Addressing the Lacuna in Critical Thinking in Kenyan Secondary School Chemistry Curriculum

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Abstract: There are numerous studies on critical thinking (CT), but very few studies have been done that relate CT dispositions especially self-efficacy in classroom theory and practice, particularly in Kenya's secondary school chemistry curriculum. This paper analyzed reports from scholars, policymakers, and the curriculum reforms for Kenyan secondary schools to establish the extent to which CT is incorporated into the curriculum. These reports were used to experiment with the standard critical thinking analysis model. The analyzed categories were used to develop key theoretical propositions for the study. Theoretical propositions formed an explanatory theory that supported the analysis. From the analysis, although education reforms recognize CT as a key skill, it is not clear how CT self-efficacy should be developed in Kenyan secondary school chemistry learners. In this paper, we argue that CT can only be realized in the Chemistry classroom if the learning approach is learner-centered as opposed to the current teacher-centered approach. CT self-efficacy indicators also ought to be infused into the secondary school education curriculum for chemistry learners to acquire CT skills.

Résumé : Il existe de nombreuses études sur la pensée critique (PC), mais très peu d'études ont été réalisées qui relie les dispositions de la PC, en particulier l'auto-efficacité dans la théorie et la pratique en classe, en particulier dans le programme de chimie secondaire du Kenya. Cet article a analysé les rapports d'universitaires, de décideurs politiques et les réformes des programmes d'études des écoles secondaires kenyanes afin d'établir dans quelle mesure l'informatique est intégrée dans le programme d'études. Ces rapports ont été utilisés pour expérimenter le modèle standard d'analyse de la pensée critique. Les catégories analysées ont été utilisées pour développer des propositions théoriques clés pour l'étude. Les propositions théoriques formaient une théorie explicative qui soutenait l'analyse. D'après l'analyse, bien que les réformes de l'éducation reconnaissent l'auto-efficacité de l'électrothérapie comme une compétence clé, il n'est pas clair comment l'auto-efficacité de l'auto-efficacité de l'électrothérapie devrait être développée chez les apprenants kenyans de chimie du secondaire. Dans cet article, nous soutenons que la PC ne peut être réalisée dans la classe de chimie que si l'approche d'apprentissage est centrée sur l'apprenant par opposition à l'approche actuelle centrée sur l'enseignant. Les indicateurs d'auto-efficacité de la PC devraient également être intégrés dans le programme de l'enseignement secondaire pour que les apprenants en chimie acquièrent des compétences en PC.

Background of the Study

This paper examines the extent to which Critical thinking skills are incorporated in the chemistry classroom in secondary schools in Kenya under the 8-4-4 curriculum. The 8-4-4 curriculum came into force in 1985 replacing the 7-4-2-3 system which had been in operation since independence in 1963. In 8-4-4 curriculum learners are required to spend eight years in primary, four years in secondary, and four years in tertiary institutions. The guiding philosophy for the 8-4-4 is "education for self-reliance" with CT as one of the key skills that learners must be equipped with. There have however been several observations and empirical studies that point to a lack of critical thinking skills in graduates of the 8-4-4 curriculum. The Kenya Institute of Curriculum Development (KICD) recognizes CT as one of the core competencies needed to ensure self-reliant learners who can competently face the challenges of the 21st Century. However, KICD curriculum review reports (2016; 2018; 2019) showed inadequate CT thinking skills in secondary school graduates. In this paper, we observe that although curriculum reviews since independence have emphasized the importance of "learner-centered" approaches that ought to produce "self-reliant" learners, there are no indicators in the classroom setting that point to the incorporation of CT thinking in Chemistry subjects.

Policymakers and curriculum developers outlining the 21st-century competencies in many countries across the world tend to include critical thinking (CT) as one of the core competencies highly searched by many employers. Hui (2016) observes that unless learners in their basic education can have a disposition to think critically, they will not be able to make capable decisions and solve future problems they may encounter.

