PRE-SERVICE PHYSICS TEACHERS' PHYSICS UNDERSTANDING AND UPPER PRIMARY TEACHER EDUCATION IN ETHIOPIA

Mekbib Alemu, Mesfin Tadesse, Kassa Michael, Mulugeta Atnafu

Addis Ababa University, ETHIOPIA

Abstract. In this study attempt was made to explore the challenges of physics teacher education in Ethiopia based on data collected from 16 Teacher Education Colleges, 432 pre-service physics teachers in their final year of study, and 31 college lecturers. From the qualitative and quantitative analysis of conceptual test results, attitude questionnaire, interviews, and classroom videos the following major results were found. At the end of one-year intervention with dialogic teaching, both the comparison and treatment pre-service teachers were found to score very low in selected TIMSS items from population 2 tests. Pre-service teachers slightly but significantly favored dialogic over didactic and naïve inquiry teaching but showed significant shift from dialogic to the other two after the intervention. Physics teacher education lecturers predominantly used the lecture method in their classrooms but intervention found to shift their style significantly to dialogical teaching. Finally, it was found that pre-service teachers learning is highly influenced by weak English language proficiency, low motivation, and expectation of low social status for the teaching profession.

Keywords: physics conceptual understanding, dialogic teaching, pre-service teachers, pedagogical orientation

Background

Low-income nations have poor educational attainment and enrolment compared to most middle- and high-income nations. Education in low-income nations is suffering from low enrolment and high dropout rates. Two decades ago, UNDP described this as a global learning crisis and aimed for "universal primary education" as one of its Millennium Goals. From 2000 to 2015 this effort paid off and enrolment in low-income nations increased from 83 to 91%. Despite this global picture, enrolment in primary education in Sub-Saharan Africa did not even reached the global threshold. In this group of countries, to which Ethiopia is a member, the fast-developing enrolment rate due to the global effort jumped from around 52% in 1990 to 80% in 2015.[1)] However, there are discomforting reports that low income nations are still falling behind from the target of enrolment rate of 100% and struggling with high drop-out rates.[2)]

A much more serious problem of the education system in low-income countries is low attainment. Even those who were enrolled in primary education at a relatively high number are leaving school without being able to read and write.[2,3)] Furthermore, participation in international learning assessments, such as PISA and TIMSS, revealed that there is as large as two standard deviations between scores of students from the low-income countries and high-income nations.[4,5)] Progress is also very low for children in low-income nations to fill the observed huge gap.[6)]

Attainment, however, maintained low and the Department for International Development (DFID) in the UK, together with the Economic and Social Science Research Council (ESRC), therefore launched a large-scale research programme, Raising Learning Outcome in Education Systems (RLO), to investigate ways of improving the overall quality of education in low-income nations. The current paper is based on a study in the RLO programme looking at STEM subjects and aims to analyse quality of physics teacher education for middle schools in Ethiopia. More specifically, the paper asks the following question:

how does the level of conceptual knowledge among Ethiopian pre-service teachers compare to students in high-income nations; what are the pre-service teachers' pedagogical orientations and conceptions of "good teaching"; what pedagogy dominates teaching in Colleges of Teacher Education (CTEs) and how does this pedagogy align with pre-service teachers' orientation.

Literature review

It has been observed from global comparative studies and global assessment results that low-income nations are struggling in STEM subject attainment far behind OECD nations. As Ethiopia did not participate in the international examination, the above data may not directly apply to this case currently. Nevertheless, other studies comparing the Ethiopian case with other developing countries attest that the problem is even much worse than what has been observed above. The Young Lives Study,[7] a long-term international study of childhood poverty in Ethiopia, India, Peru and Vietnam, has been important to analyse education in Ethiopia. The study has followed 12,000 children over 15 years and gathered information from educational authorities, homes and schools. The study points out that mass education is a relatively new phenomenon in Ethiopia compared to the other three nations and that the fast-growing expansion of inclusion rate has had a negative effect on attainment.[6] For mathematics and reading literacy, Ethiopia is the lowest scoring among the four Young Lives nations and has the faster widening learning gap as the children grow up. The nation also has a big attainment gap between urban and rural areas. The study by Joshi & Verspooy (2013) about study of Ethiopian secondary school students' achievement, to be reported to the world bank, corroborated the finding in Young Lives study. In that study it was reported that there is high rate of students' failure in national exams at grade 10 and 12, and wider achievement gaps between urban and rural and also female and male students.

