

The effect of assessment for learning on prospective teachers' learning of algebra through a professional development program

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ABSTRACT

Three mathematics teacher educators who were assigned to teach fundamental concepts of algebra course in a teacher education college, as well as their prospective elementary mathematics teachers who took the course, took part in a job-embedded, context-specific, and content-based comprehensive professional development (PD) program on assessment for learning (AfL). Three teacher educators and 129 prospective elementary mathematics teachers from three teacher education colleges took part in the study. The findings demonstrated that prospective elementary mathematics teachers in the intervention group significantly outperformed prospective teachers in both of the comparative groups in their post-test scores in algebra. Furthermore, it was found out that after the intervention, there was no statistically significant mean difference among achiever levels in the treatment group on post-test scores, despite a statistically significant mean difference among achiever levels in their pre-test scores. This research adds to our knowledge of the impact of comprehensive, job-embedded, context-specific, and content-based PD on prospective teachers' achievements in algebra in elementary school mathematics teacher education. Implications of implementing AfL as well as recommendations for further research are highlighted.

Keywords: assessment for learning, professional development, algebra, achievement

INTRODUCTION

Background

Mathematics is a very important field of study that plays a significant role in almost every field of study by giving hand in understanding the natural and social world we live in. Learning mathematics improves critical thinking, logical reasoning, rational decision-making abilities, and problem-solving skills, which are very crucial in the contemporary world of information, communication, and technology (Ferretti et al., 2018). There is a general consensus among educational experts (DeLuca et al., 2018; Gebremeskel et al., 2018) that pre-service teachers, during their study, need to have the necessary subject matter knowledge, general pedagogical knowledge, pedagogical content knowledge specific to their subject matter, practical experiences in how to deliver the subject matter to their students in an appropriate way, and theoretical and practical assessment experiences to be able to improve their future students' learning.

Preparing well qualified initial primary mathematics teachers is of utmost importance for any country that aspires to improve quality of education in primary schools. In recent years, initial primary school mathematics teacher education is given much attention globally due to its significance and impact to childhood development (Alex & Roberts, 2019; Blackley & Howell, 2015), a matter of interest to us to enter the field of the initial training of teachers who teach mathematics in primary school (Guérios & Gonçalves, 2019), and is vital because adequately-prepared teachers positively add to student performance, school effectiveness, and the efficiency of an entire system of education in a country (Tasdemir et al., 2020).

Algebra has been acknowledged as a crucial part in students' mathematics learning and much emphasis has been given to address students' challenges and difficulties in learning algebra (Wang, 2015). As one of the complex subjects, algebra is dominated by abstract concepts and has evolved over many centuries in the history of mathematics (Hodgen et al., 2018). Numerous students in various levels fail to understand fundamental concepts and principles of algebra even though they try hard, and the problem is longstanding (Cousins-Cooper et al., 2017; Kanbir et al., 2018). The teaching learning of algebraic concepts are common problems for teachers and students alike. Teachers struggle to find and use best methods to teach algebra and students struggle to learn concepts of algebra (Cousins-Cooper et al., 2017; Garzón & Bautista, 2018), and the teaching learning of algebra is difficult because of the abstract nature of the subject and variety of symbols used in the teaching learning of concepts, procedures, and problem-solving strategies (Cousins-Cooper et al., 2017; Ferretti et al., 2018). Nonetheless, improving students learning needs the use of evidence based instructional strategies and teachers are expected to have deep understanding of the content knowledge of algebraic concepts and features of interventions in the teaching learning of

algebra (Cousins-Cooper et al., 2017; Lee et al., 2020); and providing opportunities for prospective mathematics teachers and their educators to better understand challenges in learning mathematics courses helps inform classroom instruction and become successful irrespective of the scope of the intervention (Stewart & Reeder, 2017). Hence, equipping prospective elementary mathematics teachers with the necessary knowledge of algebra through innovative instructional methods is of vital importance.

