The Effect Of Concept Map Scaffolding On Learning Effectiveness For Chemistry Student

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Abstract

While concept maps are valuable tools used to organize and represent ideas, the complexity and variability in how concepts are understood, connected, and represented make learners less receptive to using concept maps. Hence, it is important to employ scaffolding and motivational strategies to help students deal with complexity in working with concept maps. Self-efficacy and perception of the helpfulness of concept maps may enhance students' responsiveness and adaptability of concept mapping. In this quasi-experimental study, we conducted a one-way multivariate ANOVA to examine the difference among chemistry students. A substantial number of students reported that the mapping activity is helpful. Theoretical and practical implications are discussed.

Keywords: Concept mapping, Scaffolding, Self-Efficacy, Helpfulness, Motivation, Chemistry Education

Introduction

Concept Maps (CM) have gained credence as effective tools among educators, learners, teachers, and researchers especially in the STEM field (Adesope et al., 2013; Novak & Canas, 2007). It serves as a valuable learning tool for visualizing and structuring conceptual knowledge by connecting nodes and links to make meaningful representation (Adesope & Nesbit, 2013; Canas & Novak, 2012). They facilitate the representation of key concepts and their interconnections to foster generative learning (Fiorella & Mayer, 2015). Generative learning relies on learners' ability to retrieve prior knowledge from long-term memory and link it to newly acquired conceptual insights (Hwang & Chang, 2021).

Despite the effectiveness of concept maps, their complexity and usability in educational settings pose considerable challenges to students, especially those who are unfamiliar with its usage (Adesope et al., 2013, 2022; Chen & Sue, 2013; Machado & Carvalho, 2020; Novak & Canas, 2007). The abstractness and symbolic nature of scientific constructs, as observed in disciplines like chemistry, contribute to the perceived difficulty and the resulting challenges, including student disengagement and suboptimal performance (Boylan-Ashraf, 2020; Cardellini, 2012; Patall et al., 2018). Research indicates that the difficulties associated with concept mapping often stem from the complexity of domain-specific concepts, intricate concept map structures, or individual differences among learners, rather than inherent flaws in the concept mapping technique itself (Adesope & Nesbit, 2013).

Notwithstanding, concept mapping has been found to enhance engagement and facilitate meaningful learning when appropriately applied (Novak & Canas, 2007; Okebukola & Jegede, 1989). Concept mapping finds diverse applications in curriculum development, instructional design, research, learning assessment, professional practice, and policy formulation (Adlaon, 2012; Mani, 2012; Schroeder et al., 2018; Wei & Yue, 2017). Notably, concept maps play a pivotal role in elucidating complex relationships among concepts, thereby enhancing learning outcomes. Concept maps help explicate conceptual relationships and improve learning in STEM courses, especially when it is scaffolded (Sundar, 2022).

Concept Map Scaffolding

Concept mapping is itself a scaffolding strategy to learning; however, a close examination indicates the need for aiding learners in using concept maps (Chen et al., 2013; Kaushik, 2017). Various empirical evidence suggests concept mapping to be an effective, powerful learning tool for enhancing deeper and meaningful learning (Novak & Canas, 2007; Kaushik, 2017; Adesope & Nesbit, 2013; Roth & Roychoudhury, 2023). Researchers are making strides in establishing the effectiveness of various dimensions of concept map scaffolding for learning, including expert-assisted or construct-on-scaffold (COS) versions, collaborative or peer-focused, schematic-assisted, feedback assistance, technology/computed-supported, augmented-reality-based concept maps (Adesope, 2008; Akinsanya & Williams, 2004; Chang et al., 2008; Chen et al., 2016; Kinchin, 2014). Instructors typically face challenges in organizing a curiculum that ensures meaningful learning, and concept maps can be helpful in this aspect, providing a clear and valid structure for instruction and componential learning support, especially for deep learning outcomes (Alt, 2021; Chang et al., 2008).

Scaffolding, associated with Vygotsky's sociocultural theory, implies the support provided by a knowledgeable person to help a learner do on their own activities beyond the individual's capability (Vygotsky, 1978). Scaffolding techniques can include asking probing questions, providing hints, offering explanations, providing structure to help the learner move from a state of dependence to greater independence. Vygotsky believed that effective scaffolding is crucial for facilitating cognitive growth and that it promotes the development of higher-order thinking skills and complex task performance.

Moreso, concept mapping, as a social cognitive strategy, is supportive and offers additional assistance or guidance for learners in the use of concept maps, providing 'metacognitive cue/prompts/intervention' which could be in the form of keyword prompt or diagram completion prompt, can enhance learning outcomes as a form of scaffolding learners (de Bruin et al., 2011). The benefit of scaffolded concept maps has been extensively researched, including cognitive load reduction, critical in supporting academic achievement more than traditional learning strategies (Aguiar et al., 2019; O'Donnell et al., 2002).

