



The Current Formative Assessment Strategies Used by Physics Teachers in Teaching Modern Physics

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Abstract: Assessment is an integral part of the teaching and learning process. Teachers are concerned with deciding how to give a lesson so that students completely understand what has been taught in their everyday teaching activities. The present study aimed at investigating the current formative assessment strategies used by physics teachers with respect to the conceptual understanding of the learners. This study was conducted in some selected schools in the Ngoma district. An explanatory research design was adopted during this study. Twelve students and three teachers were purposively selected in three schools of the Ngoma district to participate in this study. Semi-structured interviews and document reviews were used to collect data from the field. Interview analysis indicated that both students and teachers qualify the effectiveness of conceptual formative assessment to enhance students' conceptual understanding of modern physics. However, document review analysis indicated that most teachers do not use conceptual questions in their planned formative assessments. The study concluded that conceptual formative assessment strategies effectively improve learners' conceptual understanding of modern physics. Based on the conclusion of this study, it is recommended that teachers must use conceptual questions in their formative assessment, to enhance their conceptual understanding of modern physics. Rwanda Education Board (REB) should organize in-service training for teachers on how to develop and utilize conceptual questions.

Keywords: Formative assessment Strategies, Conceptual questions, Teaching process, Learning process, Concepts of modern physics

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1. Introduction

Formative assessment is also known as assessment for learning. It is commonly done during the teaching and learning process, and it is aimed to judge the intellectual capacity of the learners and decide whether to repeat the content or to proceed to the next level. Formative assessment refers to evaluations that are conducted to enhance students' learning and improve the quality of instruction rather than to assign grades (Buck & Trauth-

Nare, 2009). A test or evaluation provides data about a certain target or goal. In this sense, we test or analyze to see if a particular target or goal has been met (Kiazlik, 2012).

In education, it is commonly used to have three types of assessments: diagnostic, summative, and formative (Gonzales, 2011). Diagnostic assessment means an assessment done before starting the teaching and learning process, it aims to test the prior knowledge of the learners to know their level, while Summative assessment is the

type of assessment that is done after teaching mainly at the end of the term, end the academic year. it is mainly for grading the learners to promote them to the next level. Assessment is an integral part of the teaching and learning process. Teachers are concerned with deciding how to give a lesson so that students completely understand what has been taught in their everyday teaching activities. In the classroom, the teacher used several different learning strategies. On the other hand, students' conceptual understanding and scientific processing skills remain insignificant (Sneider & Wojnowsk, 2013).

Modern physics is a complex concept because it combines the concepts such as the concept of the photoelectric effect, the wave-particle nature of light, and waves. Teachers and learners need to have a clear understanding of previous concepts as mentioned above, this topic is complex because it is mostly a theoretical topic and not enough laboratory materials for experimentation (Kujović & Džaferović-Mašić, 2021). Although Rwanda has shifted from a Knowledge-Based Curriculum (KBC) to a Competency-Based Curriculum (CBC) to enhance the conceptual understanding of the learning content to become productive in the market, there is still a misunderstanding of the physics concepts (Ndiwokubwayo & Habiyaremye, 2018).

The study conducted by (NESA, 2022) showed that 56% of the sample of students in selected schools failed to meet the success criteria in science subjects, particularly physics. In their interview with school leaders, they have seen that the quality of teachers and formative assessment strategies used during teaching and learning in classrooms are among the major factors that hinder the students' conceptual understanding of the learned materials (content). The study conducted by Bulunuz (2017) has shown that students fail to capture the concepts learned in their studies because they used a rote learning methodology. Moreover, the end of units' assessments is composed of most questions which are helping students to apply formulae to solve physics problems. Therefore, these have led to a conceptual understanding of modern physics being insignificant. It is also due to a large number of students in the classroom that teachers tend to lose attention to learner-centered approaches where they use lecturing methodology, where the teacher is active in the teaching and learning process while learners are passive in the teaching and learning (Uwizeyimana et al., 2018).

