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Research Article

The effect of assessment for learning on pre-service mathematics teachers' higher-order thinking skills in algebra

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In teacher education, enhancing pre-service teachers' higher-order thinking skills (HOTs) is very crucial. The effect of comprehensive professional development in assessment for learning (AfL) on pre-service teachers' HOTs in an algebra course was investigated using a nonequivalent group quasi-experimental design. A total of 129 pre-service teachers who took the Fundamental Concepts of Algebra course from three different teacher education colleges [TECs] selected randomly from ten Ethiopian TECs, participated in the study. Among these students who attended the course, a group of 52 pre-service teachers with three mathematics teacher educators who gave them the course engaged in comprehensive training and professional development on AfL, while the remaining pre-service teachers were attending the course the usual way in two different TEC. A one-way ANOVA was used to determine whether there was a mean difference among the three groups and three achiever levels on their HOTs scores. The result showed that there is a statistically significant mean difference in the HOTs scores between pre-service teachers in the treatment group and the comparison groups. The results also showed that there was a statistically significant mean difference among the three achiever levels (low, medium, and high) in their HOTs scores in the treatment group before the intervention, but there was no statistically significant mean difference after the intervention. The implications of the results and recommendations are discussed.

Keywords: Assessment for learning; Higher-order thinking; Algebra

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1. Introduction

1.1. Background

Developing higher order thinking skills [HOTs] in mathematics is vital in our contemporary, constantly changing, and technological environment. Besides, teachers require assistance in terms of teacher training and guidebooks to establish a consistent understanding of HOTs, its learning approach, and the features of the assessment. Educational institutes can enable colleagues to work together in (inter)disciplinary teams on the conception and implementation of HOTs in their teaching practices, as Tanudjaya and Doorman (2020) argued. Besides, the improvement of HOTs

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of pre-service teachers is very important and it involves tremendous work on the mathematics teacher educators' behalf. They need to apply a range of teaching and learning methodologies to increase the pre-service teachers' capacities to transmit information and skills and their critical thinking and problem-solving capabilities. Moreover, peer assessment, which is one of the strategies of AfL, is a procedure that is particularly suited for this aim (Hadzhikoleva et al., 2019).

The Taxonomy of Educational Objectives is a commonly used classification system for educational aims, objectives, and standards. It offers an organizational framework that gives objectives defined in one of its categories a shared understanding, hence improving communication. The original taxonomy included six categories, almost all of which had subdivisions. They were organized into a cumulative hierarchical structure, in which mastering one talent or ability necessitated mastering the others (Krathwohl, 2002). The Revised Bloom's Taxonomy has been used in a variety of disciplines for different purposes (e.g. evaluating alignment between curriculum, teaching, and assessment has not been used very frequently in mathematics education (Radmehr & Drake, 2019). The categories of the cognitive process dimensions are meant to give a thorough set of classifications for those student cognitive processes that are covered in the objectives. The categories vary from the cognitive processes most commonly found in objectives, those connected with Remember, through understand and apply, to those less frequently encountered, analyze, evaluate, and create.

In addition, consistent monitoring of mathematics teacher educators' implementation would assist in offering useful information on their problems and tactics while implementing the system. The gathered information will provide substantial progress toward building accessible, effective, and efficient techniques for mathematics teacher educators to conduct a quality assessment. Furthermore, more proactive and effective professional development should be implemented to assist mathematics teacher educators in gaining the necessary competence on the HOTs assessment in AfL. A professional learning community should be developed and implemented in the school culture so that all mathematics teacher educators may work together to assist each other by offering ideas, assistance, and support to conduct a quality assessment (Wilson & Narasuman, 2020). As Hadi et al. (2018) argued, the most prevalent problem for students in answering test questions that evaluate HOTs is mathematics process skills. This problem is demonstrated by errors in applying the formula, errors in mathematics computation, and errors in algebraic operations and manipulation. Other issues faced by the students include difficulty in understanding the test items, which was shown by their inaccuracy in determining what is provided and what is asked on the test items. Teachers' role is very significant in developing students' competence in HOTs. In this scenario, teachers need to prepare their pupils so that they will be comfortable with solving HOTs exam items (Hadi et al., 2018). In this research, the Revised Bloom's Taxonomy was used to construct test items for the achievement test that contain eleven items that measure pre-service teachers' Lower Order Thinking Skills and eleven items that measure pre-service teachers' HOTs. Five of the eleven items used in this study to assess pre-service teachers' HOTs fall under the Analyze category in the revised Bloom's taxonomy for the cognitive domain, while six of the eleven items go under the Evaluate category.

1.1.1. Mathematics education and its role

The study of mathematics paves the way for innovative ways of thinking and practical applications that directly affect daily life, allowing for the critical interpretation and evaluation of the vast volumes of data generated in today's knowledge-based society. Additionally, it establishes citizenship behavior through rational, well-informed, and driven social decision-making processes. Without basic mathematical competency, it is very difficult to fully engage in the modern world made possible by information, communication, and technology (Ferretti et al., 2018). What stands out to be an effective AfL in the teaching and learning of mathematics for teachers is to improve their teaching approaches in three ways: using assessment to establish and identify the students' misunderstandings into teaching and learning opportunities and giving students second chances to demonstrate their success in learning (Chigonga, 2020). Nevertheless, many students find algebra difficult to learn, and the failure rate of students in algebra is considerable (Agustyaningrum et al., 2020; Cousins-Cooper et al., 2017; Hausberger, 2018; Tanışlı et al., 2020). Since algebra is crucial to students' academic futures, it is necessary to focus on the teaching approaches employed in the teaching-learning process. The problems connected to the teaching and learning of algebra in colleges are recognized by numerous researchers and educators (Cousins-Cooper et al., 2017).

