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RESEARCH PAPER

Conceptual Change Framework of Instruction Model in Teaching Chemistry to Undergraduate Students

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ABSTRACT

The use of conceptual change frame of instruction (CCFI) model is encouraging and self-motivating to address the persistent complementary conceptions of the students. However, the educators always face some difficulties in explaining the intellectual and decisive scientific concepts. The purpose of this study was to appraise the efficacy of the CCFI model in correcting the misconceptions of undergraduate chemistry students. Prior to the implementation of the CCFI model, an assessment of pre-existing knowledge of the students was performed through the structure of the observed learning outcomes (SOLO) taxonomy. For this purpose, a quasi-experimental research design was carried out. A total of 70 chemistry students from Public Sector University, divided into two intact groups, were cross-examined for the study. Further, before and after the CCFI model, an achievement test based on Chemistry concepts was conducted, covering all six cognitive domains of the Bloom taxonomy of educational objectives. Data analysis revealed that the CCFI model had a statistically significant impact on undergraduate students for elimination of their misconceptions about Chemistry.

KEYWORDS Chemistry Education, Conceptual Change Frame of Instruction, Information and Communication Technology

Introduction

The core text Acquiring a deep understanding of complex and controversial scientific concepts requires the reconstruction of intuitive notions to create a more robust scientific conceptual framework (Arabeyyat et al., 2022). The chemistry education faces the challenge of ensuring that students fully grasp the concepts that are being presented to them (Song & Long, 2022). Chemistry Education has emerged as an important research area in recent years, with applications in both traditional and advanced industries such as microprocessors, food, and textiles (Rudolf et al., 2022). As a result, there is a growing demand for chemistry education at the undergraduate level to equip students with the essential skills and knowledge needed to succeed in this field (Bartolucci et al., 2022).

Teaching chemistry to undergraduate students presents unique set of challenges due to interdisciplinary nature and the distinctive behavior of chemicals (Curreli & Rakich, 2020; Quirola et al., 2018; Sakhnini & Blonder, 2018). Nevertheless, previous research suggests that chemistry education increases students' motivation (Lati et al., 2019; Yolcua & Dyehouse, 2018), their inclination to pursue a scientific career (Rudolf et al., 2022) and encourages their curiosity and their commitment in the field of science (Li et al., 2022). Moreover, it helps improve students' understanding of the nature of modern science (Blonder & Mamlok-Naaman, 2019).

Literature Review

Several factors can influence the development of critical conceptual understanding, such as the difficulty and complexity of the subject matter (Nugroho, 2021), the type of learning assets used, and the degree of student participation (Karsh & Patan, 2016), as well as Personal viewpoints and previous knowledge (Dorsah & Okyer, 2020). The presence of these factors may lead to the formation of misconceptions, which are individual ideas, views, and understandings that are inconsistent with commonly accepted scientific meaning. Students may hold in to such misconceptions from their secondary education, and such cognitive frameworks and past experiences can hinder their integration of novel ideas (Addido et al., 2020). People comprehend the world by constructing explanations that interpret their surroundings, drawing upon their experiences and pre-existing knowledge (Slater et al., 2018).

Understanding concepts involves many different interpretations. Rather than depending solely on rote memorization, it refers to pupils' ability to produce and integrate meaningful and practical interconnected ideas and facts, according to Mills (2016). With the help of this kind of understanding, students can learn things that they can apply outside of the four walls of the classroom (Moser & Chen, 2016). From a broader standpoint, Vosniadou & Mason (2012) connected conceptual knowledge with a transformational change in attitudes and values pertaining to a particular notion, which might stir up powerful feelings, prejudices, and personal views. In the end, this method of teaching exerts a significant influence on the extent to which students grasp a concept and how well they can explain a specific phenomenon (Konicek-Moran & Keeley, 2015). When students understand the significance of the lesson and can apply it to real-world situations, learning becomes effective and lasting.

