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Theoretical Foundations Underpinning Effective Remediation of Misconceptions in Chemistry

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Abstract
Students frequently struggle with persistent misconceptions in chemistry that impede their academic progress and conceptual understanding. This research paper reviews the theoretical foundations of major models that inform effective remedial measures in chemistry education. It investigates the Mastery Learning Model, which advocates for achieving competency before progression, the Cognitive Diagnostic Model, which identifies specific cognitive strengths and weaknesses; the Conceptual Change Model, which focuses on replacing incorrect preconceptions with scientifically accurate ones; and the Diagnostic Classification Model, which categorizes learner profiles for targeted instruction. Using insights from these theories, the paper highlights how a theoretical approach can enhance remediation strategies and promote meaningful learning in chemistry.

Keywords: Chemistry, Theoretical Foundations, Educational theory, Remedial Measure.

INTRODUCTION

Chemistry as a fundamental science subject, demands a strong conceptual understanding to support student's success across various scientific discipline. However, students commonly face persistent misconceptions that hinder their academic process. Misconceptions in chemistry are common and can function as significant barriers to effective learning (Uce & Ceyhan, 2019). Misconceptions become a big hurdle in meaningful learning (Pabuçcu & Geban, 2012). It must be reduced immediately in order to not impede the process of learning the following interconnected matter (Tümay, 2016). Remedial learning can help reduce student misconceptions. In chemistry education, remedial measures mostly aim to solve identified misconceptions and enhance general learning outcomes (Islamiyah et al., 2022b and Tümay, 2016). Theoretical framework provides understanding of student learning the nature of misunderstanding and the best strategies to encourage conceptual transformation (Passey, 2020). The theoretical framework is the form which holds or supports the theories of a research study. It not only encompasses the theory, but also the narrative explanation about how the researcher is using different theories and its underlying presumptions to investigate the research problem. Several theoretical models provide frameworks to create and implement efficient remedial procedures in chemistry education (Islamiyah et al., 2022b). Among the most prominent theoretical frameworks (Figure 1.) discussed in this paper are Mastery Learning Model

(MLM), Cognitive Diagnostic Model (CDM), Conceptual Change Model (CCM), and Diagnostic Classification Model (DCM).

