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An Analysis of Common Misconceptions in Chemistry Education and Practices

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Abstract

Chemistry is highly spatio-visual based which means that chemistry conception is abstract so students are more prone to construction of misconceptions. This study is the literature review of chemical education and practices that show the common misconceptions constructed by students. The study aims to explore the literature evidences to chemistry teacher and prospective teacher on chemical misconceptions. Students improve their concrete concepts related misconceptions but find abstract misconception hard to change. For teachers' also it is difficult to resolve such misconception by traditional pedagogical approaches. So, teachers need to update the pedagogical and should use pedagogical tools to identify and eliminate the common misconception. Further the study suggested to use multiple intervention for the elimination of chemical misconceptions and to innovate their pedagogy with active & interactive ways that doesn't allow the construction of chemical misconception.

Keywords: chemical education, common misconceptions, pedagogy, literature

Introduction

In meaning full learning, students relate their real-world experience with the conception in their cognition. While planning their instructions, teacher should plan some intervention to dig deep in the prior knowledge of student to identify the incorrect information stored. The incorrect

information in the students' cognition related to the chemical conception are called misconception which prevents the subsequent learning. There are numerous studies in the literature that show the most common misconceptions in chemical education and practices [1][2][3]. As per the literature review, class room practices also cause misconceptions in students. Untrained teachers use traditional pedagogy which is without screening, identification and remediation based [4]. Some studies show that words, symbols and signs used by the teachers also causes misconceptions where students find these difficult to understand [5]. Teachers' role is prominent in providing appropriate explanation of the scientific concepts which not only make students to claim the right concept but also helpful in developing competencies. Chemistry concepts integrated with practical approach in laboratory are more sound than theoretical concepts only. Physical distancing in pandemic also boosted misconception construction [6][15][16]. Education testing and measurement integrated in the chemistry pedagogy is found more effective in the identification and understanding of chemical misconceptions [7][8][9]. Modern science education is based on practical approach where teachers use innovative pedagogy to support the students in authentic construction of chemical conception. Games used in chemistry classroom as art integrated pedagogy are also found helpful in better construction and retention of the concepts [10][11]. With the innovation and advancements in pedagogical sciences & educational technology, it requires transformation in the science pedagogy and perspective for science teaching learning in the classrooms. These advancements modified the teaching learning and several new techniques are emerged as the traditional approach were not providing the space for researching and questioning. Constructivist learning approach put the learners at the centre where students are actively engaging themselves in constituting their knowledge by performing and experiencing the chemical conceptions in various interventions.

Under the guidance of teacher as mentor, the students interpret the new information and engage in brainstorming using the prior information [12]. Misconceptions might be due to excess use of artificial intelligence-based tools where brain is not engaged in critical thinking and problem solving, studies reveal that overdependency on AI impacts the creativity [14]. So, chemistry educations and researchers engaged in chemical education and research have a consensus regarding determination and elimination of chemical misconceptions. In chemistry education, identification of misconceptions, and elimination using updated teaching methods is an important and wide field of research. Various teaching methods are used by the educators to eliminate the misconceptions and studies shows that updated pedagogy is helpful in

remediation [17][19]. So, this study discusses the common misconceptions in chemical education and practices used by the teachers in the elimination of these.

Methodology

Most of the researches in chemical education are aimed to discover the subjective views and perceptions of the students in chemical education that provide a profound understanding of acknowledgement of the subject, students and educators. Qualitative research methodology is used in the research where tools like interviews, observations, meetings and literature analysis is used. In chemical education, the literature is the important source of information to identify the students' misconception. Analysing literature means doing research on written materials that includes not only information about the subjects to be studied but also the strategies adopted by the researchers in finding the solutions for better outcomes [18].

Analysis of the literature is the most important step in conceptual analysis. Previous researches, literature and their outcomes provided the base of the study and hence it is used a tool in this qualitative research. It is used as tool because direct observation and interview was not possible for some subjects, hence it was necessary to enhance the validity of the study. It is not used here as sole methods but as supplement to other research methods. Adopting it means, a researcher can gather the required information without observation method and interview method or uses literature as research method to increase validity of the study and to support the observation and interview methods [13]. So, the literature related to the subject is examined, this literature has an accepted validity, and an expert opinion was taken for the confirmation of appropriateness of the examined literatures. Misconceptions from the literatures are included in this study and the methodology of elimination is also examined in detail, all this is compiled into report form to provide the validity of the study.

