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ORIGINAL ARTICLE

Topic-Specific Pedagogical Content Knowledge-Based Instruction and Level of Conceptual Understanding of Chemical Kinetics and Equilibrium concepts on Grade 11 Students

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ABSTRACT

The goal of this study was to assess students' level of conceptual understanding of chemical kinetics and equilibrium using topic-specific pedagogical content knowledge (TSPCK)-based instruction in chemistry grade 11 students. The research was a mixed approach that involved 159 grade 11 chemistry class students from Addis Ababa administrative city, Ethiopia, and employed a mixture of qualitative and quantitative methodologies. Purposive sampling was used for the sample procedure and four intact classes were selected as three intervention groups and one control group: curricular saliency-based, representation-based, conceptual teaching strategy-based instruction, and comparison groups. The level of conceptual understanding was assessed using reasoned questions, specifically a two-tiered multiple-choice pretest, and posttest. The findings revealed that students' conceptual understanding of chemical kinetics was higher than that of chemical equilibrium concepts. According to the findings of the students' pretest and posttest, the level of conceptual understanding increased from 27.08% to 32.21% in chemical kinetics and from 15.91% to 23.68% in chemical equilibrium. Overall, representation-based instruction and conceptual teaching tactics boosted students' conceptual knowledge and accomplishment in chemical kinetics and equilibrium concepts. This study proposes that the level of conceptual understanding of grade 11 students in chemical kinetics should take into account the horizontal relationship between mathematics and the chemical kinetics concepts, which should be taught using technology-assisted teaching strategies such as conceptual teaching strategies and three-fold mental representations.

KEY WORDS: Chemical equilibrium; chemical kinetics; Edpuzzle; level of conceptual understanding, threefold representation

INTRODUCTION

Ethiopia and other developing countries have recognized a lot of attention for implementing the constructivism learning paradigm in education, teacher development, and policy formulation (Dejene et al., 2018). A constructivist-oriented teacher education program improves student teachers' perceptions of their own teaching skills, resulting in higher confidence and better teaching practice (Darling-Hammond, 2000; Gordon and Debus, 2002; Hall et al., 2004; Lucas, 2001; Noble, 2005). Ethiopia has adopted a constructivist-oriented teacher education program since 2003 (Abebe and Woldehanna, 2013; Fenta, 2019; Hussein, 2011; Wabe and Tessema, 2011). Despite the reform efforts that advocate student-centered constructivist teaching, teachers seem to still heavily depend on traditional pedagogies at all levels. The MoE (2009) has reported that the teacher's teaching approach has not shown improvement, despite consecutive and overlapping efforts to address it. In other words, the traditional teaching approach where the teacher talks and students listen still dominates the teaching and learning process in the Ethiopian education system (Biniyam, 2014; Birhanu, 2010).

To improve learning, teachers must be knowledgeable in reasoning skills, conceptual understanding, and instructional techniques related to the subject they teach (Erinosho, 2013). Critical thinking abilities such as analysis, evaluation, and synthesis are typically referred to as reasoning skills. They also encompass broader abilities such as problem-solving, understanding things, and more abstract and creative thinking. Conceptual understanding is the ability of a person to be able to explain, differentiate, and connect the idea of what they know with new knowledge (Dali, 2014; Susilaningsih et al., 2019). Conceptual understanding is acquired when a learner creates practical and scientific paths to obtain the correct answers. Teachers employ instructional strategies to assist students in becoming self-directed, strategic learners. When students choose these strategies on their own and use them effectively to complete tasks or meet goals, they become learning strategies.

The representation of terminology plays an active part in the formation of conceptual understanding because they may misinterpret the specific chemical ideas or use vocabulary that is non-scientifically or unexpected with chemical descriptions (Sibomana et al., 2020). This is necessary for a subject like chemistry, which has often been considered conceptually troublesome and abstract for upper primary and high school learners (Erinosho, 2013). In terms of teaching chemistry, it is critical to understand the importance of concepts and how ideas

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are built in the brains of learners, as well as how chemistry teaching may be carried out through conceptual knowledge accomplishment (O'Dwyer & childs, 2017). In the chemistry classroom, students frequently struggle with simple ideas, and that in turn causes a lack of conceptual understanding (Cetin-Dinder & Geban, 2017). The cause might be ascribed to students' personal beliefs that differ from those held by the scientific community. Cetin-Dindar and Geban (2017) also explained that alternative conceptions are barriers to learning because students are unable to create meaningful connections between their daily lives and newly learned ideas.

Establishing a learning environment is not only the responsibility of teachers but also motivating students in learning chemistry is a professional obligation to enhance learning. Moreover, students' desire to learn is also influenced by the teacher's capacity to enhance students' competency, interest in the subject presented, and feelings of self-efficacy (Johnson, 2017). In order to motivate students, teachers' tasks in the teaching–learning process involve not just generating interest in the subject matter being studied but also connecting the learning materials to the students' everyday experiences.

As a result of this paper's researcher's many years of chemistry teaching at high school and college level, students have a lack of conceptual understanding; get poorer test scores, and their willingness to pursue chemistry decreases year after year. This research promises to handle the difficulties in teaching and learning chemistry and fill the research gap through the investigation of TSPCK-based instructional approach to conceptual understanding and overall achievement on chemical kinetics and equilibrium concepts of grade 11 students in some secondary schools of Addis Ababa Administrative city.

Science in general and chemistry in particular equips learners with the basic knowledge of chemical science and technology towards getting them ready for further studies in sciences and empowering them to make positive contributions to their real-life (Taber, 2013). Chemistry is one of the fields of science that helps students comprehend what is going on around them (Sirhan, 2007). Chemical kinetics is a concept of chemistry that deals with the rates of reactions, factors that affect the rate, the relationship between the reaction order, and the reaction mechanism. Furthermore, chemical kinetics has the power to provide insight into the nature of chemical reactions and processes because it ties observable phenomena with theoretical aspects of chemistry that are modeled mathematically (Çakmakci et al., 2006). In most instances, chemical kinetics topics are difficult to understand due to teachers' use of traditional teaching approaches (Bain and Towns, 2016). The concept requires mathematics skills like differentiation and derivation of more than one variable (Rodriguez et al., 2019). Thus, chemistry is full of complex ideas that are difficult for most students to grasp (Kırık and Boz, 2012). Furthermore, students who had no prior knowledge of particulate matter, chemical changes, or concentration changes were confronted with abstract and difficult concepts while studying chemical kinetics (Gegios et al., 2013).