1.1.2. Assessment for learning and its role

Students do not always learn what they are taught, so we need to establish techniques for eliciting and assessing information so that we can draw inferences about what students have in fact learned (Black & Wiliam, 2018). To this effect, AfL has gained popularity in practice and policy during the last two decades all around the world. Assessment for learning has been included in or embraced by educational assessment and evaluation policies or practices in country after country (Birenbaum et al., 2015). Siobhan et al. (2005) identified five broad strategies of assessment for learning that are effective for teachers of all subject matters and all grade levels which are listed below:

1. Clarifying and sharing learning intentions and criteria for success.
2. Engineering effective classroom discussions, questions, and learning tasks.
3. Providing feedback that moves learners forward.
4. Activating students as the owners of their own learning.
5. Activating students as instructional resources for one another.

Assessment for learning focuses on how students learn, is central to classroom practice, is a key professional skill, sensitive and constructive, fosters motivation, promotes understanding of goals and criteria, helps learners know how to improve, develops the capacity for self-assessment, and recognizes all educational achievement (Assessment Reform Group, 2002). Besides, AfL is an active and deliberate learning process in which the teacher and students collaborate to collect evidence of learning on a continuous and systematic basis with the explicit objective of enhancing student accomplishment (Moss & Brookhart, 2019).

Assessment for learning demands the adoption of a set of complicated and linked classroom procedures. While its ultimate purpose is to collect evidence that teachers and students can use to adjust instructional next steps, research results indicate that there are additional critical factors that impact that use of evidence, including teachers' planning and preparation, understanding of the domain, and ability to engage students with the assessment process (Lyon et al., 2019).

Contemporary approaches to classroom assessment have shifted away from viewing assessment as a series of events that objectively measure knowledge acquisition toward viewing assessment as a social practice that provides continuous insights and information to support student learning and influence teacher practice (Barnes & Marks, 2020). An important feature in AfL is the surfacing of each student's understandings and misunderstandings. Research on learning mathematics makes it obvious that students' conceptual issues are typically caused by over-generalization when pupils transfer existing knowledge to new areas (Burkhardt & Schoenfeld, 2019).

Hattie (2008) argued that successful learning is a function of the worthwhileness and clarity of the learning intentions, the specifications, and the success criteria; the power of using multiple and appropriate teaching strategies with a particular emphasis on the presence of feedback focused on the right level of instruction (acquisition or proficiency); seeing learning and teaching from the students' perspective; and placing reliance on teaching study skills and strategies of learning. However, in far too many classrooms, teachers and students are operating in the dark. Teachers cannot demonstrate with certainty what their pupils know and where they are concerning daily classroom learning objectives. Due to a lack of precise and current information, teachers find it especially challenging to deliver meaningful feedback that clearly defines the next actions pupils should take to develop. Without the ability to analyze and manage their learning, individuals attempt to do assignments successfully yet they do not know where they are going, what they need to do to get there, or how they will know when they will be there (Moss & Brookhart, 2019).

Teacher educators at TECs in Ethiopia implement a didactic lecture method, which is a teacher-centered method of teaching that does not encourage the active participation of students in assessing themselves and their peers while teaching their students (Alemu et al., 2019; Gemeda & Tynjälä, 2015). Despite the growing popularity of formative assessment as a teaching tool, teachers find it challenging to incorporate formative assessment procedures into their classroom practices (Kruiper et al., 2021). Engaging in formative assessment is initially difficult for teachers across various levels, and the difficulty is particularly apparent for Mathematics as instruction has historically addressed a restricted range of learning goals, mostly confined to technical abilities taught as procedures through show and practice, and thus change is clearly a challenge (Burkhardt & Schoenfeld, 2019).

1.1.3. Effective professional development

This challenge of changing an existing teacher-dominated classroom culture can be met through carefully designed professional development. Teacher professional learning is gaining popularity as a means of supporting students' development of increasingly sophisticated abilities in preparation for future education and jobs in the twenty-first century. To build student abilities such as deep understanding of difficult topics, critical thinking, complex problem-solving, effective communication and teamwork, and self-direction, sophisticated styles of teaching are required. As a result, effective professional development is essential to assist teachers in learning and refining the pedagogies needed to teach these abilities (Güler & Çelik, 2022). According to studies (Darling-Hammond et al., 2017), many professional development programs, however, are ineffectual in encouraging improvements in teaching practices and student learning.

1.1.4. The need for quality teacher education

As Ferretti et al. (2018) argued, it is critical to develop novel approaches to invest in mathematics teacher education, particularly through training courses that place teachers in collaborative planning scenarios and enable them to develop effective plans, strategies, and methodologies for teaching mathematics. It goes without saying that this entails not only research into the subject but also research into pedagogical-didactical learning strategies, particularly in the area of assessment, emphasizing the importance of AfL.