Literature from the research on misconceptions and elimination of misconceptions in chemical education is the samples of the study, it is taken from various databases. So, the study as the first step of the research requires a thorough literature analysis, an independent study of samples containing misconceptions, and samples on methodology of elimination of misconceptions was analysed. After literatures analysis, students' misconceptions, remediation including teaching methodology and assessment methods have been examined two times meticulously, and all data is stated in a chart. Based on the literature analysis criteria, the data so obtained is categorized, and coding of literature is carried out by a subsidiary coder. A correspond is tried to setup between the determined criteria and coding practices. There is

consensus in all literatures that misconceptions can be observed in any age group, and for a high conceptual framework in chemistry education, misconceptions on any concept must be eliminated by teaching learning. Based on the information obtained from the literature, this study, aim to examine the various chemical misconceptions identified chemistry research and practices, it also aimed to find out the remediation strategies applied by the educator to eliminate such misconceptions, it will provide benefits to students and educators as it contains a source for researchers and researches.

Findings of the research

The first and foremost objective of the most of researches in chemical misconceptions is to make a comparison between teaching methods and conceptual change approach. In most of the studies as analysed in the literature, subjects are divided in two groups, experimental group and control group. Research plan applied on experimental group. In the literature studies here students of the experimental group are exposed with innovative or integrated pedagogies like integration of conceptual change approach, conceptual change texts, concepts cartoons, while control group students are taught with traditional methods in chemistry education. After examining the literature, it is confirmed that traditional teaching methods leave students with many misconceptions which ultimately prevent them to learn the further chemical conception and the innovative teaching method integrated with conceptual change approach, concept cartoons, conceptual change text etc., are more efficient in remediation compared to traditional teaching methods. Assessment strategies if woven with teaching methodology is much helpful in resolving the misconception. Literature review on paradigm shift in assessment, chemical games integration in teaching as assessment and assessment as testing & measurement highlights that construction of conceptions is high in students where such strategies were interwoven with teaching methodology.

Purpose of concept cartoon, and contextual change text in the literature was to eliminate the most common misconceptions in chemistry. In the above literature, the researchers used pre and post assessment to assess the degree and level of misconceptions. Innovative pedagogy like embedded conception cartoon and contextual change text was used with the experimental group and the control group was taught with the traditional pedagogy. The researchers listed various misconceptions, classified as common misconceptions in chemical education. In literature related with embedded concept cartoons, chemical bonding conception was testing and resolved. The above literature analysis confirmed that students have several

misconceptions that prevent theme from to learn the new concepts and concluded that misconceptions in experimental group were resolved by using innovative pedagogy involving concept cartoons and contextual change text. Literature on "Concept Cartoons as A Teaching Method To be used in Science classes in respect of the contributions to the Constructivist Learning Process" [20] focus on the innovative teaching by integrating concept cartoon in chemical education. The study was carried out on grate 4 and 5 students. The researcher provided concept cartoon embedded text to the students individually once and once more discussed in classroom interaction. Following misconceptions were identified by the researcher:

Table 1: Common misconception related to solution in grade 4 and 5 students

1. For a particular amount of water, as the physical state changes, its mass also changes
2. In a mixture of sugar and water, bottom of the mixture mostly contains sugar molecules
3. In the mixture of sugar and water, top of the mixture mostly contains sugar molecules

As a result of the innovative pedagogy of embedding conception cartoon in text, there is assertation that concept cartoons can reveal the students' individual way of thinking but there is no much influence of in-class interaction, such misconceptions can be eliminated by using the concept cartoons and it is recommended by the researcher, the similar study was carried out with grade 9 and 10 students entitled "Effect of Concept Based Cartoons as art integration on Alternative Concepts in Chemical Bonding" and concluded with the recommendation of embedding the concept cartoon in chemical education but the conceptual change in primary classes and secondary classes by embedding the concept cartoon varies.

Training of teachers in developing Teaching Learning Material (TLM) is also equally important. Innovative teaching methods with new TLM are more effective in preventing the construction of misconceptions. Literature review on the study of untrained and trained teachers shows that trained teachers use innovative teaching methods that are much helpful in the construction of authentic conceptual framework. Conceptual framework and metacognitive support the individual in decision making and such students are seen with high competence

and equipped with life skills. Covid 19 not only impacted the student's mental health but also impacted the educator's mental health negatively. Lack of physical interaction and lack of trainings on digital infra impacted the conceptual construction which ultimately affected the skills, competence and mental health of the students and educators. With the emerging trends of digital transformation, these challenges impacted the science education.

