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The Use of the Revised Bloom's Taxonomy Levels in Enhancing Students'Higher Order Thinking Skills in Mathematics

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ABSTRACT

Preparing assessment tools following the Revised Bloom's Taxonomy (RBT) levels, enhances inclusiveness and develops students' higher-order thinking ability in mathematics. The present study intendedto explore how teachers administer both assessments of learning (AoL) and assessment for learning (AfL)with respect to the RBT levels (cognitive domain) and to develop students' higher-order thinking skills (HOTs) in mathematics. Secondly, the study intended to investigate how teachers prepare a balanced assessment that considers all six levels of the Revised Bloom's Taxonomy. Seventy-eight participants including 72 senior five students and six mathematics teachers were randomly and purposively selected to participate in the study respectively. Semi-structured interviews and document analysis were used to collect data. Interview results indicated that both teachers and students qualify an effective assessment like the one that considers RBT levels; with the assessment items starting from simple to complex. However, document review analysis showedthat teachers do not develop students' higher-order thinking skills of the RBT levels. Consequently, these practices do not help students to develop their cognitive thinking ability. It was also found that the way teachers distribute marks is not following the degree of complexity of the assessment items.

KEYWORDS:*assessment for learning; assessment of learning; higher-order thinking skills; lower-order thinking skills; Revised Bloom's Taxonomy levels.*

I. INTRODUCTION

To effectively conduct the assessments in schools, in 1948, a team of educators in the United States (US) took the initiative to classify educational objectives. The teamcame up with three categories that coincided with three domains of learning known as cognitive, affective, and psychomotor domains. In 1956, a team led by Benjamin S. Bloom completed the taxonomy of the cognitive domain, known as Bloom's taxonomy (Huitt 2011). Since then, this taxonomy was found to contribute importantly to educational reform at the national level, concerning the standards development and assessment delivery (Hess et al. 2009).Bloom categorized six mental levels in hierarchical order, starting from simple to complex; easier to harder. The harder involved the simpler to be achieved (Olimat 2015). These levels are knowledge, comprehension, application, analysis, synthesis, and evaluation. Later, the Bloom Taxonomy levels were revised by a team of education researchers headed by Anderson and Krathwohl in 2001, to categorize questions and activities according to their levels of abstraction (Hess et al. 2009), using '-ing' form and making creating the highest level. The six levels became remembering, understanding, applying, analyzing, evaluating, and creating. Thus, the assessment of students' cognitive abilities should refer to the Revised Bloom's Taxonomy (RBT) levels to ensure students' attainment of higher-order thinking and problem-solving in our educational systems.

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Indeed, one of the national urgencies in the education system in Rwanda is to ensure that quality education continues to be improved through closer integration of curriculum development, quality assurance, and assessment(Rwanda Basic Education Board [REB] 2015). During assessments, teachers should assess students'knowledge, skills, and attitudes with much emphasis on the RBT levels of students' cognitive developments (REB 2019). Within this context, "high levels of knowledge and understanding are crucial for a successful knowledge-based economy. It is through the focus on competencies and higher-order thinking skills in a competence-based curriculum that learners' skills and abilities are developed and, as a consequence, their knowledge and understanding are deepened"(REB, 2015b, p.28).

However, most of the teachers still practice traditional assessment which is dominated by their intention of preparing students for national examinations without checking whether they understand the content (Long & Engelbrecht, 2018). Similarly, Levent's(2020)results on the analysis of 5th-grade science learning outcomes and exam questions according to RBT showed that the most of learning outcomes are at the remembering and understanding levels. Similarly, in their study on the analysis of lesson plans from Rwandan physics teachers, the Lesson Plan Evaluation Form (LPEF),Ndihokubwayoet al. (2020)found that teachers do not use higher levels of the cognitive domain. This way of assessing, results in rote learning characterized by memorization of the subject matter. Therefore, there is a need to fill the gap by finding out how teachers employ the RBT levels in assessing mathematics in secondary schools of Rwanda. Indeed, the involvement of Higher Order Thinking (HOT)skills in the assessment of and for learningthrough RBT levels will contribute importantly to students' performance in mathematics and problem solving. Indeed, the use of RBT levels increases students' critical thinking abilities and gives the real meaning of mathematics and its application in real-life situations(Widana 2018).

