Active Learning through Assessment for Learning: A Way to Enhance Students' Understanding of Mathematical Concepts

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Abstract

Assessment for learning (AfL) is a principal key indicator that monitors the teaching and learning progress and ascertains teachers that learning is taking place. The present study is a survey-based research design that used mixed explanatory research methods, intended to analyze the extent to which teachers apply AfL, to enhance students' understanding of mathematical concepts. This study was conducted in six selected public schools in Nyamasheke district, Rwanda. The study employed 78 participants involving six mathematics teachers, and 72 senior five (grade 11) students. Semi-structured interviews were used to collect qualitative data, while the Classroom Observation Protocol for Undergraduate STEM (COPUS) was used to collect quantitative data. Data from interviews were transcribed verbatim and analyzed thematically, while data from classroom observations were generated by a COPUS visualization sheet with rating scales ranging from 0 to 1, and was analyzed using descriptive statistics. The findings showed that teachers underestimate and/or poorly apply AfL into their teaching and learning of mathematics since students are not actively engaged.

***Keywords**: active learning, AfL, COPUS, feedback, teaching and learning mathematics*

Introduction

The important change in the education of the last decade around the world intends to ensure that assessment of learning (AfL) is being employed to improve learning (Hunt & Pellegrino, 2002). AfL is a tool that teachers use to objectively judge what is in students' minds and are able to do in order for teachers to provide adequate feedback (Shepherd, E., Godwin, Coscarelli, Shrock, Mcnamara, & Phaup, 2010). AfL is known to be a motivating cornerstone of successful learning in a more resourceful context. However, AfL seems to be a difficult and tiresome task for instructors in a low-resourceful context (Govender, 2019).

Applying AfL regularly serves as a remedial treatment tool for those students who may fall below the accepted performance line (Lovely Professional University [LPU], 2012). AfL serves as a good way for students to show their potentials and interests since assessment makes students more active and get involved in the learning process (Underwood & Burns, 2014). AfL contributes to an ongoing learning process, through providing feedback that teachers can refer to, to improve teaching, evaluating students, and those who are struggling and those who may need help (Rwanda Education Board [REB], 2015; Shepherd et al., 2010).

Teachers in Rwanda are expected to integrate AfL into their lessons on daily basis, to monitor and enhance students' learning progress (REB, 2015). Students are not only expected to be assessed based on the final results but also their whole learning process, abilities and metacognition (Egodawatte, 2010). Thus, for an effective process of AfL, five main processes take place: Teachers questioning students to see what the level they are at, the teacher providing feedback on the students' task to provide ways for improvement, students understanding of what a successful work look like, students become more independent by taking part in peer and self-assessment, and summative assessments such as test or exams to help students improve (O'leary, Lysaght, & Ludlow, 2013).

This study was guided by cognitive learning theory as initiated by Edward Chace Tolman in 1920 and adopted as a learning theory in the early twentieth century (Yilmaz, 2011). Cognitive learning seeks the ways learners are taught to develop their thinking ability in interacting with the environment and is built on students' prior knowledge that is relevant and meaningful (Powell & Kalina, 2009). Through this theory, teachers provide exciting learning environments, interactions, opportunities, tasks, and instructions that foster a deep understanding of the content being taught (Walshaw & Anthony, 2008). Therefore, mathematics teachers in Rwanda are expected to cope with teaching practices that consider an individual student's ability to learn as far as students' cognitive structure is concerned (Yilmaz, 2011).

Although several times REB has provided training to primary and secondary school teachers about the effective implementation of Competence Based Curriculum (CBC) (Ndihokubwayo & Murasira, 2019) which emphasizes the use of AfL and assessment. For instance, in 2016, the first phase of the CBC training on the introduction of CBC and the rationale of changing from knowledge to competency-based teaching approach was conducted. In 2017, phase two training on CBC implementation was also conducted. In 2018, pieces of training about enriching sector-based trainers in CBC understanding took place with the intention for trainees to go and train their fellow teachers in respective sectors. Furthermore, in the same year (2018), CBC training on assessment (as phase three) was conducted (Ndihokubwayo, Nyirigira, Murasira, & Munyensanga, 2021).