Farther, Chen et al. (2013) establish that an instructional-based approach to scaffolded concept mapping is critical in meaningful concept learning and supports academic achievement more than traditional learning strategies. In another study, Oni (2021) argued that the learning outcomes of learners in the scaffolded concept maps group exceed that of learners in the non-scaffolded group. Wong et al. (2021) found that the static concept maps group performed better than the group that constructed maps with provided labels. Although the labels or linking phrases prompts provided in concept maps' construction can either be constraining or supporting, researchers have found out that providing scaffolds to learners in the form of concepts, links, or both tends to capture the focus of learners within the suggested propositions rather than in supporting them in achieving high scores and quality (Eggert et al., 2017; Yin et al., 2004).

A distinctive method for addressing this issue involves adopting supportive mechanisms to facilitate the acquisition of deeper learning (Chang et al., 2008; Eggert et al., 2017). However, prior research has shown that challenges arise when learners need more prior knowledge of specific domain topics or complex topics (Canas et al., 2012; Eggert et al., 2017).

Self-efficacy theory is central to the Social Cognitive Theory of Albert Badura, which involves cognitive self-evaluation, self-reactive and reflective capacities, concerning one's competence and capacity to effectively organize and approach particular goals (Bandura, 1977). Personal capability-related beliefs lie at the center of human functioning, including learning and motivation (Artino, 2012). Previous studies demonstrated the effectiveness of academic self-efficacy in promoting mastery goals, self-regulated learning, and achievement and revealed that self-belief would help students develop goals and increase confidence and persistence in challenging tasks (Thomas, Bennett & Lockyer, 2016; Wilson & Kim, 2019). The study suggests that students perceived self-efficacy is influenced by their ability to learn and achieve academic success through concept mapping activities (Chularut & DeBacker, 2004).

Individual perceptions or feelings of self-efficacy drive a student's choice of activities, increase their efforts, sustain their persistence even when they face difficulty, and eventually enhance their learning, achievement, and mastery (Alt et al., 2021; Bandura, 1977; Chularut & DeBacker, 2004). Invariably, students may vary in their level of efficacy, resulting in differential experience in concept maps. However, those with personal efficacy beliefs about using concept maps may likely find concept maps helpful and participate in the activity (Schaal, 2010). Further, self-efficacy in concept mapping can have 'double active' effect in application: acting proactively and retroactively (Sun & Chen, 2016). For instance, Sun and Chen (2016), in a study with fifth graders, indicated how concept maps' performance increases the self-efficacy for learning in students who had first reported high self-efficacy. However, in a pilot study, Bressington et al. (2017) indicated that nursing students' perceived learning efficacy reduced after completing concept maps. Given this mixed findings, the present study seeks to examine how self-rated (percentage scale) learning efficacy support students in motivating concept mapping performance.

Helpfulness

Perceived helpfulness, a predominant criterion and standard indicator in learning design, has been employed in learning value assessment (Scheffel et al., 2014). The effectiveness of concept mapping as a learning strategy is significantly influenced by its perceived usefulness among other motivational factors. There is limited research on the motivational implications of concept map, especially as it relates to the value of helpfulness, a factor that could help students persist in learning (Wong et al., 2021). This motivation can be improved through technology and instructor assistance (Stevenson et al., 2017). Hao & Yu (2016) found that perceived usefulness (helpfulness) has a high, favorable implication for students' attitude towards concept mapping, using the technology acceptance model (TAM). They reveal that students' attitudes towards concept maps are influenced by their perceptions of usefulness, enjoyment, and ease of use. Perceiving concept maps as helpful will in essence, increase motivation, engagement, and enhance learning achievement. Although previous works in this area have demonstrated concept maps' helpfulness in mathematics (Hao & Yu, 2016) and mental health (Bressington et al., 2018), this study aims to understand concept maps' helpfulness in chemistry learning.

Given the continual decline in STEM academic achievement, a growing interest in scientific research and motivation is imperative. Motivation is a vast knowledge area encompassing many theoretical perspectives applicable in different human endeavors, including learning, sport, and career. The value-expectancy theory concerns the perception conditioning which increases or decreases the probability that an individual will engage in it to learn (Eccles & Wigfield, 2020). An individual's choice and motive to achieve a given task are mainly dependent on his/her interpretation or perception of the value of the task, which consists of its attainment value (related to self-image), intrinsic or interest; utility (usefulness or helpfulness); and cost, including the effort, rigor, time, and other alternatives of engaging in the activity (Eccles, 2005).

The present study aims to examine how perceived helpfulness reflect the value subjectively placed on concept maps as a learning tool and explore its dimension from students' perspective.

Present Study

Because there is a scarcity of classroom-based research utilizing concept maps in STEM majors, there is a need for more ecologically valid investigations (Kihlstrom, 2021). Moreso, while recognizing the fact that self-efficacy has scientifically proven to have a significant impact on learning and academic performance, we chose to investigate the extent of students' perceived self-efficacy and helpfulness of concept maps (Hunsu et al., 2023; Alhadabi & Karpinski, 2020)self-efficacy, achievement orientation goals, and academic performance in parallel and serial mediation models. University student participants (N = 258. In this ecologically valid, classroom-based study, students created their own concept maps with prompts in the form of concept-only and concepts with labels with the time allotted and the amount of prior knowledge of the students. The added labels is aimed at providing additional supports, which may aid deeper understanding and meaningful learning (Kinchin, 2014; Yin et al., 2004).