During the teaching of physical Chemistry topics (kinetics and equilibrium), concepts are represented in three ways (macro, micro, and symbolic). This conceptual representation of chemical concepts can be simply applied through TSPCK frameworks (Taber, 2013). Similarly, chemical equilibrium is one of the fundamental concepts in chemistry, but it is a difficult concept for students to learn (Tilahun & Tirfu, 2016). As a result, chemical kinetics and chemical equilibrium are two abstract ideas in grade 11 chemistry. This difficulty could be related to a lack of experimental activities done in laboratories, unavailability of reference books, method of instruction, lack of sequencing or identifying big ideas, and inappropriate representations of materials in textbooks (Chiu, 2007).

The above-mentioned difficulties in learning chemistry are related to TSPCK knowledge components such as learner's prior knowledge, curriculum saliency (CSA), what is difficult or easy to teach, representations (REPs), and conceptual teaching strategies (CTS) that this study considered. From the TSPCK components learner's prior knowledge and what is difficult to teach regarding chemical kinetics and equilibrium concepts were already identified by different scholars (Prokša et al., 2018). Learner's prior knowledge includes the prerequisite concept that used to explain the chemical kinetics and chemical equilibrium concepts. Moreover, the misconceptions that students in their mind related to chemical kinetics and chemical equilibrium can be represented by TSPCK knowledge component called what is difficult of easy to teach (Prokša et al., 2018).

Thus, grade 11 students (students aged 17) are not exceptional in having these difficulties and misconceptions while learning the concept of chemical kinetics and equilibrium (Yıldırım et al., 2011). Difficulties in learning physical sciences in general and kinetics and equilibrium in particular at high school and tertiary level are commonly associated with teaching strategies (Lewis et al., 2014; Planinic et al., 2012). Furthermore, the difficulties that learners face are related to lack of an explicit connection between chemistry and the real world, the abstract nature of concepts (Yakmaci-Guzel, 2013), lack of threefold representations (macro, sub-micro, and symbolic) of concepts (Johnstone, 2009; Taber, 2013). Furthermore, the meaning of everyday terms such as dispersion, melting, and boiling points of substances differs from their common meaning in chemistry (Taber, 2013). Further to that, problems with learning chemistry concepts arose as a result of poor teacher preparation for the concept (Spaull, 2013) and learners' poor conceptual understanding of the required content knowledge (Gaigher et al., 2007; Mavhunga and Rollnick, 2013).

A major concern in science teacher education has been the development of teachers' content knowledge (CK) and its transformation for students in the teaching–learning process. The study carried out by Shulman (1987) found that CK is the most important tool for teachers to form concepts comprehensible to learners because it involves ‘transformation of content knowledge. Evens et al. (2015) argued that investment in prospective teachers’ pedagogical content knowledge (PCK) seems to be a good strategy. There is general agreement that teachers need to know the content knowledge they are teaching, but there is constant debate about how much they need to be able to know more than their students and what they should know about pedagogy (Kind, 2009; Rollnick et al., 2008). urthermore, Kind (2009) and Rollnick et al. (2008) indicated in their studies that teachers’ CK and PCK were the areas of research for science education researchers because good teaching is not only having content knowledge but also involving the capacity to reason soundly about teaching. However, CK is critical but not the sole requirement for the development of PCK (Rollnick et al., 2017).

Teachers are expected to develop PCK on science topics which help them to develop sound skills and knowledge required for the pedagogical transformation of content knowledge into the type that students pay attention to and comprehend (Rollnick & Mavhunga, 2016). The pedagogical transformation of CK is regarded as a PCK construct localized at a topic level and is a new version of PCK called TSPCK (Mavhunga, 2012). TSPCK is further described as the competence to transform knowledge of a topic for the purpose of teaching. TSPCK differs from generic teacher’s PCK in that it focuses on specialized topic knowledge and strategies for teaching students in the simplest possible manner. As a result, TSPCK is the knowledge necessary for transforming content knowledge on a specific topic into teachable form through the use of pedagogical reasoning (Shulman, 1987). The quality of TSPCK was measured by investigating the relationship between its components in the teaching–learning process based on both students and teachers activities in the classroom setting. The ideas behind the growth of a topic are founded on the pedagogical reasoning of concepts, with an emphasis on pedagogical transformation (Shulman, 1987).

There are validated instruments for the construction of PCK for several topics in chemistry, including the particulate nature of matter (Pitjeng, 2014), electrochemistry (Rollnick & Mavhunga, 2014), and organic chemistry (Vokwana, 2013), all of which consist of paper and pencil tests for assessing teachers’ content knowledge and PCK without assessing their impact on learning outcomes (conceptual understanding, motivation, and achievement) of their students. Most of the studies on the area of PCK shifted their view at the topic level and adopted the notion as a product of the transformation of CK through five components (Mavhunga, 2014). These components are learners’ prior knowledge, curricular saliency (CSA) and what is hard or easy for them to learn, representations (REPs), and conceptual teaching strategies (CTS). These five TSPCK components help teachers to think about the content for teaching purposes and therefore to transform it. Among the five TSPCK components, CSA, REPs, and CTS were employed on the chemical kinetics and equilibrium concepts for intervention in this study. As mentioned above, the other two TSPCK knowledge components were already identified by Prokša et al. (2018) for both chemical kinetics and chemical equilibrium and used them as distractors in the reasoned items.

TSPCK is the knowledge that enables teachers to transform their understanding of content knowledge of the specific topic. This study considered the three TSPCK components as TSPCK-based strategies (CSA, REPs, and CTS) to investigate the conceptual understanding and achievement of grade 11 students regarding chemical kinetics and equilibrium. TSPCK framework is not a straightforward process related predominantly to the simple possession of components. The knowledge construction of a specific topic is largely influenced by the interaction of the five TSPCK components (Park & Chen, 2012). In the case of this study the “learner’s prior knowledge and what is difficult or easy to teach” were used without intervention. Teachers need to acquire each knowledge component as well as their combined, interactive use in formulating explanations and responses to questions about teaching a specific topic (Mavhunga and Rollnick, 2013). Therefore, remodeling content information could be a central component of designing TSPCK-based instruction to enhance the conceptual understanding and achievement for students at preparatory schools of Addis Ababa administrative city.

