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# Scaling up Emotional Intelligence and Critical Thinking of Students in Biology Using Concept Mapping Strategies

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**Abstract**
This study aimed to scale up the emotional intelligence and critical thinking of students in Biology using two concept-mapping instructional strategies in Katsina-Ala Township. Two research questions and two hypotheses guided the study. A quasi-experimental design which involved two experimental groups and one control group was employed. One hundred and fourteen (114) Senior Secondary (SS) II students offering Biology out of a population of 3,537 were drawn using random sampling. Two instruments: The students' Emotional Intelligence Questionnaire (SEIQ) and the Critical Thinking Test (CTT) with reliability indexes of 0.82 and 0.87 using Cronbach Alpha and Kuder-Richardson 21 ($K\text{-}R_{21}$) formulae respectively were used. Trained research assistants used the lesson plans for teaching. Mean and standard deviation aided in answering research questions and Analysis of Covariance (ANCOVA) was utilised to test hypotheses at 0.05 significant level. Significant differences existed in mean emotional intelligence ratings of students in Concept Mapping Instructional Strategy (CMIS), Peer-Collaboration Concept Mapping Instructional Strategy (PCMIS) and Conventional Instructional Method (CIM) groups ($p<0.05$). Post Hoc test revealed a significant difference in the mean emotional intelligence ratings between students taught using CMIS and CIM ($p<0.05$), PCMIS and CIM ($p<0.05$), but not between CMIS and PCMIS ($p>0.05$). Findings also revealed a significant difference in students' mean critical thinking scores among CMIS, PCMIS and CIM groups ($p<0.05$). Post Hoc test revealed a significant difference in the mean critical thinking scores between students taught using CMIS and CIM ($p<0.05$), PCMIS and CIM ($p<0.05$), but not between CMIS and PCMIS ($p>0.05$). Hence it was recommended that teachers should use PCMIS strategies to improve students' emotional intelligence and critical thinking in Biology

**Keywords:** Concept Mapping, Peer-Collaboration, Emotional Intelligence, Critical Thinking and Biology

## Introduction

Scientific knowledge and skills are becoming more important in the 21st century. This is because of the opportunities that science provides for individual and national development. Biology is a science subject taught at the senior secondary school level in Nigeria. It deals with the study of living organisms, both plants and animals and their interaction with the environment (Joda, 2019). The knowledge and creative thinking acquired as one studies Biology contribute to scientific literacy (Semilarski & Laius, 2021) and aid understanding of both the flora and fauna. Qualities that may be nurtured by Biology learning are the power of observation, creativity, psychomotor skills, critical thinking, problem-solving ability and even effective communication skills and social abilities. The value of the knowledge, skills and competencies students acquire as they learn Biology is relevant to several professions like Pharmacy, Gynecology, Nursing, Food Technology, Zoology, Botany, Virology, Pathology Microbiology and Biology educators (Kpiranyam et al., 2023). These fields of study also offer jobs to citizens in health, pharmacy, food industries, security, and education sectors promoting national economic growth. Because Nigeria as a country cannot experience exponential growth without adequate professionals in these fields, it is imperative that active learning of Biology be encouraged. This, the Federal Government of Nigeria (FRN, 2013) vowed to do when the government promised to provide adequate funds for science and technology education.

As laudable as government efforts towards science education have been, it is common to see students at the secondary school level acting in ways that portray them as having low emotional intelligence and thinking abilities. Jamhari et al. (2018) note that learners come to schools with a range of prior knowledge, skills, beliefs, and concepts that significantly influence how they organize and interpret the school environment and learn. These factors as pointed out by the authors affect students' abilities to remember, reason, solve problems, acquire new knowledge, and relate with their peers. Such emotions determine how students approach learning, interact with each other and solve problems. This makes emotional intelligence pivotal to the academic life of students and the world of work. In Maguire et al. (2017) view, emotional intelligence deals with behaviour through self-motivation, regulates emotional and social skills, converting the emotional energy into positive energy. This aspect of intelligence deals with the ability to manage and identify one's emotions and response to that of others. As opined by Ronad (2018), the basic components of emotional intelligence are; self-awareness, self-regulation, motivation, empathy and social skills. Students who have high emotional intelligence may understand and control their emotions better, communicate effectively and relate with their peers, thus learning well. By implication, students with high emotional intelligence are self-aware, self-regulated and highly motivated to learn and engage in educational activities. Behera (2016) stated that an individual's ability to adapt and cope depends on how well they integrate both rational and emotional capacities. Students with high emotional intelligence may become more successful in learning and recording high performance than those with low emotional intelligence. It predicts academic success (Pratama & Corebima, 2016). This makes students' emotional intelligence an important factor worth researching.