Two problems have been targeted in several Development Programmes launched by Ethiopia's Ministry of Education: the low progress made by children over one year of education and the high failure rate of students in Grade 10. Many home factors influence these problems,[8] but quality of teachers, teaching and curricula are also seen as important[6,9] (Joshi & Verspoor, 2013). Ethiopia was not included in the ROSE project,[10] but students in other comparative African countries showed very positive attitudes towards school science. It is therefore a paradox that many researchers in Ethiopia report attitudes as one of the biggest problems for educational attainment, particularly in physics and mathematics (Awaehu, 2017; Atnafu & Michael, 2018). Attitude is also regarded as a problem for recruitment to teacher education (Tassew et al., 2009).

In Ethiopia, there are more than 80 different languages and there is a policy to provide primary education with the different vernacular languages. Different regions use the mother tongue language in primary education to a different level. Teacher education colleges use a combination of the mother tongue and the English language. For example, the 9 CTEs in this study have a teacher education for the second cycle primary with the English language as a medium of instruction in parallel to the first cycle primary teacher preparation in mother tongue language.

Methodology

The study was a mixed method design in which data was collected using different data gathering techniques. Mainly quantitative data was gathered from a sample of 432 (336 males and 96 females) pre-service teachers (Mean age 20.37 years) using a physics conceptual understanding test and pedagogical orientation questionnaire at the beginning and end of the academic year. Out of the 432 pre-service teachers, 321 (74.3%) of them were from intervention CTEs and 111 (25.7%) were from the comparison CTEs whereas 218 (67.9%) of the intervention and 78 (70.3%) of the comparison group pre-service teachers have the normal entry after completion of grade 10. Qualitative data was gathered

from 32 lesson videos (23 from intervention and 9 from comparison classrooms) and 16 CTE lecturers' interviews. The data gathering centres were 9 CTEs, from which 6 were intervention and 3 were comparison sites covering three Ethiopian regions (Amhara, Addis Ababa and SNNP).

The physics conceptual understanding test was comprised of 20 selected items from released TIMSS population 2 tests.[11] This allowed item-by-item international comparison and development of a local scale for correlation to other variables in the data set. In addition, a validated pedagogical orientation questionnaire (Smith et al., 2014) with adaption and translation to Amharic was used. It was also trailed before using it for actual data gathering. The Smith et al. (2014) questionnaire classified the 21 items into three factors as: Learning-Theory-Aligned Science Instruction (11 items), Confirmatory Science Instruction (7 items), and All Hands-on All the Time (3 items) (Smith et al., 2014). Without losing meaning of the factors, in the current study we re-named the factors into dialogic, didactic, and naïve inquiry. Therefore, pedagogical orientation was analysed based on the same three categories but with the new names appropriate to the intervention in this research. Video observations of sixteen physics lessons and individual interviews with all CTE lecturers were used to investigate pedagogical practices in teacher education. To supplement the interpretation of data from the different instruments, physics curricula for primary second cycle physics teacher education and teaching material used by the CTEs lecturers were studied in content analysis.

Scales for conceptual understanding and pedagogical orientation were analysed in SPSS, using ANOVA and correlations, after Rasch scales had been developed in Winsteps. Interviews and video observations were transcribed and translated into English for thematic analysis in the software Nvivo. Video analysis focused on communicative approach (Mortimer & Scott, 2003), including amount of time teacher and students were talking and the quality of utterances made by teachers. Analysis of interviews focused on themes related to didactic

(teacher-led) and dialogical (student-led) teaching, and contextual factors as well.