Studies done concerning CT in classroom practice have shown better results in classes where self-efficacy is practised compared to ordinary classrooms. De Ruisseau (2016) did a study on CT in learners taught using inquiry-based classrooms (or learner-centered classrooms) that support self-efficacy versus those taught using the traditional model (lecture/teacher-centered approach) that do not support self-efficacy in learners. Questions for assessment included those that need critical thought or self-efficacy. The outcome proved that the ratio of learners in the inquiry-based classroom who answered analysis and evaluation level questions was higher than those taught in the normal/traditional classroom. Learners taught using the inquiry-based class model furthermore performed best (GPA predicted, as 85.5%) against, 42.2% in the normal/traditional class model (De Ruisseau, 2016). The inquiry-based class model gives more time to higher-order thinking skills (HOTS) where CT self-efficacy is developed, whereas, the normal/traditional model gives more time to lower-order thinking skills (LOTS) (De Ruisseau, 2016).

Critical thinking (CT) in this study is broadly defined as a skilful, dispositional reasonable thought that brings good judgment because it has criteria; is self-correcting, and is sensitive to a context given (Harris, 2019; Wason, 2023). Important and generalizable criteria for CT include strength, validity, reliability, consistency, evidence, relevance, and coherence (Wason, 2023). CT self-efficacy is self-correcting and focusing on one's thought processes to rectify and discover any challenge faced. Self-correcting toward individual improvement requires an active, persistent, and critical mind. It is sensitive to the context through the specific considerations of given circumstances, for overall configurations, untranslatability of different meanings, and any special limitations in the process of thinking (Ennis, 2016).

Most general objectives across all subjects offered in the Kenyan 8-4-4 education curriculum where learners are to study eight years in primary, four years in secondary, and four years in tertiary institutions have not indicated how learners should be taught to develop critical thinking self-efficacy during the learning process in the secondary syllabus. Even without a mention of critical thinking in the general objectives of most subjects in the 8-4-4 curriculum (Basweti, 2019; Ongesa, 2020), the mode of delivery of content and involvement of learners may lead to the development of CT self-efficacy mostly in hands-on subjects' activities for example in the science subjects which are taught using projects and experiments. Even though CT is mentioned as one of the objectives that a learner should attain by the end of the training, the teacher-centered approach in Chemistry theory and Practical classes becomes a major obstacle to the realization of CT self-efficacy in the classroom. Several studies (KICD 2017; Ongesa 2020; Namwambah 2020) observe that the 8-4-4 curriculum is a teacher-centered curriculum where a learner is not actively involved in the learning process. If learners were involved in problem identification, designing experimental procedures, and doing those experiments or practical works with their teachers as guides or facilitators then that learning is likely to infuse critical thinking in those learners. To ensure CT self-efficacy, learners should also be inducted to take full responsibility for conducting chemistry experiments and analyzing and reporting data. This data analysis can be used to deduce a conclusion or form a mathematical explanation of a certain phenomenon/concept.

But in Kenyan secondary and primary schools, universities and colleges, the teacher is put at the centre of instruction and lectures are the main mode of instruction. This can arguably be said to be part of the reason why many of those who graduate from those institutions struggle to think critically (KICD 2018). Graduate teachers who lack elements of thought containing intellectual learning standards (Elder & Paul, 2019) that form part of key CT indicators cannot be expected to help secondary school chemistry learners practice self-efficacy and critical judgments. This study therefore sought to investigate the claim that secondary school chemistry learners have no self-efficacy (KICD 2017; Kithinji 2020; Harris 2019) using a reliable standard model and attempt to provide a solution on how to train learners to have self-efficacy.

Purpose of the Study

To analyze the Kenyan secondary school chemistry curriculum to establish the extent to which critical thinking self-efficacy indicators have been incorporated during teaching and learning.

Critical Thinking in Kenyan Science Education

Research conducted in 1997 in a seminal teacher educational study by Paul, Elder, & Bartell, is valid even today as it was severally cited in about 2.1 million research and about 120,000 research between November 2018 to November 2020 by studies such as (Harris, 2019; Ongesa, 2020). The study found that 88% of those teachers who participated, had a claim that CT was their main teaching/learning objective. Analyzing and evaluating their response, the study, however, found that just 10% were truly teaching CT (Paul et al, 1997). This is even worse for Kenyan secondary school teachers whose primary teaching objective is to prepare their learners for passing examinations (Basweti, 2019; KICD, 2017). As long as the main objective of a curriculum is to prepare learners for exams, it may be difficult to integrate CT as part of their instructional approach when teaching, unless part of the test items examine CT skills or the curriculum is less examination-oriented (Basweti, 2019; KICD, 2017; Namwambah, 2020).