It is extremely difficult to provide access to high-quality education without properly managing teacher education and professional development factors, such as providing high-quality pre-service and in-service training, as well as continuous professional development focused on content knowledge, pedagogy, and language skills (Workneh & Tassew, 2013). The effectiveness of classroom assessment is highly dependent on a variety of dynamics operating within and outside the classroom, including assessment task types, students' cognitive and emotional preparedness, the teacher's familiarity with his or her students and course materials, course characteristics, and the physical environment (Xu & Brown, 2016). Context-specific, job-based, and content-based teacher professional learning is especially crucial for meeting the unique requirements of students (and consequently instructors) in various situations (Darling-Hammond et al., 2017).

It is also argued that professional development must be based on a carefully crafted and clearly communicated sense of purpose as well as core ideas that are constantly scrutinized by the learning community. Teachers will be able to listen as their voices guide them in creating learning opportunities for themselves, their students, and the school if they have core convictions and a sense of purpose (Zepeda, 2013).

Optimal professional development requires teachers to feel comfortable experimenting, evaluating the impact of their innovations, conversing openly, and establishing rules for effective student learning (Wright et al., 2018). The findings of this study suggest that reforming teacher preparation programs, involving universities in the delivery of professional development, and increasing district/school-level support for teacher training and support that lasts multiple years can all contribute to schools gaining ground in their use of formative assessment (Johnson et al., 2019).

Professional development in this research entails discussions with mathematics teacher educators about the nature, principles, strategies, purpose, and challenges of implementing AfL and practical teaching practices on how to implement the five strategies of AfL when teaching a subtopic in algebra. Moreover, the training for the pre-service teachers includes how to assess themselves based on the specific objectives of the lesson; how to assess their peers by providing constructive feedback; and the importance of learning from errors they make in the teaching and learning process. According to Darling-Hammond et al. (2017), effective professional development is planned professional learning that leads to changes in teachers' knowledge and practices as well as gains in students' learning.

A considerable number of studies have been conducted worldwide to understand the effects of the implementation of improved AfL on students' achievements in mathematics in primary and secondary schools, with mixed results (Chemeli, 2019; Van den Berg et al., 2018) and on students' self-regulated learning skills and self-efficacy (Granberg et al., 2021; Rakoczy et al., 2019). Research on the effect of AfL on students' higher-order thinking in mathematics in general and in algebra in particular, is scarce. In addition, higher-order thinking could not be the same across achiever-level groups of students (low, medium, and high), and ideally, higher achievers are expected to have better higher-order thinking. In this regard, Zohar and Dori (2003) argue against the view that HOTs are appropriate only for high-achieving students, and claim that low-achieving students are, by and large, unable to deal with tasks that require higher order thinking skills and should thus be spared the frustration generated by such tasks. Although due to the effect of instructional intervention, higher-order thinking could vary, if supported with the implementation of AfL, students may bring new learning and changes to higher-order thinking among the different achievement levels, making it thus worth studying. This research was conducted with the intention of filling this gap by examining the effect of context-specific, content-based, and job-embedded comprehensive professional development for mathematics teacher educators and training on AfL to pre-service primary mathematics teachers' HOTs in algebra.

1.2. Objective and Research Questions

The main objective of this research was to investigate the effect of improved implementations of AfL on the higher order thinking skills of pre-service primary Mathematics teachers concerning the revised cognitive levels of Bloom's taxonomy in the teaching and learning of fundamental concepts of algebra course directed by the following specific research questions:

RQ (1). Is there a significant mean difference between pre-service Mathematics teachers in the treatment group and the two comparison groups on their higher-order thinking skills in algebra before and after the intervention?

RQ (2). Is there a significant mean difference among low, average and high achievers of pre-service mathematics teachers in the treatment group on their higher-order thinking skills in algebra before and after intervention?

1.3. Theoretical Framework

Vygotsky's sociocultural theory of learning is a well-known theory in the mathematics education arena. According to this theory, a student's intellect develops as a result of social engagement in the world, communication, social interaction, and cooperative activity are all significant aspects of this social world (Cottrill, 2003). The sociocultural theory of learning considers teacher development as a transforming engagement in social actions that develop their professional identities. Most sociocultural research on mathematics teacher education has focused on analyzing teachers' learning, while sociocultural viewpoints can also be used to support intervention research that involves improving classroom practice (Goos, 2013). Endorsing sociocultural theory as the most fruitful learning theory permits the co-design of instruction and assessment in a way that allows for deep learning over time. For assessment design, fine-grained explanations of learning goals and resources tied directly to frequent learning obstacles are also required, particularly to answer the key problem of "what next?" (Shepard et al., 2018).

By paying attention to both “who learners are when they join a community and who they might become,” sociocultural approaches make it possible to create interventions that address fairness in educational situations. They permit us to think about what's at stake for students when they put new information or abilities into practice in a specific situation (Shepard et al., 2018). Goos (2013) also stated that sociocultural perspectives on mathematics teacher research can be beneficial for both understanding and fostering teacher learning. Learning is understood from this perspective as involvement in social processes that assist instructors to construct their professional identities and affect the development of the same in pre-service teachers.