Moreover, participants in the present study are undergraduate students in an introductory chemistry class, a subject that many students find difficult. We chose a domain topic, quantum number, investigated among a chain of study of critical chemistry concepts students often struggle with, including enthalpy, atomic structure, gas law, and mole concepts. This study aims to investigate the impact of learning support on student academic achievement with slightly different scaffold interventions, that is, constructing maps with concepts and labels provided or working with given concepts only. The provided concepts and labels serve as extra support for students in making using concept maps (Kinchin, 2014). In addition, motivational variables (helpfulness and self-efficacy) were explored to gain more insights into the dimension of interaction students have using concept maps.

Constructing a concept map from a list of given labels (links) and concepts (Scaffold-Concept-Labels).
Constructing a concept map from a list of given concepts (Scaffold-Concept-Only)

In addition, we seek to examine the degree to which self-reported self-efficacy index and perceived helpfulness of concept maps affect students' performance in the mapping activity.
The study mainly focused on the following research questions:

1. What are the effects of two different formats of CM scaffold (Scaffold-Concepts only and Scaffold -Concepts -Labels) on chemistry learning performance?
2. To what extent do self-efficacy and helpfulness predict chemistry students' learning performance?

Methods

Participants

A total of 564 undergraduate students who registered for a required, introductory chemistry course at land-grant university located in the Pacific Northwestern region of the United States participated in the study. All participants attended pre-training lectures to gain prior exposure to concept mapping. Students were conveniently grouped to one of the two conditions using between-subjects quasi-experimental design. Specifically, 237 participants were assigned to the CM scaffold-concepts and labels condition, 169 to the comparison group further divided by class time into scaffold-concept-only level I, and 100 to the scaffold-concept-only level II. Significantly, the study underwent review and received exemptions from the Institutional Review Board of the university, affirming its adherence to ethical research standards.

Learning Materials

The study utilized two concept map scaffold worksheets to aid students in constructing their concept maps. One worksheet offered concepts alone, while the other included both concepts and labels pertinent to a Chemistry domain topic. The expert-constructed map is as shown in Figure 1. Figures 2 and 3 show the sample of student-created maps for the two scaffolding strategies. One of