To effectively address the specifics of chemistry curriculum, the Conceptual Change Framework of Instruction (CCFI) model was used in this study. It is generally accepted that students' prior knowledge of a concept significantly influences their learning process. Hence, it is vital to comprehend students' conceptual frameworks while devising classroom activities and strategies (Gafoor & Akhilesh, 2010). The CCFI model represents a learning process wherein existing concepts undergo transformation, serving as the foundation for the cultivation of precise and robust scientific knowledge (Mills et al., 2016). It is evidenced through the literature that when students are guided through a conceptual change instruction framework incorporating 3D models and interactive simulations, they tend to relinquish alternative ideas or misconceptions more readily, leading to the development of a more well-informed comprehension of scientific concepts (Barnett et al., 2015; Madaiton et al., 2022).

Hypotheses

HO1: There is no significant effect of CCFI on students' misconceptions regarding chemistry topics.

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Material and and Methods

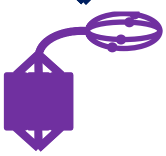
A non-equivalent control group design was used. The lesson plans, on the other hand, were developed based on the CCFI model. The experimental group was taught using CCFI model while the control group was taught using the 5E-teaching model. The impact of the intervention on students' knowledge of chemistry concepts was assessed using the pre-test/post-test. The experiment was conducted at a public sector university in the Multan district. There were 641 students who were enrolled in different chemistry courses in a public sector university. Out of these 641 students a total of 70 undergraduate chemistry students with asked questions about their concepts of chemistry. The SOLO taxonomy was used to assess their knowledge.

To assess the students' grasp of chemistry concepts, a 25-point achievement test was delivered. Item analysis was performed on the test to guarantee item difficulty and discrimination (Hamamoto Filho et al., 2020).

The SOLO Taxonomy

The students' prior knowledge was evaluated using the "Structure of the Observed Learning Outcome" (SOLO) taxonomy (Biggs & Collis, 1989). The SOLO taxonomy is a framework for comprehending and quantifying the complexities of learning outcomes. It gives a framework for understanding how pupils progress from surface-level to deep-level understanding of a topic. It consists of five levels of comprehension that establish the taxonomy levels related to the configuration and content of chemistry, as shown in Table 1.

Table 1
SOLO taxonomy levels defining the configuration and content of the chemistry

SOLO Level	Level Symbol	Level of Connecting the Chemistry Concepts
Pre-Structural		No association with the concepts of Chemistry
Uni-Structural		Specify only one connection but do not explain its relationship
Multi-Structural		Connections to several topics but do not explain their relationships
Relational		Describe the relationship to the concepts of Chemistry
Extended Abstract		Generalize and transform the concepts of Chemistry

Conceptual and Theoretical Framework

To address the misconceptions of undergraduate chemistry students about chemistry, six levels of the CCFI model were used in the lesson plans. The schematic representation of the implemented CCFI teaching model is shown in Fig. 1.

