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Exploring and Addressing Pre-Service Teachers' Ability to Correlate Macroscopic Phenomenon with its Microscopic Explanation and Symbolic Representation in Science

Dr. Mamta Rajput[1]

[1]Associate Professor; Shyama Prasad Mukherji College for Women, University of Delhi, India

[1]ORCiD ID: 0009-0000-4410-8038

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Abstract: In this research study, the ability of pre- service teachers to correlate macroscopic explanation of scientific phenomenon with its microscopic explanation and representation at symbolic level has been explored and addressed also. Twenty pre service teachers were asked to explain the process of boiling of water, freezing of water and the dissolution of sugar in water at macroscopic, microscopic and symbolic level. The findings revealed that pre service teachers could not correlate the macroscopic explanation with its microscopic explanation and symbolic representation. The limited understanding of pre service teachers with respect to shapes of molecules, molecular geometry and strength of different bonds was addressed. The implications of findings for teacher education program have been discussed.

Keywords: *Macroscopic Explanation, Microscopic Explanation, Symbolic Representation, Correlation, Pre Service Teachers, Teacher Education Program.*

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I. INTRODUCTION

Some of the aims of science education as per National Curriculum Framework for Science Education NCFSE (2023) are; to develop scientific inquiry, scientific temper, and scientific understanding of natural and physical world. These aims cannot be achieved through traditional classroom teaching where the content and its transaction is totally governed by examinations. Science teaching needs to strengthen conceptual understanding, spirit of inquiry, scientific temper, logical thinking and the ability to connect scientific ideas with observable phenomena.

For several concepts in science, developing such conceptual understanding requires learners to establish connections between what they observe at macroscopic level, explain these observations at atomic or molecular level and be able to give its symbolic representation also denoted as macro-micro-symbolic interface.

The macroscopic level involves observable phenomena, the microscopic level involves explanations in terms of particles and their interactions, and the symbolic level represents these ideas through scientific symbols, formulae, equations, and other forms of representation. "Being able to move between different representations levels is important to understand a chemical phenomenon meaningfully" (H. O. Kapici 2023). Research findings show that teachers experience various challenges and difficulties in applying a multiple representation approach (H. Widarti & others 2025, V. C. Santos & A. Arroio 2016) and focus mainly on macroscopic and symbolic level of representation(H. Widarti 2021). The ability to establish meaningful connections among these levels is therefore an important component of scientific understanding and needs to be addressed explicitly in science classrooms.

"Because pre service science teachers will teach in their future careers, it is important to encourage them to comprehend chemical phenomenon at each representation level and shift between them" (H. O. Kapici 2023). Teachers who have difficulty in understanding concepts at all three levels, may find it challenging to help students move beyond observable phenomena and develop scientifically meaningful explanations. Therefore, examining teachers' understanding of these relationships becomes important, particularly in the context of pre-service teacher education.

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In this context, the present study attempts to explore and the ability of pre-service teachers to correlate macroscopic scientific phenomena with their microscopic explanations. By examining the extent to which pre-service teachers are able to make these connections, the study seeks to identify possible gaps in their conceptual understanding and addresses it using macro-micro-symbolic teaching approach. Such an effort may contribute towards preparing teachers who are better equipped to facilitate conceptual, inquiry-oriented, and scientifically meaningful learning in their future classrooms.

II. REVIEW OF RELATED LITERATURE

L. Jaber & S. Boujaoude (2012) conducted a research study on 46 tenth grade students to identify their difficulties at macro-micro-symbolic interface in chemistry and to see the effect of macro-micro-symbolic teaching approach on students' understanding. Findings indicated that macro-micro-symbolic teaching approach focussing on interplay between the levels and inegrating various representation enriched students' conceptual understanding and learning of chemistry.

J. M. P. Sanchez (2021) conducted a research with tenth grade students to analyse their understanding of macro-micro-symbolic interface in kinetic molecular theory. The students were exposed to integrated macro-micro-symbolic teaching approach. Findings revealed that students showed improvement from a good understanding to very good understanding of concepts in chemistry.

V. C. Santos & A. Arroio (2016) in their research paper gave a comprehensive review of literature on macro-micro-symbolic interface. The work reports the outcomes of empirical and theoretical studies which present a major concern regarding the difficulties of school and undergraduate students in understanding concepts at all representational levels.

D. Treagust, D. Chittleborough, & T.L. Mamiala (2003) examined the use of submicroscopic and symbolic representation in chemical explanations with 11th grade chemistry lessons. The findings indicated that simultaneous use of submicroscopic and symbolic representation enhances learning of macro-micro-symbolic interface.