This study was initiated to analyze the current formative assessment strategies used by physics teachers in teaching modern physics. This study was guided by one research question:

What are the current formative assessment strategies used by physics teachers in teaching modern physics?

2. Literature Review

2.1 Conceptual understanding of physics

In the late 1800s and early 1900s, a succession of experimental findings of atoms that did not make intuitive sense in the context of classical physics among them we have mechanics, Optics, Thermodynamics among others gave rise to the subject of quantum physics (Leonhardt, 2003). Among the fundamental findings was the understanding that matter and energy may be thought of as discrete packets, or quanta, with a minimum value. A set frequency of light, for example, will transmit energy in quanta known as "photons." At this frequency, each photon has the same amount of energy, and this energy cannot be divided into smaller pieces. The word "quantum" derives from Latin and means "how much." Branches of modern physics include atomic models, the Photoelectric effect, the Compton effect, etc. Understanding physics concepts improves our everyday lives in a variety of sectors, including the environment, medicine, electric power generation, and even politics (Pallone & Barnes, 2016). Quantum electromagnetic radiation, as well as atomic spectra, are basic principles in science with numerous practical applications (Savall-Aleman et al., 2016).

But even though nuclear physics has shown its power in our everyday development, the governments did not provide enough laboratory materials for students to learn by experimentation for a better understanding of this physics concept (Plybour, 2015). Many students struggle to understand the photoelectric effect and how it relates to the photon model of light, according to research (De Leone, 2004). In this manner, more researchers claim that Quantum Physics learning with integrated STEM education is expected to be more difficult because this newly introduced topic differs from classical physics and has a long history of ambiguous interpretation (Markus et al., 2021). Therefore, Teachers must use different assessment strategies to reduce misconceptions and develop their learner's competencies (Liu & Sun, 2020).

2.2 Origin of Formative Assessment

According to Cauley & McMillan (2010), Formative assessment is the process of gathering assessment-elicited evidence of student learning and modifying instruction in response to feedback. The term "formative" can be interpreted in a variety of ways, but it usually means that assessment is done frequently and is planned at the same time as teaching (McDowell, 2013). Formative assessment is most effective when students understand what their teachers expect from them. (Black & Wiliam, 2005) discovered that the quality of teachers' formative assessment practices was positively related to students' learning levels. (McDowell, 2013). Formative assessment

strategies focus on both the teacher and student understanding three key things:

1. **Where the learner is now:** Techniques such as effective questioning will assist teachers in determining what individuals and groups have learned during a lesson, resulting in evidence of learning that both the teacher and students can use.

2. **Where the learner is going:** Sharing a lesson's objectives and success criteria allows students to see what they are aiming for and what they need to do to achieve those objectives.

3. **How can the learner get there?** This evidence of learning is used by teachers to make decisions about what to do next with a class or individual students. Learners can use this evidence to make learning decisions, such as how to spend their independent study time.

Therefore, Different assessment strategies can be used as a teaching tool to detect the misconceptions of learners concerned with atomic physics. Formative assessment is used to aid in the learning process rather than to evaluate what students have learned to assign a final grade (Sneider & Wojnowsk, 2013). Identifying learning goals, assessing where students are concerning those goals, and using that evaluation to inform adaptive instruction are the three components of formative assessment. "Quality of students' assessment and quality of instructions are linked together".

2.3 Reasons why conceptual formative assessments are not frequently used

Conceptual formative assessments are not frequently used in the classroom due to the following reasons as said by (Marsh, 2007): Over the years, teachers' experiences as learners have almost entirely focused on various forms of summative assessment. They quickly learned their priorities as primary and secondary school students, and the main priority for them was to perform well on high exams. These values are difficult to abandon because teachers are constantly reminded by the media and parents of the importance of high student achievement as measured by summative assessments. Many teachers promote rote learning and teaching because it is a well-known, traditional method of instruction. They are less at ease with the conceptual understanding of the subjects, and student-centered activities. According to (Boston, 2003) Preservice teacher education programs are typically "packed" with necessary knowledge and skills for student teachers to comprehend and apply.