Findings

Level of physics conceptual knowledge among Ethiopian pre-service teachers

Based on the official entry profile (grade-10) for teacher education and analysis of the curriculum, the researchers reasoned that third-year primary school teacher education to be equivalent to at least the final year of secondary school. Therefore, for an international comparison of physics conceptual knowledge among Ethiopian pre-service teachers the natural comparison would be with items from TIMSS Population 3 (Final year of secondary school). However, trialling showed these items were too difficult to the targeted pre-service teachers in Ethiopia. Items, therefore, were selected from Population 2 tests (Grade-8 students) and allocated into two groups as generalist and specialist items. A physics item was considered 'specialist' if the pre-service teachers just took a course related to the physics content to which it belongs.

The pre-service teachers in this study are supposed to teach physics in the upper primary grades (grade-7 and 8). One of the physics contents of the curriculum for these grade levels is electric circuits.[12)] Basic knowledge electrostatics (charges and charging) and electric circuits (with introduction of circuit elements and ideas of current and voltage in simple circuits) are introduced to primary school students in a lesson in grade-7. Electric circuits have extended coverage in Unit-5 of grade-8 physics. In Table 1 it is shown that 10 out of 19 lesson time in grade-8 is about electric circuits and measurement of current and voltage. In preparation to teach at these grade levels, pre-service teachers take an extended and advanced physics course in "Electricity and Magnetism" together with a laboratory work at least for a semester. The same approach is followed in the teacher education curriculum in addressing practically every content area of primary school physics.

Table 1. Contents of grade-*8 P*hysics on electric circuits

Unit 5: Electricity and Magnetism (19-lessons)		
Section	Topic	Lesson time
5.1	Modelling electric current, a circuit loop and voltage	1 period*
5.2	Modelling qualitatively an electric light bulb	2 periods
5.3	Relationship of Volts, Current and Resistance	2 periods
5.4	Measuring electric current, resistance and voltage	2 periods
5.5	Formulas to calculate services and parallel or combinations of resistors	3 periods
5.6	Electromagnetism	3 periods
5.7	Electric motor	2 periods
5.9	Generator	1 period
5.10	Transformers	2 periods
5.11	Power Transmission and conversion of energy	1 period

* 1- period is between 40- and 45-minutes lesson time

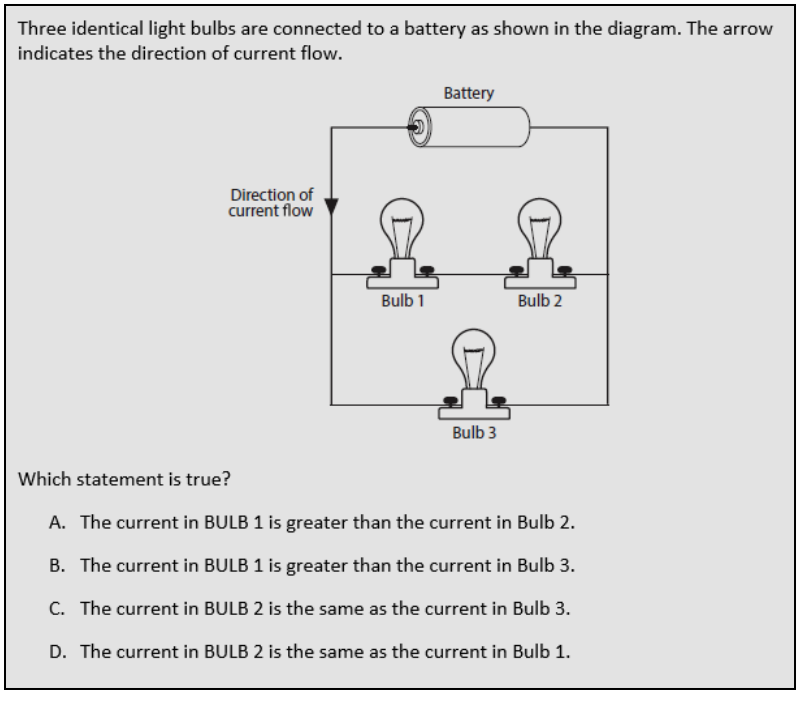

Figure 1. A typical example of multiple-choice item (El 2) in the physics conceptual understanding test[11)]

To assess the corresponding knowledge in the area physics pre-service physics teachers have, items were selected from TIMSS population-2 exam. An example of an item used in the pre- and post-test of the pre-service teachers is the one shown below (Fig. 1). Answering such questions correctly was presumed to demonstrate that the pre-service teachers have the basic knowledge to teach the corresponding topic in upper primary schools.