The present study was guided by cognitive theory (Yilmaz 2011). Cognitive learning seeks the ways learners are taught to develop their thinking ability in inteSracting with the new situation building on prior knowledge that is relevantand meaningful (Powell & Kalina 2009).Cognitive approaches to learning enhance learners' cognitive processes, knowledge, interest, ability, and aptitudes to interact with instructional stimuli towards meaningful information in memory (Ertmer & Newby, 2013). Therefore, teachers are expected to teach following the principles of cognitive learning theories. They are also advised to cope with teaching and assessment practices that consider an individual's ability to learn as far as students' cognitive structure is concerned (Yilmaz 2011).
The reliability of an assessment is a key motivator for learning activities and students' interest in academic life (Efremova, Shvedova, & Huseynova 2019). Given the prevalence of testing in mathematics, the RBTlevels applied effectively, will enhance students' reasoning abilities and problem-solving (Webb 2014), which in long run will affect positively students' performance and interest to learn mathematics. The present study seeks to investigate the extent to which mathematics teachers employ the RBT levels to effectively assess senior five students' understanding of mathematics within the Nyamasheke district in Rwanda. The findings of this study will contribute to the existing literature on how an assessment should be prepared effectively in consideration of the six levels of RBT levels. Since no child should be left behind, the findings of this study will also contribute to inclusive education that considers individual differences which deal with differences in students' learning abilities.

II. METHODOLOGY

Population: This study was carried out within public secondary schools of Nyamashekedistrict, Western Province, Rwanda. The target population of the intended study was composed of secondary school mathematics teachers in advanced level (A level) and senior five students that have mathematics in their learning subjects.

Research design and sampling: This research is an exploratory case study (Cohen, Manion, and Morrison 2007)that employed a parallel convergent-based design, intended to merge qualitative data from both semi-structured interviews and document analysisfor triangulation purposes (Creswell 2014). Twelve senior five students were randomly selected and a mathematics teacher was purposively selected respectively at each school within six 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 six schools wererandomly sampled from 56 secondary schools of Nyamasheke district.

Sample characteristics: Students were in the number of 72 senior five students (38 males and 34 females). The students' age was ranging from 16 to 24 years old. Six math teachers included four males and two females. All the teachers have a background in education. Five teachers are bachelor's degree (A0) holders, while only one teacher is a diploma (A1) holder. The average teaching experience was six years.

Research instruments: Asemi-structured interviewguide was self-constructed. It was composed of twomain questions. The first question was: How do you think homework, exercises, or quizzes should be prepared to better help learners in their future learning of mathematics? The second question was: How do you think tests or end-of-term exams should be prepared to better help your students in their future learning of mathematics? Similarly, two main questions were also prepared for students. The first question was: How do you think homework, exercises, or quizzes should be prepared to better help you in your future learning of mathematics? The second question was: How do you think the end-of-term exams or tests should be prepared to better help you in your future learning of mathematics? Besides, document review was also used for this study as combined evidence of data from interviews for comparison and interpretation(Bowen, 2009).

Thus, 25 documents composed of lesson plans, exercise books, homework books, tests, and exam papers were analyzed and evaluated by the researcher, based on the levels of the Revised Bloom taxonomy.

Validity and reliability of the research instruments: To ensure the reliability and validity of the research instruments, thesemi-structured interview was given to the expert to check its content validity. Additionally, a pilot study was conducted and subjected to one teacher within the school of the same characters butwhichis not part of the main study. The piloting phase was made to assess the content validity and internal consistency of the interview questions. A document review was also piloted for a researcher to have an overview and preliminary analysis on how teachers administer the different assessments in respect to the RBT levels.

Data analysis procedures: The interview data were analyzed using thematic analysis techniques. Themes are the major subjects that arise out of discussions and which bring out major concepts related to research focus(Kombo & Tromp 2011). Data collected from document reviews were analyzed descriptively. We used pseudonyms while reporting teachers' and students' opinions and presented documents for anonymity reasons.