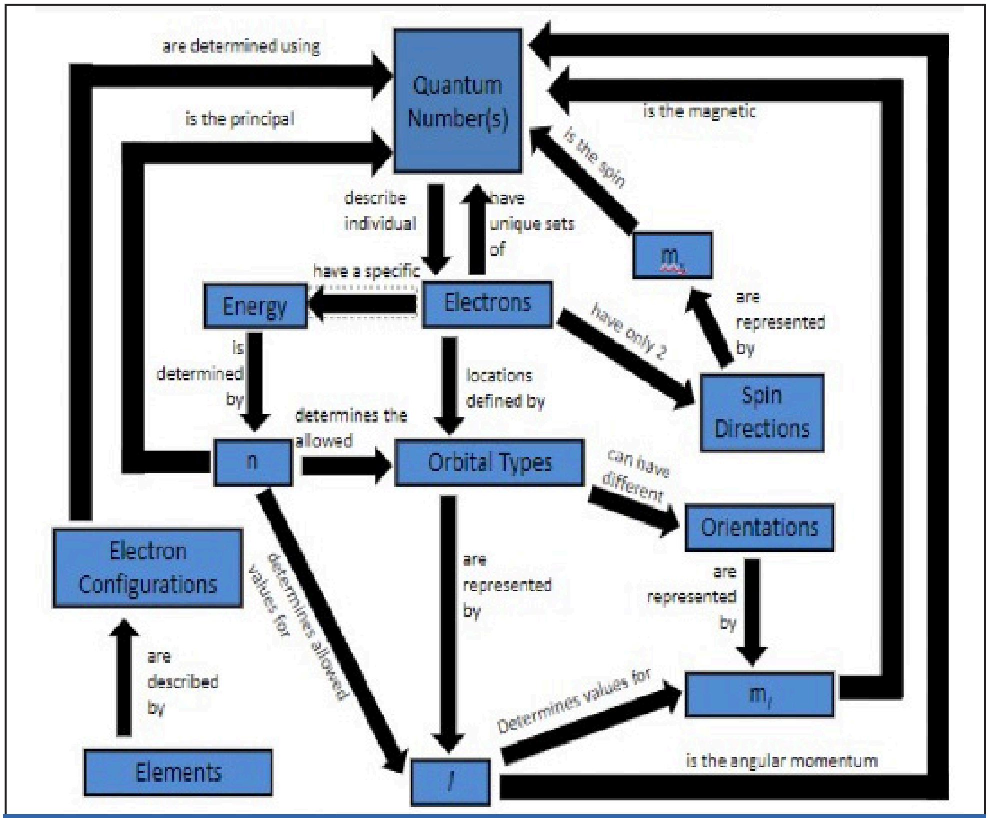
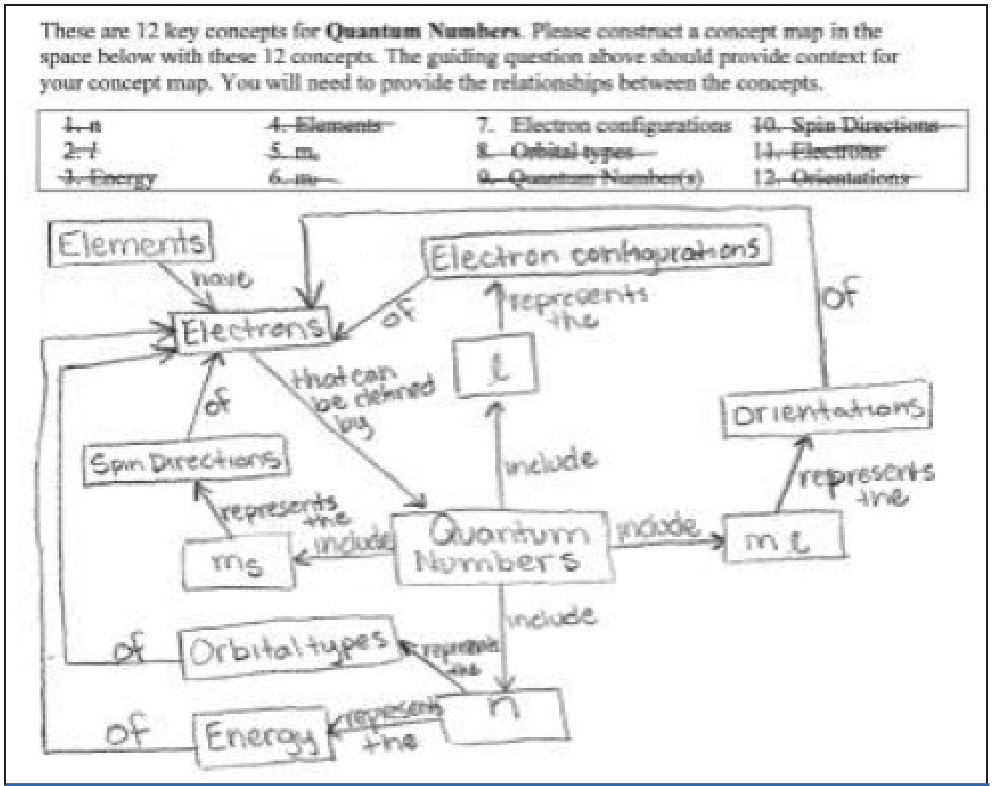


Figure 1. Screenshot of the expert constructed concepts map.

the two concept map scaffold methods contained 12 key concepts, while the other method contained additional 19 linking phrases (labels) that outlined the relationships between the 12 essential concepts of Quantum numbers. Students in both conditions constructed concept maps from scratch utilizing the given cues (concepts and labels or concepts only) as scaffolds. The course instructor developed and added guiding questions to the worksheets to help students recall previously learned topics. The guiding question aligns with the learning objectives for the class: How do Quantum numbers describe each electron within an atom?


These are 12 key concepts for **Quantum Numbers**. Please construct a concept map in the space below with these 12 concepts. The guiding question above should provide context for your concept map. You will need to provide the relationships between the concepts.

~~1. n~~
~~2. l~~
~~3. Energy~~
~~4. Elements~~
~~5. m_s~~
~~6. m_l~~
7. Electron configurations
~~8. Orbital types~~
~~9. Quantum Number(s)~~
~~10. Spin Directions~~
~~11. Electrons~~
~~12. Orientations~~

Figure 2. Screenshot of the scaffolded concepts map intervention (concepts only).