A weak background of understanding of algebraic concepts and procedural skills of college students is a source of significant struggle in solving mathematical problems. To support students in learning algebra, assessment for learning (AfL) is recommended (Stewart & Reeder, 2017). AfL has been found to dramatically improve student achievement, however there is a scarcity of research on how to best support teachers in implementing this practice (Andersson & Palm, 2018). AfL has been defined by different scholars differently and often in an overlapping way. Although Bennett (2011) argued that the term formative assessment (FA) does not represent a well-defined set of practices and artifacts other researchers and educators' emphasis the overlapping nature of the definitions given by various scholars. Black and Wiliam (2009) defined FA, as follows:

Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited.

Similarly, Wiliam and Thompson (2007) stated, AfL can be conceptualized as practices consisting of the following five key strategies:

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

AfL can also be considered as a set of elements (questioning, self-assessment, peer-assessment, quality formative feedback, and reflection) that helps in eliciting students' responses, interpreting their responses and based on the evidence adjusting classroom instruction and improve students learning. As an element of AfL, developing items (questions) aligned with specified competencies is critical to assess the learners, track their progression and gain sufficient information. Peer assessment helps students learn from each other by assessing each other's works and it also empowers students by helping them to become responsible, autonomous reflective learners. Likewise, self-assessment helps students to regulate their own learning and get motivated by identifying their own strengths and weaknesses (Fisseha & Michael, 2016).

In addition, formative feedback, which is a process through which students enhance their work and learning strategies by making sense of information from their teacher and their peers (Carless & Boud, 2018) also plays a crucial role in improving students learning and hence students need to be trained on how to receive feedback from their teachers and peers and give quality formative feedback to their peers (Andrade & Brookhart, 2016) that will be adapted later when they teach at schools. Developing reflective character is essentially important as it helps both teachers and teacher educators to develop learning behaviors of reflecting one's own experiences and from feedback they gain from others.

Researchers and educators generally acknowledged that classroom assessment practices of teachers lag behind the contemporary research base especially in AfL. Some of the reasons for this discrepancy are the conservative nature of culture of schools and absence of appropriate professional development (PD) in AfL. Besides, even though AfL is emerging as a crucial component of effective and successful educational institutions, working teachers tend to have simple and usually shallow understanding of how to properly implement these strategies and practices in their classrooms (Deluca & Volante, 2016).

In their study of the Implementation of AfL in writing classes in one of the 12 teacher education colleges of Oromia Region, Yiheyis and Getachew (2014) found out that more of quantitative feedbacks were given to prospective teachers by their English lecturers. Moreover, continuous assessments were found to be used for diagnostic purposes rarely and students were given less chance to check their progress of learning. Besides, a high emphasis of summative assessment over FA was observed and both self and peer assessments strategies were poorly utilized. Although initial teacher education is believed to have significant impact on teachers' approaches to assessment especially in the equitable treatment of students in classroom assessment (Coombs et al., 2018), most teachers are not given adequate direct instruction that can help become assessment competent teachers since educational study courses minimally address AfL concepts (Deluca & Volante, 2016).

In their studies of challenges and prospects in implementing AfL in three universities found in north Ethiopia, Teklebrhan and Samuel (2015) found out that implementation of AfL is very poor and both instructors and students were found to have poor knowledge about and negative attitude towards AfL. Similarly, Sintayehu and Ashenafi (2017) in their investigations of challenges in implementing AfL in a Southeastern university of the country found out that instructors' negative attitude for AfL, gaps in implementing AfL appropriately by instructors and using AfL results for grading purpose were major challenges related to instructors. In addition, lack of professional support on AfL to instructors, students' unwillingness to use AfL strategies and their cheating habits were found to be challenge in implementing AfL appropriately.

Teacher educators' understandings about teaching, learning, assessment and how they respond to prospective teachers' questions, dilemmas and previous experiences have huge power to shape prospective teachers and support in reshaping their previous conceptions of teaching, learning and assessment which may not necessarily reflect best practices of today's teaching learning practices (DeLuca et al., 2018). Likewise, when prospective teachers experience AfL practices in teacher education colleges, consistently and effectively, they are more likely to integrate AfL at ease in their instruction and improve their future students' learning and hence contribute to the development of AfL culture in their schools (Deluca & Volante, 2016).