Despite this bunch of training, the recent study conducted by Byusa et al (20200 in Rwanda showed that there is still a gap in how teachers in Rwanda implement CBC since students are not significantly engaged in their learning subjects (Byusa, Kampire, & Mwesigye, 2020). Most of Rwandan teachers within schools still practice traditional assessment which is dominated by assessing students for national examinations (Ngendahayo, 2014; Nizeyimana, 2003). Therefore, this study was conducted to assess mathematics teachers' implementation of active learning through the effective use of AfL, to improve students' understanding of mathematics. The findings from the study can potentially contribute to the provision of significant implication for future training of Rwandan mathematics teachers and policy-making.

Methodology and procedures

This study is a survey-based research design that used mixed explanatory research methods, to combine qualitative and quantitative data for triangulation purposes (Creswell, 2014). It was carried out within Nyamasheke district, Western Province, Rwanda. Nyamasheke district was selected based on the National Institute of Statistics of Rwanda report on Integrated Household Living Conditions Survey (IHLCS) thematic report Education, where Nyamasheke district was repeatedly ranked among the last districts with the lowest quality of education (National Institute of Statistics of Rwanda[NISR], 2012).

The target population of the study was composed of mathematics teachers and secondary school students who have mathematics among their learning subjects within 56 public secondary schools that are enrolled in 56 secondary schools of Nyamasheke district. Semi-structured interviews and classroom observation as data collection tools were collected spontaneously within the six randomly selected schools for saving expenses, time and accessibility issues (Cohen, Manion, and Morrison 2007).

All the schools under this study were government twelve years basic education schools popularly known as (12YBE) public schools, located in rural areas of the Nyamasheke district. At each school, a teacher was purposively selected on the condition that he/she teaches mathematics for senior five students. . Mathematics teachers were involved in the study based on the researcher's area of interest. Therefore, six mathematics teachers were sampled, interviewed, and afterward observed while teaching mathematics. All the observed teachers have a background in education. Five have a bachelor's degree (A0) and one has a Diploma (A1). Similarly, 12 senior five students were randomly selected from one class at each school, and also subjected to the in-depth interview. Thus, 72 senior five students participated in the interview. Students' ages were ranging from 16 up to 24.

The interview questionnaires had two main themes: The teachers' applications of assessments in mathematics lessons, and the role of feedback in increasing students' interest to learn mathematics. These questions were checked for their validity by experts (3 evaluators) from the University of Rwanda, College of Education in view of the study's objectives. To optimize the reliability of transcription of the interviews, the transcripts were sent back to the interviewees, so that they make sure that what was written revealed exactly their views for necessary amendments.

The COPUS protocol which was initially designed for under graduate level was also fitting for the secondary school level (Ndihokubwayo, Uwamahoro, & Ndayambaje, 2021), the reason why it was also adopted for use in this study. A pilot was conducted in one school of the same characteristics as the sampled participants of the study to make the observer familiar with the real classroom observation and conducting interviews.

To avoid agreements due by chance, the IRR was calculated using SPSS. Cohen's Kappa = (AO – AC) / (1 − AC) where OA is the rate of agreement between observers, and AC is the rate of the inter-observer agreement that occurred due to chance. AC is the sum of disagreement products between observers (what was observed by observer-1 only, and what was observed by observer-2 only)(Cohen, 1988). Therefore, the computed Kappa coefficient was 0.85, which is high reliability (Ndihokubwayo et.al, 2021). Besides collecting reliable data, researchers observed teachers teaching three times (Smith, Jones, Gilbert, & Wieman, 2013). Hence, 24 lessons were observed from the 3rd December 2020 until 15th January 2021.

All data collected were analyzed in terms of the percentages of the frequency of activity to happen during a lesson. The analysis was done for a combination of the whole observation of 24 lessons. After transcribing data, COPUS visualization generated a graph with corresponding percentages, reflecting students' and instructor's doing that occurred during each 2-minute time interval across the total observed periods.