Due to time constraints, lecturers are unable to present sessions in which student teachers can reflect on their assessment practices. To gain confidence in using formative assessment, student teachers must observe and

consult with other teachers about effective teaching and learning practices. Solving exercises and problems is a major part of most physics 'classes in both high schools and universities because it is a major goal of physics teaching and learning. Recent physics education research has shown that many students still struggle with fundamental concepts even after instruction (Kim & Pak, 2002).

2.4 Conceptual framework

A conceptual framework is a collection of interconnected concepts that collectively provide full knowledge of a phenomenon or set of facts (Jabareen, 2009). Therefore, this study will investigate how misconceptions of learners in science subjects particularly physics are related to the teaching, learning approaches, and assessment methodologies. Different researchers had shown that students had shown misconceptions about photoelectric effects (Taslidere, 2016). Some students tend to be good at answering questions that request them to recall information or apply the memorized formulae without understanding the concepts. Effective assessment strategies can be used as a tool to assess conceptual understanding of the given concepts by students.

Formative assessment, when applied correctly, offers students feedback on their learning, and allows them to take control of their educational progress, strengthening their autonomy and self-regulation (Buck & Trauth-Nare, 2009). Therefore, Teachers' feedback should be iterative, allowing students to demonstrate learning because of the input. Students must grasp learning goals, be able to compare their present level of performance to the learning goals and take action to develop toward those goals for feedback to be effective (Buck & Trauth-Nare, 2009). As a result, students must take an active role in their learning by evaluating their efforts considering the objectives, and sharing responsibility for taking activities that enhance learning.

3. Methodology

3.1 Research design

This study is an exploratory case study (Cohen, Manion, and Morrison 2007) that used a parallel convergent-based design to combine qualitative data from semi-structured interviews and document analysis for triangulation by Creswell (2014) as cited by (Techo, 2016)

3.2 Sample and sampling method

Four senior five students were randomly selected, and physics teachers were purposively selected respectively at each school within three schools. Both teachers and

students were subjected to semi-structured interviews (Bluman, 2012, Cohen, Manion, & Morrison 2007). Document review was also used to see how these six teachers administer different assessments to their students in respect of the revised Bloom taxonomy levels by Anderson (2001). The three schools were randomly sampled from seven secondary schools in Ngoma district which have physics at an advanced level. The total sample is made of 12 students and three teachers.

3.3 Sample characteristics

Students were 12 seniors five students (8 males and 4 females). The students' age was ranging from 16 to 20 years old. Three physics teachers were all male. All sampled teachers had a background in education. The three teachers are bachelor's degree (A0) holders.

3.4 Research instruments

A semi-structured interview guide was created by the author. It was made up of two major questions. The first question was: How do you think homework, exercises, or quizzes should be designed to better benefit learners in their conceptual understanding of the physics concepts? The second question was: How do you think assessments or end-of-term exams should be designed to benefit your students in their conceptual understanding of physics concepts? Similarly, two primary questions were provided for students. The first question was: How do you think homework, exercises, or quizzes should be designed to help you in your conceptual understanding of physics concepts? The second question was: How do you think end-of-term exams or tests should be designed to help you in your conceptual understanding? Furthermore, a document review was carried out. Thus, the researcher studied and evaluated 20 documents, which included lesson plans, exercise books, homework books, exams, and exam papers, based on whether the documents consist of conceptual questions or not.

3.5 Ethical consideration

Before starting the process of conducting research, I received research permission from the University of Rwanda- College of Education (UR-CE) Referring to this permission, I also applied for the data collection permit from the mayor of the Ngoma district. All participants have been got an explanation about the purpose of the study; all participants have voluntarily participated were free to drop any time. Data collected were used for research purposes only and not for commercial purposes, identification of participants was not indicated during the data collection process; data collected were secured and I am confident that nobody can access them; all participants signed the consent form.