Considerable research has been conducted in primary, upper primary, and secondary schools that focused on PD in AfL to mathematics teachers and the impact on students' mathematics achievements. Andersson and Palm (2017) conducted a quasi-experimental research to examine the effects of implementing combinations of FA strategies in mathematics lessons on year four students to investigate if it enhances achievements in mathematics after the teachers participated in a PD program that took six hours a week training and a total of 144 hours in Sweden. The PD consisted of lectures on the meaning, importance, and examples of practical activities of FA. The result of the study showed that the achievements of students whose teachers participated in the intervention was significantly higher than those students whose teachers were in the control group with ($p=.036$ and $d=.66$) after controlling their scores in the pre-test.

Chemeli (2019) also conducted a research on the impact of implementations of the five key AfL strategies noted above on secondary school students' achievement in mathematics in Kenya using pre-test post-test quasi-experimental method intervention design, and the study enlisted the participation of 534 students and 33 teachers, with 227 students and 15 teachers in the experimental group and 307 students and 18 teachers in the control groups. Both groups were taught same topic in mathematics for duration of six weeks with experimental group taught using the five key AfL strategies, while the control group was taught using the commonly used methods. Pre- and post-tests were administered to both groups and data were collected using student mathematics achievement test (SMAT). The data were analyzed using independent samples t-test, and the findings from the study revealed that there was a positive impact on learners' achievement ($p=0.000 < 0.05$ and $t=14.82$).

Berg et al. (2018) also conducted a quasi-experimental research to test the effectiveness of implementations of AfL in Dutch primary mathematics education on students' achievements. In the intervention group, 17 teachers used an AfL model that included daily and weekly goal-directed instruction, evaluation, and quick instructional feedback for children who required it. In the control condition, 17 teachers made a change to their normal routine. They used half-yearly mathematics assessments to measure their pupils' knowledge of learning goals, and they planned weekly pre-teaching sessions for groups of low-achieving kids. After controlling for student and teacher characteristics, the post-tests revealed no significant changes in student performance between the two circumstances. The degree to which the AfL model was implemented, on the other hand, appeared to be favorably associated to the performance of 5th-grade children.

The act of teaching requires deliberate interventions to ensure that the student's cognitive change is achieved. In this regard an experienced teacher who is familiar with a variety of learning strategies to provide the student when they don't seem to understand, to provide direction and re-direction in terms of the content being understood maximizes the power of feedback, and to "get out of the way" when learning is progressing toward the success criteria (Hattie, 2008).

Teacher education should provide prospective teachers with an opportunity to critically question their assessment related experiences and understandings using contemporary assessment principles, theories, and strategies so as to help them become good assessors for their future students. In order to fulfil this important role, implementation of AfL in the teaching learning of mathematic courses is expected to provide prospective Mathematics teachers with real life experiences on how it is implemented and how it benefits. As Deluca and Volante, (2016) stated, prospective teachers may not be experiencing effective assessment driven culture of teaching learning and lack of this experiential knowledge may lead them to have a negative view on assessment and this in turn may lead them to use practices that they are familiar only rather than a more up to date and formative conception of assessment.

As Deluca Chapman-Chin and Klinger (2019) argued, in order to support mathematics teacher educators' integrations of AfL strategies in their instruction, it is vital to identify constraints that hinder the spirit of AfL and their conceptions and implementation levels in their classrooms. Besides, it was argued that job-embedded, context specific and content-based teacher professional learning is particularly important for addressing different needs of students and teachers in various settings (Darling-Hammond et al., 2017).

Hamodi et al. (2017) in their turn argued the importance of integrating AfL within teacher education programs. They noted repeating themes as essential contributors that may have an impact on local teacher education programs and their relations with assessing temporal, programmatic, and institutional restrictions. Their key assumption underpins this argument: when pre-service teachers are exposed to AfL in a consistent and effective manner, they are more likely to instill an AfL spirit in their own classrooms. As a result, AfL integration will not only enhance pre-service teacher's learning throughout initial teacher education programs, but it may also extend to K-12 student learning across educational systems.

