environment and more recently National School Curriculum Conference in 2016, aimed at screening and rationalizing the curriculum (Wangchuk, 2019). As a developing nation, Bhutanese government advocates the importance of science education as it is central to creation of workforce in the development of the country. In order to understand the mechanism of how natural world and universe works, knowledge of science is indispensable, as the well-being and lifestyle are largely affected by the knowledge and skills of science. All the matters that exist in the universe are the subject of study that chemistry undertakes and to explore the world more, the answer lies in the study of chemistry as "chemistry is the study of substances; their properties, structures, and the changes they undergo" (Mondal & Chakraborty, 2013, p.7). As the study of science begins with the direct observation of nature particularly of matter, the study of chemistry is said to be "central" to the study of science (Modal & Chakraborty, 2013). But for a person with no chemistry knowledge, by observing from afar they will see only the "forest", not the "trees" and certainly not the atoms and molecules of which matter is composed, whose properties ultimately determine the nature and behaviour of the matter that is being examined. Therefore, learning in science should be based on scientifically valid concepts; otherwise, there are chances for having misconceptions.

Misconceptions are the ideas or concepts that are being held by students which contradicts or are not scientifically true. Misconceptions can occur in students from various sources and in various stages of their development. In the study of chemistry, owing to the fact that the chemical education encompasses the understanding of chemical concepts through three distinct level: macroscopic level (tangible), sub-microscopic level (atoms, ions, elements) and representational level (symbols, formulae, equations) (Johnstone, 2000), the occurrence of the misconception is inevitable, more so in the concepts which requires the understanding of the sub-microscopic level. PNM concepts demands understanding from a macroscopic, sub-microscopic and symbolic level; hence the topics discussed under the PNM concepts are difficult to understand, and children often use macroscopic observable characters in explaining the microscopic and sub-microscopic concepts, which is often misleading and wrong concepts leading to prevalence of misconceptions. PNM is one of the basic topics in science education, particularly in chemistry. It encompasses topics such as matter structure and properties, matter phases and phase changes, conservation of mass, chemical reactions and bonding, ions and solutions (Adadan & Savasci, 2012; Kapici & Akcay, 2016). In order to comprehend these topics, students should have sound knowledge of PNM.

Over the last three decades, the misconceptions in PNM topped the list of most researched topics and are widely reported in the literature (Badrian et al., 2011; Talanquer, 2009). However, there is no research being done on this topic in Bhutanese context. This study aims to address this gap by investigating and reporting on the misconceptions of PNM. Moreover, in Bhutan the interest of the students toward learning science is a concern; the lack of interest and poor performance in science subjects, particularly in chemistry, can be attributed to lack of basic knowledge. For instance, study by Royal Education Council of Bhutan revealed that for both basic and advance academic skills students are performing below expectations of their grade level (as cited in Chophel & Norbu, 2021), this finding is further supported by Bhutan Council for School Examination and Assessment [BCSEA] (2019) report that found Bhutanese's students having higher success rates in items requiring lower cognitive skills, while significant gap in the performance in more demanding tasks such as, analytical and logical reasoning were observed. The possible reason for the above scenario can be due to prevalence of misconceptions.

Misconceptions impede authentic learning and are nuisance in advancing the science education; if not corrected, it might mislead the learners and cause serious consequences. Therefore, it is crucial to investigate the prevalence of misconceptions and design or incorporate appropriate strategies to correct the misconceptions (Taber, 2001). As the role of a teacher is to shape and mould students' knowledge, skills, and values in becoming a person with substance and to lead a successful life (Dela Fuente, 2021). The findings of this study will be helpful to teachers in the following ways, in understanding the misconception held by the students on PNM concepts, in planning the appropriate lesson incorporating the appropriate tools to correct the existing PNM misconceptions among the students. The findings will also serve as the milestone in understanding the scenario of the misconception of PNM among Bhutanese students and will inspire fellow teachers to be reflective of their teaching and be mindful of possible misconceptions that their students might possess.