Data presentation and discussion

The interviewed students said that their teachers ask question(s) to students either at the beginning of the lesson to test their understanding of the previous lesson, or in the middle of the lesson to check their learning progress, or at the end of the lesson to see whether the lesson was understood or while leaving students with homework. Very few students (12 out of 72) reported that their teachers at least write the correct formulas when students have confusing formulas. The results from the study show that the assessment is done regularly. However, not many teachers are interested in providing feedback on students' work showing the area of improvement. O'leary et al. (2013) argued that providing feedback to students is a good track towards improvement, where students can experience what successful work looks like.

Students were also asked during interviews to tell how frequently an exercise, homework, quizzes, and tests are done and how they feel while doing these assessments. The data collected showed that at least three exercises are done within a single lesson; done individually or in collaboration with their teachers. In addition, students pointed out that at least homework is given for every end of the week. Students stated that these activities help them to master the content and prepare for the end-of-unit assessments or exams and enhance their collaborative learning. For instance, a student (6S5) reported that: *"Sometimes you cannot feel comfortable to ask the teacher, but when you are left with homework or exercises, then you can feel free to ask your colleagues, and they can explain to you even better than the teacher."* Indeed, giving exercises and homework is advantageous for students in a way that it is through these assessments that students seek actively work and get assistance from their peers. Similarly, Ukobizaba, Ndihokubwayo, Mukuka, and Uwamahoro (2019) also re-iterated that students can also learn mathematics effectively by receiving assistance from their siblings and peers. The more students do many assessments, the more their level of understanding in mathematics increases, as also supported by the cognitive learning theory that is guiding this study (Yilmaz, 2011).

During an interview with teachers, it was revealed that teachers do not know their roles in AfL administration. For instance, the interviewed teacher (T2) said: "*I first finish teaching the whole unit, then; I look for a specific time for doing exercise with students.*" The majority of the teachers interviewed (four out of six) responded that they only assess students' marks recording in their reports. Another teacher (T3) confirmed this saying that: *"My role is to prepare questions and give to the students. I often do not mark. What I want is to make them work".* This is a challenge since teachers do not sufficiently grasp the relevance of AfL and how it should be effectively conducted. The ineffective implementation of AfL has negative impacts on students' performance since the students' efforts are not well catered for to improve their performance. This shows that the observed mathematics teachers are unable to carry out AfL effectively.

Effective AfL delivery consists of giving instructions of how the assessment is going to be done, making a follow up to see if students are providing independent answers, marking students' works, providing relevant feedback on students' works, and further taking appropriate measures including providing remediation for those students who are still struggling (LPU, 2012; Shepherd et al., 2010). AfL is a co-constructed activity that involves teachers, students, and peers, (Govender, 2019), whereby teachers provide instructions that boost students' deep understanding of the subject matter being learned. This is also supported by a cognitive learning theory that states that teachers create an environment of interactions, tasks, and instructions that foster a deep understanding of the content (Walshaw & Anthony, 2008).

The majority of teachers (four out of six) reported that they mark their students and write comments/feedback on students' scripts showing the area of improvement. However, teachers reported that the provided comments are such as: 'Good! Excellent!' etc., making a cross on the wrong answer, or putting a plus or a minus sign where a student may have forgotten to put either sign. For instance, a teacher T3 said: *"While marking, I write nothing except correcting and giving marks. When a student gets good marks, I write 'good!' or 'Excellence!' as a kind of motivation"*.

However, a good comment should be intended to help students to correct their mistakes, errors or misconceptions, and improve on how they provide answers to the given questions (Shepherd et al., 2010). Giving and showing marks to students is not enough if no further measures are taken based on students' results, to improve their performance (Hunt & Pellegrino, 2002; O'leary et al., 2013).

By conducting a classroom observation of 24 lessons (24 periods of 40 minutes each lesson) for six mathematics teachers, a total of 480 segments of 2-minute time intervals were got. Table 1 displays scores and percentages (%) in descending order, showing how frequently a given activity code was marked (scores) compared to the sum of all codes marked. The table shows 25 activities including, 13-students' (1-13) and 12-teacher doing (14-25).