3.6 Validity and reliability of the research instruments

This semi-structured interview was given to an expert to ensure the reliability and validity of the study instruments. In addition, pilot research was undertaken and one instructor from the same school was treated to it, but it is not part of the main study. The piloting phase was designed to test the content validity and internal consistency of the interview questions. A document review was also piloted to provide a researcher with an overview and early analysis of how teachers give the various assessments in relation to the conceptual questions.

3.7 Data analysis procedures

Thematic analysis approaches were used to analyze the interview data. Themes emerge from discussions and bring out major issues relating to the research emphasis (Kombo & Tromp 2011). The information gathered from document evaluations was examined descriptively. To maintain confidentiality, we utilized pseudonyms while reporting on teachers' and students' comments and presenting documents.

4. Results and Discussion

Conceptual formative assessment: During the interview, most of students (10 out of 12) and all the interviewed teachers claimed that conceptual formative assessment being exercises, homework, quiz, test or end-of-term/year exams should cover the content taught, with questions that test the conceptual understanding. Students argued that both tests and exams should neither be too simple nor too difficult. A student named 1S1 for an anonymous reason said: "Both quizzes and tests/exams should be covering the content and the units taught in class and should be balanced in terms of their complex to let students get at least the pass point." Another student, 5S4, stated, "A test/exam should encompass the subject seen even in prior years, for students to prepare for the national tests that REB provides at the end of the educational cycle." However, only a few students (2 out of 12) made the point that the unseen questions can be prepared for a test to assist students to strengthen their thinking abilities.

All assessments are expected to provide education stakeholders with complete information on how students' learning has progressed to advance them to the next level of learning (Perro et al., 2020). A well-designed assessment, as Chang and Chen (2009) suggested, should promote learning, and provide meaningful feedback on students' grasp of the subject matter, allowing teachers to make appropriate decisions to enhance their teaching practices. During the interview, we asked teachers if they designed questions or tests with the goal of assessing

students' conceptual knowledge of the studied subject. Most of them said that they only use the questions that are found in the textbooks that are provided by Rwanda Basic Education Board (REB). These teachers stated that they do not place a high value on measuring students' conceptual comprehension, but they do prepare both basic and challenging questions. Even though the document analysis revealed that most of the questions given are formulae-based questions.

Only one teacher reported consulting different texts and including questions that touch on a different level of students' thinking that may require higher-order thinking (HOT). T2C, the teacher, stated, "I review several literature and construct questions that strengthen pupils' abilities to analyze, evaluate, and create new things based on the taught contents."

Teachers' use of conceptual formative assessment questions in Lesson planning and other assessments

During our document analysis, we found that almost all the physics teachers develop the learners with the ability to recall and memorize the derived formulae to solve mathematical problems. Looking into the documents such continuous assessment test prepared by a teacher named T1 on 10th March 2022. The teacher had prepared 15 questions among them 12 questions were asking the students to remember formulae and apply them to solve problems, these are examples of different exercises analyzed.

During the analysis of the documents, we collected from three teachers three lesson plans, meaning one from each teacher to explore if teachers consider the conceptual questions during the preparation of formative assessments in lesson plans, we focused mainly on the evaluation part of the lesson plans. Deep analysis was done on three exercises, three group works, three short quizzes, and three general tests. For each document analyzed, we rated each level at a 1-to 4- point Likert-type scale from 1-the conceptual questions have definitely not been asked at all to 4-the conceptual have definitely been asked. 1- Definitely not asked, 2- Probably not asked, 3- Probably asked, 4- Definitely asked.