Objectives

The study aims to identify the misconceptions on the particulate nature of matter among grade 9 students and then try to investigate how effectively use of video animations in teaching can overcome those misconceptions. Specifically, the study sought to:

1. Investigate and identify the prevalence of misconceptions regarding the particulate nature of matter among grade 9th students.
2. Investigate the effectiveness of video animations in addressing the misconceptions on particulate nature of matter.

Research questions

1. What are the misconceptions among grade 9th students on particulate nature of matter?
2. Is it possible to overcome students' misconceptions about particle nature of matter by using video animations in the classroom?

LITERATURE REVIEW

Misconceptions

Bahar (2003) summarizes misconceptions as corresponding to concepts that have peculiar interpretations and meanings in students' explanations that are not scientifically accurate. Some researchers refer to misconceptions as “alternative conceptions” to show intellectual respect to the learner who holds those ideas (Bahar, 2003). On the contrary, Abimbola & Baba (1996) further differentiates misconceptions and alternative conceptions. They defined “misconception” as an idea that is in conflict with scientific notions. Alternative conceptions, on the other hand, are ideas that have their own value and are not considered incorrect. "Naive conceptions" is another label used to indicate misconception; it is closely related to the developmental stages of children. It usually implies that conceptions are caused by children wanting to explain their environment (Ridgeway & Dunston, 2000). Regardless of how misconceptions are defined in research, they still refer to an understanding that contradicts current scientific thought (Modell et al., 2005).

Sources of Misconceptions

According to Mondal and Chakraborty (2013), despite various sources of misconceptions, broadly it can be categorized into three distinct sources: text book, school and everyday knowledge: *Textbook based misconceptions*: many studies have documented the existence of misconceptions in textbooks (Abimbola & Baba, 1996; Abraham et al., 1992). In most of the chemistry textbooks; many basic chemistry concepts either lacked precision, or invoke ideas which are unfamiliar to beginners and they have to accept it on trust (Nelson, 2003). Some of the misconceptions are conceived from varying imprecise definitions in the textbook (Taber, 2001). Some of the possible reasons of the other misconceptions in the textbook can be traced to problems of wording and specific terminology used, mainly when introducing the concepts of substances, the particles of which they consist and chemical symbols used for their representation.

School based misconceptions: as students are being lectured in the school, especially when they are learning difficult subject, the inappropriate or inaccurate language used by teacher to describe and to teach difficult concepts might lead to conceiving misconceptions (Jarvis & McKeon, 2005). Occasionally, despite the competent and qualified teachers some questions remain open and inadequately solved as a result it gradually leads to misconception as the student try to understand the question many alternative conceptions may be generated by students which might not be synchronized with scientific facts. Sometimes it is the teacher themselves who held the misconceptions (Taber, 2001; Tatar, 2011); they are prone to have misconceptions when their scientific knowledge is weak, and their confidence in the material is low (Jarvis & McKeon, 2005), or even if the instructions of teacher are accurate, children who do not have the necessary prerequisite knowledge to make the intended sense of it, creates the alternative framework that will affect subsequent learning (Taber, 2001).

Everyday Knowledge based misconceptions: use of students preconceived knowledge, belief system and previous learnings (Chin & Chia, 2004; Kapici & Akcay, 2016) and the common-sense reasoning, every day analogies influence the use of non-scientific words or language (Crespo & Pozo, 2004; Hesse III & Anderson, 1992) which leads to misconceptions gradually. Hesse III and Anderson (1992) caution teachers in using metaphors and analogies which are specific to a certain culture or locality. Moreover, the everyday knowledge hinders the understanding of the scientific concepts (Crespo & Pozo, 2004).