The mode of teaching in the Kenyan science classroom is also an obstacle to realizing CT in the classroom. A teacher-centered instructional delivery, as opposed to the learner-centered approach, has continued to be a common instruction method mostly in Kenya's secondary and primary schools (Basweti, 2019). Chemistry learning objectives at the secondary school level for example have mentioned critical thinking skills as one of the objectives to be achieved but so far no teaching-learning indicators are stated on how a learner shall develop critical thinking in the course of his/her chemistry study. Chemistry is a science where learning should be accompanied by a series of practical activities (experiments, demonstrations, and projects).

The problem to be investigated, experimental procedure, and expected observation instead are in most cases given by the teacher (Kithinji, 2020; Ongesa, 2020). A learner is only supposed to take a confirmatory test. A study process directed by others and not the learner (where the learner is not actively involved from the problem identification to the end) is not analytical, can't be creative and cannot promote the development of higher-order thinking skills or CT. A learner should be left alone to seek out factual information, inquire, examine, practice proactive planning, link with prior knowledge and experience to problems, collaborate in finding solutions to the problem, communicate the findings, adapt the findings, model and reflect on their findings if they can be transferrable (Bloch and Spataro, 2014; Sande, 2020; Schendel et al, 2022). Contrary to this observation, the problem to be investigated in the classroom according to the design of the Kenyan secondary chemistry curriculum is determined by the teacher (Ongesa et al., 2023). Tools of data collection, experimental procedure, how to write observations, tools of data analysis, discussion, and conclusion are given or dictated by the teacher; the teacher is the centre of focus (Namwambah, 2020). The chemistry learner becomes just a bank or a repository where knowledge is deposited. Knowledge of this kind cannot infuse or promote the development of critical thinking (Basweti, 2019; Ennis, 2018; Ongesa, 2020).

Experiments that promote CT should in most cases be left open where learners are only given the problem or objective to be solved and/or apparatus and then left to design their procedure, make the observation, analyze data, and/or their conclusion (Nussbaum 2020; Sande 2020). By doing so, learners are likely to develop CT. This study focuses on examining the extent to which learners are actively involved in designing the procedure in Chemistry practicals, making observations, analysing the data and making conclusions in an attempt to propose ways of making the Chemistry classroom in Kenya more learner-centered.

Methodology

As a philosophical research, the main methodological approach was a critical documentary/secondary data analysis. Sources of data included government policy documents on curriculum reform, Kenya's Ministry of Education reports, reports from education scholars, curriculum reports and syllabuses, thematic books, chemistry syllabi, and peer-reviewed journals. To gain insight into the research problem, philosophical reflection, and speculation were used under the guidance of analytical and critical methods. The part of the syllabus for secondary school chemistry selected is a representation of the whole chemistry syllabus for secondary school learners. The assumption was that every content of the syllabus should be inquiry-based because a critical thinking curriculum/syllabus/lesson is learner-centred and problem-based. Applying the critical method to the objective of this study, a valid model/criterion was sought to assess and establish the place of CT in Kenyan secondary schools' chemistry curriculum reform reports. Elder & Paul's (2019) reasoning wheel was used in the study as a standard criterion for analysis. The reasoning wheel has eight basic structures present in any form of thinking: The question at issue, the purpose of thinking, point of view, assumptions, consequences and implications, concepts, information, and, interpretation and inferences. The data generated is non-numerical because the study is reflective, speculative, and conceptual.

The Teaching of Gas Laws in Kenyan Secondary School Science

Science subjects like physics, chemistry, biology, primary science, and even mathematics are expected to promote CT because they involve hands-on activities and the manipulation of numbers. Our main focus was on the secondary chemistry curriculum to assess how it has promoted the development of CT in learners during the teaching-learning process in secondary schools. The study sought to apply elements of thought in Elder-Paul's (2019) and Paul-Elder's (2010) critical thinking teaching-learning model to assess if indeed in the Kenyan secondary chemistry curriculum, CT knowledge exists.

This study sampled some content from the chemistry secondary school curriculum to assess how CT has been integrated during the teaching-learning process. Elder-Paul's (2019) critical thinking teaching-learning model was used to assess how the teaching of chemistry has been used to promote the development of critical thinking in learners. Chemistry is a physical science subject that deals with matter, its properties, composition, and how matter interacts in the physical world mainly with energy. It is assumed that learning activities in chemistry would engage learners and, in the end, help them develop CT.