Assessment for learning is an important part of the classroom teaching-learning process and its proper implementation can enhance students’ learning, which includes their HOTs abilities, according to a growing body of research results and there are no other means to raise standards for which such a compelling case can be made(Black & Wiliam, 2010). The sociocultural theory of learning serves as the foundation for this research because it helps mathematics teacher educators, who were involved in the intervention, co-design classroom instruction in their social context in a way that fosters improved implementation of AfL strategies, gives the chance to identify the learning gaps of pre-service teachers, and offers alternatives to scaffold in helpful ways.

2. Method

2.1. Research Design

One of the most prevalent experimental designs in educational research comprises a treatment group, and a comparison group both given a pretest and a posttest, but in which the comparison group and the treatment group do not have pre-experimental sampling equivalence. Rather, the groups constitute naturally formed collectives such as classrooms, as comparable as handiness permits (Campbell & Stanley, 1963). In this study, a quasi-experimental research design with pre-test and post-test in non-equivalent groups was employed since the participants of the research are pre-service teachers in three different colleges in their natural setting, and the researcher did not assign each participant to the treatment group and comparison groups randomly. The researchers managed to control the effect of confounding variables by randomly selecting three colleges from the ten colleges and by randomly assigning one of the three selected colleges as a treatment group and the remaining two colleges as comparison groups. Moreover, all of mathematics teacher educators in the three selected colleges who give the course have a second degree in mathematics education and have similar teaching experience, ranging from 15 years to 20 years of teaching experience. The process is summarized in Figure 1.

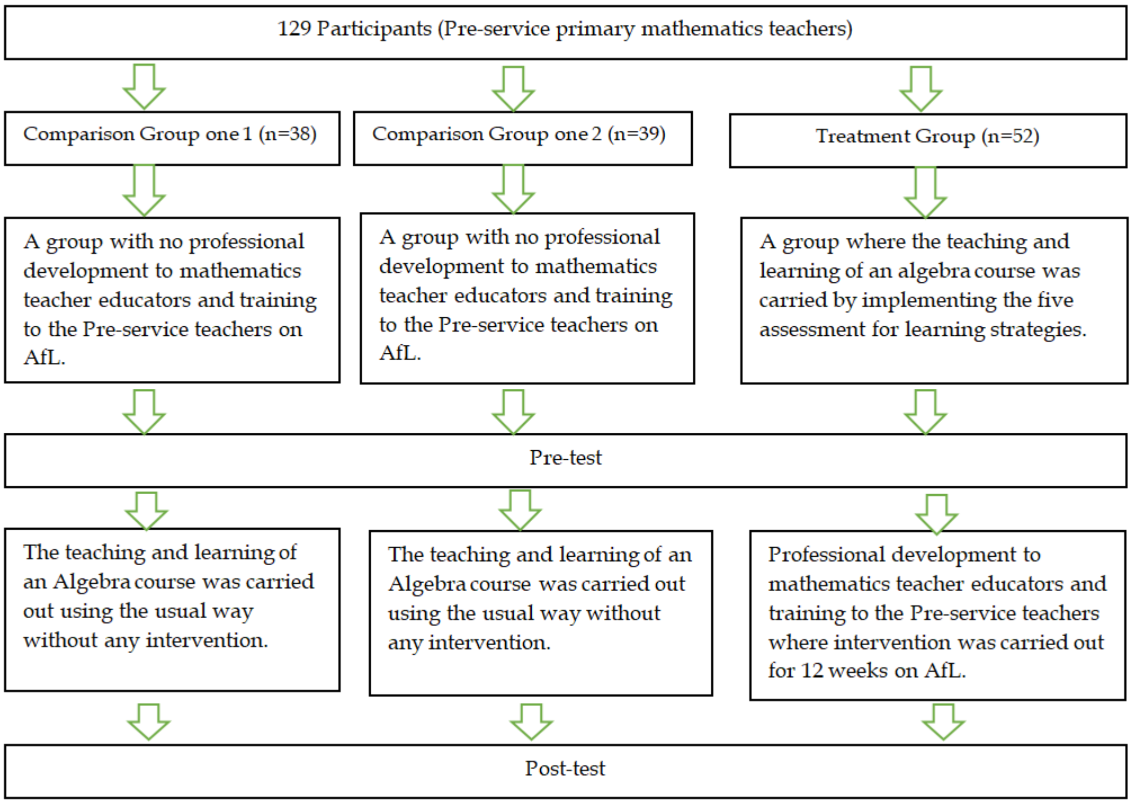
2.2. Population, Participants, and Sampling Techniques

The population of this research was all second-year pre-service primary mathematics teachers at TECs in Amhara regional state, Ethiopia. The participants of the study were second-year pre-service primary mathematics teachers learning at three TECs, which were selected randomly using a lottery system from the 10 colleges found in Amhara regional state, Ethiopia. A treatment group was picked randomly using a lottery method from the three specified colleges, and the remaining two colleges were allocated as comparison groups.