Measures

Conceptual and control inventory questions

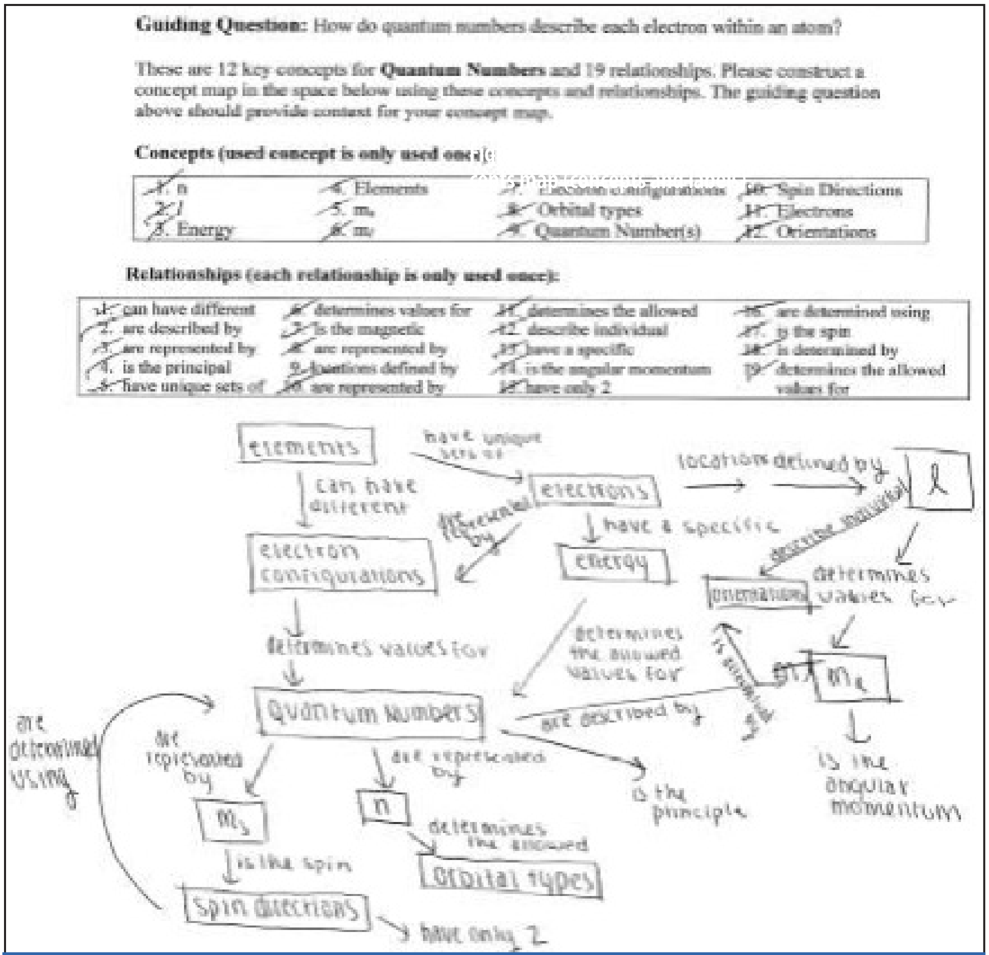
Twenty domain-specific questions were used – five for assessing prior knowledge (administered to all participants in the two conditions), and fifteen questions for assessment of posttest scaffolding interventions (provided concept and labels – group 1 and concepts only – group 2 (two classes). The prior knowledge questions evaluated the conceptual knowledge about Quantum number (for example, "What are quantum numbers used to describe? . . . correct answer: an electron). The descriptive statistics on pretest score measuring prior knowledge, ($M = 3.51$, $SD = 1.17$), show similar baseline prior knowledge levels among participants.

The post intervention scaffolding effect was measured through deeper conceptual and control inventory questions (e. g. If all of the following exist in the same type of orbital. . .correct answer: an electron with $n = 5$). The posttest was a multiple-choice test, obtained by map completion and accuracy of the concept only and concepts-labels conditions. The time spent on the task was captured for the pretest and posttest, while delayed retention points were measured. Measures of self-efficacy were obtained through a scaled question with a net promoter score system to assess students' level of perceived activity-related belief. Additional open-ended responses on concept mapping helpfulness was obtained where students were as asked "how helpful was the concept mapping activity in helping to summarize the key concepts. . ."

Procedures

The concept mapping activity occurred during a basic introductory chemistry class session in Fall 2019. After signing the consent form, participants were assigned via the learning management system to one of two conditions: (a) constructing a concept map from a list of presented concepts and (b) constructing a concept map from a list of presented relationships (labels) and concepts. The study was administered in two groups and in three sessions. Group A (8am) self-constructed scaffold concept maps with provided concepts and labels, but no concept maps structure given. In group B (1pm and 3pm), students self-constructed concept maps with the twelve given concepts only.

Prior to the research, the instructor provided each condition's participant with a blind link to the study activity on Qualtrics, an online survey provider. All processes were secured using a password that students were given before they arrived at the experimental session. Each student finished the session on their own. All participants took part in the pre-training session to statistically control for differences in domain knowledge. Following the learning phase, students in group B remained as control group, while group A were given distinct levels of scaffold intervention (in this case concepts and links).



Guiding Question: How do quantum numbers describe each electron within an atom?

These are 12 key concepts for **Quantum Numbers** and 19 relationships. Please construct a concept map in the space below using these concepts and relationships. The guiding question above should provide context for your concept map.

Concepts (used concept is only used once):

1. n	4. Elements	7. Electron configurations	10. Spin Directions
2. l	5. m_s	8. Orbital types	11. Electrons
3. Energy	6. m_l	9. Quantum Number(s)	12. Orientations

Relationships (each relationship is only used once):

1. can have different	6. determines values for	11. determines the allowed	16. are determined using
2. are described by	7. is the magnetic	12. describe individual	17. is the spin
3. are represented by	8. are represented by	13. have a specific	18. is determined by
4. is the principal	9. locations defined by	14. is the angular momentum	19. determines the allowed values for
5. have unique sets of	10. are represented by	15. have only 2	

Figure 3. Screenshot of the scaffolded concepts map (concepts and labels).