Table1. Mathematics classroom observation results

SN	Students' doing (activity codes)	Scores	%
1	Listening (L)	149	38
2	Presentation (SP)	83	22
3	Answering (AnQ)	72	19
4	Other (O)	59	15
5	Working Group (WG)	58	15
6	Thinking (Ind)	44	12
7	Whole-Class discussion (WC)	34	9
8	Waiting (W)	31	8
9	Asking (SQ)	10	3
10	Clicker Discussion (CG)	0	0
11	Other Group (OG)	0	0
12	Prediction (Prd)	0	0

13	Test/Quiz (T/Q)	0	0
	Teachers' doing (activity codes)		
14	Writing (RtW)	164	43
15	Lecturing (Lec)	136	36
16	Posing Questions (PQ)	91	24
17	Follow up (Fup)	57	15
18	Moving and guiding (MG)	42	11
19	Other (O)	34	9
20	Waiting (W)	28	7
21	One to one (1o1)	17	4
22	Demo/Video (DV)	15	4
23	Answering Questions (AnQ)	12	3
24	Administration (Adm)	2	1
25	Clicker Question (CQ)	0	0
	Overall	1138	26

Source: Primary data

With the results presented in Table 1 above, it is shown that students spent a lot of time (38%) listening to the teachers' instructions. On the other hand, a lot of time (36% and 43%) was used by teachers lecturing and writing on the blackboard respectively. The activities like Clicker Discussion (CD), Other Group (OG), Prediction (Prd), Test/Quiz (T/Q), and Clicker Question (CQ) did not occur throughout the all observed lessons.

These results show clearly that students in mathematics lessons were not sufficiently and actively engaged in the lesson. Indeed, if a teacher maximizes the time lecturing and writing on the blackboard, an occurrence of interacting with students and posing questions to test whether learning is taking place is dismissed. Thus, AfL is not applied as expected. The low involvement of the students in the lesson was also found by Byusa et.al (2020), whose COPUS-based results showed that students learn passively in chemistry. Thus, teachers need to be ensured to what extent the content taught has been understood by students during instructions (Shepherd et al., 2010).

Besides, the COPUS visualization generated the graph with the corresponding percentages of the activities that are grouped into eight collapsed or merged activities (Smith et al., 2013). The collapsed codes (merged activities) from Table 1 generated new terminology of activities (see Figure 1). For students, the merged activities are: Receiving, talking to class (answering, asking, whole-class discussion and presentation), working (thinking, clicker discussion, working group, other groups, prediction, and test/quiz), and others (waiting and others). For instructors, the merged activities are presenting (lecturing, writing, and demo/video), guiding (follow up, posing questions, clicker question, answering questions, moving and guiding and one to one), administrating, and others (waiting and others).

