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Effect of Formative Assessment on Students' Conceptual Understanding of Physics Concepts among Secondary Schools in Ngoma District, Rwanda

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Abstract: This study sought to establish the impact of formative assessment strategies on A-level students' conceptual understanding of modern physics in selected secondary schools in Ngoma District, Rwanda using the experimental research design and a questionnaire as data collecting instrument. The study used the sample of 160 students, including 70 students in the Physics Chemistry and Mathematics (PCM) combination and 90 students in the Physics, Chemistry and Biology (PCB) combination. During the intervention, the experimental group was given formative assessments mainly focusing on conceptual understanding of modern physics while the control group was assessed using the equation base problems. The study found out that assessment strategies have a significant positive effect on students' conceptual understanding of learned materials**.** Based on the findings, the study recommended that in order for students to effectively comprehend concepts in physics, teachers have to use the formative assessment approach and properly design conceptual questions in their formative assessments. When this approach is effectively implemented, students will be able to master concepts in physics and perform well in their studies.

Keywords: Formative assessment; Conceptual questions; Teaching and Learning process; modern physics.

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Introduction

Assessment is an integral part of the teaching and learning process. After assessment, teachers decide how to deliver a lesson so that students may understand better what has to be taught. (Sneider & Wojnowsk, 2013). While there are numerous types of assessment, formative assessment is frequently misunderstood. It is merely conceived as just a test or just an instrument that is administered more frequently than other types of assessment. It is taken simple as just giving tests and recording marks. This conception affects its potential ability to improve students' learning and subsequent performance (Heritage, 2016).

Formative assessment can be realized as an enabler rather than an evaluator of learning. It is implemented by teachers in collaboration with their students. The primary goal of formative assessment

is to move students' learning forward while their learning is still developing. This contrasts with other types of assessments which evaluate learning after a period of teaching. Formative assessment practice functions as a feedback loop in which both teachers and students can play active, distinct and complementary roles in enabling learning by consistently working to build and consolidate students' understanding during a lesson(Heritage, 2010). Teachers and students build up from the feedback of the formative assessment and enhance their understanding of the concepts and from the feedback, students and teachers know where improvement is needed.

There are different formative assessment strategies used by teachers during the teaching and learning process. These strategies include quizzes and open-ended questions. While some asked questions require students to remember formulae and concepts, they focus on a high level of thinking where learners are asked to analyze issues and make critical judgement about causes and effect (Ukobizaba & Nizeyimana, 2021).

Formative assessment is a cycle that involves the following stages: setting learning objectives and success criteria, gathering learning evidence and interpreting it to identify gaps, putting interventions in place to close the gaps and evaluating the effectiveness of the interventions (Harlen, 2005). It is clear that integrating assessment in teaching and learning is critical for improving the learners' conceptual understanding.

According ot Black and Wiliam (2005) and Heritage, 2010), classroom assessments largely focused on memorization of simple formulae, giving grades and competitions among students rather than improving their understanding of learned concepts. Main reasons for such poor practices were teachers' lack of knowledge and skills of formative assessment strategies, the pressure of standardized tests and summative assessments and teachers' negative perceptions of their own and students' role in the teaching and learning process.

Curriculum changes will not result in quality education unless accompanied by improved formative assessment strategies (Libman, 2010). Changes in assessment modes is part of major paradigm shifts on how stakeholders think about teaching and learning. Therefore, more research on implementation of effective formative assessment strategies in the classroom is required.

Although there is limited research regarding impact of formative assessment on students' conceptual understanding of modern physics, there are several publications on this issue (Gonzales, 2011). Some researchers in physics education investigated on teaching and learning assessment strategies for enhancing the conceptual understanding of physics concepts (Ivanjek, 2021). But still, there is a misconception about physics concepts since learners tend to memorize formulae without understanding the meaning of concept behind the formulae. Common models of formative and summative assessments do not put much emphasis on conceptual understanding of physics. Rather, these assessments are mostly dominated by solving exercises or directly applying formulae which have been memorized by students (Ndihokubwayo et al., 2020). Therefore, for implementation of the new Competency-Based Curriculum for STEM subjects, which includes physics, much effort is needed through various continuous professional development strategies (Lessing & Witt, 2007).

Based on the background, this study sought to establish the impact of formative assessment strategies on A- level students' conceptual understanding of modern physics in selected schools in Ngoma District, Rwanda.