O. Koopman (2016) investigated the science teachers engagement with all three levels of representation in chemistry during their classroom teaching. The findings indicated that the macroscopic and symbolic levels of representation were mainly focussed on by the teachers which has negative implications for the training of preservice and in-service teachers.

H. Widarti, A. Wiyarsi, S. Yamtinah, A. Shidiq, M. E. F. Sari, P. N. Fauziah, S. Natasya, C.A. Khandi, & D. A. Rokhim (2025) identified and analyzed the views of chemistry teachers on 'difficulties in multi-representation-based chemical bonds'. Findings showed that molecular geometry is the most difficult sub-material in chemical bonds, while the easiest is ionic bonds.

H.O. Kapıcı (2023) investigated pre-service science teachers understanding from symbolic representation to sub-microscopic representation by balancing chemical reactions and drawing their submicroscopic views. The findings showed that pre-service science teachers are most successful at the symbolic level and were found to have common alternative concepts with respect to drawings of atomic size and molecular geometry. They have a superficial knowledge of the molecular geometry of chemical compounds.

Eliyawati, E., Agustin, R., & Andini, R. (2020) investigated the understanding of preservice science teachers at macroscopic, symbolic, and sub-microscopic levels. The study was conducted on twenty-seven pre service science teachers. Results showed that most of pre-service science teachers could not explain the dissolution of substances in water at macroscopic, symbolic, and sub-microscopic levels. While a few pre-service science teachers couldn't write the symbol of potassium chloride correctly. All of them couldn't write the ionization reaction of acetic acid and could not describe its molecular view correctly.

Widarti, H. (2021) explored high school teachers' comprehension of macro-micro-symbolic representation. Seventy-five chemistry teachers in east java were surveyed for their understanding of macro-micro-symbolic representations. The findings suggested that 49.33% of the high school teachers do not know macro-micro-symbolic representations. The involvement of Chemistry teachers was seen to be more in macroscopic and symbolic representations rather than submicroscopic. Therefore, there is a mismatch between teachers' understanding and classroom practices with regard to the macxro-micro-symbolic/multiple representations in chemistry learning.

III. METHODOLOGY

The study used a qualitative research design. Twenty pre-service teachers were required to explain the phenomenon of boiling of water, freezing of water, and dissolving of sugar in water at macroscopic level as well as at the microscopic level and their symbolic representation. Their responses were analysed to identify their difficulty in explaining the phenomenon at all three levels and to strengthen their conceptual understanding macro-micro-symbolic teaching approach was used.

IV. FINDINGS

- *For the Phenomenon of Boiling of Water*

The findings showed that pre-service teachers could explain the phenomenon of boiling of water at the macroscopic level. However, they faced difficulty in explaining it at microscopic level. At symbolic level also participants showed their limited understanding in representing correct geometry of water molecule.

At microscopic level the pre-service teachers demonstrated their limited understanding of inter molecular and intra molecular bonds present between two water molecules and within the same water molecule. They were

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also unclear about the strength and nature of these bonds. Furthermore, they exhibited confusion regarding the nature of the bonds that are disrupted during boiling.

This confusion indicated that, although the pre-service teachers were familiar with the observable phenomenon of boiling, they lacked a clear understanding of the molecular-level processes underlying it and how to represent the correct geometry of the shape of water molecule.

Scientifically, boiling involves the overcoming of intermolecular attractions between water molecules; the covalent O–H bonds within individual water molecules remain intact. The findings therefore highlight a gap between the participants' macroscopic understanding of boiling and their microscopic understanding of the phenomenon.

➢ *For the Phenomenon of Freezing of Water*

The pre-service teachers were asked to fill a bottle made up of very thin plastic up to the brim with water and keep it in freezer overnight and bring theie observations to the class. Some of their observations were: the bottle expanded, it bulged, it developed crack. At the macroscopic level, the participants could only explain that water froze but when probed further why then bottle expanded, bulged or cracked? They had no answer. The teachers faced difficulty in explaining anomalous behaviour of water on freezing.

When further probed about the microscopic processes involved, and the symbolic representation, the participants were unable to explain the structural arrangement of water molecules in ice and how this arrangement accounts for the expansion of water upon freezing. They lacked an understanding of the open, hydrogen-bonded structure of ice, in which water molecules are arranged in a relatively stable, hexagonal network with considerable empty space between them. This structure results in ice having a lower density than liquid water, causing water to expand upon freezing.

These findings suggest that, although the pre-service teachers could identify the observable change from liquid water to solid ice, they lacked an adequate understanding of the molecular-level structural changes and symbolic representation responsible for the anomalous expansion of water upon freezing. This highlights a gap between their macroscopic observations and their microscopic and symbolic conceptual understanding of the phenomenon.