The pre- and post-test results of pre-service teachers the physics conceptual understanding test was analysed by using an item by item comparison with TIMSS scores corresponding to each item (Foy et al., 2013). An example of this item by item comparison of students of grade 8 from the international data with the final year pre-service physics teachers scores is presented below.

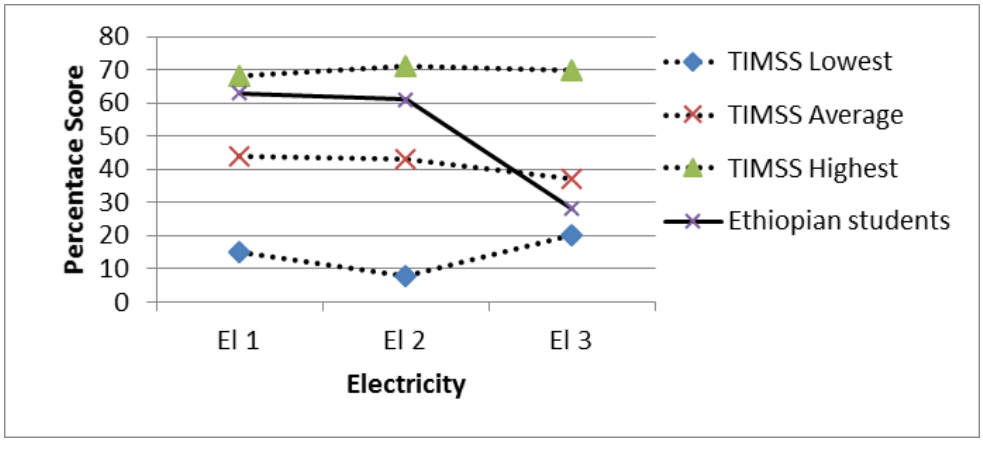

Figure 2. Percent of students who got correct on three TIMSS electricity items

It can easily be seen from the figure that Ethiopian pre-service physics teachers, in their final year teacher education, could score somewhere between the highest and lowest TIMSS score for grade 8 students internationally. What could be seen from the figure is only a fluctuation around the average score. So, even if these pre-service teachers studied the concepts in a level equivalent to

the items involved (see the discussion above) and even after taking an advanced and extended course(s) in their teacher education years, their scores were not any better than the primary school students in grade-8 internationally.

Not all of the physics conceptual items were in multiple choice format. Some of the items were open ended items requiring pre-service teachers to give their responses with brief writings. The figure below presented one example from "waves and optics" specialist test. Curriculum analysis revealed that the necessary background knowledge to answer the item like the one in Fig, 3, is contained in grade-7 and also in the "Wave and Optics" course in physics teacher education curriculum. In grade-7 5 lesson periods (on average 45 minutes each) are dedicated to the teaching of "Production and transmission of sound", "Reflection of sound", up to "Application of Echo Sounding". At CTEs, the content of sound and mechanical waves occupied up to about 37% of the course "Wave and Optics".