Another variable of interest in this study is students' critical thinking. In a world faced with complex challenges, critical thinking is very important to students globally especially those in the field of science and technology. Critical thinking is the ability to analyze opinions, and issues, evaluate facts and draw conclusions. This involves certain skills such as reasoning, problem-solving and decision-making. Critical thinking deals with logic that could be inductive, deductive or analysis and problem-solving as well as innovations and reasoning out complex approaches to proffer solutions to issues and challenges (Singh, 2022). In the 21st century, there is a need to emphasise that learners of sciences acquire and utilize the ability to think critically as it could help them cultivate higher-order thinking skills necessary for academic success (Aziz & Halim, 2020). Researchers (Samba et al., 2019; Samba et al., 2021; Samba & Kpiranyam, 2021; Singh, 2022) have noted the importance of critical thinking among students. Students with high thinking abilities are creative and curious, reflect on their actions and learning, have high imagination, and are innovative in an attempt to solve problems.

Critical thinking may be improved by engaging in practical activities, making observations about nature, brainstorming, solving puzzles, completing maps of concepts and other approaches that stimulate the brain to think. Abakpa et al. (2022) opined that critical thinking enables learners to deduce and process information more logically and to consider all possible outcomes when considering an issue for a reason out conclusion. The authors further added that critical thinking is important as it enables an individual to analyse, evaluate, explain and restructure thinking thereby reducing the possibility of acting with poor reasoning or a false belief. However, Samba et al. (2020) noted that critical thinking is often neglected. This may be because critical thinking involves the application of high-order thinking and may require much mental effort and time to plan and implement. The worry is that the use of conventional instructional strategy may limit students' ability to think critically and solve problems. Hence, the a need to use innovative instructional strategies to improve critical thinking.

Research in science education on innovative instructional strategies continues to receive great attention. Following the trend, Samba and Eriba (2012), Ajaja (2013), Nayak and Kumar 2018), Kipkemoi et al. (2019), Kyado et al. (2019), and Bizimana et al. (2022) researched method combination and modifications capabilities to bring about effective teaching and learning of science which is the foundation for national development. Some of the methods that have been effectively combined include problem-based and collaborative learning approaches (Nayak & Kumar, 2018) concept mapping and collaboration learning strategies (Kipkemoi et al., 2019; Kyado et al., 2019; Aziz & Halim, 2020), concept mapping and cooperative mastery learning strategies (Bizimana et al., 2022). However, the researchers observed that concept mapping and collaboration learning strategy are usually not introduced to students of Biology at the senior secondary school level as some Biology teachers prefer the conventional instructional strategy.