Teacher educators, in colleges of teacher education (CTEs) in Ethiopia, continue to implement a lecture method when teaching their in-service and pre-service teacher education students (Alemu et al., 2021). Besides, Geberew and Tigist (2018) emphasized that very little has been known about AfL, assessment as learning and assessment of learning in Ethiopian context and it is not clear how and when these assessments are used across different levels in the teaching learning process. To strengthen the global arguments on the role of AfL in instruction, further research is recommended on the impact of PD on AfL and approaches in implementation of AfL in different levels and contexts (Burton et al., 2018). This emanated from the importance of AfL for enhancing learning and learning progression. Hence, is a research on the effect of AfL is conducted it could help either reveal or entrench learning on its effect on the PD of pre-service teachers that is going to have impact later at schools.

Aim

The research described in this article is part of a PhD study that aimed at examining a comprehensive, job embedded, context specific and content-based PD program on AfL to mathematics teacher educators and pre-service elementary mathematics teachers and the effect on students' achievements in algebra, their self-regulated learning skills, and implementations of AfL. This paper dwells on the effect on prospective teachers' learning of algebra through a PD program of AfL. The main aim of this study was to investigate the following research questions:

1. Is there a significant mean difference in the achievements on fundamental concepts of algebra course among pre-service elementary mathematics teacher groups?

2. Is there a significant mean difference in the achievements on fundamental concepts of algebra course among the achiever levels of pre-service elementary mathematics teachers in the treatment group?

Theoretical Framework

AfL is an important part of classroom teaching learning process, and its proper implementation can enhance learners' achievement standards, according to a growing body of research results. There is no other means to raise standards for which such a compelling case can be made (Black & Wiliam, 2010). AfL practices are largely collaborative supported with realtime feedback and cooperation. For this reason, this research was guided by sociocultural theory of learning. Vygotsky's theory is well-known in the mathematics education field. According to this theory, a student's intellect develops as a result of social contact in the world, speech, social interaction, and cooperative activity are all significant parts of this social world (Cottrill, 2003). Sociocultural theory of learning regard teacher development as altering engagement in social behaviors that develop their professional identities. Most sociocultural research on mathematics teacher education has focused on studying teachers' learning, although sociocultural views can also be used to inform intervention research that involves modifying classroom practice (Goos, 2013). Endorsing sociocultural theory as the most fruitful learning theory enables 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 related directly to common learning obstacles are also required, particularly to answer the crucial issue 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 design interventions that address equity in educational contexts. They enable to think about what's at stake for students when they put new knowledge or skills into practice in a specific setting (Shepard et al., 2018). Goos (2013) also argued that sociocultural approaches on mathematics teacher research can be valuable for both understanding and encouraging teacher learning. Learning is viewed from this perspective as participation in social processes that help instructors create their professional identities and impact the development of same on the pre-service teachers.

RESEARCH METHODOLOGY

Research Design

In this research groups were assigned as intervention and comparison groups where the intervention group pursues PD guided by sociocultural theory. Accordingly, a quasi-experimental research design was used. The quasi-experimental design was used since the researchers used intact sections in three different teacher education colleges. The research also employed a pre- and post-test since the intention was to examine the effect of an intervention by controlling pre-service teachers' prior achievements in algebra.

Population, Study Group, and Sampling Techniques

Population of the study was all second-year pre-service elementary mathematics teachers in teacher education colleges of Amhara Regional State, Ethiopia. The study groups were second year pre-service elementary mathematics teachers who were learning in the three teacher education colleges, which were selected randomly using a lottery method from the ten colleges available in Amhara Regional State, Ethiopia. A treatment group was selected randomly using a lottery method from the three selected colleges and the remaining two colleges were assigned as comparison groups. Two comparison groups were used to help control potential contextual factors and replicate the traditional way of teaching with the intent of ensuring consistency of observed results. Since the teacher education is guided by a fixed curricula, inclusion of professional development on AfL which is less likely to be incorporated in the usual practice was hypothesized to empower pre-service teachers and their teacher educators, as a consequence help both to gain better in the ir practices and the learning chievement of pre-service teachers.