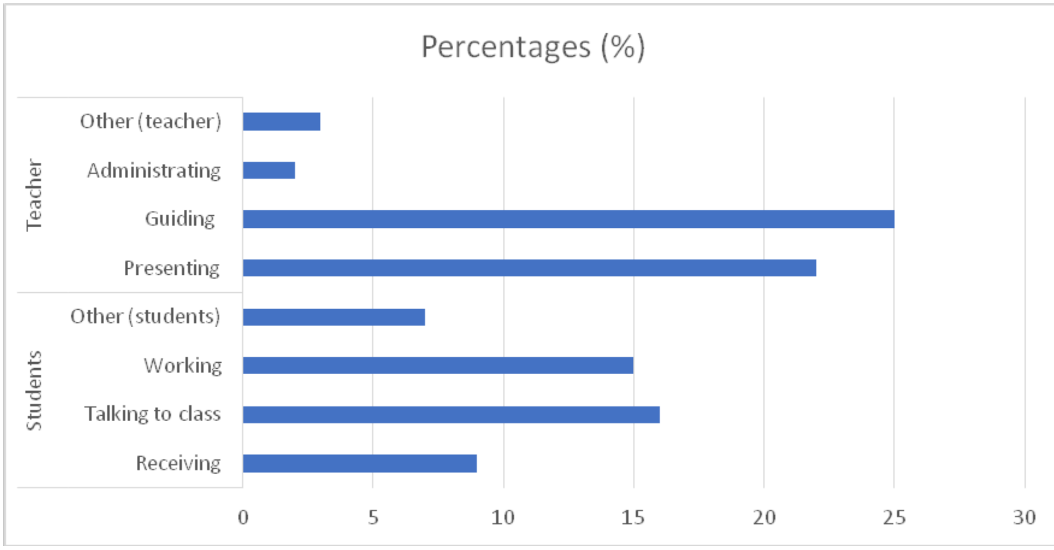

Figure1. Mathematics classroom observation results with collapsed codes

From Figure 1 above, the results showed that teachers spent much time presenting (22%) and only 15% of the time was used by students doing classroom activities. However, the results showed that teaching and learning mathematics appeared to be collaborative whereby much time (25%) was used by the teacher while guiding students.

These results are in line with the results presented in Table 1 that showed that students were not actively engaged. If a teacher uses the maximum time of presenting the content being taught, then students become passive listeners to the teacher talking. That is why, the effective implementation of AfL implies actively involving students in constructing their knowledge, whereby students are given opportunities to assess their learning progress throughout the lesson (Egodawatte, 2010). It is through AfL that students interact with teachers every minute (O'leary et al., 2013) as they are learning.

The above results from interviews and classroom observation showing that teachers do not effectively apply AfL, may be attributed to fact that: firstly; teachers lack sufficient pedagogical knowledge related to how they can actively engage the students in their teaching and learning as well as providing constructive feedback on the students work;

Secondly, teachers do not effectively apply AfL due to the heavy load they have. To this end, teachers spend more time in an attempt to finish the program and thus ignore students' understanding of the concepts;

Thirdly, large class size is another contributing factor for ineffective implementation of AfL. It is difficult for teachers to individualize the lesson by providing the feedback to each and every students' work, once the class is too large.

Conclusion

This study aimed at assessing mathematics teachers' implementation of active learning through the effective use of AfL to improve students' understanding of mathematical concepts. AfL was found to be a motivating factor to learn mathematics since it actively involves students in constructing their knowledge and enhances collaborative learning.

However, the analysis of the results from classroom observation showed that students are not actively involved in learning, which implies the underestimating and/or poor implementation of AfL by mathematics teachers. The results from students' and teachers' semi-structured interviews revealed that the comments or feedback provided on students' works are informative enough to make students improve their level of understanding of mathematical concepts.

This study was limited to a small geographical scale of Rwanda. Thus, the results may not be necessarily generalized on the country level. The data collected was also limited to senior five students. Thus, the results may not be generalized to all mathematics teachers and students doing mathematics. Based on the study's results and limitations, the present study recommends that (i) mathematics teachers should minimize time spent on lecturing and writing, and instead deliver their lessons in a way that makes students get actively involved in a lesson, (ii) mathematics teachers should provide students with constructive feedback or comments that enhance their understanding of mathematical concepts, and (iii) further studies can be conducted on a large scale of the country involving also other students of different educational levels to generalize the findings at the national level.

References

Byusa, E., Kampire, E., & Mwesigye, A. R. (2020). Analysis of Teaching Techniques and Scheme of Work in Teaching Chemistry in Rwandan Secondary Schools. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(6). https://doi.org/10.29333/EJMSTE/7833

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences (2nd Ed.)*. Lawrence Erlbaum Associates, Publishers.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). Routledge. Taylor & Francis Group. London.

Creswell, W. J. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th). SAGE.

Egodawatte, G. (2010). A Rubric to Self - Assess and Peer - assess Mathematical Problem Solving Tasks. *Acta Didactica Napocensia*, *3*(1), 75–88.

Govender P. (2019). Formative assessment as ‘ formative pedagogy ’ in Grade 3 mathematics Introduction : Towards a formative pedagogy. *South African Journal of Childhood Education*, *9*(1), 1–12.

Lovely Professional University. (2012). *Educational Measurement and Evaluation*. Pagwara. Punjab.