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The conventional instructional method is teacher-oriented. Achor et al. (2021) noted that the conventional instructional strategy still dominates the Nigerian secondary school science classroom, Biology inclusive. The researcher has observed in Katsina-Ala Township that Biology teachers still favour the conventional or expository instructional method. This method is one in which concepts and answers to questions in Biology are explained to students in class without availing them the opportunity to express themselves, discuss the concepts, brainstorm, work in assigned groups, suggest answers and agree on a consensus opinion. Concepts are the basic building blocks of knowledge and thinking. Concept mapping strategy is one in which information learned is visually displayed and ideas logically arranged to enrich understanding and nurture creative thinking. Novak and Gowin (1984) opine that a concept map is a schematic device used to represent a set of concept meanings embedded in a framework of propositions, a two-dimensional hierarchical diagram which clearly shows the interconnection between and among individual concepts. Kyado et al. (2019) view a concept map as a visual representation of a student's understanding of concepts, hierarchically organized and connected with lines which indicate relationship. When constructed by the teacher and learners during the teaching and learning processes, it becomes a concept mapping strategy. Concept mapping strategy, a teaching and learning strategy developed by Novak and Gowin (1984) based on the work of Ausubel (2000), helps represent the scientific knowledge of students to enhance understanding and has been used in teaching and learning for more than 25 years (Daley, 2010). Concept mapping strategy according to Appaw et al. (2021), involves using diagrammatic representation which shows relationships between concepts in a logical, orderly, sequential or hierarchical manner such that broad or general concepts are at the top of the map with the most specific ones at the bottom of the concept map.

A concepts mapping strategy could be constructed in the class to show a graphical representation of a topic, major information, ideas and how they are related. Woldeamanuel et al. (2020) observed that the concept mapping strategy represents knowledge which consists of networks of concepts with nodes and links. The nodes are connected through links (words) to form the meaning of propositions (statements). The authors also pointed out that such concepts are usually enclosed in circles or boxes and lines or arrows are used to indicate the relationships between concepts or propositions for better understanding. During a lesson, this strategy provides the teacher an opportunity to guide students to actively learn. Therefore, it serves as a useful tool in presenting information that is psychologically compatible and aligns with how human beings construct meaning (Kyado et al., 2019). Thus, the strategy is a cognitive and constructivist learning strategy. It could be cognitive when the learning is focused on depicting the relationships between concepts. However, it is constructivist if during the lesson a teacher guides students focusing on linking concepts to live experiences or linking live experiences to each other (Daley, 2010). Such learning can be used to nurture reflective thinking and analysis which may enhance critical thinking. Concept mapping strategy could be strengthened by encouraging peer interaction, and discussions and supporting learners to improve cognition (Campbell, 2022). Authors like Cheema and Mirza (2013), and Kyado et al. (2019) have shown that concept mapping is an effective strategy. However, a major limitation with the use of concept mapping in instruction as noted by Bennett (2003) as cited in Ajaja (2013) is that it frustrates low achievers who may not be able to master the techniques and competence needed for its use and which spurs understanding. Hence, students may benefit more if they collaboratively learn.

Peer-collaboration learning is the process whereby students interact and learn from each other to achieve educational goals or objectives. Nayak and Kumari (2018) opined that peer-collaboration learning is a strategy in which students at different performance levels collectively learn in small groups to accomplish a common aim and are accountable for their learning and that of their peers. In this strategy, students learn from each other in small groups and achieve success which increases individual students' understanding and skills (Ajayi et al., 2020; Achor et al., 2021). The strategy facilitates free interaction among learners and with materials which enhance understanding and knowledge gain. The fact that it promotes interaction and active learning means that learners exposed to such a strategy may reason abstractly, share ideas, solve problems and properly make sense of what they learn. To buttress this view, Achor et al. (2021) asserted that all peers participating in a group during learning improve their understanding, thinking skills and ideas as they explain concepts learnt to other learners. Peer collaboration learning strategy has the potential to improve students' emotional intelligence and foster critical thinking of secondary school Biology learners as it inspires knowledge creation in students especially if students complete the concept maps in groups with their peers. In this study, concept mapping strategy has been integrated into peer-collaboration instructional strategy herein referred to as peer-collaboration concept mapping learning strategy.