Literature Review

The Origin of Formative Assessment

According to Cauley and McMillan(2010), formative assessment is the process of gathering assessment-elicited evidence of learning so as to modify the instruction in response to attained feedback**.** The term "formative" usually implies the assessment done frequently and planned at the same time as teaching (McDowell, 2013). Formative assessment is most effective when students understand what their teachers expect from them. Black and Wiliam (2005) discovered that the quality of teachers' formative assessment practices was positively related to students' learning levels.

According to McDowell (2013), formative assessment strategies focus on both the teacher and student understanding three key aspects which are explained before and illustrated in figure 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.

Where the learner is going to be: 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.

How the learner can get there: The evidence of learning is used by teachers to make decisions about what to do next with the class or individual students. Learners can use this evidence to make learning decisions such as how to spend their independent study time in order to attain the intended objectives**.**

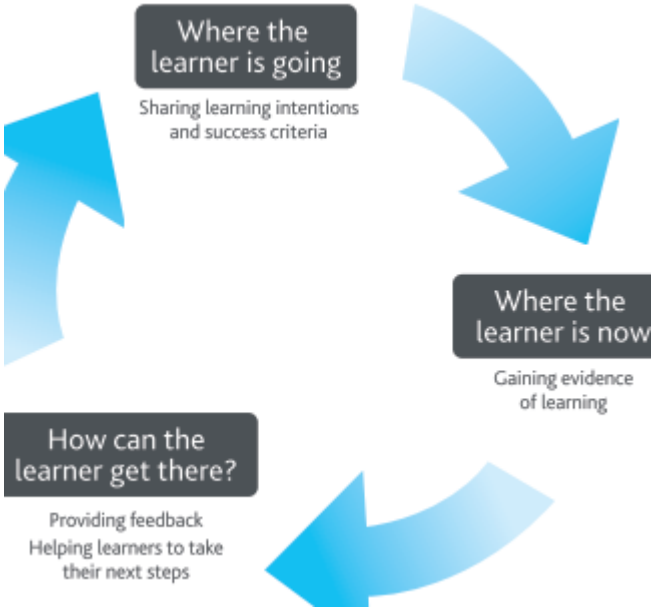

Figure 1: Formative assessment, source (McDowell, 2013)

Theoretical Underpinnings

This study was guided by the constructivism theory of learning. The term constructivism got its meaning for the first time from Jean Piaget in 1929, in his book "The construction of Reality in the Child" (Sjoberg, 2007). The work of Lev Vygotsky expanded constructivism by emphasizing the social and cultural aspects of learning(James, 2006). For constructivists, learning is an active process and it is tied to the individual experience (existing idea) about the world (Cauley & McMillan, 2010; Taras, 2010). In the constructivist view of learning, knowledge is actively constructed by the learner rather than passively received from the outside environment (Sjoberg, 2007). Hence, the teaching-learning process should take into account learners' prior knowledge of the phenomenon. Constructivism is a widely accepted learning theory in the teaching-learning field (James, 2006)**.** According to constructivist learning theories, instruction should focus on problem-solving skills, conceptual development and improved students' abilities to recognize and apply meaningful patterns of information(Heritage, 2016; Shepard, 2000; Sjoberg, 2007). Constructivism learning theories concern student-centered, knowledge-centered, assessment-centered and community-centered learning environments. Constructivism is a dominant and powerful theoretical perspective in science education today, particularly in assessment practice (Sjoberg, 2007).

While formative assessment is an integral part of constructivism (Shepard, 2000; Taras, 2010), constructivists believe that it is necessary to stimulate students' prior knowledge or schema through effective dialogue, questioning, self and peer assessment, open-ended assignments and concept-mapping in order to support learners in applying concepts and strategies in real-world situations (Cauley & McMillan, 2010).

Methodology

Research Design

This study used a descriptive research design to establish the effect of formative assessment on students' conceptual understanding of modern physics. Descriptive research is a quantitative technique that aims to gather measurable data in order to statistically analyze the population sample (Morgan, 2017).

Population and Sampling

There were 8 schools in Ngoma District whose combination has physics. This study was conducted within two public secondary schools in the District with the population of 289 students. The sample size was made up of 160 students, including 70 students in the Physics Chemistry and Mathematics (PCM) combination and 90 students in the Physics, Chemistry and Biology (PCB) combination.

Research instruments

The study used a questionnaire made of two sections. The first section was related to basic information about respondents. The second part consisted of the Modern Physics Conceptual Assessments. Thirty multiple choices items were used to establish students' conceptual understanding of modern physics. Pretest and posttest were conducted before and after the intervention. During the intervention, experimental and control groups were taught modern physics but during the teaching, the experimental group was given formative assessments mainly focusing on conceptual understanding of modern physics while the control group was assessed using the equation base problems.