Part of the content that is done practically includes the preparation and collection of gases such as carbon (II) oxide, nitrogen (IV) oxide, sulphur (IV) oxide, and hydrogen sulphide that are thought to be hazardous (KLB Chemistry book 3, 2018). The other part of chemistry done theoretically is the periodic table, gas laws, and chemical families among other chemistry topics. Some of this content was analyzed and assessed in this study using Elder-Paul's (2019) critical thinking teaching/learning model. Elder-Paul's (2019) standard model for experimenting with existing models in secondary chemistry has elements of thought containing intellectual learning standards that can be used to establish the extent to which the content in question has infused CT.

The study assessed gas laws in chemistry as part of the content done theoretically using Elder-Paul's (2019) CT Model and established the extent it had infused CT. Gas laws describe the relationship between the volume, pressure, and temperature of gases (KLB Chemistry Book 3, 2018; KICD, 2017). The relationship between a fixed mass of a given pressure and the volume of the same gas is explained by Boyle's Law. The relationship between the volume of a fixed mass of gas and the temperature of the same gas is explained by Charles' law. Whereas the relationship between the pressure of a gas and the temperature of the same gas is determined by Pressure law. Our study focuses on these gas laws, but, the main emphasis is put on Charles' law which deals with the relationship between the volume of a fixed mass of a gas and its temperature.

The following are the main objectives to be achieved by learners at the end of learning gas laws. By the end of this topic, the learner should be able to: State an ideal gas law (Boyle's, Charles, Graham's, and Gay-Lussac's laws); verify gas laws experimentally; explain how the absolute zero temperature may be obtained from the volume-temperature and pressure-temperature graphs; convert the Celsius scale to Kelvin or the absolute scale of temperature; state the kinetic theory basic assumptions of gases and explain the relationship between gas laws and the kinetic theory of gases; solve numerical problems using gas laws equations (KLB Chemistry book 3, 2018).

All the stated objective verbs: state, explain, convert, and apply are lower-order thinking objectives that cannot promote CT (Wason, 2023). It should be noted that the gas that obeys all gas laws; pressure law, Boyle's law, Gay Lussac's law, Charles' law, and Grahams' law of diffusion is an ideal gas according to the proponents of the kinetic theory of gases and gas laws as deduced in KLB chemistry book three (2018). Gases that do not obey all gas laws are real gases.

Four main assumptions held by all the gas laws stated above are:

> That gas particles have no forces acting among them; that particles do not occupy any space or volume; that gases are in a continuous random motion and; that the

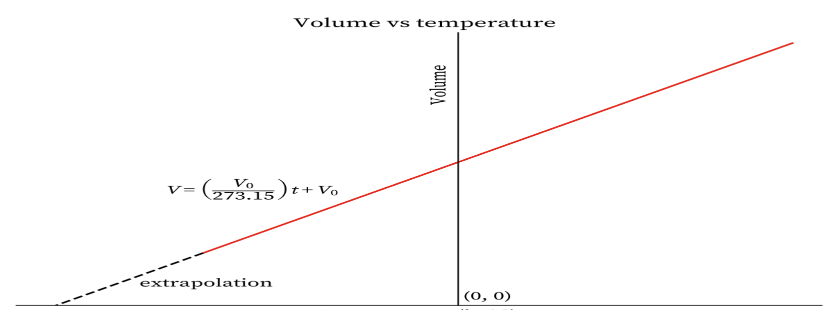
> mass of gases must be held constant when verifying those laws otherwise the relationship may not be accounted for (KLB Chemistry book 3, 2018, p. 6).

The above-stated assumptions cannot be visualized by a learner, hence gas laws cannot be verified since the conditions stated can't be attained in a normal school environment. This means that the learner is not actively involved in analyzing and verifying gas laws. Such a form of learning cannot promote the development of CT.

Boyle's law and Charles' law are drawn from the ideal gas equation/law which provides the simplified form of ideal gas law. This means that Boyle's law and Charles' law relate all three physical conditions (volume, pressure, and temperature). Charles' law is used to investigate the relationship between the volume of a given mass of gas and the absolute temperature (temperature measured in Kelvin). According to Charles' law, the volume of a fixed mass of gas varies directly from the absolute temperature when the pressure of that gas has been kept constant.