To the best of these researchers’ knowledge, studies which consider TSPCK as a teaching strategy in chemistry to investigate conceptual understanding and achievement are rare. There is a scarcity of research conducted on the impact of TSPCK-based instruction on student conceptual understanding and achievement in learning chemistry. Furthermore, there was debate about whether teacher PCK/TSPCK framework had a significant impact on students’ outcomes (achievement, conceptual understanding, and so on) when learning chemistry concepts. Therefore, this study was investigating the effect of TSPCK-based instruction on the conceptual understanding and achievement on the chemical kinetics and equilibrium at preparatory school students (grade 11) of Addis Ababa Administrative city. Furthermore, this study sought to determine the difficulty level of both chemical kinetics and equilibrium of grade 11 students through intervention with respect to conceptual understanding and overall achievement.

Statement of the Problem

Due to their threefold representations and higher mathematical concepts, chemical kinetics and chemical equilibrium topics in chemistry are more difficult to teach and learn at any level of education (Çalik and Ayas, 2005; Chairam et al., 2009; Coll et al., 2010). Physical Chemistry topics (kinetics and equilibrium) are made more difficult due to teachers’ use of traditional teaching approaches (Justi, 2003), lack of threefold representations of chemistry concepts, and unable to use mathematics proficiency issues (Teo et al., 2014), and a lack of appropriate teacher preparation in the subject matter (Johnstone, 2009).

According to the third and sixth national learning assessments (NLA) assessed in Ethiopia, the achievement scores of grades

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10 and 12 students in chemistry were lower than the cut-off point (50%): 34.59 % for grade 10 and 43.69% for grade 12. The concept of chemical kinetics and chemical equilibrium are parts of the national learning assessment that the researcher considered in this study. This supports the argument that there is difficulty in teaching chemistry in grades 10 and 12, which necessitates further investigation (NEAEA, 2017, 2020).

At the third NLA, 75.8% of Ethiopian grade 10 students performed below basic, 21.1% performed basic, 2% performed proficiently, and only 1.1% performed advanced. Similarly, the performance level of grade 12 students in chemistry as measured by the 3rd NLA demonstrated that none of the students performed at an advanced level. Similarly, secondary school students performed poorly owing to the complicated nature of chemistry topics that needed three levels of representation, such as chemical reactions, carboxylic acids, and atomic structure (NEAEA, 2017, 2020).

The achievement of students in chemistry by content domain shows that organic chemistry (37.04%), substances (36.42%), and structure of substances (35.98 %) were relatively higher than chemical reaction (31.32%) and structure of the atom (29.30%). This indicated that advanced-level teaching of chemical reactions and atomic structure is required, such as mental representation, identifying big ideas, and selecting conceptual teaching strategies for specific chemistry topics (NEAEA, 2017). Chemical reaction and atomic structure concepts are the prior knowledge to taught both chemical kinetics and chemical equilibrium which needs advanced level of teaching in our case TSPCK-based strategies.

The annual report of Oromia Regional State Educational Bureau (OEB) indicated that about 70% of the integrated and generalist modality college students obtained less than the cutoff point (50%) in science (biology, chemistry, and physics) and mathematics subjects in the final year competency examination (OEB, 2018). The lower academic performance of the College students is not only regional problem but also national concern which is largely associated with teachers' teaching strategies, lack of content knowledge, and the abstract nature of Chemistry topics (Planinic et al., 2012). Likewise, the colleges of teachers' education examination results show that the quality of education at the college is declining regarding the science concepts. In Ethiopia and other developing countries, the difficulties with chemistry topics are attributed to teachers' inadequacy in content knowledge, poor preparation, and pedagogical content knowledge (Rollnick & Mavhunga, 2014). Solving all of these problems at once is difficult, and it raises issues of priority. From both the researcher's teaching experience and contemporary studies regarding chemical education, the instructional approach is the most influential factor to overcome the learning problems in Chemistry.

According to the constructivist model of learning, all of our knowledge is the result of the construction of knowledge through interactions (Trunper, 1997). The constructivist view is a "very powerful and influential perspective" (Mathabatha, 2005, p. 20) on many science education research studies. There are numerous studies that have been conducted in the area of PCK but fewer in TSPCK as a model for measuring both content knowledge and conceptualized pedagogical content knowledge on the teachers (Rollnick & Mavhunga, 2014). This technique denotes a teacher's level of content understanding as well as pedagogical content knowledge without considering its impact on the conceptual understanding and achievement of students (Mavhunga, 2015). There were debates among academics over whether content knowledge is a requirement for building effective teaching knowledge. To the best of this researcher's knowledge and from teaching experience, the mean scores of high school students and pre-service teachers in college of teachers' education (CTE) are relatively lower in the two physical chemistry topics of chemical kinetics and equilibrium than in other chemistry topics. This may be because these concepts require higher mathematical concepts (differentiation and integration) and require threefold representation to understand the chemistry concepts (Johnstone, 2009; Taber, 2013). Johnstone (2009) and Taber (2013) believe that the difficulty has emerged from misconception, lack of understanding of prior knowledge in a given topic, and teaching strategy incompatibility to the specific topics of chemistry. As a result, learners at high schools and higher educational institutions face lack of conceptual understanding and motivation related in learning chemical kinetics and equilibrium topics. Students' academic achievement in chemistry in general, and chemical kinetics and equilibrium in particular, suffers as a result of less understanding and less motivation to learn in both high schools and colleges of teacher education. This researcher would argue that these issues arose as a result of instructional strategies and a failure to connect chemistry concepts to student's daily life.

TSPCK-based instruction is an effective instructional technique that encourages students to develop knowledge on their own and with their peers, as well as initiate higher-order thinking due to it uses computer assisting teaching strategies. The TSPCK-based technique is predicted to improve grade 11 students' conceptual understanding and achievement in learning chemistry concepts. As a result, the purpose of this research was to investigate the effect of TSPCK-based instruction (curriculum saliency, representations, and conceptual teaching strategies) on grade 11 students' conceptual understanding and achievement (learning gains) in chemical kinetics and equilibrium. Moreover, the study was identifying the level of grade 11 students' conceptual understanding and achievement during learning of chemical kinetics and chemical equilibrium.