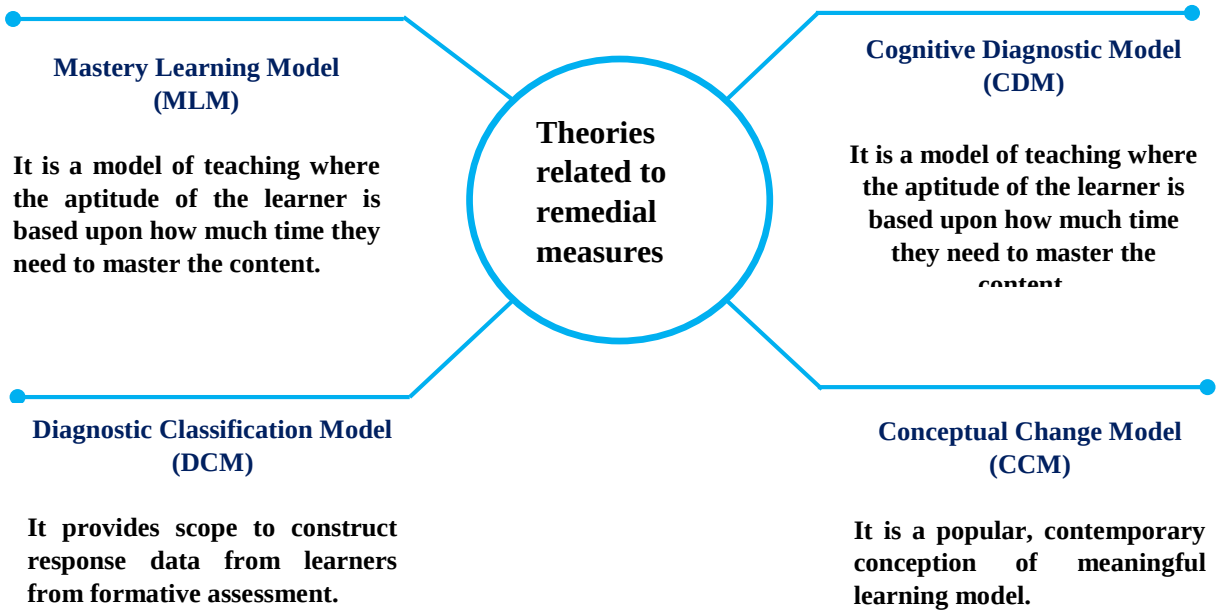

Figure 1. Various Types of theories in related to remedial measures

The objectives of the study are

1. To examine the theoretical foundations providing the origins and persistence of remedial measures for misconception in chemistry.
2. To explore the theoretical underpinnings of major remediation models for eradicating misconceptions in chemistry.

Methodology

A systematic literature review approach was used to examine the foundational models that inform effective remediation of misconceptions in chemistry.

Theories in related to remedial measures

Mastery Learning Model

Mastery learning, also known as Learning for Mastery (LFM) is a model of teaching where the aptitude of the learner is based upon how much time they need to master the content. A lot of innovations of remedial teachings include elements of comparatively already established strategies. Among these research-supported strategies, one of these most powerful ones is Mastery Learning (Guskey, 2010). Now days, Mastery Learning is considered to be one of the important tools for remedial measures in teaching students. As every remedial measure approach, this also focuses on presenting students personalized to their level of understanding (Enyedy, 2014). According to Bloom's (1968) theory, usually this adaptation follows the form in which students are asked to master one topic before proceeding to the next topic. Mastery Learning is an instructional process in which educational progress is based on demonstrated performance. Students undergo practice and retest repeatedly, until they reach the mastery level; the final

level of achievement is the same for all, although time may vary to individual (Yudkowsky et al., 2015). Winget and Persky (2022), stated that this model comprises of the methods where the students acquire knowledge, skills, or attitudes and then complete formative assessments on that learning. If they are able to achieve the desired level, they can proceed to enrichment activities. Students who are unable to meet the desired level of mastery proceed through corrective activities eventually. A recent review along with meta-analyses has shown tremendous positive effects of Mastery Learning on students' achievement, especially in the field of misconceptions. It has been also hypothesized that mastery-based treatments will soon be able to produce "2-sigma" (i.e.,2 standard deviation) increases in achievement (Slavin, 1987). It can be concluded that, mastery learning is a philosophical approach to the framing of classroom environments that is creating new innovations in the educational research and development community (Block & Burns, 1976).