Three mathematics teacher educators who were assigned to deliver the Fundamental Concepts of Algebra course in the college, assigned as a treatment group, participated in the professional development program that was conducted for twelve weeks. A total of 129 pre-service primary mathematics teachers (52 in the treatment group, 38 in the first comparison group, and 39 in the second comparison group) participated in the study. The pre-service teachers were pursuing their

Figure1

Quasi-experiment Procedures



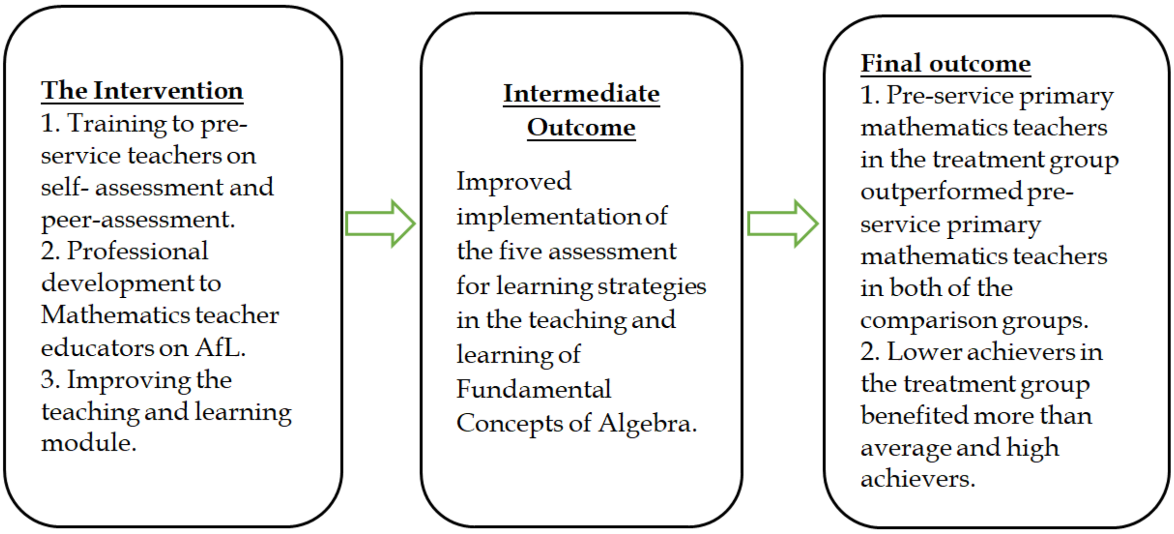
diploma programs, which take three years to finish, at these colleges. The researchers got permission to conduct the research from the three colleges and the participating pre-service teachers were told that they could withdraw from the research at any time if they wanted to. Moreover, the researchers got the consent of the three mathematics teacher educators who were involved in the intervention, and they were told that they could withdraw from participating in the research at any time. Pre-service teachers in the treatment group were divided into three achiever levels (low achiever, average achiever, and high achiever) based on their pretest scores so as to identify which of the three achiever levels will benefit more from the intervention. Pre-service teachers who scored approximately one standard deviation below the mean score were leveled as low achievers, and those who scored approximately one standard deviation above the mean score were leveled as high achievers. The remaining pre-service teachers were leveled as average achievers. As a result, the 52 pre-service teachers in the treatment group were categorized into three groups: low achievers (n = 19), average achievers (n = 19), and high achievers (n = 14).

2.3. Process

The comprehensive professional development was designed for the mathematics teacher educators based on information gathered from them by using semi-structured interviews about their conceptions of the nature, purpose, strategies, and principles of AfL and the challenges of its implementation. Moreover, information acquired from the three teacher educators' classroom observations, utilizing classroom observation techniques in their application of AfL, was integrated as part of the professional development. The teaching module of the course was upgraded by adding learning objectives for each subtopic, providing summaries of important topics presented in each chapter, and incorporating new summary activities for each chapter. The pre-service teachers were trained on self-assessment and peer assessment using examples.

The pre-service teachers were also provided orientations with examples on the necessity of grasping mathematical terminologies, making mistakes as natural and common in the teaching-learning of mathematics, and learning from errors is extremely essential. Besides, pre-service teachers were oriented on the necessity of responding to questions (both oral and text) and asking questions in the teaching-learning of mathematics. For the improvement of implementations of the five AfL strategies identified by Siobhan et al. (2005), mathematics teacher educators made classroom observations of one another once every two weeks, and they provided feedback and scaffolding to one another on how to enhance implementations of AfL practices. They were trained on how they can improve implementing AfL strategies in the teaching and learning of algebra course using examples. They were provided with multiple ways of clarifying learning intentions of subtopics under discussion, identifying possible misconceptions and difficulties from research findings and from their experiences in teaching the course, designing appropriate oral questions and class activities, and providing quality and constructive feedback to the pre-service teachers, taking into account their strengths and gaps, encouraging them to assess themselves and their peers based on learning intentions by giving and receiving quality feedback. They were also encouraged to observe one another's classes using a classroom observation protocol that helps rate implementations of the five strategies of AfL in a single classroom period, reflect, give feedback, and scaffold each other on possible ways of improving the implementation of AfL strategies. Intervention process is as presented in Figure 2.

Figure 2
Visual illustration of the intervention



2.4. Instrument

Fundamental Concepts of Algebra course is a second-year course provided to pre-service primary teachers in the first semester. The course contains six chapters, which are: 1. Elementary Mathematical Logic; 2. Theory of Sets/Set Theory/; 3. Algebraic Structure; 4. The System of Integers; 5. Elementary Theory of Numbers; and 6. The Rational Numbers. Pre- and post-tests were conducted using an achievement test with 11 HOTs questions specifically designed for this study. The achievement test was self-developed in consultation with the three mathematics teacher educators who were engaged in the research as implementers of the intervention.