Research Questions

1. What are students' level of conceptual understanding on the chemical kinetics and equilibrium after intervention?
2. What are the areas that students misunderstand or lack of any understanding of chemical kinetics and chemical equilibrium?
3. Which TSPCK-based instruction do the students achieve more or perform better learning gains due to intervention?

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Objectives of the Study

1. To investigate students' levels of conceptual understanding on the chemical kinetics and chemical equilibrium.
2. Identify areas of difficulty in learning chemical kinetics and chemical equilibrium.
3. Examine the learning gains of both treatment and comparison groups based on pre-test and post-test scores.

RESEARCH METHODOLOGY

This study used mixed methods as the research method. The term mixed methods as used in this study refers to a developing methodology of research that progresses the systematic integration, or mixing, of quantitative and qualitative data within a single investigation (Wisdom & Creswell, 2013). This study combined both quantitative and qualitative research methods. Using a quantitative method involves transforming data into a numerical form and analyzing by means of quantitative analysis techniques (Azorín and Cameron, 2010). Whereas the qualitative method involves collecting data in textual or narrative form and analyzing by employing qualitative data analysis techniques (Creswell, 2013).

Choosing mixed methods in this study was based on two reasons. The reasons include: an underlying principle investigating an issue requires different research methods; the fact that this study explores social issues (students' level of understanding and motivation); and the need of mixing both qualitative and quantitative methods in the process of analyzing the same data. First, it was based on the underlying principle that investigating an issue holistically from different perspectives requires different research methods. Frels and Onwuegbuzie (2013) argued that the fundamental premise of mixed methods is that integration of the two methods involved may give a better understanding of the research problems and complex phenomena than the individual approach does alone.

Second, the mixed methods is further recognized to be of active roles in studies that explore social-related issues and the significance of intervention programs in addressing TSPCK construct (Luft et al., 2011). Maries and Singh (2013) referred to such student learning as a social activity. Thus, the secondary school students learn to develop as they engage in the process of learning. Smith and Banilower (2015) attested to the argument that "conceptual understanding and motivation through TSPCK is a complex, multidimensional construct specific to a topic/idea" (p. 99). So, investigating conceptual understanding and motivation of secondary school students (grade 11) through TSPCK-based strategies becomes a social issue as they learn to teach. As a result, the effectiveness of using a mixed methods approach in this study is found in examining the complex nature of the secondary school students' conceptual understanding and motivation on TSPCK-based instruction in the two Chemistry topics chemical kinetics and equilibrium. Such an examination requires a research design that gives an in-depth understanding with valid reasons and evidence. This makes mixed methods the most appropriate in this study.

Research Setting, Sample, and Sampling Techniques

The study site for this research was the Addis Ababa city administration. Addis Ababa city administration has lately been clustered into 11 sub-cities. In this connection, the target population of this study was grade 11 students in rolled in Addis Ababa city administration during 2021/2022 academic/school year and details of the sampling technique are presented underneath.

In this study, multistage sampling techniques were adopted. In the first stage, simple random selection was used to select one of eleven sub-cities in Addis Ababa city administration. As a result, the Yeka sub-city was chosen at random. Second, secondary schools in the Yeka sub-city were chosen using a whole/comprehensive sampling technique. That is, according to information collected from the Yeka education office, there are four secondary schools in the sub-city, and all of them are included in this study. Third, one section was chosen from each secondary school in the Yeka sub-city with relatively equal teacher experience and the same qualification. That is, one section was chosen from each school using a purposive sampling technique. Because the participants of the study were expected to have similar characteristics such as educational background, family characteristics, age level, and experience related to chemistry topics. There was no randomization of participants into each of the groups because the researcher was taken intact classes in the school setting. These include 38 for curricular saliency-based instruction, 26 for representation-based instruction, 35 for conceptual teaching strategy-based instruction, 60 for conventional-based teaching, and four for chemistry teachers.

Variables of the Study

In quasi-experimental research, the investigator manipulates or changes the independent variable to see what influence it has on the dependent variable. In this study, the independent variables that causes the dependent variables are the TSPCK-based instructions namely, curriculum saliency, representations, and conceptual teaching strategies. These variables were probably affected by the dependent variables after intervention. The dependent variables that may be influenced by independent variables are the conceptual understanding of grade 11 students in learning chemistry concepts.

Instruments for Quantitative Data Collection

Conceptual understanding test (CUT)

Conceptual understanding is the interrelationships among the basic elements within a larger structure that enable them to function together. It includes knowledge of classifications and categories, knowledge of principles and generalizations, and knowledge of theories, models, and structures (Anderson et al., 2001). Procedural knowledge is how to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods. The grade 11 chemistry concept was analyzed at the start to identify the objectives, course descriptions, and activities of the laboratory for chemical kinetics and equilibrium. Literature was reviewed to identify students'

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misconceptions regarding the topic under investigation. To study the effects of the different modes of TSPCK-based strategies employed, conceptual understanding and concept related to the reason of grade 11 students' chemistry tests were developed.

Conceptual Understanding Test (CUT), which consisted of limited multiple-choice questions addressing related standards in the chemistry curriculum that covered the competencies in learning the chemistry of the grade 11 students. Three secondary school chemistry teachers, my supervisors, language experts, and two chemistry education Ph.D. candidates validated the questions. The responses to the CUT's items were examined with SPSS (20), and a specific number of questions were eliminated or amended based upon the difficulty index and discrimination power of the items. Kuder-Richardson coefficient of reliability (KR-20) was computed for conceptual understanding tests.

Chemistry topics' CUT was made up of two tiers: the first tier needs a content response and the second tier that provides possible reasons for the response. In the first level, students were asked to select one of four given options. The second tier included the correct choice as well as the misconceptions reported in previous research. Students who correctly answer both tiers received 2 points; those who incorrectly answer one of the tiers (content or reason) received 1 point. When both questions are answered incorrectly received 0, it indicated that no understanding occurred. Student responses were examined at four levels: no understanding (NU) if both tiers were incorrect, partial understanding (PU) if the concept item is right and the reason item was answered incorrect, Misconception (M) if the concept item was wrong and the reason item is right, and full understanding (FU) if both tiers have got right.