National Institute of Statistics of Rwanda. (2012). *EICV3 District Profile: Nyamasheke*. Available at http://statistics.gov.rw/sites/default/files/publications/a45cb0b0-4295-4fca-97b0-09604a6eb0fc/Nyamasheke.pdf. Retrieved on 22.04.2020

Ndihokubwayo, K., Nyirigira, V., Murasira, G., & Munyensanga, P. (2021). Is Competence-Based Curriculum well Monitored? Learning from Rwandan Sector Education Officers. *Rwandan Journal of Education,* Vol. 5, No. 1

Ndihokubwayo, K., & Murasira, G. (2019). Teachers’ training college learners’ expectations for their future teaching. *LWATI: A Journal of Contemporary Research*, *16*(2), 1–10. https://doi.org/https://www.ajol.info/index.php/lwati/article/view/185978

Ndihokubwayo, K., Uwamahoro, J., & Ndayambaje, I. (2021). Classroom Observation Data Collected to Document the Implementation of Physics Competence-Based Curriculum in Rwanda. *Data in Brief*. https://doi.org/10.1016/j.dib.2021.107055

Ngendahayo, E. (2014). Rethinking Rwandan higher education assessment system and approaches. *Rwanda Journal of Education*, *2*(2), 31–47.

Nizeyimana, G. (2003). Teacher perceptions of the impact of public examinations on curriculum practices: A survey in two districts of Kigali city, Rwanda (Unpublished Dissertation), University of Natal, Pietermaritzburg, South Africa.

O’leary, M., Lysaght, Z., & Ludlow, L. (2013). A Measurement Instrument to Evaluate Teachers’ Assessment for Learning Classroom Practices. *The International Journal of Educational and Psychological*, *14*(2). https://doi.org/10.13140/2.1.1289.0241

Powell, K. C., & Kalina, C. J. (2009). Cognitive and Social Constructivism : Developing Tools for an Effective Classroom. *Education*, *130*(2), 241–250.

Powell, Katherine C., & Kalina, C. J. (2009). Cognitive and social constructivism: Developing tools for an effective classroom. *Education*, *130*(2), 241–250. https://doi.org/10.1037/0022-0663.93.3.571

Rwanda Education Board. (2015). *Teacher Training Manual: Roll out of the Competence-Based Curriculum*.

Kigali

Shepherd, E., Godwin, J., Coscarelli, W., Shrock, S., Mcnamara, B., & Phaup, J. (2010). *Assessments through the Learning Process*.

Smith, M. K., Jones, F. H. M., Gilbert, S. L., & Wieman, C. E. (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices. *CBE Life Sciences Education, 12*, 618–627. https://doi.org/10.1187/cbe.13-08-0154

Smith, K., M., Vinson, L., E., Smith, A., J, Lewin, D., J., & Stetzer, R., M. (2013). *A Campus-Wide Study of STEM Courses: New Perspectives on Teaching Practices and Perceptions,* CBE-Life Sciences Edu, 13(4), pp. 624–635.

Underwood, J. B., & Burns, E. (2014). The disconnect between college and reality. *Phi Delta Kappan*, *95*(8). https://doi.org/10.1177/003172171409500821

Ukobizaba, F., Ndihokubwayo, K., Mukuka, A., & Uwamahoro, J. (2019). *Insights of teachers and students on mathematics teaching and learning in selected Rwandan secondary schools*. T*he African Journal of Educational Studies in Mathematics and Sciences, 15*(2), 93–107. https://doi.org/10.4314/ajesms.v15ii2.8

Walshaw, M., & Anthony, G. (2008). The Teacher's Role in Classroom Discourse : A Review of Recent Research Into Mathematics Classrooms. *Review of Educational Research*, *78*(3), 516–551.

Watts, S. (2014). User Skills for Qualitative Analysis: Perspective, Interpretation and the Delivery of Impact. *Qualitative Research in Psychology*, *11*(1), 1–14. https://doi.org/10.1080/14780887.2013.776156

Yilmaz, K. (2011). The Cognitive Perspective on Learning : Its Theoretical Underpinnings and Implications for Classroom Practices. *The Clearing House*, *84*, 204–212. https://doi.org/10.1080/00098655.2011.568989