	Descriptive Statistics					
	Concept plus Labels (n = 260)		Concept Only I (n = 187)		Concept Only II (n = 117)	
Dependent Measure	Mean	SD	Mean	SD	Mean	SD
Pretest	3.55	1.14	3.4	1.19	3.6	1.19
Posttest	8.36	2.83	8.11	2.4	8.9	2.74
Delayed Retention	1	1.19	0.99	1.13	0.92	0.99
Open-ended	1.46	1.56	1.18	1.47	1.77	1.66

Table 1. Means and Standard Deviations of Outcomes for Each Condition

Additional multiple-choice and open-ended questions were included, and students were explicitly instructed not to refer to their notes or any external materials at any point during the exercise. The entire study was conducted at the pace of the learners and had a duration of approximately 50 minutes. To provide a clear timeline of our study organization, we allocated 5 minutes to the pre-test, 10 minutes for the learning intervention, and utilized the remaining time for the posttests. There were no requests for more time from students. Students rated their self-efficacy level on percentage score points. In this study, we coded the open-ended questions to identify the emerging themes and patterns (Oni et al., 2021).

First, a coding protocol was developed to identify and count the occurrences of target terms, and this protocol was rigorously and consistently applied by a single coder throughout the analysis. Then we independently conducted a pilot coding and double-check coding to verify the accuracy and consistencies of the frequency counts using Excel and MAXQDA software. The results revealed the frequency of each term or element in the dataset, providing valuable insights into the prevalence of these concept map helpfulness and moderating constructs within the responses. These frequency counts offer a quantitative perspective on the open-ended data, contributing to a better understanding of the themes and patterns present in the dataset. Detailed frequency data can be found in Figure [4-6], which displays the frequency counts for each term along with any additional relevant information.

Results

Preliminary Analysis

We conducted preliminary analyses to examine if the groups performed differently on the pretest score. We assessed variables to ensure accurate data entry, identify outliers, and evaluate the normality of distributions. According to Levene's test, the variances for previous knowledge were homogeneous. The analysis showed no signifi-

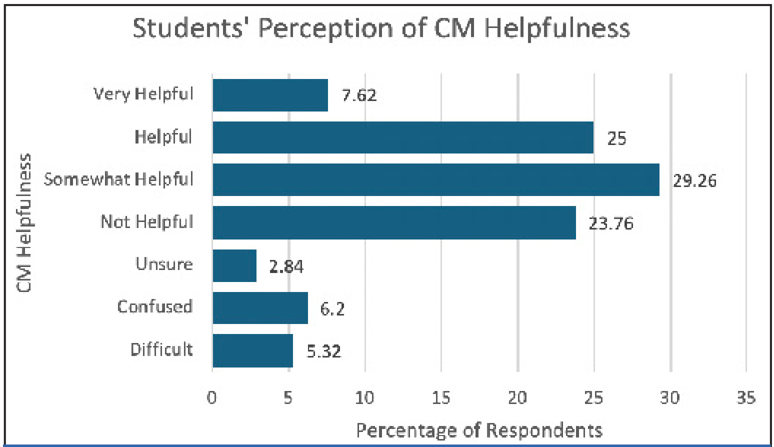


Figure 4. Participants' feedback on concept map helpfulness

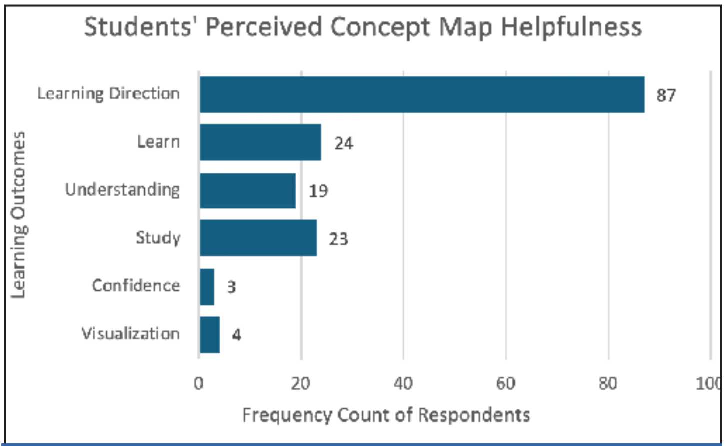


Figure 5. Participants' feedback on concept map helpfulness reflecting learning outcomes.