Instruments for Qualitative Data Collection

Classroom observation checklist

The CSA-based instruction, REP-based instruction, CTS-based instruction (treatment), and conventional-based teaching (comparison) groups were observed while they are at work during selected teaching sessions in different stages: beginning, intermediate, and final. Teaching sessions with the same activity were selected for observation. It was designed to enable the researcher to observe how grade 11 students and the implementer teacher educator in the treatment and comparison groups are actually engaged in the process. In this study, qualitative data was obtained from teaching sessions through observation at different stages of the intervention. The observation checklist were contained 16 items of class observation that oversee, students engagement, motivation, teachers use of TSPCK strategies, and students interaction with the chemical kinetics and equilibrium. The observation data were analyzed to triangulate and clarify the information obtained from quantitative data. Some aspects of the three stages of observation were identified to investigate the extent of implementation of the intervention as of the plan or expectation. In sum, the qualitative data analyzed were used for triangulation purpose.

Semi-structured interview

In research studies, an interview is regarded as "a good way of accessing people's perceptions, meanings, definitions of situations; and construction of reality"(Punch, 2009, p. 28). McMillian and Schumacher (2010) also added that interview is the most prominent data collection tool in qualitative research as it involves accessing people's perceptions, meanings, and definitions of situations and construction of reality. Meanwhile, there are basically two kinds of interviews: structured interviews and semi-structured interviews. Structured interviews are used when a research study is of a very large sample from which results are to be generalized (Creswell, 2012). Structured interview in most cases prevents respondents from sharing important information with the researcher since there are specific answers that they have to choose (Mcmillan & Schumacher, 2010). As a result, this would not be appropriate for this study since the researcher is interested in the participants freely expressing their mind regarding strategies for planning a new chemistry topic. Hence, a semi-structured interview was used as it gives opportunities for respondents to provide the needed information without any restriction to what they might want to say. According to Creswell (2013), semi-structured interviews were used as a research instrument; it increases the data with details as it allows respondents to be flexible while responding to the questions. Thus, the use of semi-structured interview in this study helped in getting useful information from the secondary school students during their learning of chemistry concepts. This was done to enhance the validity of the research findings. Conducting an interview with the students helped in gathering more evidence of the impacts of TSPCK intervention as seen in the written work of the participants. To avoid possible bias during transcription the researcher was audio-record each segment of the interview conducted. In support of this, Creswell (2012) pointed out that audio-recording of information is efficient when collecting data from a small group of people than in the real classroom teaching.

Validity of the Instruments

To test the content and face validity, the instruments were developed and given to two supervisors, three experienced chemistry teachers from high schools, and two chemistry Ph.D. candidates who have a chemistry education research background. Following this, the researcher used their feedback to modify the instruments. In order to check construct validity, the instruments were first pilot tested and the scores from the instruments were compared with students' previous achievement.

Reliability of the Instrument

To check for the reliability of the items, the instruments were pilot tested on grade 12 students that have already taken the concepts of chemical kinetics and chemical equilibrium in Addis Ababa administrative city but were not included in

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this study. After the pilot test, Kuder–Richardson coefficient of reliability (KR-20) was computed for the conceptual understanding test. Questionnaires for motivation were evaluated using Cronbach's alpha coefficient of reliability. Finally, the results from the pilot test administration of the instruments were used to review the items of the instruments. Besides, item difficulty and item discrimination indices were calculated to ensure the appropriateness of the instruments.

Table 1 depicted that the difficulty index and discrimination power of both the conceptual understanding of chemical kinetics and chemical equilibrium. This showed that both the concept-based and reason-based items were found in the acceptable range of difficulty index and discrimination power. From both 40 items of the concept based and reason based of the concept under investigation each, 28 items were directly retained, and 2 items were revised for further investigation of this study. The 28 items had acceptable values of difficulty level (0.40–0.625) and discrimination power (0.40–0.71), respectively. Whereas two items of the conceptual understanding questions were revised due to its difficulty index (DI = 0.40) and discrimination power (DP = 0.20) found in the boundary range which had a room for revision. Finally, the remaining 10 items' difficulty index and discrimination power were below the acceptable range and considered as very difficult items and less discrimination power and then rejected from the final items for further investigation. As a result, 30 items of the conceptual understanding on chemical kinetics and chemical equilibrium were selected for the next pre-test and post-test scores investigation and analysis.

Table 2 reveals that the internal consistency of the multiple-choice items on the chemical kinetics and chemical equilibrium calculated Kuder-Richardson reliability using the Microsoft excel operating system. As observed from the data the KR-20 values were >0.7 and also in an acceptable range. Therefore, both concept-based and reason-based items have internal consistence and reliable to use the items for the further investigation.

Table 1: Validity of concept and reason based multiple choice items

Type of items	Number of items	DI	DP	Interpretation	Decision
Concept based	28 (2)	0.40–0.625	≥0.25	Medium-high	Retained
Reason based	28 (2)	0.40-0.71	≥0.25	Medium-high	Retained
Rejected items	10	≤0.40	≤0.20	Very difficult	Rejected

DI: Difficulty index, DP: Discrimination power

Table 2: Reliability of multiple-choice questions on the chemical kinetics and equilibrium

Items	Number of items	KR-20
Concept based items	30	0.786
Reason based items	30	0.810

KR-20: Kuder-Richardson coefficient of reliability

Table 3: Criteria for categorizing student's level of conceptual understanding in chemical kinetics and equilibrium concepts

Tiers		Categories
First tier	Second tier	
Correct	Correct	Full understanding
Correct	Incorrect	Partial understanding
Incorrect	Correct	Misconception
Incorrect	Incorrect	NU

NU: No understanding

Table 4: Chemical kinetics and equilibrium concepts under consideration

Serial number	Chemistry concepts	Question numbers
1	Rate of chemical reaction	1, 2, 3, 4
2	Theories of rate of reaction	5, 6
3	Factors affecting rate of reaction	7, 8, 9, 10, 11
4	Rate law and order of reaction	12, 13, 14, 15, 16
5	Reaction mechanism	17, 18, 19
6	Basic concepts of chemical equilibrium	20
7	Equilibrium expression and constants	21, 22, 23, 24
8	Factors affecting chemical equilibrium	25, 26, 27, 28
9	Le Chatlier's principle	29, 30

RESULTS AND INTERPRETATION

Tables 3 and 4 indicate the conceptual understanding interpretation and the ideas of chemical kinetics and equilibrium under discussion, respectively. Chemical kinetics and chemical equilibrium from the grade 11 chemistry curriculum were examined. The data revealed that the level of conceptual understanding was categorized as no understanding if both tiers answered incorrectly, partial understanding when the first tier was correct and the second tier was incorrect, and Misconception, if the first tier was correct and the second tier is correct and full understanding categorized when both tiers were correctly answered.