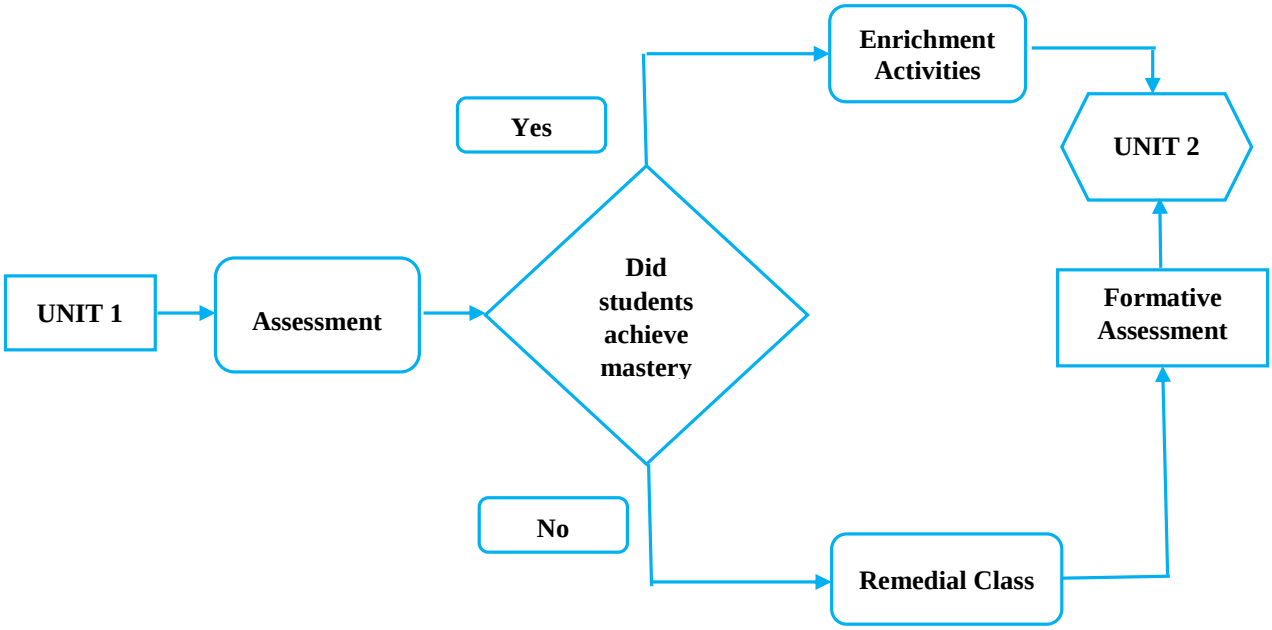

Figure 2. Basic Elements of Bloom's Mastery Learning Approach

According to Bloom's Mastery Learning framework (Figure 2), initially a certain content (here Unit 1) is taught and students go under formative assessment. If it's found that they are unable to achieve mastery in the content, they undergo remedial classes again, and then formative assessment takes place again. After that they are prepared to proceed to next content (here Unit 2). In the case, they have achieved mastery in the content, various enrichment activities are arranged and eventually they proceed to the next content (i.e. Unit 2).

Cognitive Diagnostic Model

Cognitive Diagnostic Model (CDM) is one of the most distinct and concealed variable models which are developed particularly to identify, collect, analyse and report diagnostic data which is ideal for formative assessment which acts as remedial tool for teaching students. CDMs include a few class models that portray the relationship of responses or performances of students to specific disciplines. As emerged from educational measurement, several aspects of this model seem well suited to use in assessment and

diagnosis of student's misconceptions in certain contents. This it can be used as a source of remediation inside the classroom (Templin & Henson, 2006). Sinharay and Almond, (2007) described the Cognitive Diagnostic Model as uses information from educators to describe and conclude the relationships between learners' performances and posited proficiencies. This furthermore increases students' comprehensive ability and consequently helps in remediation. Based on the idea of "assessment for learning" and focusing on enhancing the quality of students' learning, the pattern of objectively quantifying the learning status and providing feedback after application of this has been increasingly successful in the course of remedial teaching. Cognitive Diagnostic Model (CDMs) aims at providing individualized diagnostic feedback for each student which actually clarifies students' learning status, along with providing a reference for following up self-remedy of students and also targeted remedial teaching of teachers (Yu et al., 2020). CDMs lay out a distinct classification to diagnose conceptions as well as misconceptions held by students, immediately for their overall development. According to an experimental result of some real datasets, this method outperforms wonderfully even in a small-classroom situation. Researches also demonstrate that this remedial course is executing better results than traditional remedial teaching (Li et al., 2022). It has also been observed that the CDM surpasses the traditional remedial instruction program in school. CDM has been beneficial for all students, especially for medium and low achieving students (Wu, 2018).