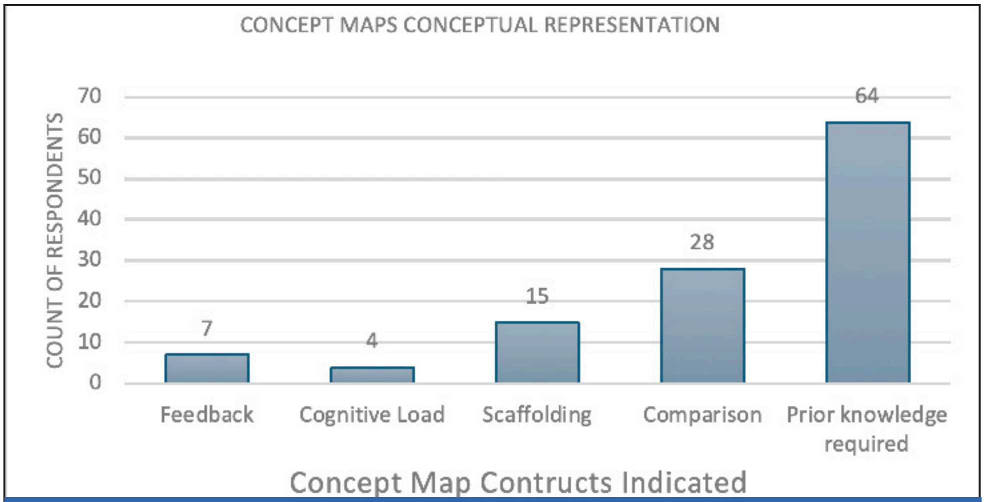


Figure 6. Participants' feedback on concept map constructs.

cant difference in performance between groups, F(2, 561) = 1.33, p = .27. Performance on the prior knowledge test was generally moderate for all groups (Scaffold-Concept plus labels: M = 3.55; SD = 1.143; Scaffold -Concepts only I: M = 3.40; SD = 1.193; Scaffold -Concepts Only II: M = 3.60; SD= 1.189). The pretest score was not used as a covariate in our analysis since there were no discernible differences between the groups.

What are the effects of three different formats of CM scaffold (Concepts and Labels and Concepts only) on chemistry learning performance?

With further assumptions met, a one-way MANOVA was conducted with three independent variables (conditions) and three dependent variables (DV)- map completion scores, total open-ended, and delayed retention, which were all proxies for learning performance. Results showed a statistically significant difference between the scaffold conditions on the dependent variables, F(6, 1002) = 2.359, p = .029, Wilks' Λ = .972, partial η2 = .014. In line with RQ1, a follow-up analysis was obtained to determine the between-subject effect. The result showed statistically significant difference between the two scaffold conditions and (1) map completion score, F(2, 503) = 3. 733, p < .025; partial η2 = .015; (2) open-ended, F(2, 503) = 4. 728, p < .009; partial η2 = .018; but no statistically significant effect between concept map scaffold formats and (3) delayed retention, F(2, 504) = 0. 203, p < .816; partial η2 = .001. Hence, Tukey's HSD pairwise comparisons showed a mean difference between group B (concepts only I and II), (.910, 95% CI [0.12, 1.71], p = .020), but no group differences was found for other pairs.

To what extent do self-efficacy and helpfulness predict chemistry students' learning performance?

In line with RQ2, participants reported aggregate moderate self-efficacy with the learning activity (M =29.52, SD = 33.12). A further analysis of the frequency showed that of these respondents, 50.4% reported very low self-efficacy (0.3 to 10%), 11.8% reported low self-efficacy(14% to 45%); 17.6% reported moderate self-efficacy (46% to 69%); while 20.1% reported high self-efficacy. Additionally, the ranked scores were transformed into a scaled score and a one-way ANOVA was conducted to determine the significant differences between the groups' efficacy level. Results showed a statistically non-significant difference between the scaffold conditions on self-efficacy, F(2, 538) = 0.211, p = .810.

On the other hand, students' responses to the open-ended questions on the helpfulness of the concept mapping activity was examined to understand further significant implications on learning and instructional design. Over 60% of the participants reported positive dimension to the helpfulness of the concept map activity (i. e. somewhat helpful, helpful, or very helpful). About 23% of the participants reported the concept mapping activity as not helpful, 6.2% as confusing, 2.84% as unsure, while 5.32% implied that concept map activity is difficult.

The student responses not only shed light to the effect of concept map scaffolding but also unveiled additional dimensions. These encompass various instances of learning outcomes that highlight how students perceive the helpfulness of concept mapping, including its role in visualizing essential concepts (4), boosting confidence (3), identifying areas for focused study (23), enhancing understanding (19), improving learning achievements (24), and providing guidance for future learning endeavors (87).

Furthermore, our analysis of student responses unveiled various constructs that hold potential implications for the study of concept mapping. The frequency data revealed recurring themes, including the necessity for feedback (7), cognitive demands encountered during map construction (4), the importance of scaffolding (15), comparisons with previous concept mapping activities (28), and the relevance of prior knowledge (64).