Ethical consideration: Before starting data collectionin schools, the researcher got an ethical research permit from the Research and Innovation Unit at the University of Rwanda-College of Education. The researcher requested authorization to research the schools within the district of Nyamasheke. At school, the researcher handed in a letter requesting permission to collect data within the school, after presenting a copy of the authorization from the district office. Before data collection, the participant has been explained the purpose of the study and was given a consent form to sign accepting to participate in the study voluntarily. The participant was ensured that the provided information will be kept anonymously and with confidentiality.

III. DATA PRESENTATION AND DISCUSSION

Quality of an effective assessment: During the interview, the majority of students (58 out of 72) and all the interviewed teachers claimed that an effective assessment being exercises, homework, quiz, test or end of term/year exam should be covering the content taught, with questions starting from simple to complex. Students argued that both tests and exams should neither be too simple nor too difficult. A student named 8S1 for 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 difficulties to let students get at least the pass mark." Another student named 4S4 said: "A test/exam should be covering the content seen even in the previous years, for students to prepare for the national exams that REB prepares during the end of the educational cycle."However, few students (14 out of 72) come up with the point that the unseen questions can be prepared for a test, to help students develop their thinking abilities.

All assessments are expected to inform education stakeholders with full information that learning has improved to promote students to the next level of learning (Dixson & Worrell, 2016; Harlen & Deakin, 2002; Harrison et al., 2014). Like Chang and Chen (2009) argued, a well-designed assessment should promote learning and provide relevant feedback on students' understanding of the subject matter that allows teachers to make appropriate decisions to improve their teaching practices.We asked teachers during the interview whether while preparing questions or exams, they prepare questions having in mind the aim to assess students' levels of the RBT of the cognitive domain. The majority of teachers (4 out of 6) said that they only refer to the questions that are found in the textbooks that are provided by Rwanda Basic Education Board (REB). These teachers reported that they do not put much of their emphasis on assessing the students' levels of RBT, but they argued that they prepare both simple and difficult questions. Even though, it was observed through the document analysis that the majority of questions set are of the Lower Order Think (LOT). Only two teachers reported that they consult different books and include questions that touch on a different level of students' thinking that may require higher-order thinking (HOT). The teacher named T2C said: "I consult different books and prepare questions that enhance students' ability to analyze, evaluate and be able to create new things, based on the learned materials."

The teachers' use of the RBT in lesson planning and other assessments: The RBTlevels are six and are made of two main parts. The first part consists of the three lower-order thinking (LOT) levels which are: remembering, understanding, and applying. The second part consists of the three higher-order thinking (HOT) levels which are: analyzing, evaluating, and creating. Some of the specific verbs used while assessing the first level of remembering include*:* list, define, tell, repeat, state, etc. The verbs used for the second level of understanding include: discuss, classify, describe, explain, identify, etc. For the third level of applying, there are: execute, calculate, determine, find, show, use, implement, solve, etc. For the fourth level of analyzing, the verbs used are: differentiate, organize, relate, compare, and contrast, etc.

For the fifth level of evaluating, the commonly used verbs are: appraise, defend, judge, select, support, etc. While for the sixth level of creating, the specific verbs used are known as design, develop, assemble, construct, and formulate, among others(Anderson 2001; REB 2019). During our analysis, we found that the majority of mathematics teachers (5 out of 6 teachers) mainly develop the third level of related to the application level of students' cognitive domain. Looking into the exam prepared by the teacher named T2 on 12th December 2020, the teacher prepared 12 questions among which, eleven questions were at the third level (applying) of lower-order thinking skills (LOTs) development. The majority of the questions prepared by the teachers encompassed the verbs like find, calculate, simplify, prove, express, solve, and show. All these verbs are of the application level. Only one question that was requiring HOTs. However, the teacher T2 was found trying to assess other LOT levels and HOT levels while preparing the assessment. In the general quiz composed of four questions given on 22nd December 2020,one teacher prepared the following question:

The equation $x^2 + 4x = 2$ *has two toots one near* $x = 0$ *and the other near* $x = -4$

a) Using $x_{n+1} = \frac{2}{x_{n+4}}$ *with* $x_0 = 0$*, find the root near* $x = 0$*, correct to two decimal places.*

b) Why could we not use the formula $x_{n+1} = \frac{2}{x_{n+4}}$ *with* $x_0 = -4$*?*

For the above question on sub-question (*b),* the teacher is bringing in questions the concept of 'why'. This is a question of the second level of RBT, whereby a student is asked to explain. When a student can explain why, this shows that he/she is at a level of deep understanding the subject matter learned.