Three mathematics teacher educators who were teaching fundamental concepts of algebra course in the selected college participated in the PD program that lasted for twelve weeks guided by sociocultural theory. The theory guides the social interactions, in this case interactions among the three teacher educators, and the mentors, in this case one of the authors of the study and the roles they perform. In addition, the pre-service teachers and the teacher educators perform the PD program through co-developmental social interaction. The PD was designed for a semester long duration which is 12 weeks, with the remaining weeks for testing and gathering of reflections. A total of 129 pre-service elementary mathematics teachers (52 in the treatment group, 38 in the first comparison group, and 39 in the second comparison group) participated in the research. The pre-service teachers were attending their diploma program, which takes three years to complete, in these colleges.

The Intervention

The comprehensive PD was designed for three mathematics teacher educators based on information gathered from them using semi-structured interviews about their conceptions of the nature, purpose, strategies, and principles of AfL and challenges of its implementation. Moreover, information gathered from the three teacher educators' classroom observations using classroom observation protocol in their implementation of AfL was incorporated in the PD. The teaching module of the course was improved by incorporating learning objectives of each subtopic, including summaries of main concepts discussed in each chapter and incorporating additional summary exercises for each chapter. Pre-service teachers were trained on self-assessment and peer assessment supported by tools for continuous monitoring and follow-up.

The pre-service teachers were also given orientations with examples on the importance of understanding mathematical definitions, making mistakes as natural and common practices in the teaching learning of mathematics, and learning from errors as very important. Besides, pre-service teachers were oriented about the importance of responding to questions (both oral and text) and asking questions

in the teaching learning of mathematics. To observe the improvement of implementations of AfL strategies and provision of scaffolding to mathematics teacher educators, classroom observation was conducted once every two weeks. Teacher educators were given feedbacks on how to improve implementations of AfL strategies. They were provided with multiple ways of clarifying learning intentions of subtopics underdiscussion and identifying possible misconceptions and difficulties. They were also supported with inputs from research finding and from their experiences in teaching the course how to design appropriate oral questions and class activities. Provided were also ways of quality and constructive feedback to their students taking in to account their students' strengthes and gaps, encouraging their students to assess themselves and their peers based on learning intentions and by giving and receiving quality feedbacks. They were also encouraged to observe one another's classes using a classroom observation protocol that helps them to rate implementations of the five strategies of AfL in a single classroom period, reflect to each other and give feedback by scaffolding to each other on possible ways of improving the implementation of AfL strategies.

Instrument Used, Reliability, and Validity

Fundamental concepts of algebra course are a second-year course given to pre-service elementary teachers in the first semester. The course comprises of six chapters are, as follows:

1. Elementary mathematical logic
2. Theory of sets/set theory
3. Algebraic structure
4. The system of integers
5. Elementary theory of numbers
6. The rational numbers

An achievement test, specially prepared for the research was used as a pre- and a post-test. The achievement test was prepared by one of the researchers in collaboration with the three mathematics teacher educators who were involved in the research as implementers of the intervention and the co-researchers.

Initially, proportional number of specific objectives from each chapter were selected and corresponding questions were developed to be included in the achievement test. The test was a two-tier type with multiple choice items and elaborating reasons for the answers. These were developed based on the established action verbs. The test was validated by experienced mathematics teacher educators working at Addis Ababa University and Dessie College of Teacher Education who are professional teacher educators and their comments regarding difficulty levels of the items, content validity and face validity were incorporated in preparing the test. The test was pilot tested on 35 third year pre-service elementary mathematics teachers who already took the course and two items that were not answered correctly by all pre-service teachers were modified. The modified achievement test was again pilot tested on 36 third year pre-service elementary mathematics teachers in another college and the reliability of the test was checked using Kuder-Richardson 20, KR-20 test. The KR-20 value was found to be 0.73, which suggests acceptable internal consistency for the test within the sample.

The difficulty level of the achievement test was also calculated and the difficulty levels of each of the 22 items were between 0.28 and 0.80 with the average value 0.535, which indicates that each of the items were neither very difficult not very easy, nor are in acceptable range. Besides, the discrimination indexes of each of the 22 items were calculated and the results ranged from 0.20 to 0.80, with average value of 0.43, which means that each of the items were in the acceptable range of discrimination index. Item-total correlations also indicated acceptable range of associations.