Results from document analysis

| SN | date | Document code | Number of questions | Number of conceptual questions | Conceptual questions (point Likert-type scale) |
|------|-----------|---------------|---------------------|--------------------------------|--|
| 1 | 10/5/2022 | LPT1 | 2 | 0 | 1 |
| 2 | 12/5/2022 | LPT2 | 3 | 0 | 1 |
| 3 | 14/5/2022 | LPT3 | 2 | 0 | 1 |
| 4 | 11/2/2022 | EXT1A | 7 | 2 | 2 |
| 5 | 24/2/2022 | EXT1B | 10 | 3 | 2 |
| 6 | 11/3/2022 | EXT1C | 18 | 6 | 2 |
| 7 | 10/2/2022 | EXT2A | 7 | 1 | 2 |
| 8 | 9/3/2022 | EXT2B | 8 | 0 | 1 |
| 9 | 9/5/2022 | EXT2C | 6 | 3 | 3 |
| 10 | 15/2/2022 | EXT3A | 7 | 2 | 2 |
| 11 | 10/3/2022 | EXT3B | 10 | 2 | 2 |
| 12 | 10/5/2022 | EXT3C | 4 | 1 | 2 |
| 13 | 11/5/202 | GWT1 | 8 | 3 | 3 |
| 14 | 5/5/2022 | GWT2 | 10 | 4 | 3 |
| 15 | 28/4/2022 | GWT3 | 5 | 0 | 1 |
| 16 | 3/5/2022 | SQ T1 | 4 | 1 | 2 |
| 17 | 6/5/2022 | SQ T2 | 3 | 0 | 1 |
| 18 | 13/5/2022 | SQT3 | 3 | 1 | 2 |
| 19 | 19/5/2022 | GTT1 | 15 | 3 | 2 |
| 20 | 26/5/2022 | GTT2 | 10 | 2 | 2 |
| Mean | | | | | 1.9 |
| SDV | | | | | 0.04 |

Lesson plan (LP), GW=Group Work, GT=General Test, T1 means Teacher 1, T2 means Teacher 2, EX means Exercise

From the table, the mean score for conceptual questions is 2. From this analysis, this indicated that the conceptual questions probably not asked, the teacher mainly focused

on such questions that enforced the learners to apply the formulae.

Formative assessment strategies are now recognized as an essential component of the teaching-learning process for actively engaging and encouraging students in the process of constructing, modifying, and deepening their knowledge by developing positive self-esteem, confidence, motivation to learn, self-regulation skills, and self-efficacy among

students(David & Debra, 2006). As a result, substantial research evidence supports its decisive power, particularly in science education, to improve students' understanding of scientific ideas, reasoning ability, scientific competencies of gathering and using evidence, scientific attitudes, ability to communicate using appropriate scientific languages, and application of scientific problem-solving skills in novel situations(D. Bell et al., 2013).