For the question requiring HOTs, the teacher asked the following question:

Draw the graph of $y = x^3$ *and* $y = -2x + 20$.

For this question, the teacher is developing students' creativity when asking students to draw a graph. In addition, different skills like analysis and evaluation are developed, since students will need to measure the units on the paper to get the exact graph's coordinates. Students will not only be limited to graphing but will also be able to interpret the graph following the mathematical concepts related to graphing mathematical functions.

To synthesize our findings from document analysis, we investigated the quality of eachassessment given concerning the RBT of the cognitive domain (Huitt, 2011, Levent, 2020). We have collected from the six teachers, 9 lesson plansto explore how teachers prepare lesson plans especially in the evaluation section, considering the RBT levels. We also collected andanalyzed six exercises/group works/homework, five small quizzes/tests, four general quizzes/end of unit assessments, and one exam, all dating also from 2020 to 2021. We computed scores on cognitive levels of the RBT. For each document collected, we rated each level at a 1-to 4-point Likert-type scale from 1-the level has not appeared at all to 4-the level has definitely appeared (see Table 1).

Table1: Results from the reviewed documents: 1-Definitely not appeared, 2-Probably not appeared, 3-Probably appeared 4-Definitely appeared.

SN	Documents' Codes	Date	Cognitive Levels of Revised Bloom's Taxonomy					
			Remembering	Understanding	Applying	Analyzing	Evaluating	Creating
1	LpT1A	8/12/2020	2	3	4	1	2	2
2	LpT1B	9/12/2020	2	2	4	1	1	1
3	LpT1C	14/1/2021	2	2	4	1	1	1
4	LpT3A	2/10/2020	2	3	4	1	2	1
5	LpT3B	4/3/2020	2	2	3	1	2	1
6	LpT3C	8/12/2020	4	3	3	2	2	2
7	LpT4	13/1/2021	2	2	4	1	1	1
8	LpT5	12/02/2021	2	2	3	1	2	1
9	LpT6	10/12/2020	2	3	2	1	2	1
10	ExeT3A	4/3/2021	2	3	4	1	2	1
11	ExeT3B	8/12/2020	2	2	3	1	1	1
12	ExeT3C	1/12/2020	2	3	4	3	2	1
13	ExeT5	6/1/2021	1	2	3	1	1	1
14	ExeT6A	7/1/2021	2	2	4	3	2	1
15	ExeT6B	16/02/2020	2	2	4	3	2	2
16	SqT2	23/1/2020	2	2	4	1	1	1
17	SqT4	18/2/2021	2	2	4	1	1	1
18	SqT5	6/1/2021	2	2	4	3	2	1
19	SqT6A	7/1/2021	2	3	4	2	1	1
20	SqT6B	14/1/2021	2	2	4	2	1	1
21	GqT2A	11/3/2020	2	2	4	2	1	1
22	GqT2B	6/11/2020	2	2	4	1	2	1

23	GqT2C	22/12/2020	2	3	4	2	1	3
24	GqT6	18/02/2021	2	2	4	2	2	1
25	ExaT2	12/2/2020	2	2	4	2	2	1
Mean			2.04	2.32	3.72	1.6	1.56	1.2
St. Dev			0.454	0.476	0.541	0.763	0.506	0.5

Keywords: Lp =Lesson plans; Exe = Exercises, homework, and group work; Sq = Small quizzes, small test; Gq = General quiz, general tests, end of unit assessments; Exa: Exams

Table 1presents the 25 mathematics assessments that were given to students in 2020 and 2021. Although table 1 shows that the six levels were explored by the teachers, the LOT levels like remembering, understanding, and applying are explored with the means scores 2.04; 2.32, and 3.72 respectively. Since the mean scores of each level of LOT are above 2, this means that these levels have probably happened. The fact that the mean scores for analyzing, evaluating, and creating are 1.6; 1.56, and 1.2 respectively; the mean scores which are between 1 and 2, means that these levels have probably not happened. However, the 'apply' level was highly applied (mean=3.72 and SD=0.541) while preparing both assessments for learning (AfLs) and assessments of learning (AoLs). Olimat (2015) explains 'apply' as when students are solving mathematical problems using the acquired rules(Hess et al., 2009).