The level of conceptual understanding in chemical kinetics of the 19 questions is shown in Table 5. According to the data, item 16 has the lowest conceptual knowledge of the nature of reactant on the rate of reaction at 3.8% (six out of 159 students) in post-test scores and 11.9% (19 out of 159 students) in pre-test scores. This demonstrated that the majority of students' conceptual understanding of the idea of reactant nature on reaction rate failed 43.4% and 49.1% of the time in the pre-test and post-test, respectively. Furthermore, 26.4% and 25.2% of the students failed the conceptual understanding misperception categories on both pre-test and post-test scores on the type of reactant on the rate of reaction, respectively.

This might suggest that students were perplexed when utilizing the computer during the Edpuzzle and experimental sections of teaching the notion of reactant nature at the pace

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Table 5: Level of students' conceptual understanding of pre-test and posttest scores on chemical kinetics

Number of items	Level of conceptual understanding on chemical kinetics							
	Number understanding		Partial understanding		Misconceptions		Full understanding	
	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)
1	23.9	20.1	17.0	18.2	34.6	8.8	24.5	52.8
2	23.9	15.7	16.9	14.5	2.5	10.7	64.8	59.1
3	25.8	20.1	35.8	30.2	8.2	9.4	30.2	42.1
4	46.5	34.0	13.8	14.5	3.8	9.4	35.8	42.1
5	30.2	34.6	22.0	18.9	15.7	13.8	32.1	32.7
6	23.3	14.5	15.7	17.0	13.8	20.1	57.2	48.4
7	23.3	28.9	35.2	24.5	8.8	9.4	32.7	37.1
8	46.5	59.1	6.3	15.1	28.9	12.6	18.2	13.2
9	30.8	36.5	18.2	17.6	18.2	7.5	32.1	38.4
10	31.4	17.0	32.1	34.0	11.3	6.3	25.2	42.8
11	35.2	27.7	26.4	20.1	10.1	7.5	27.7	44.7
12	44.7	37.1	8.8	4.4	30.2	22.0	16.4	32.1
13	46.5	37.1	20.1	14.5	17.6	28.3	15.7	20.1
14	45.9	28.9	10.1	19.5	25.8	32.7	18.2	18.9
15	59.1	54.1	13.8	10.7	20.1	21.4	5.7	13.8
16	43.4	49.1	18.2	22.0	26.4	25.2	11.9	3.8
17	59.7	49.7	18.2	19.5	16.4	15.7	5.7	15.1
18	23.3	22.6	25.2	22.6	17.6	13.8	34.0	40.9
19	33.3	47.8	7.5	15.1	32.7	23.3	26.4	13.8
Average	36.67	33.40	19.02	18.57	18.04	15.68	27.08	32.21

of chemical kinetics. In addition to item 16, the difficult ideas in the chemical kinetics chemistry themes of the Ethiopian curriculum at Addis Ababa administrative city secondary schools were items 8, 15, and 19. These challenging chemical kinetics concepts were reactant surface area, half-life of the second-order reaction, and reactant collision with inadequate activation energy.

In posttest scores, the total level of conceptual understanding of chemical kinetics concepts was 33.4% of no understanding, 18.57% of partial understanding, 15.68% of misconception, and 32.21% of full understanding. As a result, there were difficulties in acquiring chemical kinetics concepts in the chemistry curriculum for grade 11 learners from selected secondary schools in Addis Ababa's administrative city. Despite the fact that TSPCK-based instruction increased conceptual understanding levels from pre-test to post-test scores, there was still an issue with misunderstandings about chemical kinetics concepts. This was owing to students' inability to comprehend the notions of half-life and order of reaction due to a lack of mathematical concepts like integration and derivation. As a result, students should understand mathematical concepts before learning about chemical kinetics. This may indicate an issue with the horizontal link between the chemistry and mathematics curricula at Addis Ababa Secondary School in Ethiopia.

Table 6 shows the proportion of conceptual understanding of chemical equilibrium in grade 11 chemistry curriculums before and after the intervention. According to the results, item 29 was the most challenging concept of chemical equilibrium, with only 13.2% and 10.7% of grade 11 students (n = 159) fully understanding the idea in pre-test and post-test scores, respectively. In the post-test results demonstrated that the level of conceptual understanding of grade 11 pupils in studying chemical equilibrium ideas (Le Chatlier's principle) was 44% of no understanding, 16.4% of partial understanding, and 13.2% of a misconception. As a result, even though TSPCK-based instruction increased knowledge from pre-test to post-test scores, there was some confusion about learning Le Chatlier's principle in chemical equilibrium ideas. Furthermore, items 22, 25, and 26 were also relatively difficult, with low full understanding and high levels of no understanding, partial understanding, and misunderstandings. The relatively complex chemical equilibrium concepts were the calculation of reaction species at equilibrium, the influence of solid reactant at equilibrium (adding or removing), and effect of temperature on the equilibrium constants. This might be because students were mystified while utilizing Edpuzzle and mental representations of equilibrium principles at the macro, micro, and symbolic levels when using technology.