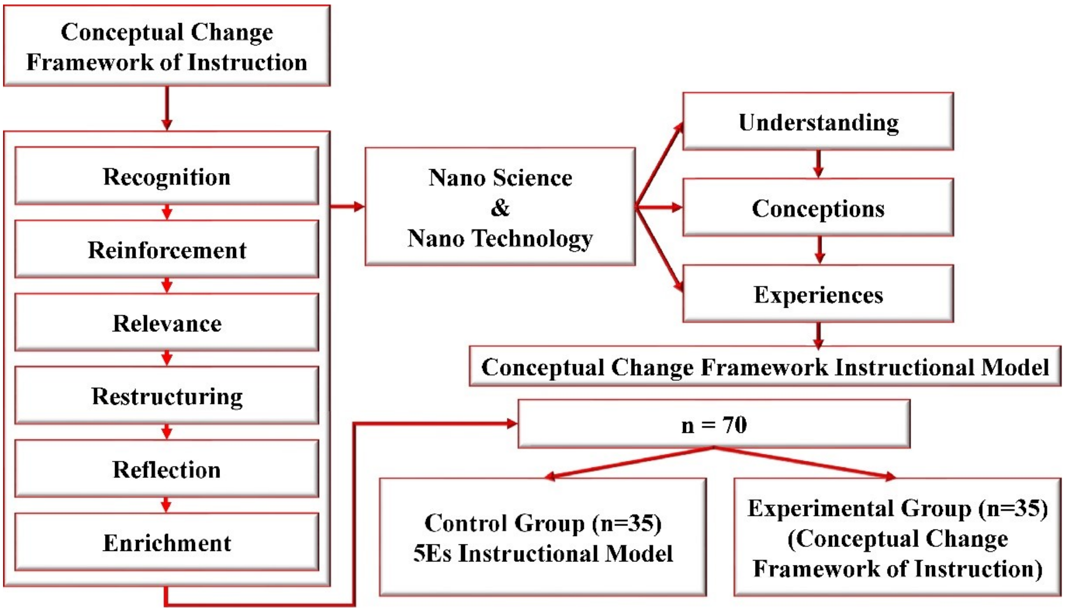


Fig. 1. Schematic outline for implementation of CCFI teaching model.

Stage one was the recognition stage. In this phase, we examined students' prior knowledge of chemistry concepts. The next stage was reinforcement. In this stage we used teaching aids that can make our lecture interesting and understandable. The third stage was relevance. In order to connect the learner's context with the principles of chemistry, we aim to bridge the gap, we used localized examples and scenarios that were pertinent to the students throughout the relevance phase. The next step was restructuring. We provided students the freedom to reorganize prior knowledge and newly acquired information to provide feedback to empower them to take ownership of their learning and encourage critical thinking. The next step was reflection. At this stage, students had the opportunity to reflect on how they might apply the concepts in real-world situations to reflect on their education. In the final phase of the framework, we deepen students' understanding of the concepts of chemistry topics through practice or reinforcement with additional materials. We gave the lectures on how to put them into practice. In order to determine whether there is a significant difference in the level of knowledge of the students, pre-test and post-test measures were used to evaluate the students.

Statistical Analysis

To explore the impact of CCFI on students' misconceptions about chemistry curriculum, the data as-obtained were analyzed using a statistical data analysis involving repeated measures, a paired-sample t-test, and an independent-sample t-test. The paired-sample t-test was conducted to find the difference between the mean scores before and after the same group tested, and the independent-sample t-test was used to find the mean score difference between two independent groups. These statistics were used because the study variables were continuous, observations/tests were independent, variables were normally distributed with no outliers, and both groups were independent.

Results and Discussion

The SOLO taxonomy provides an extremely valuable framework for understanding and quantifying learning outcomes. Using the SOLO taxonomy, teachers designed effective assessments and instructional strategies that helped students develop a deep understanding of the topics they were studying. The knowledge of different students was evaluated through tasks, assignments, quizzes and tests on content related to chemistry. We got some alarming results and found that students have some serious, well-known misconceptions about chemistry concepts.

Almost all students have the same misconceptions about the topics. We then developed an achievement test. A pre-test and post-test was carried out in both groups.

Table 2
Comparison of Achievement Test on the basis of pre-test and post-test mean scores

Groups	Mean	SD	t-value	Df	Sig. (2-tailed)
Experimental group pre-test	12.68	.989	-28.625	34	.000
Experimental group post-test	20.32	1.341			
Control group pre-test	12.53	.959	-1.000	34	.313
Control group post-test	12.57	.940			

Note: p=0.05 and n=35

The table provides information about the means, standard deviations, t-values, degrees of freedom (df), and significance levels (Sig.) for the pre-test and post-test scores of the experimental and control groups. For the experimental group, the mean score on the pre-test was 12.68 with a standard deviation of .989. The t-value of -28.625 indicates a significant difference between the pre-test and post-test scores. The degrees of freedom (df) are 34, and the p-value (Sig.) is 0.000, suggesting a highly significant difference. The note indicates that the significance level (p) is set at 0.05, and the sample size (n) is 35. This means that a p-value below 0.05 is considered statistically significant.