Procedure of Data Collection

An achievement test that was primarily designed for this research was used as a pre- and a post-test to measure the achievements of pre-service teachers in the three groups so as to study the effect of AfL practices implemented by Mathematics teacher educators and their students in the three groups. In the first week of January 2021, the beginning of the semester, pre-test was administered to all second-year pre-service elementary mathematics teachers in each of the three groups. In addition, in April 2021, at end of the semester the post-test was administered to all second-year pre-service elementary mathematics teachers in each of the three groups. Since AfL is formative in nature, observation data with the support of observation tool was also conducted every two weeks, the results of which were used to improve mathematics teacher educators and pre-service elementary mathematics teachers practices as part of the PD, to enforce the PD intervention.

Data Analysis

To examine whether there is a significant difference in the achievements of pre-service elementary mathematics teachers on algebra among the three groups, a one-way analysis of covariance (ANCOVA) was conducted. The assumptions of ANCOVA were checked before running the analysis using SPSS version 20. Achievement test results of the three groups are independent of one another, since the three teacher education colleges are at least 200 km apart. Normality of the dependent variable was checked by Skewness and Kurtosis using SPSS and the results shown that the data were approximately normally distributed for each group (the value of both Skewness and Kurtosis were between -1 and 1). Homogeneity of variance was also checked by Levene's test, and it was found that the assumption was not violated ($p=0.303>0.05$). The relationship between the covariate and the dependent variable was also found to be linear. Besides, there was no violation of assumption of homogeneity of regression slopes. Moreover, to measure effect size, partial eta squared was used. The observation data was used for the implementation of the PD and are not included as part of data analysis on this paper.

Table 1. Adjusted & unadjusted group mean & variability of achievement in algebra of three groups using pre-test as a covariate

Groups	n	Before treatment		After treatment unadjusted		After treatment adjusted	
		M	SE	M	SE	M	SE
Treatment group	52	6.87	.403	14.33	2.102	14.325	0.305
Comparative group one	38	6.39	.365	8.61	2.717	8.817	0.358
Comparative group two	39	7.31	.517	9.85	2.870	9.643	0.353

Table 2. ANCOVA for achievement in algebra of the three groups as a function of post-test using pre-test as a covariate

Source	Type III sum of squares	df	MS	F	P	η_p^2
Pre-test	208.843	3	208.843	43.310	0.000	0.257
Group	816.873	2	408.437	87.702	0.000	0.575
Error	602.755	125				

Note. R-squared=0.634 (adjusted R-squared=0.625)

Table 3. Multiple comparisons of post-hoc tests among the three groups

Dependent variable	(I)Group	(J)Group	Mean difference (I-J)	Standard error	Sig.
Post-test	Treatment group	Comparative group one	5.508	0.470	0.000
		Comparative group two	4.682	0.466	0.000
	Comparative group one	Comparative group two	-0.826	0.504	0.104

Table 4. Adjusted & unadjusted group mean & variability of achievement in algebra of 3 achiever levels using pre-test as a covariate

Groups	n	Adjusted		Unadjusted	
		M	SE	M	SE
Low achiever	19	14.158	0.480	14.16	2.167
Average achiever	19	13.947	0.480	13.95	2.321
High achiever	14	15.071	0.559	15.07	15.92

RESULTS

A one way within group and between groups ANCOVA was conducted to examine the effect on pre-service elementary mathematics teachers' achievements in algebra from improved implementation of AfL by mathematics teacher educators and pre-service elementary mathematics teachers who participated in the comprehensive PD program. The dependent variable was post-test score of pre-service teachers on algebra achievement test. The comprehensive PD program constituted the group variable (treatment group) while the two comparison groups conducted their teaching the usual was. Besides, the pre-test scores of pre-service teachers constituted the covariate of the study.

The results of one way ANCOVA after adjusting for the pre-test scores show that there was a significant mean difference in the post-test achievements among the three groups ($F[2,125]=84.702$ and $p=0.000<0.05$) and the effect size after controlling pre-test scores as a covariate was $\eta_p^2=0.575$, which is a moderate effect size. Post-hoc analysis was also conducted using Bonferroni test to determine within which pair of the three groups the significant mean difference existed. The result showed that there is a statistically significant mean difference between the treatment group ($M=14.325$) and comparison group one ($M= 8.817$) as well as between the treatment group ($M=14.325$) and comparison group two ($M=9.643$). However, there was no statistically significant mean difference in the post-test scores of comparison group one ($M=8.817$), and comparison group two ($M=9.643$) (see **Table 1**, **Table 2**, and **Table 3**).