Finally, in the posttest scores, the level of conceptual understanding of selected grade 11 students in Addis Ababa administrative city in chemical equilibrium concepts was 23.68% fully understood, 15.91% misconception, 14.53% partial understanding, and 43.55% no understanding. This meant that only 23.68% (36 out of 159) of students understood the concept of chemical equilibrium, 30.44% (about 48 out of 159) were confused, and 43.55% (69 out of 159) did not understand the chemical equilibrium concepts of the

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Table 6: Level of conceptual understanding of students on chemical equilibrium concepts

Number of items	Level of conceptual understanding on chemical equilibrium							
	Number understanding		Partial understanding		Misconceptions		Full understanding	
	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)
20	47.8	30.8	15.1	22.0	16.4	23.3	20.8	23.9
21	54.1	30.8	10.7	10.7	14.5	19.5	20.8	39.0
22	60.4	62.9	10.1	11.3	16.4	9.4	13.2	16.4
23	49.1	37.1	15.1	15.1	18.9	15.7	17.0	31.4
24	44.7	31.4	10.7	5.0	23.3	19.5	19.5	44.0
25	57.2	44.0	17.6	12.6	11.9	10.7	13.2	17.0
26	56.0	47.8	15.7	22.6	11.3	10.7	16.4	17.0
27	53.5	57.2	13.2	13.2	15.7	11.3	17.6	18.9
28	60.4	49.1	21.4	20.8	7.5	11.3	10.7	18.9
29	56.0	44.0	11.9	16.4	18.9	28.9	13.2	10.7
30	40.9	44.0	24.5	10.1	22.0	26.6	12.6	23.3
Average	52.74	43.55	15.09	14.53	16.07	16.99	15.91	23.68

chemistry grade 11 curriculum in Addis Ababa administrative city, Ethiopia. This demonstrated that students in grade 11 in Addis Ababa's administrative city had trouble comprehending chemical equilibrium concepts in general and needed to improve. Even though posttest scores improved, TSPCK-based instruction in teaching chemical equilibrium concepts did not meet expectations owing to a lack of Edpuzzle and mental representation of the ideas at the macro, micro, and symbolic levels through the use of technology.

Compared to the conceptual understanding levels of grade 11 students in Addis Ababa secondary schools, 32.21% and 23.68% of the students had a full understanding of chemical kinetics and equilibrium, respectively. This suggested that students in Addis Ababa administrative city understood chemical kinetics ideas more thoroughly than chemical equilibrium concepts. This is because, in contrast to chemical equilibrium concepts, chemical kinetics concepts can be easily represented as metal representations (macro, micro, and symbolic).

Figure 1 depicts the achievement levels of grade 11 students in chemical kinetics topics before and after intervention. According to the figure, all post-test scores of learners were greater than pre-test scores except for curricular saliency-based instruction. Curriculum saliency-based instruction, CSA (48.82%); representation-based instruction, REPs (53.24%); conceptual teaching strategy-based instruction, CTS (70.3%); and conventional method, CM (56.41%) had the highest average mean scores. This meant that students in the CTS group outperformed than CSA and (interventions groups) and comparison groups. This was due to the fact that the subject of chemical kinetics was taught in the CTS intervention group utilizing Ed-puzzle as the more interactive method of teaching in the sampling lesson.

The achievement of students after the intervention was discussed by using learning gain for each group. Therefore, learning gains during topic-specific PCK-based teaching were 11.2% for CSA, 33.17% for REPs, 4.82% for CTS, and 8.38

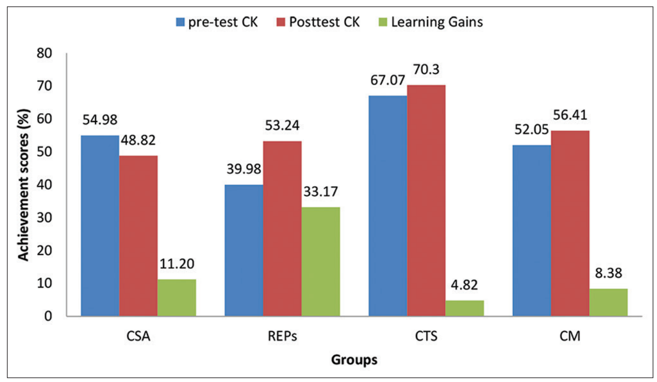

Figure 1: Learning gain of grade 11 students on the chemical kinetics concepts

for CM. This demonstrated that REPs-based instruction groups were more beneficial in learning chemical kinetics concepts by categorizing the ideas into macro, micro, and symbolic levels of understanding using animated videos on the rate of reaction, rate law, and reaction mechanism. This is because REPs-based instruction used visualization and the use of graphs to clarify chemical kinetics concepts.

Figure 1 indicates that the post-test scores in the CSA-based instruction were less than the pre-test scores. This showed that students had problems identifying big ideas, subordinate concepts, and sequencing them in a proper manner.

The interview obtained from one of the students from the group supported the above as:

> *Identifying chemical kinetics as big ideas and sequencing them is so difficult to me and makes me confused in learning it. As to me, it is better if the teacher identifies the big ideas, the students are easily sequence them.* (Student A)

Similarly, student B was asked to explain the ideas of chemical kinetics and what makes the chemical kinetics topic difficult mentioned as follows:

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Chemical kinetics concepts are somewhat better to understand than the equilibrium concepts if I memorize the formula to calculate the change in concentration and half-life formulas for zero, first, second order reactions. But I am confused when the teacher derived these equations by using calculus concepts and this makes the kinetics concept more difficult to me.

From the above excerpt, it can be concluded that students a lack of mathematics concepts (integration or derivation) to understand the concept of chemical kinetics. This needs the horizontal relationship between chemistry and mathematics curriculum in the Addis Ababa administrative city secondary schools particularly and in Ethiopian secondary schools in general.

Interview obtained from student C supports the above ideas as:

For me, identifying chemical equilibrium concepts as big ideas, subordinate concepts and sequencing them not as such difficult. For instance, dynamic equilibrium, equilibrium constants, Le Chatlier's principle and factors affecting equilibrium are some of them.

Regarding using conceptual teaching strategies in teach chemical equilibrium concept student D explained:

This technology supported teaching method is more interactive, makes the chemical equilibrium concepts visible and entertains the lesson through videos and animations. But, using this Edpuzzle by my mobile is so difficult at home because some videos did not open.

Figure 2 shows the achievement levels of grade 11 students on chemical equilibrium topics before and after intervention in the four groups. This revealed that the average posttest mean CSA, REPs, CTS, and CM scores were 46.77%, 30.77%, 52.2%, and 40.25%, respectively. This showed that the conceptual teaching strategy-based instruction group outperforms than the other interventions and comparison group in terms of student success in chemical equilibrium concepts. This was due to the use of Edpuzzle in teaching chemical equilibrium ideas, which made it interactive for students to answer the selected questions with their classmates and teacher. In addition, curricular saliency-based instruction was chosen as an instructional technique for teaching chemical equilibrium concepts. This is due to the fact that during CSA-based instruction, students were required to identify big concepts, subordinate ideas, arrange them, and evaluate them. In terms of student learning gains, the CSA-based instruction groups outperformed the other intervention and comparison groups (Figure 3). The learning increase from CSA-based instruction on chemical equilibrium was greater (38.36%) than in the other groups. This is because the method called for the main ideas, ordered them sequentially, and concepts that were difficult to understand in the chemical equilibrium.