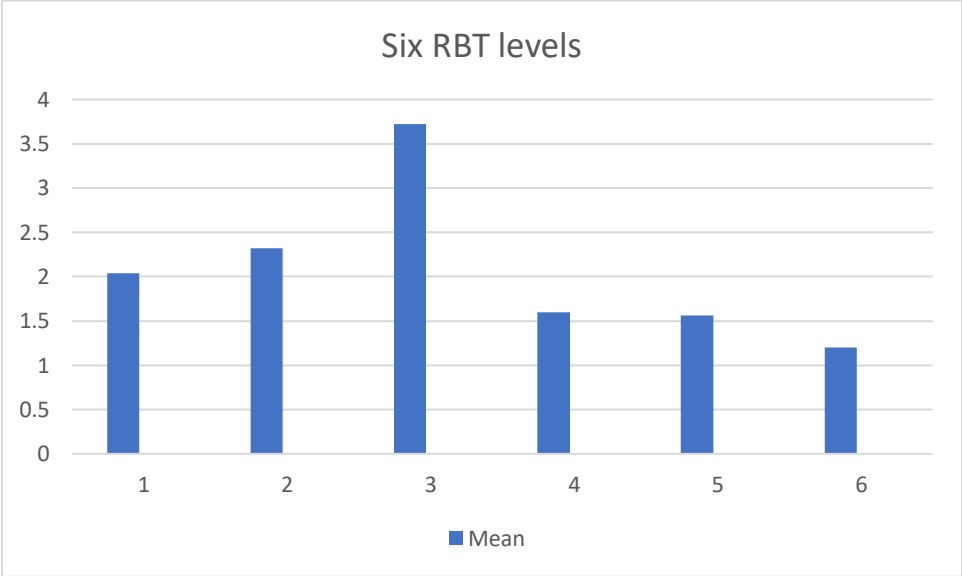

Figure 1: Teachers' application of RBT levels during assessments. Where, 1= remember, 2= understand, 3= apply, 4= Analyze, 5= Evaluate, and 6= Create

Figure 1, shows that although teachers tried to use all the six RBT levels, whereby 'apply' level dominated since it has the highest mean. Levels like remembering and understanding were not explored sufficiently, though significant. With the LOTs, students can find some questions to answer during assessments, which enhances inclusiveness and motivation. HOTs like analyzing, evaluating, and creating were poorly considered during the assessment prepared by the teachers. This implies that in the assessments prepared in a mathematics lesson, teachers do not take care about preparing questions that require students to analyze, evaluate or create. We, therefore, agree with Ndihokubwayo et al. (2020) and (Olimat 2015)who found that students are exposed to LOTs in science, biology, social studies, geography, and mathematics. A teacher should, for instance, bring in the assessments, items, or questions asking a student for instance to reproduce the formula learned (remember), to compare or contrast the formulas (understand). The failure to explore all RBT levels risks excluding some students whose learning pace is slow, and those for whom learning ability is at a low level. This can also demotivate students. If the assessment is not balanced, students may risk getting zero if the items prepared within the assessment are at the same level (Olimat 2015). In addition, HOTs are not aimed at, while these skills are ultimately needed to cope with today's challenges in life (Widana 2018).