Misconceptions on PNM

Many researchers have explored on PNM (Griffiths & Preston, 1992; Harrison & Treagust, 2002; Nakhleh & Mitchell, 1993; Othman et al., 2008; Özalp & Kahveci, 2015; Tsai, 1999) owing to the confusing nature of knowledge involved. Collectively, by summarizing the studies done on PNM; the misconceptions can be broadly categorized into four themes i.e., all matter is made of discrete particles, space between the particles is empty, particles are in constant random motion and bonds or forces exist between particles.

The prominent misconceptions among students are that they think matter as continuous and that it exhibits bulk properties (Harrison & Treagust, 2002; Nakhleh, & Mitchell, 1993; Othman et al., 2008). Likewise, Tsai (1999) reported that even though students have learned that the matter is made of discrete particles with constant motion and has empty space between the particles, students find it difficult to apply this theory to new situations. Moreover, Ozalp and Kahveci (2015) in their study with middle and high school students found that students most often tended to attribute properties of macroscopic matter to it sub-microscopic particles. Therefore, students tend to think that there is no empty space between particles, and that the particles are static (unmoving) (Griffiths & Preston, 1992: Nakhleh & Mitchell, 1993: Othman et al., 2008; Özalp & Kahveci, 2015).

Remedies to Misconceptions

There can be range of strategies to remediate misconceptions such as use of lab-demonstration, conceptual change, video animations and mind-mapping, etc., However, by understanding the nature of the misconceptions and the source of misconceptions that are associated with the PNM concepts, the video animations were deemed be the most appropriate strategy that can be employed to explain the concept clearly on the macroscopic and sub-microscopic level. Moreover, many studies (Chang et al., 2009; Ozmen, 2011; Stojanovska et al., 2012; Yezierski & Birk, 2006) also recommends video animation as an effective strategy in correcting the misconceptions related to PNM concepts.

METHODS

Research design

The research adopted mixed method approach: quantitative data is obtained via experiment, whereas qualitative data is obtained via semi-structured interview. Experimental design has several possible variations. One of these is a pre-experimental design where a single group of subjects undergoes a pre-test before being subjected to a treatment and post-test (Cohen et al., 2007; Örnek, 2007). A pre-experimental one group pre-test/post-test design was used in this study as shown in the Figure 1.

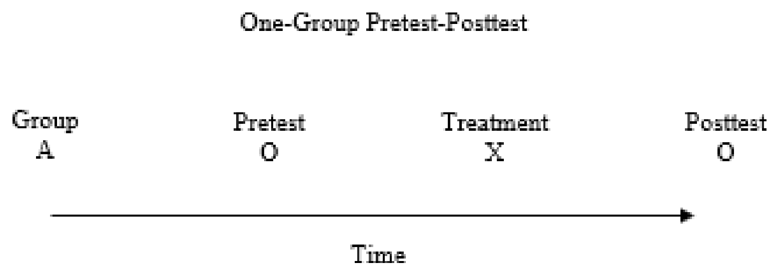

Figure 1. One-Group Pre-test – Post-test design (Source: Örnek, 2007)

Population and sample of the study

From the population of 150 grade nine students in the Daga Central School. The sample was selected using simple random sampling. All the students (population) are assigned number from 1 till 150 and then random number generator (using random online application: https://random.org) (Random.Org, 2021) was used to select the 20 participants (see Figure 2). The study consisted of 7 males, and 13 females, a total of 20 students. For the qualitative data collection, the researcher adopted purposive sampling, which included fair representation of gender, i.e., 2 males and 3 females a total of 5 students.

Research instrument

The instrument that was used for the diagnosis of the misconception was a closed format test items (MCQ) embedded with the Certainty Response Index (CRI). CRI technique is widely used in many misconception studies (Darwan, 2018; Hakim & Kadarohman, 2012; Mustami, 2016). This tool operates on the basis of certainty, by assigning the CRI index value of 0-5, which is similar to Likert type scale (6-point scale); [0] Totally guessed answer [1] Almost a guess [2] Not sure [3] Sure [4] Almost certain [5] Certain. This tool categorizes the response of a participant into four-quadrant, if a participant gets the answer wrong and his or her certainty index value to the response is low then it is just the *lack of knowledge*, not misconception, similarly if a participant gets the answer correct but his or her certainty index value to response is low then it is just the *lucky guess*, similarly if the participants get the answer correct and his or her certainty index value to response is high then he or she *knows the concept*, however, if the participant gets the answer wrong and has high certainty index value to response (he or she believes his or her answer is certain) then he or she has *misconception* (Table 1).