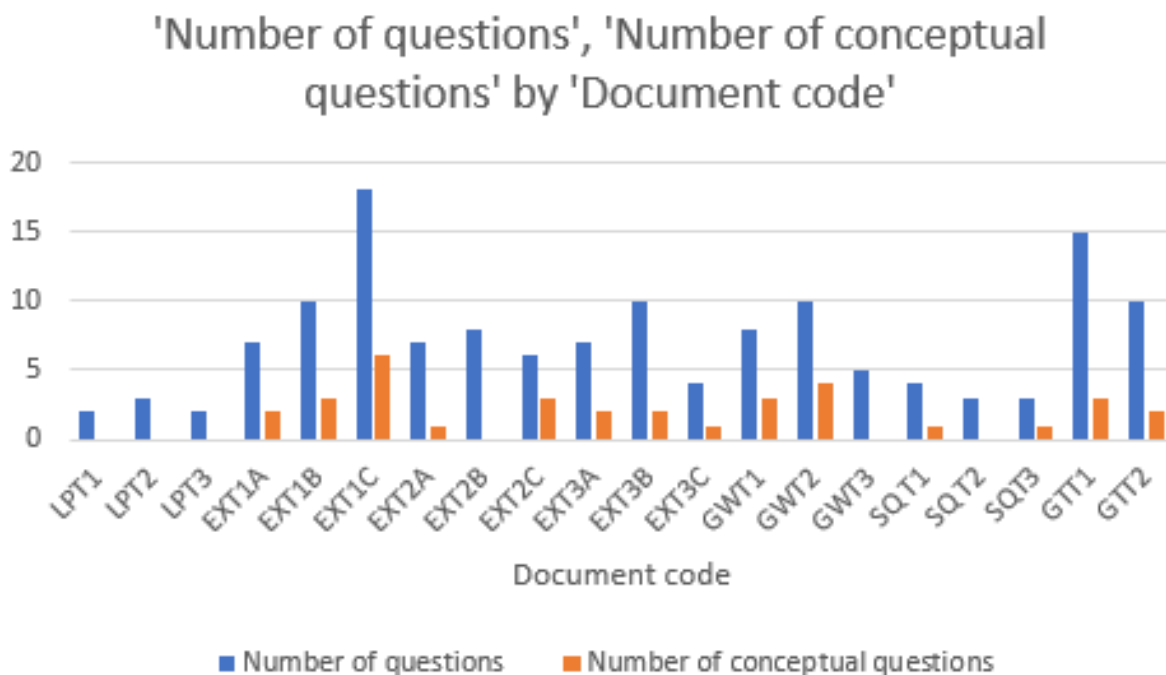


Figure 1: Teachers' use of conceptual questions

From analysis of figure 1, it was observed that most of the teachers in their assessments, assess the memorization of formulae. Some reported that these are because of the textbooks provided by Rwanda Education Board (REB).

“It is well known that pre-existing knowledge and beliefs can strongly influence how new concepts are understood”(Halloun & Hestenes, 1985). Misconceptions are a common term used to describe preexisting views that conflict with current scientific knowledge, and it will be utilized in the sentences that follow. An essential initial step in designing education to encourage significant conceptual change is understanding students' misunderstandings, specific areas of difficulty, and any potential underlying causes for these.

Solving 1000 traditional physics problems using physics formulae does not overcome conceptual difficulties faced by students in understanding the concepts of physics(Kim & Pak, 2002). “Conceptual diagnostic surveys can be a

useful tool to assess students’ understanding and to compare the effectiveness of different types of instruction”(Kohnle et al., 2011).

5. Conclusion and Recommendations

The purpose of the study was to investigate the quality of tests produced for and provided to students regarding conceptual knowledge. During interviews, both teachers and students stated that a good evaluation should encompass the material taught, with question items ranging from simple to complicated. Teachers do not develop students' conceptual grasp of the studied subject, according to a document analysis of teacher assessments. This is because the instructor chalk-and-talk style dominates how physics is taught, which reflects on the type of questions supplied by teachers, which are dominated by mathematical computations. Although textbooks were not examined in this study, because most teachers reported

referring to accessible books when preparing assessments, teachers critiqued textbooks for including evaluations that primarily develop students' recollection of equations. It was also discovered that the way teachers allocate marks does not correspond to the degree of complexity of the assessment items.

As a result, we determined that the way formative assessments are delivered is ineffective and cannot help students develop their conceptual knowledge of physics ideas. This article discusses how conceptual questions can help students learn and problem solve using concepts they have learned in school. The article suggests that the Ministry of Education and the Rwanda Basic Education Board need to come together and hold workshops for teachers to help them better understand how to prepare assessments that respect the student's understanding of concepts. Additionally, the article suggests that teachers should prepare questions that focus on developing conceptual understanding of the material being learned.

Recommendation to teachers and suggested areas for future research

To school headteachers: School head teachers must organize in service training concerned with the impact of conceptual questions to understand the physics concepts.

To teachers: Physics teachers are encouraged to use conceptual questions during their formative assessments.

To further researchers: Researchers are encouraged to conduct research on the factors hindering the effectiveness of using the conceptual assessment strategies in the selected schools.

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