The results of **Table 2** indicate the existence of statistically significant difference among the groups. A follow-up post-hoc test (**Table 3**), however, dissociated the groups that are significantly different.

ANCOVA within the treatment group was also conducted to examine whether there is a significant mean difference among achiever levels in their post-test scores. The result showed that there is no statistically significant mean difference on the post-test scores (lower achiever group mean=14.16, average achiever group mean=13.95, and high achiever group mean=15.07) among the three achiever levels ($F[2,49]=1.262$ and $p=0.292>0.05$) (see **Table 4** and **Table 5**).

DISCUSSION

The main aim of this study was to examine the effect of job embedded, context specific and content based comprehensive PD on AfL in a teacher education college on pre-service elementary mathematics teachers' achievements in algebra. A socio-cultural context was employed to provide access for pre-service teachers to discuss, and make reflective experiences guided by teacher educators to enable them gain from their social interaction and stage a formative nature of co-development of their professional capability. The provision of job-embedded, context-specific, and content-based comprehensive PD program on AfL was meant to build the overall learning progression and development of pre-service teachers' competence. In this regard, tests were provided to measure their changes from pre-intervention to post-intervention phases.

Table 5. ANCOVA for achievement in algebra of the three achiever levels as a function of post-test using pre-test as a covariate

Source	Type III sum of squares	df	MS	F	P	η_p^2
Intercept	10,550.730	1	10,550.730	2,411.289	0.000	0.980
Post-achievement	11.040	2	5.520	1.262	0.292	0.049
Error	214.402	49				

Note. R-squared=0.634 (adjusted R-squared=0.625)

A one-way ANCOVA was used to examine whether or not there is a statistically significant mean difference in achievement between the treatment group and the two comparison groups while controlling the effect of the pre-test as a covariate. The results of the study show that pre-service elementary mathematics teachers in the treatment group significantly outperformed both of the pre-service elementary mathematics teachers in the two comparison groups in their achievements in fundamental concepts of algebra. The result also showed that there was no statistically significant difference in achievements in fundamental concepts of algebra course between the two comparison groups. Besides, a one-way ANCOVA was used to examine whether or not there is a statistically significant mean difference in achievements among achiever levels in the treatment group, while controlling the effect of the covariate. The result of the study shows that there was no statistically significant mean difference in post-test scores of achiever levels, although there was a significant mean difference in their pre-test scores between each pair of the achiever levels. This finding agrees with the argument of Black and Wiliam (2010), which states that although AfL can benefit all students, it is especially beneficial to low achievers since it focuses on specific faults with their work and provides them with a clear grasp of what is wrong and how to fix it. Manandhar et al. (2022) in their study indicated that students were influenced and encouraged by textbooks, teachers, and learning activities to develop procedural skills, memorize formulae, and solve problems. They further noted that lack of well-trained teachers, poor management of teacher training and PD programs, a heavy number of contents, large number of students, etc., affect the implementation of students-centered approaches, though they found that students can learn mathematics concepts when they play with problems related to their day-to-day life using more contextual examples which this study tried to incorporate.

As part of the PD program classroom observation was conducted every two weeks and we learned that the PD helped teacher educators to clarify learning intentions to their students on each subtopic when discussing with their students which was continually developed through observation and discussions after conducting observation. It also helped them create effective classroom discussions, questions, and learning tasks that can elicit evidence of learning that helps identify students' difficulties and misconceptions and provide constructive feedback both for individual students and for groups that moves learners forward. Moreover, the PD helped pre-service elementary mathematics teachers to understand learning intentions of each subtopic, learn from their own errors and errors made by their peers, and assess themselves and their peers. In general, the PD helped teacher educators identify their students' gaps, difficulties, misconceptions, and strengths and use these to improve the teaching-learning. It also helped pre-service teachers to regulate their own learning and learn from the interactions they make with the materials, their teacher, and their peers.

