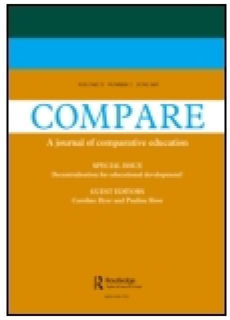

The knowledge gap between intended and attained curriculum in Ethiopian teacher education: identifying challenges for future development

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Abstract:	This investigation of physics teacher education in Ethiopia reveals a significant gap between the physics knowledge of pre-service teachers (PSTs) attained during training and that of the intended curriculum setting out expectations for their knowledge. Data were obtained by a test probing PSTs' physics knowledge (attained curriculum); analysis of teacher education curriculum documents (intended); and video-recording, observation and analysis of lectures delivered to pre-service teachers at four Colleges of Teacher Edu-cation (implemented). These illustrate that implementation focuses on high level, abstract knowledge delivered mainly via mathematical approaches, offering limited opportunities for learning basic concepts by debate. An outcome of current practice is that physics teachers lack the necessary subject knowledge to teach effectively, leading successive generations of Ethiopian students to under-achieve. The paper argues for change to enable Ethiopia to achieve its aim of raising educational achievement and societal productivity to become a low-middle income nation by 2025.

The knowledge gap between intended and attained curriculum in Ethiopian teacher education: identifying challenges for future development

Introduction and context

This study examines input into and outcomes from primary physics teacher education in Ethiopia. Ethiopia is a low income country[1] with ambitions to become a low-middle income country by 2025. At present, 83 nations, 43% of the world's total, are identified as having low or lower- middle income economies[2]. The United Nations Educational, Scientific and Cultural Organization (UNESCO, 2013b) identifies a global learning crisis affecting these nations, which experience low rates of educational inclusion and poor attainment. Improving inclusion rates has been at the forefront of international aid projects, resulting in progress. However, although inclusion in primary education in sub-Saharan Africa increased from 52% in 1990 to 80% in 2015 (United Nations, 2015), this remains below the 100% expected and found in high-income nations. Improved literacy rates have shown similar progress, although despite a high proportion of children being enrolled in primary education, many still leave without being able to read or write (Global Partnership for Education, 2014; Hill & Chalaux, 2011). Thus, the quality of educational outcomes in low-income nations remains variable for a variety of reasons. These factors contribute to the enormous learning gap revealed by international comparative studies such as the Programme for International Student Assessment (PISA, Organisation for Economic Co-operation and Development, OECD, 2016) in which low-income nations score as much as two standard deviations below the OECD mean (OECD, 2012). Based on data from PISA, the Trends in International Mathematics and Science Studies (TIMSS, International Association for the Evaluation of Educational Achievement, 2018) and the Southern African Consortium for Monitoring Educational Quality (SACMEQ[3], Hungi, 2011) Beatty and Pritchett (2012) estimated that 150 years for reading literacy and 134 years for mathematics are required for low-income nations to reach OECD attainment levels. This represents alarmingly slow progress in improving education. In practice therefore, many nations may never reach OECD mean standards, so multiple, successive generations will experience educational outcomes far below internationally acceptable levels. Although Ethiopia's students to date have not participated in international comparative studies, as nationals of a low-income nation they can be considered within this extensive group. Hence, research and aid aimed at improving

[1]The World Bank defines low-income economies as those with a Grand National Income (GNI, formerly referred to as GNP) per capita of $1,025 or less in 2015 and lower middle-income economies GNI per capita between $1,026 and $4,035. High-income economies have GNI per capita of $12,476 or more. (https://datahelpdesk.worldbank.org/knowledgebase/articles/378832-what-is-the-world-bank-atlas-method)

[2] The paper will refer to both groups as low-income nations.

[3] Testing mathematics and reading among African nations only

the quality of education is a major contribution to solving this crisis, making study of the quality of teacher education in low-income nations timely.

The "Young Lives" study illustrates the Ethiopian situation more precisely. Ethiopian children's progress was compared with those of other low-income countries, namely Peru, Vietnam and India (Andhra Pradesh). In reporting longitudinal data, Rolleston (2014), and Woldehanna and Gebremedhin (2016) point out that Ethiopian children are the weakest, and that the already huge learning gap observed with other nations increases as children get older. This point is discussed in detail below. The extent of the learning gap is also demonstrated in outcomes of Ethiopia's national learning assessments (National Educational Assessment and Examinations Authority, 2008a &b) and examination results (Ethiopia Ministry of Education, MoE, 2011 & 2015).

