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Addressing Critical Thinking Lacuna in Gas laws Taught at Kenyan Secondary School Physics

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Abstract: There are numerous studies on critical thinking (CT), but very few studies have been done on CT gap in gas laws Kenyan physics curriculum. This paper analyzed the Kenyan physics curriculum resources on gas laws. The study found that learners were not actively involved in verifying gas laws relations with problem identification, study procedure, making observations, and finding solutions to Boyle's and Charles' law. It is evident, therefore that CT gap exist is in Kenya's secondary physics curriculum. Learners', therefore, need to be actively engaged in identifying the problem and finding solutions to address any fallacy that relate gas laws.

Keywords: Critical thinking, problem-based learning, Charles' Law, Curriculum, Gas Laws.

Introduction

Studies done concerning CT in classroom practice have shown better results in classes where inquiry-based learning is practised compared to ordinary classrooms. Critical thinking (CT) in this study is broadly defined as a skilful, reasonable thought that brings good judgment because it has criteria; is self-correcting, and is sensitive to a context given (Roberson et al., 2021). Important and generalizable criteria for CT include strength, validity, reliability, consistency, evidence, relevance, and coherence. CT involves self-correcting by 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 (Ongesa et al., 2023). 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, 2018).

Of interest in this study is gas laws Kenyan secondary physics curriculum teaching-learning resources. The focus is how the teaching of gas laws can develop in learners a mindset that can think critically. Physics is a science where learning should be accompanied by a series of practical activities (experiments, demonstrations, and projects). Experiments and demonstrations follow an empirical approach. Given the problem or the task to be investigated, tools of data collection that include apparatus and chemicals are assembled and ready to investigate the task or the problem. This is followed by an experimental procedure where steps on how data is to be collected and analyzed are listed (see also Nussbaum, 2020). Data is then collected and its trend is recorded in form of tables or statements. Data collected is then analyzed qualitatively (where statements that follow logical order are examined to come to a valid conclusion) or quantitative where data is analyzed in the form of tables and graphs and the relationship in variables can form a theory or a law when the same experiment shows consistent result through several tests.

Even though CT is not mentioned as one of the objectives that a learner should attain by the end of the training, experiments done by learners may be a CT indicator (Schendel et al., 2022; Ongesa et al., 2023). This though may not be the case in our current secondary school physics curriculum. Ongesa's 2020 paper on 'Critical thinking gap in the Kenyan schools' and Namwambah's 2020 paper on 'centrality of critical thinking on value-creating education in Kenya' observe that the Kenyan secondary education curriculum is a teacher-centered curriculum where a learner is just an observer. If learners are involved in problem identification, designing experimental procedures, and doing those experiments with a teacher as just a guide then that learning is inquiry-based and can develop in learners critical thinking. Learners too should be inducted to take full responsibility for analyzing and reporting data. This data analysis can be used to deduce a conclusion or form a mathematical explanation that can used to verify or solve the problem being studied.

The study assessed gas laws in physics using Elder & Paul's (2019) CT Model. Gas laws are a part of the physics content that examines how the relationship of physical conditions (volume, pressure, and temperature) affect the properties of gases (Ongesa et al., 2023). 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. My study focuses on these three gas laws, but, the main emphasis is put on Charles' law which investigated the relationship between the volume of a fixed mass of a gas and its temperature. The focus of this study was CT on the formulation of these gas laws. Gas laws investigated were Charles' law and Boyle’s law. To be addressed was the CT gap during teaching/learning Charles’ and Boyle’s laws.

Research Results

From the analysis of gas laws physics resources, it emerged that four main assumptions are held by all the gas laws: pressure law, Boyle's law, Gay Lussac's law, Charles' law, and Grahams' law of diffusion. Learners verifying all these gas laws must know theoretically that:

- gas particles have no forces acting among them,
- particles do not occupy any space or volume,
- gases are in a continuous random motion and,
- the mass of gases must be held constant when verifying those laws otherwise the relationship may not be accounted for.