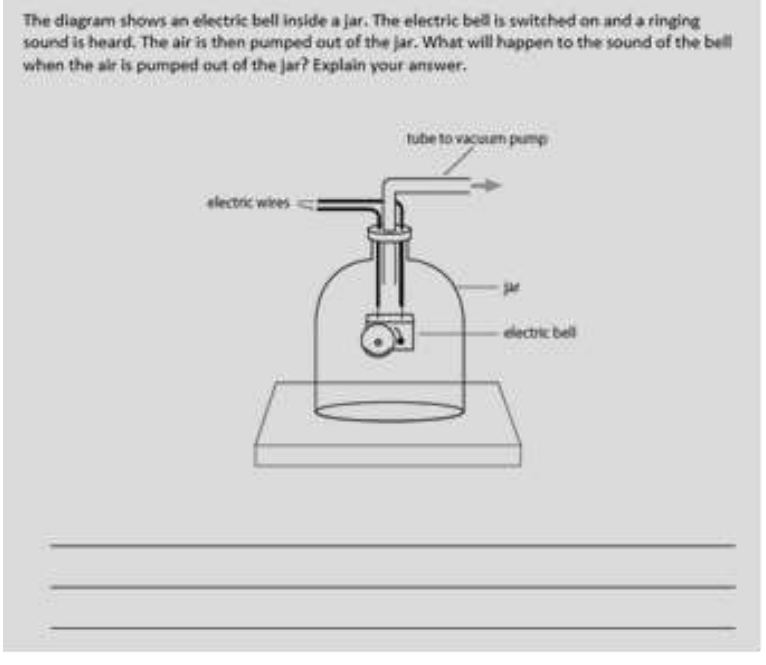

Figure 3. A typical open-ended specialist item (SW 1) from "Wave and Optics"[11)]

Ethiopian pre-service teachers score corresponding to this item, as can be seen from Table 2 (Item Sound Wave 1) is 22 points less than the international TIMSS average for grade-8 students.[13] In general, the pre-service teachers scored very low in items related to sound waves even if they took an advanced and extended course in waves and optics. Another example of the relatively lower score of the pre-service teachers is presented in the table blow.

Once again, we can see that in all of the three sound wave items Ethiopian pre-service teachers scored less than the TIMSS average and a little bit higher than the lowest.[13] That is, final year Ethiopian pre-service physics teachers had a level of conceptual knowledge similar to Grade 8 students in the international tests.

Table 2. Percent of students who got correct on TIMSS sound wave items

Item	TIMSS Lowest	TIMSS Highest	TIMSS Average	Ethiopian Average
Sound Wave 1	15	68	65	43
Sound Wave 2	10	76	36	15
Sound Wave 3	11	71.5	32	17

When considering the scores of pre-service teachers generally, they scored substantially lower on all open-ended items requiring writing, but higher on some multiple-choice items. This might be an indication to the pre-service teachers' language difficulty in general. In general, it could be seen from the item by item comparison that Ethiopian pre-service physics teachers scored not better than the grade-8 students elsewhere. The best score for the pre-service teachers was 63% for Electricity item (item El 1) which is close but less than the highest TIMSS score.[13] And, the worst score of the pre-service physics teachers was 17% for Sound Waves items (item SW 2) which is only a little above the minimum TIMSS score.

The physics conceptual understanding test was used as a pre- and post-test with the intervention with dialogic teaching. When the test was repeated towards the end of the academic year, progression was low with an average increment of 0.2 of a standard deviation. Slightly better performance was observed among grade 12 entry pre-service teachers compared to those from grade 10. Table 3 presents the data for three Electricity items, as an example.

Table 3. Percent of Grade 10 (N=) and Grade 12 (N=) entry students who got correct on the three TIMSS Electricity items

Item	TIMSS Lowest	TIMSS Highest	TIMSS Average	Ethiopian Average	
				Grade 10	Grade 12
Electricity 1	15	68	44	56.6	78.9
Electricity 2	8	71	43	57.8	66.7
Electricity 3	20	70	37	25.0	33.3

Student entering teacher education from Grade 12 scored significantly higher than students entering at Grade 10, and this difference increased over the academic year. This better performance implies that those with better entry profiles will better benefit from teacher education program than those with weaker profiles, as far as conceptual learning of physics is concerned. This is a conformation of results found elsewhere, for example studies by Sadler et al. (2013) for middle school students and Baumert and his associates revealed similar results for mathematics pre-service teachers (Baumert et al., 2010).