Table 3
Comparison of Independent Groups on the basis of pre-test and post-test scores for SAT

Groups	M	SD	t-value	df	Sig. (2-tailed)	Cohen's d
Experimental group pre-test	12.68	.989	.610	68	.526	
Control group pre-test	12.53	.959				
Experimental group post-test	20.32	1.341	32.350	68	.000	7.5
Control group post-test	12.57	.940				

Note: p=0.05 and n=35

For the experimental and control group, the pre-test mean score was 12.68 and 12.53 with a standard deviation of 0.989 and 0.959. The t-value of 0.610 indicates a small difference between the pre-test scores of experimental and control group. The degrees of freedom (df) are 68, and the p-value (Sig.) is 0.526, which suggests that the difference is not statistically significant.

For the experimental and control group, the post-test mean score was 20.33 and 12.57 with a standard deviation 1.341 and 0.940. The t-value of 32.350 indicates a large and highly significant difference between the pre-test and post-test scores. The p-value (Sig.) is 0.000, indicating a statistically significant improvement. The effect size (Cohen's d) is 7.5, which signifies a very large effect.

Information provided in the table 2 and table 3 is about comparison regarding understanding of chemistry topics of experimental and control groups before and after the test. The values showed that the experimental group performed better in post-test scores. This improved score of the experimental group in the post-test to resolve the misconceptions related to chemistry topics was predicted due to the intervention of CCFI.

The CCFI model is widely used in various educational settings, particularly in science classrooms, where learners often have misconceptions that need to be dispelled in order to develop accurate scientific understanding. It is recognized that changing misconceptions is a complex process that requires active engagement, reflection and the reconstruction of learners' mental models. In such crucial situations, we planned to eliminate these misunderstandings among the students and applied the CCFI model. By applying this approach, we have imparted the real knowledge and eliminated the students' misconceptions about chemistry topics. In teaching chemistry through conceptual changes, we have also used a context-based approach as it is believed to be facilitating the connection of scientific concepts to real-life contexts, CCFI proves effective in dispelling student misconceptions and alternative ideas (Picardal, 2019).

Discussion

The study showed how the newly developed instructional paradigm known as CCFI helped students understand and accurately conceptualize scientific ideas. The experimental group's degree of student comprehension of chemistry concepts increased significantly. This significant finding in favor of CCFI may be explained by its suitability for the online learning environment in which the instruction was administered for both the delivery process and the different phases of the instructional model. The purpose of CCFI was to give teachers and students another alternative when it came to lesson planning, which was similar to Kural and Kocakülah's (2016) proposal that was for a novel teaching model named Teaching Model for Hot Conceptual Change (TMHCC), which consists of eight phases of learning syntaxes designed to foster conceptual change.

The acquisition of 21st century abilities has been regarded as being facilitated by conceptual shift as a viable teaching strategy (Djudin, 2021). Posner et al. (1982), relying on Posner as the main proponent of conceptual change theory, explained that for conceptual change to occur, four conditions must be met: CCFI takes into account all the criteria for conceptual change, which include (1) dissatisfaction with the initial conception, (2) improved ease of understanding the new concept, (3) increased plausibility of the new concept, and (4) recognition of the usefulness or fruitfulness of the new concept. These criteria are evident in the various levels of instruction and are reflected in the students' enhanced comprehension and transformed concepts. CCFI specifically emphasized the significance of identifying the contributions that students make to the classroom. To encourage conceptual understanding, it is essential to acknowledge students' past knowledge (Dorsah & Okyer, 2020). Additionally, it is crucial to keep in mind that in order for students to completely grasp the lesson, the activities must be successful in piqueing their interest and making them want to engage in the discussion rather than just listen to the teacher (Slater & Gelderman, 2017).