Discussion

This study investigated the effect of concept map scaffold formats on chemistry learning outcomes in an ecologically valid setting. The findings revealed that scaffold intervention, regardless of the CM scaffold format, had a positive impact on participants' chemistry learning, as indicated in previous research (Chang et al., 2001, Oni et al., 2021). Notably, the concept map scaffolds formats of concepts only as well as concepts and labels have some similar theoretical structure (Wong et al., 2021) and support learning outcomes equally. In essence, participants who constructed concept maps with provided concepts and labels and those who constructed concept maps with provided concepts experience the same results. One would expect the added links to impact learning more than constructing with concepts only. The difference was only indicated with a deeper analysis of the constructed maps as the links used seems monotonous. More study is needed to investigate the underlying variables that may explain the impacts of various concept mapping scaffolds on various measures of learning outcomes (such as recall, meaning making, and transfer). The main effect of the two concept map formats indicates that students in the scaffold-concepts and labels condition benefited from the scaffolding no less than those in scaffold-concepts only condition . These findings suggest that scaffolding students in constructing concept maps have beneficial impact on their learning outcomes (Eggert et al., 2017).

Theoretical Implication

In line with Vygotsky's perspective, when learners are scaffolded, their understanding is enhanced by constructing or completing concept maps while integrating the new material with their existing knowledge for meaningful learning (Fiorella & Mayer, 2016; Eggert et al., 2017). More so, generative learning theory suggests that moving from linear text to a visual representation, such as a concept map or related exercises, can facilitate learning, one of which is scaffolded practice (Fiorella, 2023). However, some studies indicate that self-constructing concept maps from scratch might place higher cognitive demands on learners, potentially hindering their learning outcomes (Chang et al., 2001; O'Donnell et al., 2002). To address this issue, scaffolding students in different concept map activities relevant to their prior knowledge might be beneficial. Cognitively, concept map scaffolding produces a limited effort toward critical thinking necessary for optimum learning experiences but allows immediate support in connecting the nodes and links (Eggert et al., 2017). Consequently, scaffolding students in concept mapping activity reduces the cognitive overload they may encounter if no such support is given.

Practical Implication

Scaffolding students in mapping activity, especially in a difficult subject like chemistry, leads to positive attitude towards the subject or content topic, reduces anxiety and frustration, increases motivation and engagement, and in turn, can further enhance the learning process (Chang et al., 2002; Okebukola & Jegede, 1989). The metacognitive prompts (concepts and labels) provided serves as an immediate feedback that support students in these condition, hence the comparison indicated in between the two scaffold formats (Wong et al., 2021). Students who view concept maps as valuable aids are more likely to use them actively, which can contribute to a deeper understanding of the material and better retention of knowledge.

In addition, students perceived self-efficacy, and their perception of the helpfulness of concept maps interacted with their learning performance on concept maps. The variability in the participants' confidence level may result from several subjective factors (Wilson & Kim, 2016). The feedback on concept maps helpfulness revealed assorted responses, with participants indicating beneficial effect such as "extremely helpful" "very helpful;" while others indicated a negative disposition such as "not helpful," "not at all helpful in any way," "not sure," "I am so confused right now." These validations possess potential cues that can be harnessed toward designing and implementing concept map learning strategy, and to foster motivation in students to use concept maps. The subjective range of functionality and direction of concept maps described by the participants helped to gain deeper understanding of the importance of concept maps and also provides clues for further investigation of concept maps for instructional support. The analysis also revealed a dimension of the functionality of concept maps and important feedback on students' expectations of the learning strategy (Appendix. Figure 5). While some students may find them to be very helpful and pleasant, others might not connect with this specific strategy. Therefore, in order to meet the various learning needs of students, teachers and researchers should consider explore students' preference of concept mapping as an instructional tool.

Limitation and Further Study

When interpreting the findings of this study, certain important considerations should be observed. First, it is notable that the analysis excluded data from students who spent less than a minute on the delayed retention measurement. This inclusion might have influenced the outcomes of the studied variable. To gain deeper insights, future research should delve into students' engagement and persistence in mapping activities and their potential impact on overall performance.

Second, the feedback observed from the survey regarding the helpfulness of concept maps highlighted a range of diverse learning needs among participants. These encompassed requirements for more training, reviews, performance feedback, addressing a lack of prior exposure to the studied concepts, and accounting for personal characteristics. It is advisable for future research to extend the duration of their implementation before assessing their impact on learning achievements and administer concept maps as instructional and formative assessment tools.

Third, the administration of the self-efficacy survey was done after repeated concept mapping activity resulting in a univariate data. Notably, some students initially expressing high self-efficacy later reported the activity as unhelpful. To provide a more comprehensive understanding, future studies are recommended to assess self-efficacy both before and after the test, allowing for a comparison that elucidates the mapping activity's influence on perceived learning efficacy.

Finally, it is important to acknowledge that, like many classroom-based studies, the sample size employed in this study was large, but the study context was limited to one college, which may restrict the generalizability of the findings. To ascertain the transferability of the effects observed in this study, future research should investigate whether similar outcomes can be replicated across different topics, subjects, and alternative scaffold formats for concept maps in another geographical domains. Furthermore, exploring other motivational factors within the value-expectancy model, as well as considering additional models such as self-determination and achievement goal orientation, should be taken into consideration for a more comprehensive understanding of the role of motivation in conceptual learning.

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