Difficulties in the Definition of Matter States

Taha Massalha

Abstract— **A matter in liquid state is known to attain the shape of the vessel which holds it – water is a glass will assume the shape of the glass. Solids, however, will retain their own shape wherever they are contained. What do these statements rely on and are they always valid?**

Index Terms—**Matter States, definite volume, definite shape, Moving particles.**

I. INTRODUCTION

Over the years, we have come up with a general picture of liquids and solids: **liquid matter has no definite shape but rather assumes the shape of its vessel**, whereas **solid matter has its own definite shape which remains unaffected by the shape of its vessel**. This is how the first property of solids and liquids is commonly perceived by the senses in the macro world. The second property, which comes from the micro world, is the density and movement of the particles. This property of solids and liquids is abstract and therefore less dominant in learners trying to establish whether a matter is in liquid or solid state. Local and world studies and text books all consistently support these definitions and perceptions of liquids and solids. This study will examine the limits and validity of these definitions.

The distinction between solids and liquids is further misguided by the failure of both definitions to consider amount as characterized by the ratio of the volume of a matter to that of the vessel volume which holds it. This study will therefore also review some relevant studies and suggest some pertinent conclusions.

II. LITERARY REVIEW

A. Liquids

The following quotes from the literature illustrate how liquids are commonly defined and how these definitions fit within their physical environment.

1. Freeman [1] defines liquid as “a state where the matter has no shape of its own but rather assumes the shape of the vessel which holds it.”

2. Horton’s [2] definition is that “A liquid is a matter of a definite volume however with no definite shape. When poured from one vessel to another, it assumes the shape of the vessel yet its volumes remains unchanged regardless of the vessel’s shape.”

3. According to Biggs [3], “Moving particles: Matter is made of moving particles. The state of the matter is determined by the amount of energy stored in the particles… the particles of a liquid matter move faster and have enough energy to move, allowing the liquid to attain the shape of the vessel which holds it.”

4. Dobson’s [4] definition is that “liquids have the capacity to assume the shape of the vessel into which they are poured.”

Also, our perception or description of reality may often be incorrect. With half the glass filled with water, we say that the water is shaped like the glass, however, in reality, it is only shaped like a half glass. Considering, therefore, that water assume the shape of a certain proportion of the glass, the most “realistic” definition is provided by Marshland [5]: “Liquid: A state or phase of a matter where the matter has a definite volume with no definite shape. Liquids assume the shape of the vessel portion which they occupy”.

Fig. 1: Dew drops have no definite shape! All the dew drops will have a definite shape!

On page 477 of their new book, “The Basics of Physics”, Galili & Ovadia [6], claim that “Since the properties of a liquid’s particles are unaffected by their orientation, they can easily change their mutual position and therefore attain the shape of the vessel where they are contained.”

B. Solids

Below are some conventional definitions of solids:

1. According to Freeman [1], “Solid: A state where the matter has a definite volume and a definite shape.”

2. Horton [2], holds that “Solid is the state of a matter which has a definite shape and a definite volume.”

3. Bigg's [3], definition reads: “Moving particles: Matter is made of moving particles. The state of the matter is determined by the amount of energy stored in the particles… the particles of a solid matter dangle in a fixed location and remain close to one another, providing the solid matter a definite shape as well as a definite volume.”

4. Dobson’s [4], definition is that “Solids have a definite shape and a definite volume.”

Taha Massalha, Head of M. Ed. Program for Science Education. The Academic Arab College for Education – Haifa, Israel. Phone/ Mobile No. 972 – 50 – 8226400.

5. Marshland [5], defines solids as "the state or phase of a matter which has definite shape and volume."

III. COGNITIVE DISSONANCE IN THE DEFINITION OF THE LIQUID AND SOLID STATES OF MATTER

Is it possible for the shape of a matter in "liquid" state to remain unaffected by the shape of the vessel which contains it? Consider, for instance, a drop of water, which does not assume the shape of the vessel where it rests. Is the answer, then, Yes? Some of the students may think so, and hence also that a water drop is not liquid, judging by the definition of liquids as reflected in the literature. Can this be true?