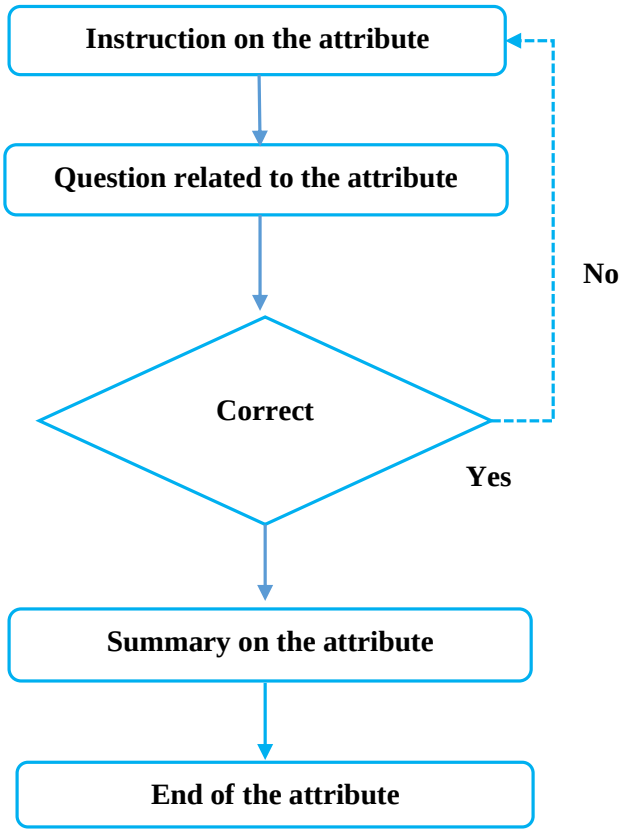

Figure 3. Schematic diagram of remedial instruction on the attribute

As Wu, (2018), in his study, displayed the steps of remedial instruction on a specific attribute (Figure 3). First, instructional approach has to be executed on learners on the specific attribute. Then a few questions related to the attribute will be asked to check the effectiveness of the remediation given. If the learners are found to answer correctly, then the summary of the attribute will be presented and end of the remedial instruction on this attribute will be closed. In case, if the learners are responding incorrectly, then again

the initial step will be executed followed by second step. This is repeated only once as the remedial instructions generally possess shorter time period.

Conceptual Change Model

Conceptual Change Model is a popular, contemporary conception of meaningful learning model. It tells about the changes in conceptual frameworks i.e. Mental Models or personal theories that learners form to comprehend a context (Jonassen et al., 2005). In addressing issue of misconceptions of learners regarding several contexts, the analogy between individual learning and conceptual change in the disciplines has been fruitful to provide a suitable framework. The model also identifies the importance to address an individual's existing conceptions. As a result, it pinpoints how it can be effectively used as a tool for remedial measure to influence learning of students (Hewson, 1981). Accepting, practising and executing this model as "methods" of conceptual change in particularly science, requires expanding notions of scientific reasoning to encompass forms of creative reasoning. This model mainly focuses on three instruments as generative of conceptual change in science as follows, (i) analogical modelling, (ii) visual modelling, and (iii) thought experimenting. These instruments are interpretations of the processes of remediation (Nersessian, 1999). Conceptual Change researchers such as Özdemir and Clark (2007), have made significant development on two prominent theoretical perspectives of this model. These perspectives can broadly be classified as (i) knowledge as theory perspectives and (ii) knowledge as elements perspectives. These perspectives can be summarized in terms of how effective these are in real classroom situations to serve learners' comprehensive purpose. One of the best parts of this model lies in the hypothesis of changing teachers' conceptions of teaching about improvement in their teaching practices as a source of remediation along with execution to learners (Ho, 2000). Yet it has been observed that Conceptual Change Model is difficult to execute to some extent and but it gives rise to rectification of misconceptions when it requires the revision of fundamental presuppositions of the framework theory (Vosniadou, 1994). This diagram (Figure 4.) illustrates the conceptual change model as applied to remedial measures for addressing misconceptions in chemistry, guided by appropriate pedagogy (Anggoro et al., 2019).