Pre-service teachers' pedagogical orientation

Smith et al. (2014) questionnaire for pedagogical orientation had three dimensions: didactic (teacher-led), dialogical (student-led) and naïve inquiry led teaching. The questionnaire was used as a pre and post measures. Both the pre- and post-test data showed some problems with the pre-service teachers' responses. They seemed to be strongly positive to everything, and did not show the contrast indicated in the theory. Even though it was expected that there will

be a contrasting preference between dialogic and didactic teaching orientations, strong correlations (about r =0.64 with p=0.000) among the pre-service teachers' ratings in the three categories. We also had a problem with ceiling effects. Neither in the pre-test nor in the post test, a significant orientation differences were observed between the treatment and comparison groups.

To minimize the problems in the measurement, some of the pre-service teachers' responses were dropped from the subsequent analysis. In relation to this, 36 questionnaires from the treatment and 22 from the comparison groups were dropped if questionnaire were filled either as 1 or 6 throughout the 21 items or significant number of items were left not responded to. When such problems were observed either in one of the cases (during pre- or post-testing) or both cases, the filled questionnaires corresponding to that individual were totally dropped. The analysed data for 374 pre-service teachers both from the treatment (N=285) and comparison (N=89) is presented in Table 4.

Table 4. Paired sample t-test for pre-service teachers' pedagogical orientation by the three dimensions

			Pre-test		Post-test			
Orientation	**Group**	**N**	**Mean**	**SD**	**Mean**	**SD**	**t**	**p**
Dialogical	Treatment	285	5.27	0.8	5.11	0.9	2.243	0.025
	Comparison	89	5.14	0.6	5.09	0.75	0.491	0.624
Didactic	Treatment	285	4.26	0.79	4.43	0.85	2.473	0.014
	Comparison	89	4.56	0.59	4.48	0.67	0.843	0.399
Naïve Inquiry	Treatment	285	4.23	0.61	4.36	0.91	2.003	0.046
	Comparison	89	4.39	0.69	4.46	0.85	0.603	0.547

From the data in the table above, two distinct observations can be made. One of these is that the pre-service teachers slightly but significantly favoured dialogic over didactic teaching and quite sharply favoured both of these over

naïve inquiry teaching. One-way ANOVA analysis confirmed this observation ($F=62.165$, $p<0.001$) for total (treatment and comparison) scores and grouped comparisons for pre- and post-test scores. The second observation (with paired sample t-test) was that all the treatment group responses exhibited statistically significant changes. In general, there is a small but significant migration from dialogic to didactic and Naïve inquiry orientations between the pre- and post-tests. This is against the intension of the intervention and the theory (Friedrichsen et al., 2011).

As discussed above, all scales, however, had low reliability and ceiling effects, suggesting many pre-service teachers struggled to see the difference between the constructs and exhibited random dispositions to the three orientations. In interviews, the pre-service teachers talked heartily about student involvement as good teaching and wanted physics teaching to be less abstract and more related to everyday contexts. What has been observed could possibly be a conflict between the intention of the teacher education program and what pre-service teachers experience as students. It seems that teachers' knowledge originates from teachers' own school learning experiences, teacher education and professional development programs, and teaching experiences (Friedrichsen et al., 2011; Smith et al., 2014). Obviously, for these pre-service teachers, the last one does not apply as they do not have teaching experience that affects their knowledge about the different teaching approaches. The general rhetoric around teachers and teacher education is about "student centred" teaching and in the teacher education program the pre-service teachers are lectured about the importance of student-involving instruction. Nevertheless, since their school years, including CTE classes, they are predominantly being taught with didactic approaches. Thus, the observed difference in students' preference to didactic teaching over dialogic and enquiry-oriented teaching in the questionnaires from their talks in the interviews is an indicator of this confusion.

Pedagogy dominating teaching in teacher education

Qualitative analysis of classroom videos, especially from teachers' camera, in both the comparison and the intervention groups helped to identify the different pedagogical approaches the physics teacher educators employed. Comparison between treatment and comparison classes were made in early stage of the intervention as well as at the end of the year. The table below presents the data from the post-intervention video records for the 31 lecturers.