Initially, a proportional number of particular objectives from each chapter were selected, action verbs were identified, and matching questions were designed to be included in the achievement exam. The exam was validated by other experienced mathematics teacher educators and their recommendations regarding the difficulty index of the items, content validity, and face validity were considered in constructing the test. The exam was first pilot tested on thirty-five third-year pre-service primary mathematics teachers, and two items that were not answered correctly by all pre-service teachers were amended. The redesigned achievement exam was again pilot tested on thirty-six third-year pre-service primary mathematics teachers in another college, and the reliability of the test was evaluated using the Kuder-Richardson 20 (KR-20) test. The KR-20 score was found to be .73, which implies adequate internal consistency for the test within the sample (McCowan & McCowan, 1999).

The difficulty index (the proportion of pre-service teachers who answered the item correctly) of the achievement test was computed, and the difficulty index of each of the items was between .28 and .80, with an average value of .54, which suggests that each of the items was neither very difficult nor very easy, and is in an acceptable range. Besides, the discrimination indices of each of the items were computed and the results varied from .20 to .80, with an average value of .43, suggesting that each of the items was in the permissible range of the discrimination index (McCowan & McCowan, 1999). Item-total correlations also revealed an appropriate range of acceptable relationships (see Appendix 1 for the test items).

2.5. Data Collection

An achievement test that was primarily designed for this research to measure pre-service teachers' HOTs in algebra was used as a pre-test and a post-test to examine the effect of AfL practices implemented by mathematics teacher educators and their pre-service teachers in the three groups. In the first week of January 2021, the beginning of the semester, a pre-test was conducted for all second-year pre-service primary mathematics teachers in each of the three groups. In addition, after April 2021, at the conclusion of the semester, the post-intervention exam was administered to all second-year pre-service primary mathematics teachers in each of the three groups.

2.6. Data Analysis

A one-way ANOVA was conducted to assess if there was a statistically significant difference in the HOTs of the pre-service primary mathematics teachers on algebra among the three groups and among the three achiever levels in the treatment group. The assumptions of ANOVA were confirmed to be satisfied before starting to examine the data using SPSS version 20. The HOTs test scores of the three groups are independent of one another, as the three TECs are at least 200 km apart, and no one knows what was done elsewhere. The normality of the dependent variable was evaluated by Skewness and Kurtosis using SPSS, and the findings revealed that the data is approximately normally distributed for each group (the values of both Skewness-1 and 1, and Kurtosis were between-2 and 2). The homogeneity of variance was also verified by Levene's test, and it was discovered that the assumption was not violated ($p >.05$) for each case.

3. Results

A one-way ANOVA was conducted to examine whether or not there was a significant mean difference in the HOTs scores among the three groups before and after the intervention. The result showed that there was no statistically significant mean difference in the HOTs scores of pre-service primary mathematics teachers in algebra in the three groups before the intervention ($p > .05$).

The result also showed that there was a statistically significant mean difference among the three groups on their HOTs after the intervention, [(F(2, 126) = 34.89, $p < .05$, η = .36)]. The score of the treatment group (M = 3.95; SD = 1.66) is significantly higher than the scores of comparison group one (M = 3.95; SD = 1.66) and comparison group two (M = 4.33; SD = 1.71) (see Table 1 and Table 2).

The post-hoc analysis also showed that there was a statistically significant mean difference in their HOTs after the intervention between the treatment group and the two comparison groups ($p < .05$) and there was no statistically significant mean difference in their HOTs after the intervention between the two comparison groups $p > .05$ (see Table 1 and Table 2).

Table 1
Descriptive statistics of HOT skills scores of the three groups before and after the intervention

Groups		*HOTs Before Intervention*		*HOTs After Intervention*	
	N	M	SD	M	SD
Treatment group	52	2.44	1.55	6.58	1.56
Comparison group one	38	2.74	1.83	3.95	1.66
Comparison group two	39	3.08	1.86	4.33	1.71
Total	129	2.72	1.74	5.12	2.02

Note. M: mean; SD: Standard Deviation

Table 2
One-way ANOVA summary table of measures of HOTs scores of the three groups after the intervention

Source	*df*	*SS*	*MS*	*F*	*p*
HOT Scores before intervention					
Between Groups	2	8.98	4.49	1.50	.22
Within Groups	126	376.96	2.99		
Total	128	385.95			
HOT Scores after intervention					
Between Groups	2	186.76	93.38	34.89	.00
Within Groups	126	337.25	2.67		
Total	128	524.01			

Note. SS: Sum of Squares; MS: Mean Square

A one-way ANOVA was also conducted to examine whether there was a significant mean difference among the achiever levels of pre-service primary mathematics teachers in the treatment group on their HOTs in algebra before and after the intervention. The result showed that there was a statistically significant mean difference among the three achiever level groups of pre-service primary mathematics teachers on their scores of HOTs [$F(2, 49) = 20.52$, $p < .05$] before the intervention. The post-hoc result also showed that the higher achiever group significantly outperformed both average achievers and lower achiever groups in HOTs scores. Besides, the post-hoc result showed that lower achievers were significantly outperformed by average achievers in HOTs scores (see Table 3).

Moreover, the result of one-way ANOVA showed that there was no significant mean difference among achiever levels on their scores of HOTs [($F(2, 49) = 0.59$, $p > .05$] in algebra after the intervention (see Table 4).