Peer-collaboration concept mapping learning strategy is a hybrid classroom learning discourse which provides students opportunity to learn in small groups and share ideas. Kipkemoi et al. (2019) asserted that collaboration is achieved among the group as they evaluate, question, discuss and debate with each other. Teachers of Biology can effectively orchestrate classroom discourse so that students check their understanding together and build on what they already know. This strategy combines both the constructivism and social learning theories (Bizimana et al., 2022). Several researchers have found that utilising concept mapping and peer-collaboration learning improved students' science learning outcomes (Ajaja, 2013; Kipkemoi et al., 2019; Kyado et al., 2019; Parveen et al., 2019; Bizimana et al., 2022). Although, these strategies could enhance students' emotional intelligence and critical thinking. However, there is scarce research evidence on their implementation in Biology, in secondary schools in Nigeria, particularly the in study area. Moreover, no study in the literature has demonstrated the effectiveness of these strategies on students' emotional intelligence and critical thinking to the best of the knowledge of the researchers. In response to these gaps, this study sought to find out if the emotional intelligence and critical thinking of students in Biology will be scaled up using peer-collaboration concept mapping strategies.

**Aim and Objectives of the Study**

This study aimed to find out if the emotional intelligence and critical thinking of students in Biology can be scaled up using two concept mapping strategies in Katsina-Ala Township. The study specifically sought to:

1. examine the effects of concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method on students' emotional intelligence in Biology.
2. ascertain the effects of concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method on students' critical thinking in Biology.

**Research Questions**

The following research questions were answered in this study.

1. What is the difference in the mean emotional intelligence ratings of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method?
2. What is the difference in the mean critical thinking scores of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method?

**Hypotheses**

The following null hypotheses were formulated and tested at a 0.05 level of significance.

1. There is no significant difference in the mean emotional intelligence ratings of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method.
2. There is no significant difference in the mean critical thinking scores of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method.

**Methodology**

Quasi-experimental, non-randomised control group pre-test and post-test design was adopted. The study used three intact classes comprising of two experimental groups (concept mapping and peer-collaboration concept mapping instructional strategies) and one control group (conventional instructional method). The research was conducted in Katsina-Ala Township of Benue State, Nigeria. This area was used because of the observed low critical thinking ability of the students. The population comprised 876 Senior Secondary Two (SS II) students offering Biology in 22 public and private senior secondary schools in the 2021/22 academic session (Benue State Teaching Service Board, Makurdi, 2022). The sample for the study was 114 SS II students in three intact classes from three public secondary schools drawn using simple random sampling. The instruments for data collection were the Students' Emotional Intelligence Questionnaire (SEIQ) with 30 items and the Critical Thinking Test (CTT) with 25 questions both constructed by the researchers and validated by two Science Education experts and one Measurement and Evaluation expert all from Benue State University, Makurdi. Kuder-Richardson 21 (K-R 21) and Cronbach alpha formulae were used to test the internal consistency of CTT and SEIQ respectively which gave reliability indexes of


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0.82 and 0.87 respectively. The study lasted for six weeks. Three Biology teachers from three sampled schools were trained during the first week and used as research assistants. The treatment lasted for four weeks. Pre-test was administered at the first week and post-test after treatment at the sixth week to the entire groups. Experimental groups one and two were taught ecological management concepts in the SS II curriculum using lesson plans designed following tenets of Peer-Collaboration Concept Mapping Instructional Strategy (PCMIS) and Concept Mapping Instructional Strategy (CMIS) respectively while the control group was taught the same concepts using tenets of Conventional Instructional Method (CIM). The researchers monitored and ensured that all the research assistants followed the lesson plans for each instructional strategy and students were administered pre-test and post-test. Research questions were answered using descriptive statistics of mean and standard deviation while hypotheses were tested using inferential statistics of Analysis of Covariance (ANCOVA) at 0.05 alpha levels.

**Results**

Data collected were analysed, and interpreted and are presented below.

**Research Question One:** What is the difference in the mean emotional intelligence ratings of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method?