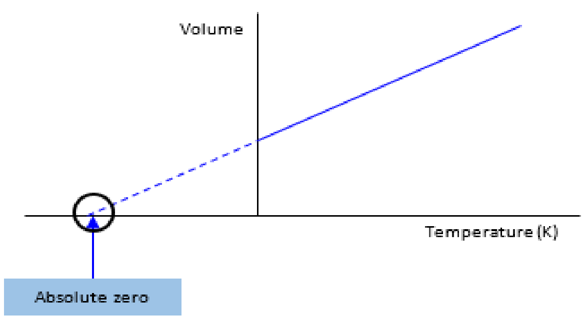
The stated assumptions are imaginary and cannot be visualized by a learner, hence gas laws cannot be verified since the conditions stated can't be attained in a normal school environment. This means that the learner is not actively involved in analyzing and verifying gas laws. Such a form of learning cannot promote CT. For example, a learner using a syringe to compare changes in pressure and volume is likely not to get accurate data if the assumptions are not met.

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 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.

From the analysis, temperature in degrees Celsius (^{0}C) does not vary directly with volume according to Charles' law. This is because at zero degrees Celsius the gas still has some volume. Zero degree Celsius according to ideal gas law is equal to 273K and at this temperature, the gas has some volume. The argument given by the proponents of ideal gas law which this study discounts are 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. These observations cannot be obtained by a learner working in normal school conditions using available apparatus. The scale is called the absolute scale and it varies directly to volume according to Charles' law.

Figure 1

The graph showing the relationship between pressures against volume (Charles' Law Physics)



Source: authors own development

As we shall see later and from existing literature see also Nussbaum (2020) information like such cannot promote the development of CT. All gases liquefy before attaining the said zero Kelvin or negative 273 degrees Celsius where the volume of a gas is assumed to be zero see also Ongesa (2020).

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.

The concept of absolute zero temperature and absolute temperature is therefore flawed and cannot be used to develop CT in those who are learning. Charles' law to this end may not be giving clear/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.

Relating the understanding of gas law with 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 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 Schendel et al. (2022). Learners have not been given room to identify the problem associated with the three physical quantities (volume, pressure, and temperature), tools for collecting data, and procedure due to several assumptions. To this end, therefore, we conclude that Charles' law is not drawn logically and cannot be used in developing CT in learners.

Evidence provided under which Charles' and Boyle' are based lacks consistency and logical validity since gases do not attain zero kelvin. Gas laws as presented in the Kenyan secondary physics book three and physics book three have failed to meet Elder & Paul's (2019) intellectual learning standards (relevance, validity, true, logical, precision, etc.) (Elder & Paul, 2019). 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 learning gas laws cannot develop CT since the information given is contradictory (does not make sense at all) and is not logical.

Physics is a science where learning should be accompanied by a series of practical activities (experiments, demonstrations, and projects). Learners should be given opportunity to identify problem associated with the relationship of the three physical conditions (volume, pressure, and temperature) using appropriate tools and apparatus. Design their procedure, make observations, test the results using standard conditions, and draw a valid and logical conclusion. Doing this will develop in those learners a mindset that can always reason and think thereby developing critical thinking. A model for promoting teaching of CT in gas law physics has been developed by the study. The model known as the Critical Thinking Learning Model (CTLM) requires that learners in every content be taught higher order thinking (analysis, synthesis, and evaluation), key critical thinking dispositions (inquisitiveness and open mindedness), how to make assumptions, evaluate evidence obtained or given and make logical conclusion.

Conclusions

Boyle's laws and Charles' laws as presented in secondary physics curriculum for Kenyan learners are not drawn logically and cannot develop in secondary school learners that can reason consistently and think critically. These laws have not properly defined how CT is to be developed in physics learners doing gas laws during the teaching/learning process. Almost all gases liquify before attaining the said 0K by kinetic theory of gases. Charles' law and Boyle's laws as presented are premised on wrong assumptions that gases have 0K. such a content, therefore, cannot be used to develop in learners critical thinking aspects. For one to know the nature of the problem, strategies (deductive and inductive reasoning) for how to go about solving the problem are required. The Kenyan physics curriculum on gas laws needs to be revised to include philosophical methodologies (mainly logic, higher order of Bloom's taxonomy, CT dispositions (self-efficacy, inquisitiveness, and open-mindedness), recognize assumptions, and make logical conclusions or CTLM model to guide teachers and learners on how to develop CT.

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