Similarly, can a matter in "solid" state assume the shape of the vessel which contains it? Consider, for instance, iron pellets which take on the shape of the glass bowl holding them. Is the answer, then, Yes? Some of the students may think so, and hence also that iron pellets are not solid, judging by the definition of solids as reflected in the literature. Can this be true?

Fig 2: One apple do not take the box shape, all the apples took the box shape!

In over thirty years of providing teachers training and refresher courses for elementary, intermediate and high school science (physics, chemistry and biology) teachers [7], we have repeatedly encountered the same erroneous perceptions which mostly originate in a very narrow view of the basic concept definitions, and the same lack of critical thinking – both in scientific studies and in science teachers (which explains the misconceptions held by their students).

The comparison between liquids and solids and between their respective capabilities of assuming the shape of the vessel or retaining their own original shape is inadequate and lacking, as we shall show hereunder. **We suggest that liquids may sometimes retain their original shape and not assume that of the vessel, which they occupy** (see fig. 1), whereas **solids may sometimes assume the shape of their holding vessel** (see fig. 2). None of the definitions of liquids and solids as provided above, when relating to the properties of liquids and solids, takes into account the important element of the **amount** of the matter [7].

A more thorough investigation of the properties of solids will show that everything we hold true by definition does not necessarily conform to the definition.

Fig 3: All the sand grains took a definite shape!

Let us consider sand, for example (see fig. 3). In a glass filled with "dry" sand grains, the sand will take the shape of that portion of the glass which it occupies. The same will hold true for rocks and apples: Apples will assume the shape of the box where they are stored (see fig. 2), with air filling up the spaces just like in the case of sand in a glass. Each individual rock, apple or sand grain is of a definite shape and volume, yet, together, they all assume the shape of their container.

Let us now take a deeper look into the properties of liquids (water). If we take a water drop and put it in a glass, will it be shaped like the glass? Apparently, a drop of water will retain its original shape and volume, except under an external effect (e.g. evaporation), just like a sand grain or a rock (see fig. 4). Yet, if we take a large number of water drops (a large amount of water), this property will change, similarly to the effect observed in rocks and apples.

Fig 4: Water drops on a glass

Nevertheless, a water drop, which would retain own original shape in a glass will indeed assume the shape of a narrow tube once put within.

How many drops of water are required for water to start taking the shape of the glass portion which it occupies? If we take a glass of a larger diameter, will this number of drops (amount of water) remain identical? Is there a specific proportion of the vessel's volume which we need to fill in order for a certain amount of water to start assuming the shape of the glass portion it occupies? The ratio between the volume (amount) of the matter (number of water drops, sand grains or apples) and the volume of the vessel can be established by a simple test, which can be run at any time and in any place.

IV. ANOTHER DEFINITION OF LIQUIDS AND SOLIDS IN RESPONSE TO THE LIMITATIONS OF THE CURRENT DEFINITION

The conventional definition of the "liquid" state of matter holds true in all instances when the volume of the liquid drop (amount of matter) is of the same order of magnitude as that of the vessel portion, which holds it. However, where the ratio between the volume of the drop (liquid) and that of the vessel approaches zero (the volume of the drop is very small as compared with that of its holding vessel), the drop will not assume the shape of the vessel but rather another shape, which property is not attributed to liquids. Hence, the question "Is a water drop liquid?"

The conventional definition of the "solid" state of matter holds true in all instances when the amount of the solid matter approaches zero (the ratio of the solid volume to the vessel volume is very small). Yet, where the amount (number of particles) of the solid matter increases significantly (the ratio of the solid volume to the vessel volume approaches 1), the solid matter (sand grains, iron pellets, rocks or oranges) will assume a definite shape – that of the vessel which they occupy. Hence, the question "Is an iron pellet solid?"

V. SUMMARY

The current definitions of the liquid and solid states of matter are but partial. Since we have always described these states as we perceive them rather than as they actually are, without considering their "**amount**", we have also created misconceptions in the minds of our students. Think of what students should think when they read or learn about how solids do not take the shape of their container, and later that day walk into a grocery store only to see with their own eyes how the oranges fill up the box and take up its shape. In our teacher's refresher courses, teachers are often stunned by this new view of how solids and liquids really behave.