'According to Charles' law (KLB Chemistry Book Three, 2018, pp. 4-8):

> Temperature in degrees Celsius (^{0}C) does not vary directly with volume. This is because, at zero degrees Celsius, the gas still has some volume. Zero degrees Celsius according to ideal gas law is equal to 273K and at this temperature, the gas has some volume.'



A graph of volume against absolute temperature in Kelvin (K) (Charles' Law) (KLB Chemistry book 3, 2018 p. 8)

The argument given by the proponents of ideal gas law which this study discounts is that the volume of a gas will be zero when the temperature is negative 273 degrees Celsius ($-273\ ^{0}C$). Negative 273 degrees Celsius is called absolute zero temperature since the volume of the gas is assumed to be zero. The scale is called the absolute scale and it varies directly to volume according to Charles' law. As we shall see, later and in Sande's (2020) observations, information like such cannot promote the development of CT since it is imaginary in the mind of a learner (a learner is not allowed to test the stated conditions). According to KLB Chemistry Book Three, 2018 p. 7:

> 'All gases liquefy before attaining zero Kelvin or negative 273 degrees Celsius. The volume of a gas at this temperature is assumed to be zero' (KLB Chemistry Book Three, 2018 p. 7).

Absolute temperature is defined as the temperature measured on the Kelvin scale where one degree Celsius is equal to 273 Kelvin (K). Whereas absolute zero temperature is defined as the temperature at which the internal energy of a gas is assumed to be theoretically zero. This means that the volume and pressure of a gas at this temperature are assumed to be zero. If the energy of a gas or any substance is zero (the volume of that gas is zero and the pressure of the same gas is also zero), then that gas or that substance does not exist. The concept of absolute zero temperature and absolute temperature is therefore flawed and cannot be used to develop CT in learners. Charles' law to this end may not be giving factual information that can be relied on in finding a solution to the problem of the relationship between the volume of a fixed mass of a gas and temperature. This is because if the energy of a gas is zero, its volume and pressure are also zero which means that the gas does not exist. If that gas is assumed not to exist, then the law is not drawn logically (see also Harris, 2019) and the law, therefore, is invalid hence it is wrong. Such laws as Charles' law cannot provide the learner with the opportunity to develop critical thinking.

Applying elements of thought in Elder-Paul's (2019) critical thinking teaching-learning model having intellectual learning standards, it is clear that gas laws and especially 'Charles' law' is not free from ambiguity or confusion. This is because absolute zero temperature is a theoretical value, not a practical value that cannot be empirically verified given that all gases liquefy before attaining the said absolute zero temperature. At absolute zero temperature, all the gases under study are in the liquid state and do not have the properties of a gas. Ideal gas law and in this case Charles' law cannot be empirically or theoretically tested or verified. Since all gases liquefy before attaining zero kelvin and no gas practically exists at zero kelvin, then, we doubt Charles' law (see also Basweti, 2019). To this end, therefore, we conclude that Charles' law is not accurate, hence, not free from distortion and thus cannot be used in developing CT in learners.

Evidence given by the proponents of gas laws (Charles' law and Boyle's law) does not make sense altogether, since no ideal gas exists (a gas that obeys all gas laws). Given that those gas laws are derived based on the understanding of ideal gases, the evidence provided under which the gas laws are based lacks consistency and logical validity since gases do not attain zero kelvin. Gas laws as presented in the Kenyan secondary chemistry book three have failed to meet Elder-Paul’s (2019) intellectual learning standards (relevance, validity, truth, logic, precision, etc.). Some of the standards for example; having no contradiction, being free from bias or distortion, and being free from confusion or ambiguity are not met by gas laws. This means, therefore, that learners of gas laws cannot develop CT since the information given is contradictory (does not make sense at all) and is not logical.

The chemistry of writing chemical formulae was also assessed using elements of thought in Elder-Paul’s (2019) critical thinking teaching/learning model containing intellectual learning standards. The chemical formulae of oxides of Sulphur, oxides of nitrogen, carbon (II) oxide, and many other chemical formulae that form the greater part of secondary chemistry are not well defined or written since they violate the basic principle of writing chemical formulae and do not follow chemical writing logical processes (principle of interchanging valences of the combining atoms). If well written, then, the explanation on how to go about writing those chemical formulae is missing, not well stated, or comes later when the learner has already been introduced to those chemical formulae.