➢ *For the Phenomenon of Dissolution of Sugar in Water*

The findings showed that , at the macroscopic level, the participants could readily explain that sugar dissolves in water. It has not diappeared in water but has dissolved. When the pre-service teachers were asked to explain the process at the microscopic level, they explained that sugar particles become trapped in the spaces between water molecules.

To probe their understanding with respect to symbolic representation, the participants were asked why sugar dissolves in water whereas sand remains insoluble, although the apparent size of sugar crystal is big than the small grain of sand. They were unable to provide a satisfactory explanation for this difference and showed their limited understanding with respect to the polarity of molecule, molecular structures and sizes of water, sand and sugar molecules.

These findings suggest that there is a gap between pre-service teachers' macroscopic observations and their microscopic and symbolic conceptual understanding of the phenomenon.

Addressing Pre-service teachers' ability to correlate macroscopic phenomenon with its microscopic explanation and symbolic representation through macro-micro-symbolic teaching approach.

➢ *For the Phenomenon of Boiling of Water*

Pre-service teachers understanding at microscopic and symbolic level was addressed by carrying out explanations and discussions with respect to shape of water molecule, its geometry through visual models, presence of intramolecular strong covalent bonds within water molecule, weak intermolecular hydrogen bonding between two water molecules, role of kinetic energy and what happens during the process of boiling by integrating all three representation levels.

➢ *For the Phenomenon of Freezing of Water*

Pre-service teachers understanding at microscopic and symbolic level was addressed by carrying out explanations, discussions and visual representations with respect to difference in shape of water molecule and arrangement of water molecules in ice(open, hydrogen bonded,hexagonal network with lot of empty space in between). integrating all three representational levels to explain the expansion of water on freezing.

➢ *For the Phenomenon of Dissolution of Sugar in Water*

Pre-service teachers understanding at microscopic and symbolic level was addressed by carrying out explanations, discussions and visual representations with respect to attraction between water molecules and sugar molecules, interaction of sand with water, molecular structure of sugar and sand.

V. DISCUSSION

The findings clearly show that pre-service science teachers do have the understanding of scientific phenomenon at macroscopic level which generally teachers focus on in regular classrooms(O. Koopman, 2016, H. Widarti 2021) but face difficulty in applying multiple representation approach(H. Widarti & others 2025, E. Eliyawati& others 2020). It is generally assumed that students entering a teacher education programme possess adequate subject-matter knowledge. However, the present findings suggest that their understanding of the microscopic explanations underlying various scientific phenomena requires considerable improvement.

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The participants demonstrated a lack of clarity regarding the shapes and geometries of molecules (H. Widarti & others 2025), as well as the nature and relative strengths of different types of chemical bonds within molecules and intermolecular forces between molecules. These conceptual gaps may hinder their ability to explain scientific phenomena accurately and meaningfully, clarify students' misconceptions and address their queries and doubts. Research suggest that teachers explain what happens at the macroscopic level in classroom ignoring the explanation at micro level (O. Koopman 2016) thus compelling them to learn without understanding as explaining why and how these phenomena occur requires a sound understanding of the underlying molecular and particulate processes.

It was also seen that addressing Pre-service teachers' ability to correlate macroscopic phenomenon with its microscopic explanation and symbolic representation through macro-micro-symbolic teaching approach strengthened their conceptual understanding. Hence, teacher education programmes need to place greater emphasis on strengthening pre-service science teachers' macro-micro-symbolic representation of scientific phenomena. For this, direct macro-micro-symbolic teaching approach focussing on interplay between the levels and inegrating various representation should be practised as it enriched students' conceptual understanding and learning.(L. Jaber & S. Boujaoude 2012, J. M. P. Sanchez 2021)

VI. CONCLUSION

The present study reveals that pre-service science teachers face considerable difficulties in explaining scientific phenomena at the microscopic level, despite their presumed familiarity with the relevant scientific concepts. The findings indicate that their understanding of the molecular nature of matter, molecular geometry, and the forces operating within and between molecules is not sufficiently developed to explain several everyday scientific phenomena accurately. This suggests that knowledge of scientific facts alone may not be adequate for effective science teaching; teachers must also understand the underlying mechanisms that explain observable phenomena.

Therefore, teacher education programmes need to place greater emphasis on developing pre-service teachers' microscopic understanding of scientific concepts and their ability to relate microscopic explanations to macroscopic observations. Learning experiences that encourage conceptual reasoning, the use of molecular models, visual representations, and the explanation of everyday phenomena may help strengthen this understanding. Developing such an integrated understanding is essential for preparing science teachers who can explain concepts meaningfully, address students' misconceptions, and facilitate deeper scientific learning in the classroom.

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