**Table 1: Mean and Standard Deviation of Emotional Intelligence Ratings of Students Taught Biology using CMIS, PCMIS and CIM**

| Group | | Pre-SEIQ | | Post-SEIQ | | Mean Gain |
|---|---|---|---|---|---|---|
| | n | Mean | SD | Mean | SD | Within Groups |
| Concept Mapping | 42 | 2.20 | 0.36 | 2.91 | 0.37 | 0.71 |
| Peer-Collaboration Concept Mapping | 33 | 2.12 | 0.43 | 3.16 | 0.32 | 1.04 |
| **Mean Diff. Between Groups** | | **0.08** | | **0.25** | | **0.33** |
| Concept Mapping | 42 | 2.20 | 0.36 | 2.91 | 0.37 | 0.71 |
| Conventional Method | 39 | 2.32 | 0.45 | 2.86 | 0.29 | 0.54 |
| **Mean Diff. Between Groups** | | **0.12** | | **0.05** | | **0.17** |
| Peer-Collaboration Concept Mapping | 33 | 2.12 | 0.43 | 3.16 | 0.32 | 1.04 |
| Conventional Method | 39 | 2.32 | 0.45 | 2.86 | 0.29 | 0.54 |
| **Mean Diff. Between Groups** | | **0.20** | | **0.30** | | **0.50** |

Table 1 shows that the overall mean difference between students taught Biology using CMIS and PCMIS was 0.33 in favour of PCMIS. By implication, students taught Biology using PCMIS had higher emotional intelligence than those taught using CMIS. Similarly, the overall mean difference between students taught using CMIS and CIM was 0.17 in favour of CMIS. This means that students in CMIS group had higher emotional intelligence than those in CIM group. In the same vein, the overall mean difference between students in PCMIS and CIM group was 0.50. This difference is in favour of PCMIS. This signifies that students taught using PCMIS had higher emotional intelligence than those taught using CMIS and CIM. Meanwhile, students taught using CMIS had slightly higher emotional intelligence than those taught using CIM.

**Research Question Two:** What is the difference in the mean critical thinking scores of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method?

**Table 2: Mean and Standard Deviation of Critical Thinking Scores of Students Taught Biology using CMIS, PCMIS and CIM**

| Group | | Pre-CTT | | Post-CTT | | Mean Gain |
|---|---|---|---|---|---|---|
| | n | $\bar{x}$ | SD | $\bar{x}$ | SD | Within Groups |
| Concept Mapping | 42 | 27.21 | 12.36 | 57.22 | 7.35 | 30.01 |
| Peer-Collaboration Concept Mapping | 33 | 26.20 | 12.16 | 60.25 | 6.12 | 34.05 |
| **Mean Diff. Between Groups** | | **1.01** | | **3.03** | | **4.04** |
| Concept Mapping | 42 | 27.21 | 12.36 | 57.22 | 7.35 | 30.01 |
| Conventional Method | 39 | 24.23 | 9.16 | 47.54 | 12.75 | 23.31 |
| **Mean Diff. Between Groups** | | **2.98** | | **9.68** | | **6.70** |
| Peer-Collaboration Concept Mapping | 33 | 26.20 | 12.16 | 60.25 | 6.12 | 34.05 |
| Conventional Method | 39 | 24.23 | 9.16 | 47.54 | 12.75 | 23.31 |
| **Mean Diff. Between Groups** | | **1.97** | | **12.71** | | **10.74** |

Table 2 shows that the mean gain difference between students taught Biology using CMIS and PCMIS was 4.04 in favour of PCMIS. This implies that students taught using PCMIS had higher critical thinking than those taught using CMIS. Moreover, the mean gain difference between students taught Biology using CMIS and CIM was 6.70 in favour of CMIS. This means that students in CMIS group had higher critical thinking than those in CIM group. Besides, the mean gain difference between students in PCMIS and CIM group was 10.74. This difference is in favour of PCMIS. By implication, students taught using PCMIS had higher critical thinking than those taught using CMIS and CIM. Meanwhile, students taught using CMIS had slightly higher emotional intelligence than those taught using CIM.

**H01:** There is no significant difference in the mean emotional intelligence ratings of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method.