Table 3
Descriptive statistics and HOTs scores of the three achiever levels before and after the intervention

Groups		*HOTs Before intervention*			*HOTs After intervention*	
	N	M	SD	N	M	SD
Low Achiever	19	1.37	0.96	19	6.74	1.63
Average Achiever	19	2.37	1.12	19	6.26	1.70
High Achiever	14	4.00	1.47	14	6.79	1.31
Total	52	2.44	1.55	52	6.58	1.56

Note. M: mean; SD: Standard Deviation

Table 4
One-way ANOVA summary table of measures of HOTs scores of the three achiever levels before and after the intervention of the treatment group

Source	*df*	*SS*	*MS*	*F*	*p*
HOT Scores before intervention					
Between Groups	2	55.985	27.992	20.52	.00
Within Groups	49	66.842	1.364		
Total	51	122.827			
HOT Scores after intervention					
Between Groups	2	2.967	1.483	0.59	.55
Within Groups	49	121.726	2.484		
Total	51	124.692			

Note. SS: Sum of Squares; MS: Mean Square

4. Discussion

The primary goal of this study was to look at how job-embedded, context-specific, and content-based comprehensive professional development to mathematics Teacher Educators and training to pre-service teachers on AfL at a teacher education institution affects pre-service primary school mathematics teachers' HOTs in algebra. A one-way ANOVA result revealed that there was no statistically significant mean difference in HOTs scores among achiever levels in the intervention group, despite a substantial mean difference in HOTs scores between each pair of achiever levels before intervention. This study partially supports Black and Wiliam's (2010) thesis that, while AfL can assist all students, it is especially advantageous to low achievers because it focuses on specific flaws in their work and gives them a clear understanding of what is wrong and how to remedy it. This result indicates that AfL narrowed the HOTs differences between achiever group levels. Furthermore, compared to average and high achievers, this study offered empirical data on the influence of a job-embedded context-specific and content-based professional program on low achiever pre-service primary teachers' HOTs in algebra. This study also adds to the body of empirical evidence on the influence of enhanced implementation of AfL strategies in TECs on pre-service teachers' HOTs on three achiever levels.

Furthermore, a one-way ANOVA was conducted to see if there was a statistically significant mean difference in the HOTs between the treatment and comparison groups, and between the three achiever level groups within the treatment group. The study's findings show that pre-service primary mathematics teachers in the treatment group outperformed both pre-service primary mathematics teachers in the two comparison groups for their HOTs of Fundamental Concepts of Algebra after the intervention, even though there was no statistically significant mean difference in their HOTs before the intervention. The results also revealed that there was no statistically significant difference in HOTs in the Fundamental Concepts of Algebra course between the two comparison groups. The results of the research are in agreement with the results of the research findings of Moyo et al. (2022) that revealed a significant positive effect of implementing AfL on grade four students' achievements in higher order thinking skills in mathematics.

When discussing each subtopic with their pupils, the teacher educators who were involved in the professional development were observed to be better at clarifying learning aims for their pre-service teachers. The professional development also assisted them in developing successful classroom discussions, questions, and learning activities that elicit evidence of pre-service teachers' HOTs, identify pre-service teachers' misconceptions and difficulties, and give constructive feedback to both individual pre-service teachers and groups, so moving learners ahead as Andersson and Palm (2017a) argued. Furthermore, the pre-service primary mathematics teachers in the intervention group were found to have been better at understanding the learning intents of each subtopic, learning from their own and their colleagues' errors, and assessing themselves and their peers. In general, the teacher educators involved in the professional development were better at identifying gaps, challenges, misunderstandings, and strengths in their pre-service teachers and using these to enhance teaching-learning. It was also revealed that pre-service mathematics teachers in the intervention group were observed to demonstrate improvement in self-regulating their learning and learning through interactions with the teaching and learning material, mathematics teacher educators, and their peers.

The improvement of the course's teaching-learning module allowed teacher educators to easily discuss and clarify learning intentions (objectives) with their pre-service teachers, as well as select appropriate problems for class activities. Furthermore, the summaries offered assisted pre-service teachers in determining if they had comprehended the key concepts and ideas addressed in each chapter. Pre-service mathematics teachers also utilized the module as a quick reference for what they should expect in each of the subtopics of the chapters. Furthermore, training pre-service teachers in self-assessment and peer assessment provided them with the chance to evaluate their own and their peers' work based on learning intentions, as well as to offer and receive quality and constructive feedback and scaffolding.

The findings of this study showed that improved practices of implementation of AfL strategies by mathematics teacher educators and pre-service primary mathematics teachers improved pre-service mathematics teachers' HOTs in fundamental concepts of algebra, and these are consistent with the research findings by Andersson and Palm (2017b); Chemeli (2019); and Kyaruzi et al. (2019), which show that implementation of AfL strategies in primary and secondary schools can improve achievement.

The study also found that the comprehensive professional development program provided mathematics teacher educators and pre-service primary mathematics teachers with enough support to implement AfL in the classroom teaching and learning of algebra in a randomly selected TEC, resulting in a statistically significant positive effect on pre-service teachers' HOTs in Fundamental Concepts of Algebra.