Consistent with many countries, education in Ethiopia occurs on three levels: primary, secondary and higher (MoE, 2015). Eight years of compulsory primary education is divided into two cycles. The first cycle primary education, from grades 1 to 4 (ages 7 – 10) has language literacy and numeracy as its focus (MoE, 2015; Joshi & Verspoor, 2013; Shibeshi, Mekonnen, Semela, & Endawoke, 2009). Ethiopian government sources report high inclusion rates for primary education, but a high dropout rate from first cycle primary is observed (MoE, 2011 & 2015). In addition, learning assessments reveal a significant number of children pass to the second cycle of primary education (grades 5 – 8, ages 11 – 14) without being able to read and write (National Educational Assessment and Examination Agency, NEAEA, 2008a &b; Woldehanna & Gebremedhin, 2016). In many of Ethiopia's nine regions and two administrative cities, the medium of instruction changes from mother tongue to English language in second cycle primary. Specialised science instructions are also introduced at this level. A small proportion of primary school children achieve the national policy pass mark (50%) in all subjects. Their weakest scores are in language, mathematics and sciences (MoE, 2015; Shibeshi, et al., 2009).

Secondary education in Ethiopia extends from grades 9 to 12 (ages 15 – 18). This level is divided into two cycles. The first ends with a high stakes national examination taken at the end of grade 10. Achievement is very low in this examination, as only about 20% of first cycle secondary students pass to the second cycle (preparatory) level (MoE, 2011 & 2015; Joshi & Verspoor, 2013). Students who cannot continue their education to the preparatory level to progress to higher education join technical and vocational training in many fields, which includes teacher education. Thus, the major source of teachers for primary education is students scoring the lowest marks in grade 10 assessments (Joshi & Verspoor, 2013; Semela, 2014). A proportion of secondary school graduates who fail to achieve pass marks in their grade 12 national university entrance examination enter colleges of teacher education (CTEs) with grade 10 completers. All trainee teachers study the same curriculum for three years.

Teacher educators in CTEs hold Master's degrees in their respective specialisations. They receive little or no specific training as teacher educators (Gemeda & Tynjälä, 2015). For example, few physics teacher educators in this study took courses that contribute to their profession. Attempts to address this gap have been made with a one year higher diploma training for teacher educators taken in situ, that is, while participants are working in their posts (FDRE, 2004). However, the effectiveness of the diploma programme has been questioned, not least due to its' general nature (Admasu, 2016). Although the diploma emphasises "active learning" methods (FDRE, 2004), teacher educators in general, and physics teacher educators in particular continue to adopt a didactic lecture-style when teaching their pre- and in-service teacher education students. Thus, the project on which this study is based, was named "Transforming the Pedagogy of STEM Subjects" (TPSS, Kind, 2018) and implemented to fundamentally change the pedagogy physics teacher educators utilise in their classrooms when training future physics teachers.

This paper describes a study undertaken for second cycle primary teachers (teaching students aged 11 – 14, Ethiopian Grades 5 to 8), analysing and comparing conceptual levels in the intended, implemented and attained Ethiopian teacher education curriculum for physics. Attention focuses on attainment, because, as indicated above, pre-service primary physics teachers (PSTs) frequently enter teacher education with poor physics knowledge. Extant research points towards a potential gap between attained and intended learning outcomes (Rolleston, James, & Aurino, 2013). The paper utilises TIMSS achievement data for international comparison. Although targeting students, not teacher education, the TIMSS assessment offers frameworks (Mullis & Martin, 2013) and test items (e.g. TIMSS, 2011) that permit comparison between two levels of conceptual knowledge: 13-year-olds (Population 2 in TIMSS), who pre-service teachers are trained to teach; and last year of secondary education (Population 3 in TIMSS), which some teachers achieve prior to entry to teacher education. After presenting findings, the discussion raises implications for Ethiopia and other low-income nations.

Teacher education in Ethiopia

Ethiopia's Ministry of Education (MOE) designed and implemented four Education Sector Development Programmes from 1994 onwards. During the programmes, teacher education was expanded and standardised to fit the school structure. Secondary teachers are educated in degree programmes at universities while primary teachers, the focus for this paper, complete three year diploma programmes in Colleges of Teacher Education (CTEs). Pre-service teachers may enter Diploma programmes directly from Grade 10 (age 16) or Grade 12 (age 18). Regardless of entry point, all study the same three year curriculum. For teaching Grades 5-8, pre-service teachers follow a linear Diploma programme with "major" and "minor" teaching subjects. Hence, teachers for Grades 5 to 8 are subject specialists. In future, this specialism may be strengthened through revisions that aim to upgrade second primary cycle teacher education to a degree programme (United Nations Educational

Scientific and Cultural Organisation, UNESCO, 2013a). English language is used in some regions (Heugh, Benson, Bogale, & Yohannes, 2007) including CTEs in this study. Entry criteria (UNESCO, 2013a) include passing the Ethiopian General Secondary Education Certificate Examination (EGSECE, taken in Grade 10) with a minimum Grade Point Average (GPA) of 2.00 (out of 4) and achieving pass standards in the PST's intended specialist subject(s). In 2011/12, 51,637 teachers were trained via linear Diploma programmes (UNESCO, 2013a). In 2010/11 83.3% of primary teachers were qualified with a diploma or above (MOE, 2011).