**Table 3: ANCOVA for Mean Emotional Intelligence Ratings of Student Taught Biology using CMIS, PCMIS and CIM**

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 2.048[a] | 3 | .683 | 7.185 | .000 |
| Intercept | 27.187 | 1 | 27.187 | 286.102 | .000 |
| Pre | .269 | 1 | .269 | 2.828 | .095 |
| **Group** | **1.965** | **2** | **.983** | **10.340** | **.000** |
| Error | 10.453 | 110 | .095 | | |
| Total | 1015.859 | 114 | | | |
| Corrected Total | 12.501 | 113 | | | |

a. R Squared = .164 (Adjusted R Squared = .141)

Table 3 indicates that $F(2,110) = 10.340$; $p = 0.000 < .05$. Therefore, the null hypothesis is rejected. It implies that there is significant difference in the mean emotional intelligence ratings of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method. The R squared value of 0.164 for strategy implied that 16.4% of the difference in the students' emotional intelligence ratings can be accounted for by the strategy. This indicated a small effect size.


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**Table 4: Bonferroni Post Hoc Comparison for Mean Emotional Intelligence Ratings of Student Taught Biology using CMIS, PCMIS and CIM**

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig.[b] |
|---|---|---|---|---|
| CMIS | PCMIS | -.064 | .069 | .100 |
| CMIS | CIM | .257* | .072 | .002 |
| PCMIS | CIM | .321* | .074 | .000 |

Table 4 reveals that the mean difference (I-J) between CMIS and PCMIS is -0.064 and is not significant at p>0.05. This connotes that there is no significant difference in the mean emotional intelligence ratings between the students taught Biology using CMIS and PCMIS. However, Table 4 also shows that the mean differences (I-J) between CMIS compared to CIM and PCMIS compared to CIM are 0. 257* and 0.321* which indicates significant results at p<0.05. Thus it infers that there is a significant difference in the mean emotional intelligence ratings between students taught Biology using CMIS and PCMIS compared to CIM.

**H02:** There is no significant difference in the mean critical thinking scores of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method.

**Table 5: ANCOVA for Mean Critical Thinking Scores of Student Taught Biology using CMIS, PCMIS and CIM**

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 13647.054[a] | 3 | 4549.018 | 73.641 | .000 |
| Intercept | 14785.906 | 1 | 14785.906 | 239.359 | .000 |
| Pretest | 10379.263 | 1 | 10379.263 | 168.023 | .000 |
| **Group** | **2176.996** | **2** | **1088.498** | **17.621** | **.000** |
| Error | 6795.016 | 110 | 61.773 | | |
| Total | 362438.000 | 114 | | | |
| Corrected Total | 20442.070 | 113 | | | |

a. R Squared = .668 (Adjusted R Squared = .659)

Table 5 reveals that F(2,110) = 17.621; p = 0.000 <.05. Therefore, the null hypothesis is rejected. By implication, there is a significant difference in the mean critical thinking scores of students taught Biology using concept mapping instructional strategy, peer-collaboration concept mapping instructional strategy and conventional instructional method. The R squared value of 0.668 for strategy implied that 66.8% of the difference in the students' critical thinking scores was accounted for by the strategy. This indicated a high effect size.

**Table 6: Bonferroni Post Hoc Comparison for Mean Critical Thinking Scores of Students Taught using CMIS, PCMIS and CIM in Biology**

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig.[b] |
|---|---|---|---|---|
| CMIS | PCMIS | -3.930 | 1.830 | .102 |
| CMIS | CIM | 6.902* | 1.761 | .000 |
| PCMIS | CIM | 10.832* | 1.864 | .000 |

Table 6 reveals that the mean difference (I-J) between CMIS and PCMIS is -3.930 and is not significant at $p>0.05$. This connotes that there is no significant difference in the mean critical thinking scores between the students taught Biology using CMIS and PCMIS. Nevertheless, Table 6 also shows that the mean differences (I-J) between CMIS and PCMIS compared to CIM are 0.257* and 0.321* which indicates significant results at $p<0.05$. Thus it means that there is a significant difference in the mean critical thinking scores between students taught Biology using CMIS and PCMIS compared to CIM.