VI. CONCLUSIONS

1. The macro properties of a liquid matter should be taught as well as its micro properties.
2. In the representation of the limit cases as provided herein, an analysis should also be provided of the significance of the various characteristics of solids and liquids [8], to demonstrate that the one characteristic which remains unchanged regardless of the amount of matter is the movement of its particles (the micro level). This, therefore, should be the most dominant element of the definition, however abstract and difficult to perceive as it may be.
3. (In this context, a general discussion may follow of the various elements of the definition and of their relative weights, which discussion goes beyond the limits of the examples provided herein but which can indeed assist critical thinking [9].

We believe that our research contributes to the field by shedding light on the possible role, nature and effects of cognitive conflicts in teaching initiatives that aim at generating "conceptual changes". This by providing some evidence that attempts to fragile nonscientific initial conceptions might not be as effective as teaching "the right stuff" first; and also by suggesting that cognitive conflict might be more—or at least as—useful if it aimed at discriminating ideas instead of disqualifying (or diminishing) them. [10].

REFERENCES

[1] I. M. Freeman, "Physics Made Simple, Made Simple Books", (Bantam Doubleday Dell Pub. Group), revised Ed. 1990, pp. 181 – 183.
[2] P. Horton, E. Werwa, T. McCarthy, and D. Zike, "The nature of Matter", (National Geographic, Teacher Wraparound Ed. Glencoe/ McGraw-Hill), 2005, pp. 41 – 42.
[3] A. P. Biggs, L. Daniel, R. M. Feather, E. Ortleb, S. L. Snyder, and D. Zike, "Science: Level Red, National Geographic", (Teacher Wraparound Edition, Glencoe/ McGraw-Hill Company), 2005, pp. 74.
[4] K. P. Dobson, J. Holman, and M. Roberts, "Science Spectrum: Physical Science", (Holt, Rinehart and Winston, A Harcourt Education Company), 2006, pp. 71-72.
[5] G. Galili, and D. Ovadia, "the Basics of Physics", (Yesh Book Distributions Ltd, Holon), 2007, pp. 477-478.
[6] D. Marshland, "Science and Technology Concepts for Middle Schools: Properties of Matter, Student Guide and Source Book" (Smithsonian, the National Academies, National Science Resource Center), 2000, pp. 238-239.
[7] T. Massalha, and P. Gluck, "Defining Solids and Liquids", (Physics Education), 2010, (pp 433-435), Vol. 45(4).
[8] G. O. Young, "Synthetic structure of industrial plastics", (Book style with paper title and editor)", 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.
[9] H. Gardner, "Five Minds for the Future", (Harvard Business School Press), 2006, Ch. 2.
[10] P. Potvin, E. Erik Sauriol, and M. Riopel, (2015). "Experimental Evidence of the Superiority of the Prevalence Model of Conceptual Change Over the Classical Model and Repetition", (J. of Research in Science Teaching), 2015, pp. 1082-1108, Vol. 52(8).

Dr. Taha Massalha: A short Biography

- **Academic Degrees**

Dr. Massalha received his M.Sc. Degree in physics from the Hebrew University in Jerusalem. In 1986, he received his D.Sc. in Solid State Physics from the Physics Department in Technion - Institute of Technology in Haifa, where he became a physics lecturer at the Faculty of Technology and Science Education. In 2005, he got the Prize of Excellence for Physics Teacher in Israel, for the years 2004 and 2005 from Weizmann Institute of Science in Israel.

- **Occupations**

From 1984 to 2002, he worked as an advisor of Physics Teaching at the Science Education Department at Weizmann Institute of Science – in Israel, where he was involved in science education and leadership programs. He Massalha has been a lecturer of physics and mathematics at the Academic Arab College for Education in Israel – Haifa for 30 years. He became the Head of the Physics Department and established a special laboratory for physics education at the College. In 1997, he headed the program of Excellent Students for 10 years. At present, Dr. Massalha is the Head of the M.Ed. program in Science Education at the College.

- **Publications and Educational Programs**

Dr. Massalha published many articles in physics, teaching physics and in science education. In recent years, he was intensively involved in developing a unique science education program for physics teachers, science teachers and for their students. The program will help users to discover the misconceptions they are using, and will guide them to achieve deep understanding of science concepts. This approach aspires to lead to a new conceptual change among science teachers and their students.