As shown in Figures 1 and 2, representation-based instruction outperformed the chemical kinetic concepts and curricular

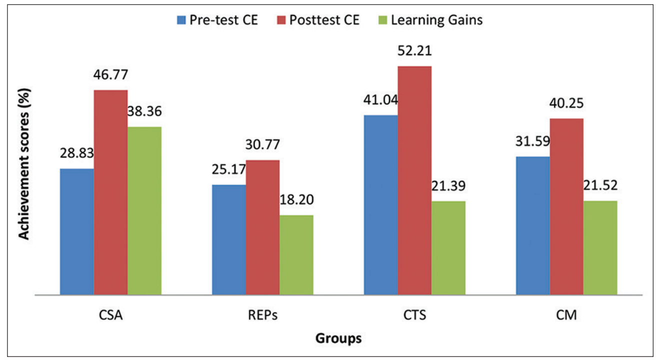

Figure 2: Learning gains on chemical equilibrium

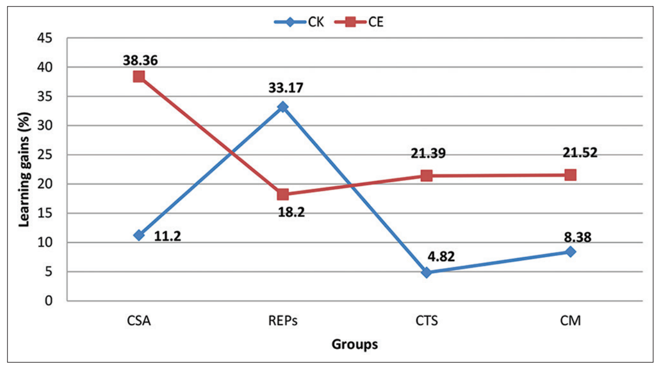

Figure 3: Comparison of learning gains Using TSPCK based instruction

saliency-based instruction outperformed well in teaching chemical equilibrium concepts. The total learning gains of grade 11 pupils who received TSPCK-based instruction favored chemical equilibrium concepts more. This suggests that by employing TSPCK-based instruction, chemical equilibrium ideas were more intelligible than chemical kinetics concepts.

The class observation and the interview results also revealed that students were engaged in learning more chemical kinetics and equilibrium during using TSPCK-based instruction and student E was interviewed as:

The conceptual teaching strategy what you call it Edpuzzle is more exciting because it shows the invisible concepts by using videos and animation. After watching video and animation there are interactive questions that related to chemistry concepts and make me more interested in learning chemistry in such way.

Similarly, student F also answered on the how you see representation-based instruction in teaching both chemical kinetics and equilibrium as follows:

I am impressed learning chemistry by using three-fold representation like macro, micro and symbolic levels. Using 3D animations and visualization in learning chemistry so interesting and engaged me in learning.

Classroom observation in the comparison class indicated that the engagement of the student in the classroom learning was

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not as such interesting and the involvement and participation of students were less as compared to intervention groups. This showed that TSPCK-based instruction makes the students more attracted engaged in learning chemistry concepts at this grade level. Even though he TSPCK-based instruction makes the students interesting, engaged, there was a lack of awareness, commitment and ICT facilities of teacher and school authorities to implement the instructional approach as expected.

CONCLUSIONS AND RECOMMENDATIONS

Within the scope and limitation of this study and basis on the findings, the researcher has concluded that TSPCK-based instruction such as curricular saliency; representation and conceptual teaching strategy were associated with the conceptual understanding of grade 11 students at Addis Ababa administrative city on the chemical kinetics and chemical equilibrium concepts.

Representation-based teaching improves student conceptual understanding and achievement of the students by explaining chemistry concepts based on three-fold representations (macro, micro, and symbolic levels) on the chemical kinetics concepts. Curricular saliency and conceptual teaching strategy-based instruction also increase the conceptual understanding and achievement of students in learning chemical equilibrium concepts.

Based on the findings and conclusions drawn the following recommendations are offered.

1. The results of the study can be made available to teacher and curriculum developer to serve as the basis for improved TSPCK-based instructional design in teaching both chemical kinetics and equilibrium and suitable ways in developing students' three-fold representations and interactive Edpuzzle teaching strategies to create meaning-making learning approaches.
2. On further studies, the complex relationship between students' learning approach and levels of conceptual understanding should be investigated making diverse questions that could reveal further conceptual difficulties of the students.
3. Further enhancement of this study can be done involving eater number of grade 11 samples of students and wider research locate to strengthen the generalizability of the result of this study.

Ethical Statement

All the processes of research highlighted in this study begun and ended with ethical considerations. Educational researchers claim that ethical issues and considerations encompass the whole process of research (Cohen et al., 2007). Thus, efforts were made from selecting and designing methods to reporting and disseminating of findings. Accordingly, the researcher taken letter of cooperation from the Department of Science and Mathematics Education of Addis Ababa University and it used to get permission from secondary schools of Addis Ababa administrative city. The study started with obtaining permission from four secondary school principals of Addis Ababa administrative city. Thereafter, consent forms given to the grade 11 students and four teachers who indicated their willingness to voluntarily participate in this study. The form explained the purpose of the research study, its benefits, the confidentiality and anonymity of the data collected. It indicated in the consent form that the students made free to withdraw at any stage without any negative effect on them and this was strictly adhered to in this study. There were close follow-up during pre-test, during intervention, and post-test. Most importantly, data confidentiality (using codes and pseudonyms when necessary) is given due emphasis. The researcher attempted to minimize bias while collecting and processing data and made sure that all the findings reported were based on the data collected. Finally, ways to provide compensation for participant of those grade 11 students under consideration were done to maximize their learning since they were disturbed by what they already have practiced. To sum it all, while reporting in this study, the assigned codes to the participating secondary schools of the selected were used and no personal identities were revealed in any way.

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