Observations from classrooms generally demonstrated a strict didactic regime despite the attempt to transform the classes into dialogic approaches. We observe substantial differences between treatment and comparison groups. In the comparison group, teachers on average spent 72.77% of the time on lecturing. This is reduced to 21.97% in the treatment group. In contrast, teachers on average spend 4.96% on group work in the comparison group, while teachers in the treatment group spent 42.35% of the time on group work. Although students in some lessons did problem solving, students' ideas and answers were rarely discussed in plenary in neither the comparison nor the treatment groups.

Table 5. Percent of lesson time spent on different teaching activities by CTE physics lecturers

	Treatment (N=22)		**Comparison (N=9)**		**Total (N=31)**	
Teaching Activity	**Percent time**	**Std. Dev.**	**Percent time**	**Std. Dev.**	**Percent time**	**Std. Dev.**
Teacher Introducing	5.66	4.23	4.18	7.11	5.23	5.15
Teacher Lecturing	21.97	17.8	72.77	20.9	36.71	29.8
Group Work	42.35	26.34	4.96	7.01	31.5	28.22
Whole Class Dialogue	11.45	8.96	0.66	0.89	8.32	9.01
Individual Seatwork	2.17	4.09	6.64	8.65	3.46	5.99
Students Talk Individually	5.11	9.12	2.39	2.6	4.32	7.85
Teacher Revises	1.64	2.36	1.76	1.66	1.67	2.15
Teacher summarising	8.82	7.83	1.52	2.24	6.7	7.45

Dialogical teaching (teacher having a whole class (true) dialogue) which occurred in the treatment group occasionally (11.45% of class time), was almost none-existing in the comparison group. An important type of teaching for dialogic teaching, which is "meta-teaching" that involves whole class discussion and teacher summarizing the discussion are occurring less frequently in the comparison groups compared to the treatment group. A "mean" (50 minutes) lesson in the comparison group has 2-3 minutes' introduction, 38 minutes lecturing, 6 minutes with students solving tasks individually or in groups, and 1-2 minutes summary by individual students and 1-2 minutes general summarising by the teacher. The similar lesson in the treatment group has 3-4 minutes on the introduction, 8-9 minutes on lecturing, 22 minutes on group work, 8-9 minutes on dialogical teaching and occasional individual presentations by students, and 5 minutes on general summarising by the teacher. In other words, the big difference is in lecturing versus group work, but also a more balanced use of time across more types of activities in the treatment group compared to the comparison group. This is the "mean" picture.

While a pedagogic shift has been observed from comparison group to the treatment group, a distinct variation also observed among the individual lecturers. Looking at the variation in lessons we find many differences, however, more so in the treatment group than the comparison group. The comparison group (ordinary teaching) has a strong dominance of lecturing in ALL lessons, with time allowed to individual problem solving (individual seatwork in Fig. 2) being the only deviation. As the comparison group lecturers had little choice they all seem to depend on lecturing throughout. The bar chart in the figure below presents the case of two lecturers from the treatment CTEs from the video data towards the end of the year.

However, as can be seen from the figure, the treatment group lecturers seem to significantly differ from each other though they abandon lecturing and replace it with group learning in general. In the example displayed in Fig. 4, lecturer 1 dominated his teaching by group work, lecturer 2 moderated group

work with more of dialogic teaching components. The important elements of dialogic teaching, such as whole class discussion and teachers' summaries are given appropriate considerations in the case of lecturer 2 in contrast to the other one.