The improvement of the teaching-learning module of the course by incorporating learning intentions (objectives) of each of the subtopics in the six chapters of the course, summary of each chapter and additional summary exercises helped teacher educators to easily discuss and clarify learning intentions (objectives) to their students and select appropriate problems for class activities. Besides, the summaries included helped pre-service teachers assess themselves whether they have grasped main ideas of the topics discussed in each chapter. Pre-service teachers also used the module to easily refer what they are expected of in each of the topics. Besides, the training of pre-service teachers on self-assessment and peer assessment gave them an opportunity on how to evaluate work of themselves and their peers based on the learning intentions and how to give and receive quality and constructive feedbacks and scaffoldings.

The results of this study, which showed that improved practices of implementations of AfL strategies by mathematics teacher educators and pre-service elementary mathematics teachers in fundamental concepts of algebra improved achievements agrees with research findings of Andersson and Palm, (2017) in which a PD to mathematics teachers of year four students on AfL that improved students' achievements in mathematics. Besides, the result of this research agrees with research findings of Chemeli (2019) in Kenya that showed the improvement of achievements of secondary school students in mathematics due to improved implementations of the five strategies of AfL in the teaching and learning of mathematics. Moreover, the result of this research agrees with the findings of research conducted by Kyaruzi et al. (2019) in Tanzania that argued improved implementations of AfL strategies in secondary schools can improve students' performances in mathematics.

Cousins-Cooper et al. (2017) also noted that students enrolled in emporium classes (that combine several instructional components such as cooperative learning, online instruction, computer-assisted instruction, and immediate feedback from instructors) outperformed students enrolled in traditional, lecture classes on post-test, and this suggests the role assessment for learning can contribute to better learning as it has the cooperative nature and provides a realtime feedback. Despite these, Darling-Hammond et al. (2017) ensured effective PD (PD) is an important strategy for ensuring that educators are equipped to support deep and complex student learning in their classrooms. However, research shows great variation in the extent to which PD programs accomplish this goal. This study also provided empirical evidence on the impact of job embedded context specific and content-based PD on pre-service elementary teachers' achievements in algebra.

The study shows that the comprehensive PD program provided mathematics teacher educators and pre-service elementary mathematics teachers with sufficient support to implement AfL in the classroom teaching learning of algebra in a randomly selected CTEs that brings a statistically significant positive impact on pre-service teachers' achievements in fundamental concepts of algebra course compared to those in the two different comparison groups. Moreover, this study provided empirical evidence on the impact of job embedded context specific and content-based PD on low achiever pre-service elementary teachers' achievements in algebra compared to average and high achievers.

This research also contributes to the available empirical evidence on the impact of implementation of improved AfL practices in teacher education colleges on pre-service teachers' achievements. But it can be seen that the main sources about PD were not consulted, and this can be taken as a shortcoming in this study.

CONCLUSION AND RECOMMENDATIONS

Implementations of the five AfL strategies by mathematics teacher educators and pre-service elementary mathematics teachers has a positive effect on pre-service teachers' achievements in algebra. There was a positive significant mean difference in achievements of fundamental concepts of algebra between the treatment group and the two comparison groups after an improved implementations of the five AfL strategies. Improvement of the teaching learning module, training of pre-service teachers on how to implement self-assessment and peer assessment improved pre-service teachers' awareness of the learning intentions in each subtopic of the course, collaboration with their friends, participation in the class and learning from their own errors. Job embedded, context specific and content-based PD on AfL and a follow up feedback and scaffolding helped Mathematics teacher educators to implement AfL well in algebra course.

The findings of this study added valuable insight to mathematics teacher educators, curriculum developers and policy makers on the need to improve implementations of AfL strategies in teacher education colleges. Based on the research findings, job embedded, context specific and content based comprehensive PD on AfL is recommended to mathematics teacher educators to improve implementations of the five AfL strategies and improve preparation of initial elementary mathematics teachers. In addition, suggestions for further study includes a comparative study on the impact of AfL on other mathematics courses in teacher education colleges to uncover the effect of context and nature of subject.

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