Validity and Reliability

Two education experts looked into the content of the questionnaire and provided recommendations on how it would be improved prior to data collection. Before the actual data collection, the researchers admitted the same test to a class of the same level to test the reliability of the questionnaire and a Cronbach's Alpha of .78 was yielded which means the questionnaire was reliable for data collection.

Ethical Considerations

Before starting the process of conducting the study, the researchers received a research permit from the Research and Innovation Unit at the University of Rwanda- College of Education (UR-CE) and from the mayor of the Ngoma District. Respondents were given freedom to participate and withdraw at any time of data collection period. Anonymity and confidentiality were maintained to safeguard the right of the respondents.

Statistical Treatment of Data

The data collected from the pretest and posttest sessions were analyzed using descriptive statistics which involved mean scores and standard deviations so as to establish the difference between the pretest and the post test results.

Discussion of Results

This section presents the results of the study. The findings of the study are further discussed by the use of literature.

Demographic Characteristics

This section indicates the demographic characteristics of respondents whereby 100 (62.5%) were males while 60 (37.5%) were females. On the other hand, 50 (31.25%) respondent's' age ranged between 14 and 16 while 110 (68.75) respondents' age was between 17 and 20 years.

Impact of Using Concept Tests Initial Stage Results

To determine the impact, the researchers distributed the questionnaire to the control and the experimental groups so as to establish the initial scores as reflected in table 1.

Table 1: Results of the Pretest

		Mean	N	Std. Deviation	Std. Error Mean
Pretest	Control group	42.83	80	.6380	.713
	Experimental group	42.89	80	.5291	.592

Table 2: Paired Differences for Pre-test Results

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Control Group Pretest/100 - Experimental Group Pretest/100	-.063	7.304	.817	-1.688	1.563	-.077	79	.939

From table 1, the mean score for the control group was 42.89 with a standard deviation of .6380 while that of the experimental group was 42.89 with a standard deviation of .5291. . The paired sample test in table 2 indicates the Sig. of .939 which is greater than the critical value. This implies that the mean difference between the control and the experimental groups was similar at the initial stage of the study, before the intervention. This means that the two groups were at a similar level of understanding of modern physics concepts at the initial stage of the study.

Final Stage Results

Prior to the post-test session, the researchers made the intervention to the experimental group. For a period of 2 weeks, the experimental and control groups were taught modern physics but during the teaching process, the experimental group was given formative assessments mainly focusing on conceptual understanding of modern physics while the control group was assessed using the equation base problems. After two weeks of intervention, both groups sat for a post-test and results are displayed in table 3.

Table 3: Results of the Post-test

		Mean	N	Std. Deviation	Std. Error Mean
Post test	Control Group	49.31	80	.9794	1.095
	Experimental Group	57.65	80	.7929	.886

Table 4: Paired samples Test of Post-test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
CG Posttest/100 - Exp posttest/100	-8.34	12.741	1.424	-11.173	-5.502	-5.853	79	.000

From the table 3, the mean score for the control group was 49.31 with a standard deviation of .9794 while that of the experimental group was 57.65 with a standard deviation of .7929. The paired sample test in table 4 indicates a Sig. of .000 which is lesser than the critical value. This implies that the mean difference between the control and the experimental groups was significantly different. The experimental group which used the formative assessment outperformed the control group which used the conventional method of assessment during the intervention period. Therefore, formative assessment is a powerful strategy in enhancing the A- level students' conceptual understanding of modern physics in Selected Schools of Ngoma District, Rwanda. Results in this study are in harmony with findings of Docktor et al. (2015) who established that students involved in conceptual problem solving significantly scored higher than those not taught through conceptual problem solving approaches. The study findings are also supported findings of Kim and Pak (2002) who concluded that conceptual problem solving approaches are important for effective students' achievements.

Conclusions and Recommendations

Conclusions

Based on the results of this study, it is concluded that assessment strategies have a significant positive effect on students' conceptual understanding of learned materials**.** This conclusion is based on the fact that the group of students taught through formative assessment outperformed the group of students taught through conventional methods. Therefore, formative assessment is a powerful strategy in enhancing the conceptual understanding of modern physics.

Recommendations

It is therefore recommended that in order for students to effectively comprehend concepts in physics, teachers have to use the formative assessment approach and properly design conceptual questions in their formative assessments. When this approach is effectively

implemented, students will be able to master concepts in physics and perform well in their studies.

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