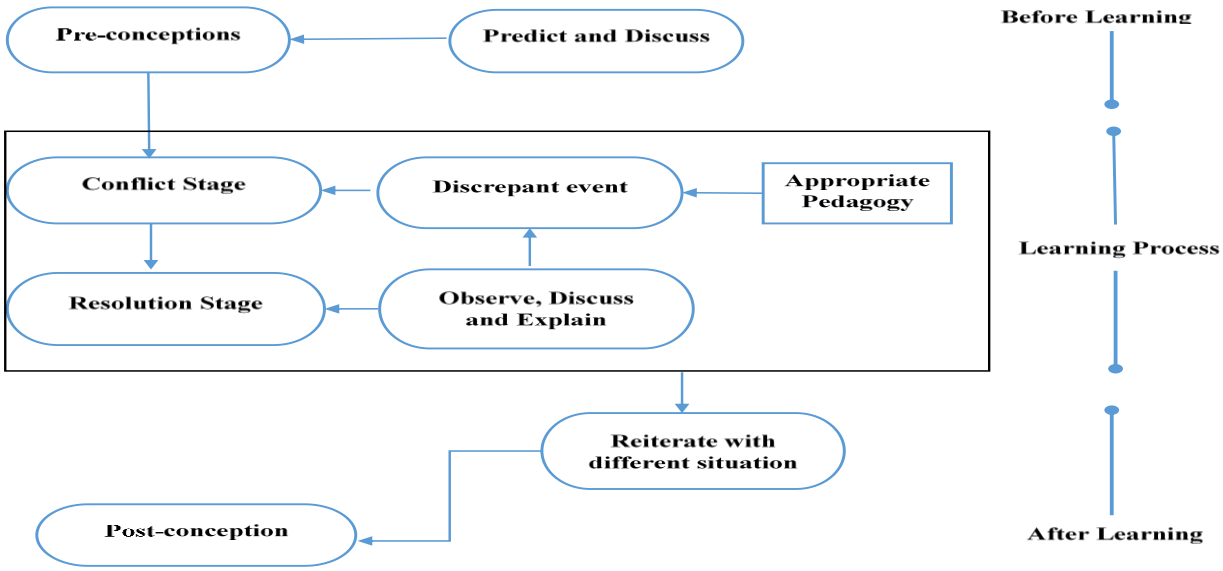

Figure 4. Schematic diagram remedial instruction through conceptual change model

It demonstrates how students' progress from pre-existing inaccurate idea (Pre-conceptions) scientifically accurate understanding (post-conceptions) through a structural learning sequence.

Diagnostic Classification Model

Diagnostic Classification Model (DCM) provides scope to construct response data from learners from formative assessment. According to this model, each student is classified into knowledge content groups for remedial teaching (Sessoms & Henson, 2018b). DCM is very much encouraged by psychometricians now a day, as an important modelling alternative to analyses students' learning difficulties and overcoming it (Rupp & Templin, 2008). As per the study of Sessoms and Henson, (2018) DCMs are classified learners based on the conceptions they have mastered given their assessment performance. This classification enables targeted feedback that can inform remedial instruction much effectively in a detailed way. Some studies, which are based on theory and simulation-based results, show how DCMs uniformly provide greater learner estimate reliability than conventional methods for remediation (Templin & Bradshaw, 2013). Diagnostic Classification Model for formative purposes has been a successful provision that support meaningful instructional approach that leads to careful diagnostic assessment (Kunina-Habenicht et al., 2009). This flow chart (Figure 5.) depicts a diagnostic classification model for enhancing students' understanding for chemistry concepts. It first identifies