Table 1. Decision matrix for an individual student and for a given question.
Based on combinations of correct or wrong answer and of low or high CRI

	Low CRI (< 2.5)	High CRI (> 2.5)
Correct answer	Correct answer and low CRI (CL) Lack of knowledge (lucky guess)	Correct answer and high CRI (CH) Knowledge of correct concepts
Wrong answer	Wrong answer and low CRI (WL) Lack of knowledge	Wrong answer and high CRI (WH) Misconceptions

(Source: Adopted from Hassan et al., 1999, p.296).

The diagnostic test had two-part. Part A for demographic details and Part B with Multiple choice items coupled with CRI. There were 10 items in total, categorized into four broad themes, as shown in the Table 2.

Table 2. Items constructed based on the four themes identified under PNM concept

Description (thematic concept)	Code	Items
All matter is made of discrete particles	T-1	1-3
Space between the particles is empty	T-2	4-5
Particles are in constant random motion	T-3	6-8
Bonds or forces exist between particles	T-4	9-10

For qualitative data collection: semi-structured interview consisted of five guiding questions relating to the students experience on how video animation enhanced their understanding of PNM concepts.

Validity and reliability

The CRI embedded diagnostic test items were validated by a group of senior chemistry teachers and pilot tested in one of the schools in the same district. The guiding interview questions was also pilot tested and reframed to enhance its clarity.

Research process

Pre-test

The CRI embedded diagnostic test was administered and analysed to identify the presence of misconceptions.

Pre-test Data analysis

Data collected were analysed using descriptive analysis. The pre-test data revealed the existence of the misconception. In each theme, there were at least five (23%) or more people having misconceptions *(See Table 4)*.

Intervention

After understanding the prevalence of the misconceptions among students on PNM through the analysis of the pre-test, intervention to remediate the misconception was carried out. The main strategy used was video animations followed by discussion. The students were briefed about the video animations that they were going to watch and then it was followed by discussion sessions. Students raised their question and the researcher answered the questions with canonical scientific knowledge on PNM concepts. The video animations included in the intervention were selected using inclusion criteria inspired from the work of A. H. Johnstone on the concept of teaching and learning chemistry. He argues that understanding the chemistry concept requires understanding of the concepts on three levels: macroscopic (tangible), sub-microscopic (atomic and molecular) and symbolic (symbols and mathematics) level (Johnstone, 1993; 2000). A total of 120 open-source videos from the open video project, internet archive and YouTube were scanned, of which 12 videos animations in English medium were selected containing the representation of PNM concept from all the three levels.

Post-test

The post-test was conducted after the intervention, to understand if the misconception of participants has been corrected, how many have understood the concepts and how many still have the misconceptions. Additionally, another aim of the post-test was to check the effectiveness of the intervention. In the post-test, the same survey questionnaire was administered and then the data was collected and analysed to understand the effectiveness of the intervention used by examining the percentage of the students who understood the concept, still has the misconceptions, and do not know the concept.

Post-test data analysis

The data collected after the intervention was analysed and the interpretations and comparative analysis were done. The comparison highlights: how there was a change in the percentage of people having misconceptions before and after intervention, how the percentage of people who do not know the concept changed before and after the intervention, and how the percentage of people with correct concept changed before and after intervention. The key findings, interpretation, and discussions of the study are presented in the following section.

Interview

A semi-structured interview was conducted after the intervention to understand the effectiveness of video animations in clarifying their misconceptions.