In a study on innovative teaching learning, the researcher used model in teaching chemical bonding, the study titled with "Using Model in Teaching Chemical Bond: Ionic bond, Covalent bond, Dual and Triple Bonds, Hydrogen Bond and Molecular Geometry", [21] focus on developing new TLM and using them in classroom for preventing construction of misconceptions. In this study, first misconception was identified and then models from play dough were prepared so that students can perceive the chemical bonding better. So, the main emphasis was to remove the misconceptions. Misconceptions were identified and tested by using pre-test and post-test.

Table 2: Some common misconceptions on chemical bonding based on literature review

1	Shape of water molecule is linear
2	Hydrogen chloride have intramolecular ionic bond or hydrogen bond
3	Hydrogens of ammoniac are at equal distance to each other
4	Bond length and bond angle increase with rise in temperature
5	All covalent bonds involve equal sharing of electrons
6	Intermolecular covalent bond is a weak bond
7	Polar covalent compounds are charged
	There is no influence of electron pair which is not involved in the bond on centre atom
8	On geometrical shape of molecule
	Polarity of the bond is defined by electron pairs not involved in bond formation and
9	Present in each atom.
10	Non-bonding electrons in a molecule turn the molecule in to polar.

The literature review on chemical bonding misconceptions and used of model as innovative pedagogy is helpful in prevent the construction of misconceptions.

In a literature on "Narratives and Teaching Chemistry" [22], chemistry education is associated with daily life for better conceptual construction. The major objective taken were connecting social and technological structures in chemistry classroom, and rising students with scientific literacy. This approach improves the conceptual framework of students and makes the learning meaningful. Teaching program based on narratives, explanatory narratives and information about the usage of chemistry narratives in learning environment was aimed on better and meaning learning. A literature on "The Impact of Problem-Based Learning Approach in Terms of Teaching Electrolyze and Battery", emphasizes on the student-centred approaches involving engaging the students in ability to construct learning by itself, conducting teamwork, making information functional, defining learning requirements, that involves thinking and problem-solving skills. In this study problem-based learning methods were used. Experimental methods like electrochemistry achievement test, chemistry attitude scale and scientific processing skill test were applied. The study concluded that in experimental group where PBL approach was used, students conceptual learning gradually improved.

All literature review concluded that the level of meaningful learning and eliminating misconceptions in the students of the experimental group is much better than in the control group students.

Table 3: Literature review in chemical education

Methods	Subjects	Sampling
Conceptual Change Approach	Solubility Equilibrium	Grade 10th students
Paradigm Shift in Assessment	Chemical Education	Grade 9 and 10 students
Concept Cartoons	Chemical Bonding	Grade 9 and 10 students
Contextual Change Text	Chemical Bonding	Grade 9 and 10 students

Developing Teaching Learning Material: Trained/ Untrained Teachers	Chemical Education	School Teachers
Modelling in Teaching	Chemical Bonding and Chemical Species	Students and Freshmen
Concept Cartoons	Solutions	Grade 4 and 5 students
Narratives and Chemistry Education	Periodic System	Secondary School Students
Problem-Based Learning	Battery & electrolyze	Prospective Chemistry Teachers

Analysis of the above chart shows that various studies are carried out in chemistry education in terms of misconceptions, and all studies concludes that the constructivism approach-based teaching methods are impactful and preferred to eliminate chemical misconceptions.

The main objective of the research is to examine the chemistry misconceptions in chemical research literatures, and to study how these misconceptions are eliminated. As a conclusion of the research literature analysis, misconceptions are identified in solubility equilibrium, chemical education, chemical bonding, solutions, periodic systems, electrolyze and battery.

Another objective of the study is to analyse the literature on the elimination of misconceptions. Traditional pedagogy is effective for the elimination of misconceptions, teaching methodology based on constructivism are found effective to eliminate the misconception as recommended in various literatures. In this study literature analysis, the constructivist approaches like concept cartoons, conceptual change text, modelling, problem-based learning, narrative and chemistry education are found effective with better outcomes in conceptual framework. Teachers should be trained on diagnosis of misconceptions and integration of assessment with teaching methodology for the elimination of misconceptions.

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