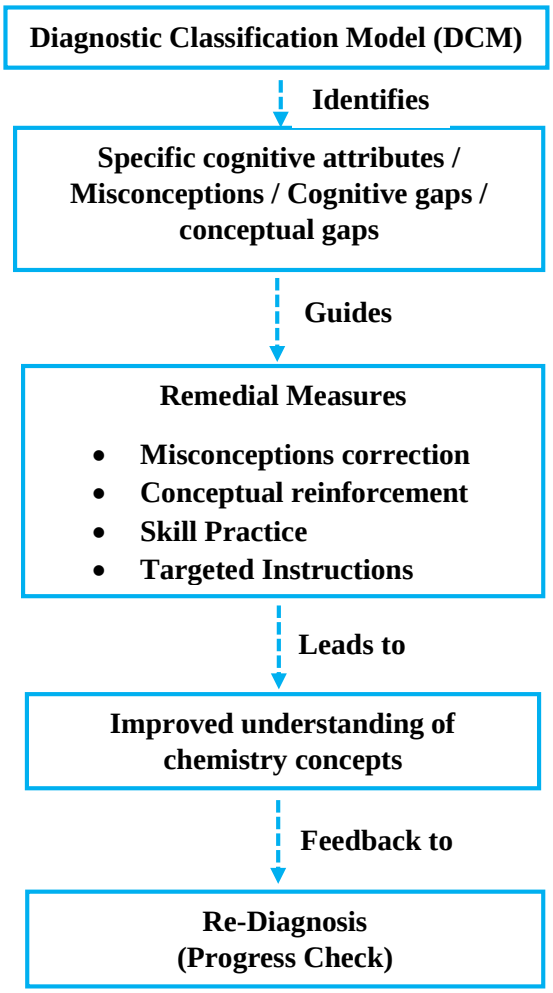

Figure 5. Flowchart of diagnostic classification model (DCM)

specific cognitive attributes such as misconceptions, cognitive gaps and conceptual weakness. These diagnostics guide the development of remedial measures including misconceptions correction, conceptual reinforcement, skill practice and targeted instructions. As a result, students achieve an improved understanding of chemistry concepts. This progress is then fed back into the re-diagnosis phase which assesses learning outcomes and adjust treatments resulting in a continual cycle of diagnostic teaching and learning.

Discussion

The findings of this study highlight the necessity of utilizing theoretically grounded ways to resolve persisting misconceptions in chemistry. Each of the models contribute uniquely to the remediation process. The Mastery Learning Model (MLM) emphasizes the need of acquiring a high degree of understanding before moving further. This methodology promotes structured instruction and formative assessment while enabling students to learn at their own pace until competency is reached. The Cognitive Diagnostic Model (CDM) provides a more detailed assessment by identifying specific cognitive strengths and deficiencies. This model enables extensive learner profile and assists teachers in developing interventions that directly address the source of conceptual misconceptions, making remediation more accurate and personalized. The Conceptual Change Model (CCM) provides insight into the psychological and cognitive barriers that prevent students from replacing misconceptions with scientifically accurate information. By acknowledging learners' existing knowledge and leading them through cognitive conflict and restructuring, this strategy promotes long-term change in conceptual understanding. The Diagnostic Classification Model (DCM) is a cognitive diagnostic assessment framework that categorizes students based on distinct patterns of knowledge, abilities, and misconceptions. These models help to build instructional frameworks that not only correct misconceptions but also foster deeper learning and engagement with chemistry concept.

Conclusion

This study reveals that remedial measures of misconceptions in chemistry is best supported by theoretical frameworks that address different dimensions of learning. This study focused on the distinct contributions of four key educational model: The Mastery Learning Model (MLM), the Cognitive Diagnostic Model (CDM), the Conceptual Change Model (CCM), and the Diagnostic Classification Model (DCM). Each provides a valuable lens through which remediation might be understood, created, and implemented through which remediation can be understood designed and implemented. Integrating these frameworks allows educators to progress toward more focused, diagnostic, and responsive instruction. These theoretical foundations allow for the development of strong instructional frameworks that not only efficiently resolve misconceptions, but also foster long-term conceptual understanding and learner engagement.

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