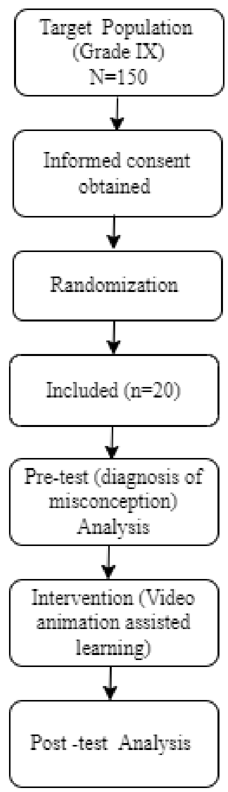

Figure 2. Flow chart showing the research process

RESULTS AND DISCUSSION

The pre-test analysis revealed that the students had misconceptions in all the four thematic concepts (as shown in Table 3). For instance, under the first theme (T-1), 45% of the students had misconceptions whereas 42% of the students did not know the concept while only 10% of the students knew the concept (see Table 3). Similarly, under the second theme (T-2), 55% of the students had misconception whereas 25% of the students did not know the concept while only 5% of the students knew the concept (see Table 3). Likewise, under the third theme (T-3), 35% of the students had misconceptions whereas 27% of the students did not know the concept while 29% of the students knew the concept (see Table 3). In addition, under the fourth theme (T-4), 23% of the students had misconceptions and 37% of the students did not know the concept while only 17% of the students knew the concept (see Table 3).

The post-test analysis revealed that there was overall improvement in the percentage of the students knowing the concept and notable decrease in the percentage of the students having misconceptions. For example, under the first theme (T-1), 75 % of the students knew the concept whereas only 25% of the students still had misconceptions (see Table 3). Similarly, under the second theme (T-2), 97% of the students knew the concept whereas only 3% of the students had misconceptions (see Table 3). Likewise, under the third theme (T-3), 97% of the students knew the concept whereas only 3% of the students still had misconceptions (see Table 3). Additionally, under the fourth theme (T-4), 97% of the students knew the concept whereas only 3% of the students did not understand the concept while there were no misconceptions being recorded (see Table 3).

Table 3. Comparisons of the Pre-test and Post-test data

Theme	N	Category	Pre-test	Post-test
			F (%)	F (%)
All matter is made of discrete particles (T-1)	20	Having Misconception	9 (45)	5 (25)
		Do not know the concept	8 (42)	0 (0)
		Knowing the concept	2 (10)	15 (75)
		Lucky guess	1 (3)	0 (0)
The space between the particle is empty (T-2)	20	Having Misconception	11 (55)	1 (3)
		Do not know the concept	5 (25)	0 (0)
		Knowing the concept	1 (5)	19 (97)
		Lucky guess	3 (15)	0 (0)
Particles are in constant random motion (T-3)	20	Having Misconception	7 (35)	1 (3)
		Do not know the concept	5 (27)	0 (0)
		Knowing the concept	6 (29)	19 (97)
		Lucky guess	2 (9)	0 (0)
Bonds or forces exist between particles (T-4)	20	Having Misconception	5 (23)	0 (0)
		Do not know the concept	7 (37)	1 (3)
		Knowing the concept	3 (17)	19 (97)
		Lucky guess	5 (23)	0 (0)

Item analysis of the theme *T-1* revealed that students had misconceptions that, *depending on the nature of the matter, the smallest/ fundamental particle will change*. Many of the students thought that the smallest particle in a brick is an atom, whereas the smallest particle in water is molecules. Additionally, students had the misconception that the water molecule in steam is smaller than ice and the particle (atom) will become larger or smaller with the change in temperature. Thus, these misconceptions are possibly the result of thinking that *particles are continuous and that it exhibits bulk properties* unable to distinguish macroscopic and sub-microscopic characteristics (Harrison & Treagust, 2002; Nakhleh, & Mitchell, 1993; Othman et al., 2008). Similarly, in *T-2*, students had misconception that *there will be always something filled in between the particles,* some believed that there is presence of air, pollutant, fluid, etc. they believed that space is non-existent and the particles are closely packed - there is no space between them "or" no place is completely empty. Thus, these misconceptions would have been possibly emerged from the conflict between their everyday life and the atomic model. Every day they see matters which are bulky and continuous without apparent empty space (Griffiths & Preston, 1992; Nakhleh & Mitchell, 1993; Othman et al., 2008). Moreover, teacher's use of language such as "Any empty space can be occupied by air" could have led to conceiving the idea of no place is completely empty.