**Discussion**

This study found that the difference in the mean emotional intelligence ratings of students taught Biology using CMIS, PCMIS and CIM was statistically significant. The post-hoc comparison for emotional intelligence ratings among the groups revealed that students taught Biology using CMIS and PCMIS had significantly higher emotional intelligence ratings than their counterparts taught using CIM. The explanation for this finding may be that as students are exposed to PCMIS, they develop social skills even more than those taught with CMIS. Hence they understand the concepts learnt better, control their emotions, communicate effectively, and are motivated to learn and engage in educational activities due to shared responsibility and accountability which may account for the improved students' emotional intelligence. The finding in this study agrees with Nayak and Kumar's (2018) finding that students exposed to problem-based collaborative learning approaches significantly improved their social skills compared to those exposed to the conventional strategy. The findings of this study also support that of Kipkemoi et al. (2019) which revealed significant differences in attitudes towards learning in favour of peer-collaborative concept mapping teaching strategy compared to the conventional method of instruction. Since peer-collaborative concept mapping learning strategy provides learning opportunities in the classroom for students that encourage their engagement in group and whole class discussions, as well as sharing of ideas, teachers should be encouraged to adopt peer collaborative concept mapping strategy to enhance students' emotional intelligence.

Furthermore, this study found that the difference in the mean critical thinking scores of students taught Biology using CMIS, PCMIS and CIM was statistically significant. The post-hoc comparison of critical thinking scores among the groups revealed that students taught Biology using CMIS and PCMIS had significantly higher critical thinking scores than their counterparts taught using CIM. This finding may be explained because as students evaluate, question, discuss and debate with each other during lessons in PCMIS, it may have increased their mental activity even higher than CMIS and generated higher thinking and meaningful understanding of concepts learnt and improved critical thinking. This finding agrees with that of Adolphus et al. (2013) which found significant differences in problem-solving abilities among students taught using collaborative instructional strategy and those taught using conventional instructional strategy. The finding also supports that of Husamah and Pantiwati (2014) who reported that students' team achievement division project-based learning strategy significantly improved students' thinking skills. Similar to this finding, the study by Samba et al. (2020) found a significance difference in the critical thinking of students in experimental groups when compared with a discussion group. The finding also tallies with that of Achor et al. (2021) which found that students taught using peer-collaboration instructional strategy had more significant cognitive ability than those taught using conventional instructional strategy.

By contrast, this finding does not support that of Kpiranyam et al. (2022) which found that the student team achievement division collaborative strategy was not significantly effective in enhancing the critical thinking of students in Biology compared to the assertive questioning instructional strategy. It should be noted that the study by Kpiranyam et al. (2022) compared two innovative instructional strategies which are known to be equally effective. It will thus be helpful if teachers of Biology incorporate the collaborative concept mapping instructional strategy in their classroom teaching practices to stimulate high critical thinking abilities in their students.

**Conclusion**

The findings of this study led to the conclusion that peer-collaborative concept mapping learning strategy is more effective in improving the emotional intelligence and critical thinking of students in Biology compared to concept mapping and conventional strategies. Thus, the adoption of a peer-collaborative concept mapping learning strategy will be appropriate for the teaching and learning of Biology and provide a way of enhancing the emotional intelligence and critical thinking of students at the senior secondary school level. The continuous usage of

conventional instructional methods for teaching and learning Biology could be a hindrance to the proper understanding, emotional intelligence and critical thinking of students in Biology.

**Recommendations**

Based on the findings of the study, the following recommendations are made:

1. Peer-collaborative concept mapping instructional strategy should be adopted by Biology teachers to teach Biology as it has been proved that it is capable of improving students' emotional intelligence and critical thinking in Biology.
2. Federal and State Ministries of Education, Benue State Teaching Service Board, school administrators and the Science Teachers Association should partnership to organize conferences, seminars and workshops to sensitise science teachers especially those teaching Biology to improve their skills and stimulate their interest in the use of peer-collaborative concept mapping instructional strategy aimed at enhancing students' emotional intelligence and critical thinking in Biology.

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