Mathematics teachers should teach and assess with their primary intention of developing students' HOTs. Indeed, the relevance of mathematics is captured through HOTskills development. Through mathematics instructions, students should be able to analyze, evaluate, and create, based on the content learned in the mathematics classroom. For instance, in geometry, if a student comes to learn a circle, s/he should not only be limited on finding its area or circumference using chalk or a pen calculation, but he/she should be involved in

activities that will make him/her be able to draw the circle, make a circle using pieces of paper, or be able to make a circle using other materials found in his/her environment, for other important purposes. The issue of developing HOTs within students is also found in how books are prepared. Olimat (2015) noted that science and mathematics books are prepared to emphasize low-level questions. The author added that students are not exposed to high-level questions which impact their cognitive style. In addition, Hess et al. (2009) argued that a student's deep understanding of the content occurs when a student can transfer the acquired knowledge in a new or more complex situation. Levent (2020) suggested:

> The quality of both teaching and evaluation can be increased by the fact that teachers first determine the level of learning outcomes, they perform the education at the level they have determined and at a higher level, and evaluate this. Also, asking evaluation questions related to the learning outcomes in existing curriculums can strengthen the relationship between curriculum, teaching, and evaluation. Therefore, it is suggested that teachers should be informed about taxonomies and necessary in-service training should be given (p. 66).

Based on the observations made, two reasons may explain why mathematics teachers do not prepare the questions that require both LOTs and HOTs. First, the teaching methods of mathematics in secondary schools do facilitate HOTs development (Ndihokubwayo et al. 2020). The majority of teachers were observed using chalk and talk methods which involve teachers' illustrating, explaining the mathematical concepts(Nsengimana et al., 2017), and finding solutions to various mathematical equations. With these teaching practices, teachers are also interested in preparing questions that are limited to many calculations based on solving mathematical equations. Second, when you look into the textbooks used by teachers in schools, you find that the majority of the assessment questions included in the textbooks are also based on LOT levels of the RBT as was also noted by Olimat (2015). That is why while preparing an assessment, teachers refer to the textbooks and give those questions that develop mainly students' LOTs. Fewer, are word problems found in textbooks that require students to use HOT skills like analyzing, evaluating, and creating.

Linking the RBT levels related questions with marks distribution : With the competence-based curriculum (CBC) implementation as it is also adopted in Rwanda, the questions that require HOTs of RBT levels should be given higher marks than those questions that require knowledge and comprehension(REB, 2020). However, the reviewed pieces of assessments showed that the way teachers distribute marks is not professional. We found that the majority (4 out of 6) of teachers give the marks which almost have the same weight from the first question to the last question of an assessment. This distribution of marks confirms how teachers do not mind the levels of question complexity that they prepare during mathematics assessments. In 16 analyzed homework, exercises, quizzes, tests, and exams, only four assessments were having questions that were arranged in ascending order of their level of complexity, concerning the weight of marks. Indeed, the marks distribution should be in proportionality with the degree of question complexity. When you read the national examination past papers done in Rwanda, you find that most of the time the rule of starting with simple to complex questions and the proportional increasing order of marks distribution is respected. Thus, teachers in secondary schools are advised to refer to the past papers' exams, now prepared by REB, and check on how questions are prepared and how marks are distributed, to be able to prepare their usual assessments effectively.

IV. CONCLUSION

The study intended to explore the quality of assessments prepared and given to students concerning the RBT levels. During interviews, both teachers and students claimed that a good assessment should be covering the content taught, whose question items start from simple to complex. The document analysis of the assessments given by teachers showed that teachers do not develop students' HOTs of the RBT levels. This is due to the teacher chalk and talk approach dominating how mathematics is taught, which also reflects on the kind of questions prepared by teachers which are dominated by mathematical calculations. Although textbooks were not evaluated in this study, since the majority of teachers reported that they refer to the available books while preparing assessments, authors, therefore, criticized the textbooks for containing the assessments which mainly develop students' LOTs. It was also found that the way teachers distribute marks is not following the degree of complexity of the assessment items. We, therefore, concluded that the way both AfLs and AoLs are administered is not effective and cannot help students to improve their performance in mathematics and by considering all the six levels of RBT in mathematics assessments make teaching and learning inclusive. No student is left behind and every student can find some questions that s/he can answer. Developing HOTs help students to solve mathematical real-life problems. There is a need for the Ministry of Education (MINEDUC) in collaboration with the Rwanda Basic Education Board (REB)to organize workshops for teachers and train them on how to prepare assessments that respect the RBT levels. Teachers should prepare question items having in

mind the idea of developing both LOTs and HOTs within students. Within the same vein, teachers should be trained on how to order questions and distribute marks according to the level of complexity of the question items.

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