5. Limitations

The absence of existing research on the impact of AfL on students' HOTs in mathematics in general and in algebra in particular is one of the study's weaknesses. Additionally, there is a dearth of evidence on how AfL affects math HOTs for students who perform below average compared to average and high achievers. Additionally, although though ANCOVA is the proper analysis method in this study, ANOVA is used to compare the groups because just one of ANCOVA's assumptions was violated while none of ANOVA's assumptions were. Additionally, the test that measured pre-service teachers' HOTs in mathematics was developed using multiple choice questions rather than workout items. This decision may have had an impact because pre-service teachers are able to guess their way to the correct response to a question.

6. Conclusion and Recommendations

Mathematics teacher educators' and pre-service primary mathematics teachers' enhanced implementation of AfL strategies have a positive effect on pre-service teachers' HOTs in algebra. After enhanced implementations of AfL techniques, there was a positive significant mean difference in HOTs in Fundamental Concepts of Algebra between the treatment group and the two comparison groups. The teaching-learning module was improved, and the pre-service teachers were trained on how to use self-assessment and peer-assessment. This intervention improved pre-service teachers' awareness of the learning intentions in each subtopic of the course; collaboration with their friends; class participation; and learning from their own mistakes. Professional development on AfL that was integrated into the job, as context relevant and subject-focused, as well as follow-up feedback and scaffolding, assisted mathematics teacher educators in successfully implementing AfL in an algebra course.

The results of this research provide mathematics teacher educators, curriculum developers, and policymakers significant insight into the need to enhance implementations of AfL techniques in teacher education institutions. According to the findings, mathematics teacher educators should be provided job-embedded, context-specific, and content-based comprehensive professional development on AfL to improve the implementation of the AfL strategies and improve the preparation of initial primary mathematics teachers. A quasi experimental research on the influence of AfL on other mathematics courses on pre-service teachers' higher order thinking is also suggested as a research topic for further study.

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Appendix 1. The achievement test

I. For each of the questions choose the correct answer from the given alternatives and put the letter of your choice on the space provided.

______1. Which of the following propositions is *false* if the universe is $\mathbb{R}$?
A) $(\forall x)(x \leq x^3)$ B) $(\exists x)(2x \geq 4x)$ C) $(\exists x)(x^4 < 1)$ D) $(\forall x)(1 > -x^2)$

______2. Which of the following argument is valid?
A) $p, q \Rightarrow \neg p \vdash q$ B) $p \vee q \vdash p \wedge q$ C) $p \wedge q \vdash p \Rightarrow q$ D) $p \Rightarrow q \vdash p \wedge q$

______3. If $A \subseteq B$ and $B \subset C$ where A, B and C are sets which of the following relations is ***false***?
A) $C \subseteq A \cup B$ B) $A \cup B \subset C$ C) $A \cap B = A$ D) $A \cup B = B$

______4. Which of the following relations is true for any sets A, B if $A \subset B$?
A) $A \triangle B = \emptyset$ B) $B - (B - A) = A$ C) $A \triangle B = A - B$ D) $A \cap (A \triangle B) = A$

______5. Which of the following total orderings is a well ordering, where $\leq$ is the usual less than or equal to relation?
A) $(\mathbb{R}, \leq)$ B) $(\mathbb{Q}, \leq)$ C) $(\mathbb{N}, \leq)$ D) $(\mathbb{Z}, \leq)$

______6. Which of the following functions is the inverse of $f(x) = x^3 - 4$?
A) $g(x) = \sqrt[3]{x+4}$ B) $g(x) = \sqrt[3]{x-4}$ C) $g(x) = x^3 + 4$ D) $g(x) = \frac{x+4}{3}$

______7. Which one of the following homomorphisms is not an Isomorphism?
A) $f: (\mathbb{R}, +) \longrightarrow (\mathbb{R}^+, \times)$, defined by $f(x) = 2^x$ B) $f: (\mathbb{Z}, +) \longrightarrow (5\mathbb{Z}, +)$defined by $f(x) = 5x$
C) $f: (\mathbb{R}, +) \longrightarrow (\mathbb{R}^+, \times)$, defined by $f(x) = 3^{-x}$ D) $f: (\mathbb{Z}, +) \longrightarrow (\mathbb{R}, +)$ defined by $f(x) = x$

______8. Which of the following sets with the usual multiplication operation, •,is a group?
A) $(\mathbb{R}^-, \bullet)$ B) $(\mathbb{Z}^+, \bullet)$ C) $(\mathbb{Z}, \bullet)$ D) $(\mathbb{Q}^+, \bullet)$

______9. Which of the following rings is an integral domain?
A) $(\mathbb{Z}_6, \oplus_6, \odot_6)$ B) $(\mathbb{Z}_7, \oplus_7, \odot_7)$ C) $(\mathbb{Z}_8, \oplus_8, \odot_8)$ D) $(\mathbb{Z}_9, \oplus_9, \odot_9)$

______10. Which of the following integral domains are Ordered Integral domains?
A) $(\mathbb{Z}_{17}, \oplus_{17}, \odot_{17})$ B) $(\mathbb{Z}_5, \oplus_5, \odot_5)$ C) $(\mathbb{Z}_{11} \oplus_{11}, \odot_{11})$ D) $(3\mathbb{Z}, +, \bullet)$
______11. If the GCD of a and $b = (a, b) = p$, a prime, what is the values of (a^5, b^3)?
A) p B) p^2 C) p^3 D) p^5