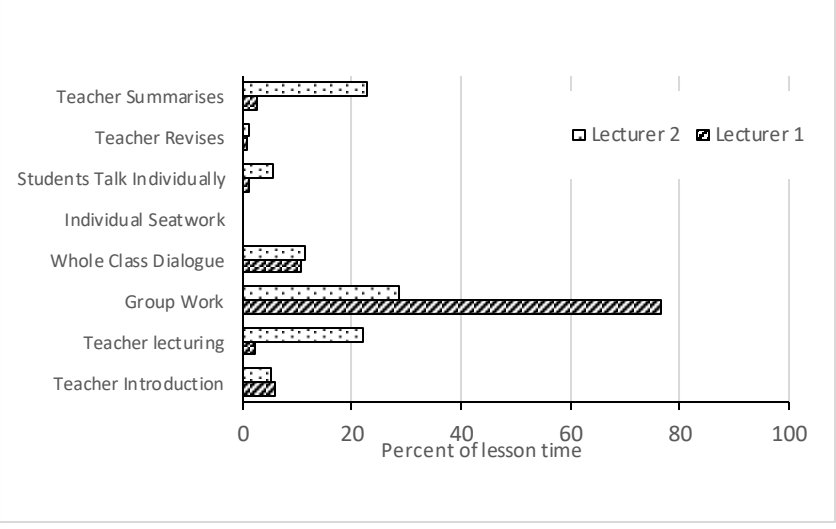

Figure 4. Percentage of lesson time used for different activities by two lecturers from the treatment group

Contextual factors influencing teacher education

In Ethiopia, the medium of instruction, especially starting from upper primary (Grade 7 and 8) and in teacher education, is formally the English language. Thus, the physics teacher education in the linear program is expected to be conducted in English. Nevertheless, in this study the English language emerged as a problem from interviews, conceptual tests and classroom observations. Both CTE lecturers and pre-service physics teachers were observed to have difficulties in expressing their ideas and engage in classroom discussions using the official language of instruction. Most of the lecturers were limited to stating textbook information in the English language instead of using it as a communicative means. In both small group and whole class discussions pre-

service teachers mostly use the Amharic language with sporadic mentioning of physics technical terms and phrases in English. Thus, the research implied that the desire to use the English language in Physics teacher education without proficiency is a serious impediment system wide.

From pre-service teachers' interviews (focus group interviews) what repeatedly immerged is that they neither their chose to join teacher education nor wanted to study physics. Even those who claimed to have some degree of motivation to become physics teacher qualify their motivation as a "profession for the time being". This problem of motivation seriously affects their learning as well as desire to implement effective but demanding pedagogical approaches in their future teaching. Most of the time, pre-service teachers attribute their low motivation to the "too-low salaries for teachers" and the difficult nature of the subject matter of physics "to learn as well as to teach" it. Furthermore, many of the pre-service teachers are also worried about the low status of teachers in society.

Conclusion

Findings in this study suggest that low level of physics attainment in compulsory education in Ethiopia (Little & Rolleston, 2014) carries on as a problem into teacher education. The nation is in need of strong academic candidates for engineering education and sends the weaker candidates to teacher education. The curricular content as implemented in the classroom was found to be very advanced compared to students' level of conceptual knowledge revealed in the tests. Lecturers typically aimed their teaching at the highest achieving students. The existing physics curriculum is far too abstract for the majority of pre-service teachers and suited only for the best candidates recruited from Grade 12. The majority of them (77%) are recruited from Grade 10, and many with failed exams in physics. Due to a didactic teaching tradition, not suited for the academically weaker students, the gap between the two groups of students is growing through the teacher education years. Similar problems are known from

other low-income nations,[14] and caused partly by the international push for increased enrolment. The Government in Ethiopia has chosen to let candidates into teacher education and further into teaching jobs in spite of failing exams at both levels and also strong evidences of low motivation to the teaching profession. The research suggests changes should be made to the physics curriculum and that pedagogy needs improvement. The current study illustrated that changing the pedagogy in teacher education is possible. However, low entry profile and contextual factors seem to militate against the effectiveness of the change in resulting in the desired learning outcomes. A longer-term solution should focus on the role of English as a teaching language and introduce standards for pre-service teachers going into teaching jobs.

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NOTES

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✉ Dr Mekbib Alemu (corresponding author)
Department of Science and Mathematics Education,
Addis Ababa University,
Addis Ababa, Ethiopia
E-Mail: mekbib.almu@aau.edu.et

✉ Dr Mesfin Tadesse
Department of Physics,
Addis Ababa University,
E-Mail: mesfin.tadesse@aau.edu.et

✉ Dr Kassa Michael
Department of Science and Mathematics Education,
Addis Ababa University,
E-Mail: ftkassa2010@yahoo.com

✉ Dr Mulugeta Atnafu
Department of Science and Mathematics Education,
Addis Ababa University,
E-Mail: mulugetaayele97@gmail.com