To have a clear understanding of writing chemical formulae, elements of thought having intellectual learning standards similar to Elder-Paul’s (2019) critical thinking teaching/learning model is needed in our secondary teaching of chemical formulae. This can be done when the knowledge or content to be taught is true, relevant, precise, related to the matter at hand and makes sense altogether (being logical). When the writing of chemical formulae is well understood, precise to the level of knowledge of the learner, accurate, logical, clear, and related to the matter at hand, deep and free from error or distortion its understanding would be easy. Learners too who are being taught are likely to develop a mindset that can enable them to think deeply and wider to promote the development of CT that in turn can help them solve other problems associated with the learning of chemistry. Critical thinking, therefore, in the teaching/learning process of chemical formulae, and gas laws that extend to the rest of chemistry cannot be developed in secondary learners by applying an ordinary teaching-learning approach. A constructivist or learner-centered teaching-learning approach may be important at this point.

A constructivist or learner-centered teaching-learning approach is more effective than the conventional or teacher-centered teaching approaches in enhancing students' achievement in all topics of Chemistry. This study's findings are in line with Kibo's (2015) observations:

> 'Consequently, measures were put in place in the post-test to adjust for those differences. Similarly, at the post-test level, there was a statistically significant difference in the mean scores and standard deviations between the students in the Experimental group, E1(X=11.37, SD=1.87) and Control group, C1(X=9.35, SD=2.35), suggesting that students in the Experimental group or constructivist students gained significantly higher after treatment compared with their counterparts in the control groups. From the mean gain analysis it was found that the Experimental or learner-centered group E1 gained more (Mean Gain = 6.82) than the control group, C1 (Mean Gain = 3.95)' (Kibos, 2015 p. 38).

These findings are also in line with several earlier studies by Harris (2015); Paul et al., (1997); Omwirhiren (2002) and Akinbobola;(2006) on the effect that the constructivist teaching approach involves the learners more in the instructional process both individually and in groups.

Basweti (2019), Hui (2016) and Esen (2004) also found that the constructivist teaching-learning approach led to higher students' academic achievement than the ordinary lecture methods. They have observed:

> 'Learners taught by the constructivist instructional approach or learner-centered approach had a significantly better acquisition of scientific conceptions related to chemical bonding and gas laws, and fewer misconceptions than the students taught by the ordinary designed Chemistry instruction' (Kithinji, 2020, p. 6)

Evidently, teachers should focus on their students' conceptions when teaching the topic.

> 'Learners should become aware of their existing ideas and teachers should provide learning experiences and appropriate scaffolding that help students to restructure their cognitive schemas' (Kigotho, 2022 p. 5).

Study Findings and Discussion

From the analysis and assessment using Elder-Paul's (2019) critical thinking intellectual learning standards containing elements of thought it is evident that most of those elements of thought that promote the development of critical thinking are missing in the Kenyan secondary school chemistry curriculum for learners. All curriculum reform reports on secondary chemistry in Kenya have only cited an example of what learners should practice in developing CT. The study found that the elements of thought as outlined by Elder-Paul (2019) and Lai (2011) are missing in the Kenyan secondary chemistry education curriculum. It is therefore difficult to claim that there is CT in Kenyan secondary school chemistry syllabus. If the current chemistry curriculum is modified to encourage a CT culture in learners, critical thinking will develop in those learners.

By thinking critically, self-efficacy learners in secondary school chemistry will be able to answer questions that are inferential in text, solve mathematical problems with ease, do experiments and at the same time evaluate text written by others, books, and teachers. Developing CT within the chemistry curriculum, the professional identity of those applying it is paramount. The chemistry curriculum reports have not properly defined a method appropriate for teaching/integrating CT. Failure by the chemistry syllabus to define how CT is to be developed and integrated (no model defined for integrating CT) makes it difficult for secondary school chemistry instructors to infuse integrate or transfer CT to their learners during the teaching/learning process. The following is the summary of the study findings from the research question: To what extent have curriculum reforms in Kenya addressed the critical thinking gap for secondary school chemistry learners?