Likewise, in *T-3*, i.e., the students had the misconception that *ink or perfume diffuses into the water and room respectively because of some unexplainable external force*. The source of this misconception can be attributed to their everyday life experiences, when they spread ink in the bottle of water, they only see the ink (macroscopic) spreading but not the atoms of the ink in constant motion (sub-microscopic), hence the source of misconceptions could be due to disharmony between the understanding of macroscopic and sub-microscopic level of PNM concepts (Kind, 2004; Nakhleh & Mitchell, 1993). Similarly, in *T-4*, i.e., the students had the misconception that the *reason why the gas remains uniformly distributed in the vessel and they don't fall to the bottom is due to repulsive and attractive forces between the particles*. The attractive and repulsive force ideas imply to static particles, confirming that particle movement in gas is difficult to understand. The 'attractive forces' suggestion supports the "clumped together" model, while the notion of repulsive forces "explains" the uniform distribution of particles (Kind, 2004). In addition, the students had the misconception that the pressure exerted by the air inside the tyre is due to attractive forces between the particles. Indicating that students are unable to understand that the gas particles are in constant motion. The source of these misconceptions can be attributed to the lack of understanding of concepts in a macroscopic and sub-microscopic level, the atoms (sub-microscopic) are always in motion, while the object (macroscopic) are static (Kind, 2004; Nakhleh & Mitchell, 1993).

Table 4. Students Misconception in Summary

Concept	Misconception
All matter is made of discrete particles (T-1)	(1) The smallest particle in water is a molecule. (2) The water molecules in steam are smaller than a molecule in ice. (3) The particle will become larger or smaller with a change in temperature.
The space between the particle is empty (T-2)	(4) Oxygen fills the spaces between the particles. (5) There is water vapour between the particles. (6) There are pollutants between the particles. (7) The space between the two particles is filled with fluids.
Particles are in constant random motion (T-3)	(8) Some unexplainable external force helps in the diffusion of perfume in the room. (9) The diffusion of ink in a beaker of water is because ink takes shapes of the beaker.
Bonds or forces exist between particles (T-4)	(10) The pressure exerted by the air inside the tyre is due to attractive forces between the air particles.

The considerable increase in the percentage of students knowing the correct concept from 10% in pre-test to 75% in the post-test in T-1, 5% in pre-test to 97% in post-test in T-2, 29% in pre-test to 97% in post-test in T-3 and from 17% to 97% in T-4, could be due to two possible reasons. First, students who can visualize chemical phenomena at the atomic or molecular level tend to develop good conceptual understanding. Perhaps the animations assisted the students in creating mental models of particle behaviour that they could use to answer the conceptual questions on the post-test. If students previously had inadequate particle models or did not even have particulate models, the animations could have helped in filling that void. A second plausible explanation is that conceptual change occurred. If the students previously had scientifically incorrect mental models of particulate nature of matter concepts in four identified themes, and the animations showed contrary but believable representations of particulate nature of matter. Thus, the students could have reconstructed their knowledge to be consistent with the canonical scientific explanation.

Although both of these explanations are plausible, exactly how the treatment worked is not known. However, the qualitative data revealed that the video animations were successful in explaining the sub-microscopic behaviour of particles, helping students to separate the macroscopic behaviour from sub-microscopic behaviour of particles. Five from five students agreed that the video animation elicited the sub-microscopic behaviour sufficiently.