The study's findings corroborate Yldz-Feyziolu and Dimitri's discovery that open inquiry appears to have profound enough impacts to modify students' conceptions. They also showed greater satisfaction with the fact that the CCFI phases featured differentiated educational activities. The reflection step may also be one of the CCFI's key features for encouraging conceptual change. The similar claim about the benefits of a metacognitive method in teaching science topics was made by Antonio and Prudente (2021). Since the majority of these children were digital natives, the online activities they engaged in may have also contributed to their learning gains.

The CCFI was developed to adapt to the new learning modality and enable continuous learning. According to Shatri (2020), incorporating information and communication technology offers several advantages, empowering students to optimize their learning experience. Notably, concept mapping has proven to be an effective technique for fostering conceptual understanding, as demonstrated in a study by Bakouli and Jimoyiannis (2014), who found that concept mapping facilitates idea integration and enhances learning. In line with this, the CCFI places significant importance on utilizing diverse instructional materials suitable for online learning within the educational context.

According to Adkins (2020), the purpose of using instructional materials is to enable students to integrate the knowledge presented to them. Consequently, CCFI provided students with a tool that not only facilitated a comprehensive understanding of chemistry concetps but also made the learning experience enjoyable. It is important to note, however, that this study does not claim that conceptual change progresses in a strictly linear manner in accordance with the stages of the instructional model. Individual students may experience conceptual change at different points in their learning journey, and the pace of change can vary, especially within the constraints of limited instructional time. Djudin (2021) also emphasizes the same point, acknowledging that while conceptual change may occur, learners might not completely abandon their earlier conceptions. Nevertheless, the study's confirmation of CCFI's ability to enhance conceptual knowledge and promote conceptual transformation among students holds significant value.

Conclusions

In this study, different paradigms of teaching techniques are used to assess instructional settings in lesson plans and examine the effectiveness of the CCFI model in correcting misconceptions of students. The CCFI model proves to be an effective approach for teaching chemistry concepts to students. The application of the CCFI model has resulted in significant improvements in understanding and comprehension of the complex concepts among students. By adopting this instructional framework, educators can encourage conceptual change and enhance the learning experiences of students in chemistry teaching. The finding highlights the potential of the CCFI model as a valuable tool for chemistry education, ensuring that students can actively engage and succeed in learning challenging chemistry concepts.

Recommendations

As per our proposed study, here are some recommendations for future research:

- Longitudinal studies may be conducted to examine the long-term effects of implementing the CCFI model in teaching chemistry, physics and biology concepts to students. This would help determine whether the conceptual changes achieved by the Conceptual change frame of instruction model are sustainable over time.
- Generalizability may be investigated of the CCFI model across different age groups and educational settings. Its effectiveness may be assessed in teaching chemistry concepts to students in diverse populations and cultural contexts.

- There may be a training programs for science teachers to explore the effective implementation of the CCFI model. Examine how science teachers' knowledge, attitudes and instructional practices affect the outcomes of using the CCFI model to students.
- A mixed-methods research design may be employed that combines qualitative and quantitative measures to provide a comprehensive understanding of the effectiveness and implementation of the CCFI model. This could include collecting both quantitative data on learning outcomes and qualitative data on students' experiences, perceptions and attitudes towards the instructional approach.
- Investigation may be done to the integration of technology tools and digital resources into the CCFI model to improve engagement and learning outcomes of students. Discovery may be done for the potential of multimedia materials, simulations, and virtual labs to support conceptual changes in chemistry education.

Considering these research recommendations may provide additional insights into the effectiveness, generalizability, and instructional strategies associated with the CCFI model in teaching chemistry concepts to students. These insights can help refine and improve Science, Technology, Engineering and Mathematics educational practices for students with diverse learning needs.

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