The Education Sector Development Programmes aimed to improve teaching quality by implementing a new teacher education curriculum emphasising active learning and student-centred approaches (MOE, 2010) and increasing numbers of qualified teachers. Ethiopian education relies on a deep-rooted educational tradition of "the lecture method" that resists change (MOE, 2011). Obstacles to the change were raised, including that the curriculum was imposed top down; did not consider comments from teachers; was donor driven; and based on western cultures and research. Although student-centred pedagogies received rhetorical support, changes to educational practices are slow to embed, in part due to the high pupil: teacher ratio of around 50:1. In three regions, Southern Nations, Nationalities and Peoples (SNNP), Somali, and Oromiya, the class size averaged over 60 students (MOE, 2011).

Levels of teacher knowledge: attainment and competition for candidates

Attainment tests in reading, literacy and mathematics carried out in 2006, 2009 and 2013 as part of the *Young Lives*[4] project show Ethiopian children to be the weakest of the four populations (Ethiopia, India (Andhra Pradesh), Peru and Vietnam) studied (Rolleston, 2014). Their attainment remains low even when late enrolment and consequent shorter exposure to schooling are compensated, suggesting the quality of education received is influential. Singh (2014) shows the learning gap across the four *Young Lives* countries widens with children's age. Furthermore, Woldehanna and Gebremedhin's (2016) analysis of Ethiopian attainment scores for 12 year-olds in 2006 and 2013 show a 30% drop in attainment for reading, literacy and mathematics. National assessment data (National Educational Assessment and Examinations Agency, NEAEA, 2008a, 2008b) show increased enrolment from 79 % to 86 % over the same period. Hence, Woldehanna and Gebremedhin (2016) suggest attainment fell because schools accommodated more students without additional equipment and qualified personnel, while increased school drop-out and repetition rates (Woldehanna & Hagos, 2012) were also observed.

However, percentages of students achieving Grade Point Average 2 in Grade 10 and Grade 12 examinations increased between 2006/7 and 2010/11 (MOE, 2011). Pass rates in mathematics and sciences remain low: for example, only 10.1 % of students passed (50% or above) Physics in 2009/10 (MOE, 2011). Ethiopia aims to recruit 70% of university graduates

[4] www.younglives.org.uk

into science and technology (MOE, 2006). Hence a rank order of candidates has developed, with engineering studies getting the best qualified physics candidates, university-based physics studies the next best and CTE-based teacher education any remaining. The mean National Higher Education Entrance Examination scores for candidates studying engineering in 2008/9 were 30% higher than for those studying physics; those becoming teachers are even less-well qualified (Semela, 2010). Semela (2010) also shows university students lack interest in physics because students are often assigned to programmes regardless of personal choice.

Determining a typical attainment level for pre-service primary physics teachers in Ethiopia is problematic. Although CTE programmes apply recruitment criteria, the pool of candidates is small and the best are steered towards upper secondary education and universities. Physics recruitment struggles with motivation, because students find the curriculum and teaching unsatisfactory.

Resources for education: physical and personnel

In Ethiopia, resource differences are observed between urban and rural areas. Typically, in rural areas, school classes are larger (pupil: teacher ratio about 60:1) and basics are scarce. For example, in 2011 tap water was available in 95% of Addis Ababa primary schools compared to only 1 % in the Somali region (MOE, 2011). Teaching in under-resourced areas is difficult and has less prestige. Ethiopian authorities assign newly qualified teachers to rural areas. This creates a motivational problem (Abebe & Woldehanna, 2013) as teachers can move to "better" jobs in urban areas only with experience. Teachers generally have low salaries and poor societal status (VSO, 2009). A Ministry of Education evaluation of teacher education (UNESCO, 2013a) showed that rural areas, linguistic and ethnic minorities were under-represented among PSTs, and that around 90 % had not chosen teaching as their preferred career. Another complicating factor is language of instruction. Ethiopia has more than 80 different languages and a national policy introduced with the Education Sector Development Programmes in 1994 that students when starting schools should be taught in the languages dominant to their region. By secondary school, language of instruction should change to English. Some areas make this transition earlier and teaching material is commonly available in English from Grade 5 and onwards. Some regions, like the SNNP, contain such a variety of languages that they use the national language Amharic for teaching from Grade 1. Teacher education, with a few exceptions, uses English for instruction in all programmes. Several studies have demonstrated that the transition to English as language of instruction in schools is difficult and that students taught in English have lower attainment than students taught in local languages (Heugh, Benson, Bogale, & Yohannes, 2007; Ramachandran, 2012). Surveys also show that teachers often do not have the requisite skills to teach in English (Vujcich, 2013). Little information is found about how this problem affects teaching and learning in teacher education programmes.