For instance, student 3 (S3) opined that:

> *When we learn the PNM concept with the help of video animations, we are able to visualize the microscopic behaviour and properties of particles. Thus, we are able to understand the concept such as existence of empty space between the particles, constant random motion of the particles, etc. If not for the video animation, we cannot visualize or think.*

Similarly, S5 concurred with the above opinion:

> *I would prefer learning PNM concepts with the help of video animations in future, because the animations are an excellent way to represent the particles in visible manner, illustrating its behaviour and movements, thus helping us to understand its nature more precisely.*

From the above narratives, an important inference is that that teaching of PNM concepts using video animations helps to understand the concept in particle-level (sub-microscopic). This could have resulted in a significant increase in the percentage of people understanding the concept. As the analysis of the pre-test and the post-test data (see Table 3) the effectiveness of the intervention was evident: before intervention there were 45% of the student with misconception which considerably reduced to 25% after intervention in T-1. Likewise, misconceptions in T-2 considerably reduced from 55% to 3%, whereas misconceptions in T-3 also reduced considerably from 35% to 3%. Additionally, misconceptions in T-4 reduced to 0% from 23%. Thus, as suggested by the existing literature, use of particle-level animations does have a positive impact in addressing the misconceptions related to PNM concepts (Chang et al., 2010; Ozmen, 2011; Stojanovska et al., 2012). It is also interesting to observe that the effectiveness of the intervention varied across the four identified themes, however the analysis of this particular effect was beyond the scope of this paper.

CONCLUSION AND RECOMMENDATION

In chemistry, the particulate nature of matter serves as the foundation for the study of other concepts. Unfortunately, many students do not understand the relationship between the macroscopic and sub-microscopic representations in chemistry. Students simply transfer properties of the bulk substance to the particles that make up the substance. The concept of the particulate nature of matter is considered as one of the ‘simpler’ topics to be dealt with quickly at the beginning, and students generally do find questions on the particulate nature of matter the easiest in the examinations. However, as indicated by the diagnostic test in this study and other existing literature, the students have not understood the fundamental ideas of the theory. Misunderstanding of this concept then cascades to other topics such as chemical bonding, as it serves to establish an alternative framework in students’ minds that causes them to ‘misunderstand’ further material presented to them. This finding attests to the earlier point—that inaccurate prior knowledge would cause students to make sense of new material differently from the way it is intended.

The objectives of the study were to investigate and identify misconception and to investigate the effect of video animations in remediating the identified misconceptions related to PNM. The result of the study revealed the prevalence of ten kinds of misconceptions under the four themes in PNM concept. In addition, most of the misconceptions that have been identified revealed a weak understanding of the currently accepted model of matter. In this model, the matter is composed of small, mobile particles such as atoms, molecules, and ions. Thus, the particulate and kinetic aspect of the current model is poorly understood by the students. Students view the matter as the continuous medium that is static and space-filling. The result also revealed that among other possible strategies to remediate the misconceptions related to PNM, teaching with video animations can be a plausible alternative.

However, there were a few limitations of this study, researcher employed only one strategy to remediate the misconception due to time constrain. Future researches can compare the two intervention methods based on their effectiveness. In addition, the researcher didn't employ an interview tool to gather in-depth information on the misconception, which could be another potent technique future researchers can explore. Likewise, due to small sample (N=20), it cannot be possibly generalized as representative of the larger population.

Understanding PNM concepts requires the understanding of the chemical concepts beyond just the observable macroscopic level. Therefore, prior to teaching concepts related to PNM, teacher should understand students' prior knowledge and consider possibilities of presence of the misconceptions which are discussed here in this study, and take time to design and explain the concepts in sequential way: macroscopic level first, followed by sub-microscopic, and symbolic level to create relational understanding of the concepts as recommended by Talanquer (2009). As indicated by the findings, particle-level animations could be used frequently in chemistry classrooms to help students visualize particle-level behaviour. In conjunction with the animations, students should be also given opportunity to discuss and interpret the phenomena presented in the video and relate it to their everyday experiences and observations.

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