The knowledge that can promote CT is detailed, and verifiable, and should be relevant and valid to the context according to the study findings, Kigotho (2022), and Elder-Paul's (2019) observations. The study found that those properties of broader and deeper content are missing in the chemistry curricula. The chemistry syllabus analyzed promotes the teaching of lower-order content that is shallow and narrow. Such content cannot promote the development of CT. The chemistry secondary syllabus is a teacher-centered curriculum where a learner is just an observer of the teaching-learning process. If learners are involved in problem identification, designing experimental procedures, and doing those experiments or practical works with minimal supervision by their teachers, then, that learning is likely to promote the development of critical thinking in those learners. Contrary to the above observation, the problem to be investigated following the 8-4-4 chemistry syllabus design is in most cases determined by the teacher. Tools of data collection, experimental procedure, how to write observations, tools of data analysis, discussion, and the conclusion are given or directed by the teacher (the teacher is the centre of focus). Most of the intellectual learning standards containing elements of thought that can promote CT are either missing in the chemistry secondary curriculum or discussed vaguely in a manner that cannot promote CT the study found. Therefore, critical thinking cannot be developed during the teaching/learning process when some or all intellectual learning standards are missing.

The problem-based learning (PBL) approach is yet to be implemented in the chemistry secondary curriculum. Problem-based learning requires many factors to be put in place; students' self-determination, well-constructed teams/communities of inquiry, competent tutors, well-structured problems, prior knowledge activation, and group dynamics. Most of these factors are missing in our Kenyan secondary chemistry syllabus or if they are there, then, most of them have not been put into practice in the teaching/learning process of chemistry. Unless these factors are put in place during the teaching/learning process of chemistry at the secondary level, the development of CT may be a challenge. Going forward this factor should be put in place during the teaching/learning process of chemistry to develop CT.

To this end, therefore, the chemistry syllabus has not properly defined how CT is to be developed in learners during the teaching/learning process. The Kenyan chemistry syllabus needs to be revised to include philosophical methodologies (mainly logic (inductive and deductive reasoning) and epistemology (constructivism), and CT dispositions especially self-efficacy on how to develop CT. Through logic, and using deductive reasoning techniques, learners should be required to break information they see as complex or abstract into small units that can be understood and a clear meaning of the problem or the question at issue can be drawn. Inductive reasoning is possible in situations where ideas such as teaching strategy in one chemistry topic for example chemical families to promote CT can be generalized to other core and non-core topics of the chemistry curriculum to promote CT holistically.

In this study students in the constructivist class work together in groups to resolve dilemmas, hence a cooperative activity. This is in agreement with a study by Wachanga and Mwangi (2004), who found that:

> 'Learners taught through the Cooperative or Collaborative Class Experiment (CCE) method performed significantly better in Chemistry than those taught by the regular teaching methods. Thus, the teacher or instructor created a learning environment where students could use their prior knowledge and become aware of their existing conceptions' (Kibos, 2015 p. 44).

Conclusion and Recommendation

From the analysis and assessment, it is now clear that Kenya's secondary school chemistry curriculum since its independence has identified CT as one of the learning objectives but not indicated how CT is to be integrated during the teaching-learning process. The 8-4-4 chemistry curriculum is a teacher-centered curriculum that cannot promote the development of CT in the teaching-learning process. The chemistry curriculum reform reports in Kenya haven't given critical thinking due consideration during the teaching-learning process. Most of the elements of thought according to Elder-Paul's (2019) critical thinking learning model containing intellectual learning standards are missing in all the reform processes in the Kenyan secondary school chemistry curriculum. Rules of reasoning or thinking or the logical elements (inductive and deductive reasoning) have not been given due consideration by the chemistry curriculum reform process for learners in secondary schools. Constructivism as a learner-centred teaching-learning approach that requires learners to be placed in small communities of inquiry, was found also to be missing in the Kenyan secondary school chemistry curriculum. To this end, critical thinking indicators containing elements of thought are missing in the Kenyan education curriculum reform process for learners in secondary school chemistry. Therefore, the critical thinking self-efficacy gap exists in the chemistry curriculum for learners in Kenyan secondary schools. Hence, the Kenyan chemistry curriculum needs revision to include learner-centered teaching-learning methodologies most especially collaboration and community study, inquiry-based learning, self-reflection, digital literacy, and critical confirmation to help instructors and learners to develop a CT culture in school.

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