This study analyses and compares physics conceptual levels in the intended, implemented and attained curriculum in Ethiopian teacher education for second primary cycle physics teachers. Specifically, the study investigates the learning gap between these curricula, with a view to providing evidence that may prompt change in teacher education practice in low-income nations.

Materials and methods

The study employed a mixed method design. The attained curriculum was analysed via a physics knowledge test given to PSTs at the beginning and end of their third, final academic year. Test items were accessed from the publically available TIMSS item banks (Gonzales & Smith, 1998; Gonzales, Smith & Sibberns, 1998) meaning that item score (facility) values were known. This permitted comparison of Ethiopian pre-service teachers' attainment scores on individual items with international mean values and extreme values, that is, the highest and lowest scoring nations in TIMSS. The test comprised a "general" section featuring items from the full physics curriculum and a "specialist" section featuring items taught in physics courses attended by students in that academic year. Note that the curriculum for the linear teacher education Diploma programme for all colleges is the same, but PSTs completed different specialist courses in the same semester in the CTEs involved. The three year teacher education was assumed to make-up for PSTs low entry profile and bring up their knowledge level at the level of grade 12. To test for this, general items were selected from TIMSS Population 2, designed for 13-year-olds. In trialling, Population 3 items designed for students in their last year of compulsory secondary education proved to be very difficult for Ethiopian PSTs, generating low facility values. So, general physics items in the final version were all from Population 2. Specialist items were prepared for three topics, namely *Electricity and Magnetism, Thermodynamics,* and *Waves and Optics*. Specialist items included some from Population 3, because PSTs received teaching on these topics through at least half of the academic year in which they were tested, so their knowledge level could be expected to have improved from their point of entry. The final test design featured 27 general items organised in three sub-sections each of nine questions. PSTs responded to two sub-sections, that is, 18 items each time they were tested. This design is possible when a test score is established using equating techniques in modern test theory (Lord, 1980) and permits comparison of tests with overlapping items in which some but not all items are the same in two tests.

The specialist section featured two sub-sections each of six questions, that is, twelve items in total. Each sub-section tested knowledge about one topic. The same specialist items were included in both administrations of the instrument. The final version of the test comprised 18 general physics and 12 specialist items.

When analysing data, we compared facility of general physics items with data available from TIMSS Population 2. We calculated PSTs' overall scores in Winsteps software (Linacre & Wright, 2001) based on Rasch modelling (Rasch, 1960) to compare attainment at the beginning and end of the academic year. Data analysis of specialist section responses compared raw score scales at the beginning and the end of the academic year for the same respondents. Raw score scales were used because the number of items in each test section was small.

The intended curriculum was investigated using document analysis (Bowen, 2009). The analysis identified conceptual knowledge in thirteen curriculum documents for teacher education physics courses featuring major subject physics and minor subject mathematics. A framework for analysis was devised from guidelines produced by the UK's Institute of Physics (IoP, 2011) and TIMSS (Mullis & Martin, 2013). These guidelines identified three physics knowledge levels: for Grades 8-10 (ages 14-16); Grades 11-12 (ages 17 – 18); and university undergraduates. At each level the framework describes three characteristics or "dimensions". These are: solving physics problems; ways of using mathematics; and ways of carrying out investigations. Data were analysed thematically (Fereday & Muir-Cochrane, 2006) and by coding learning objectives in NVivo (2012). When coding, each learning objective was placed in one of the nine framework categories, that is, for example "Grades 8 – 10, Solving Physics Problems" or "University Level, Use of Mathematics". To interpret curriculum learning objectives, course content and suggested literature were examined. Coding was dual checked by authors. Discussions to reach agreement was reached where discrepancies in interpretation occurred. Overall outcomes give a good estimate of the level of knowledge PSTs are expected to achieve.

The implemented curriculum was analysed via classroom observations. Eight lessons given to PSTs by CTE teacher educators were video recorded and analysed qualitatively. For analysis, a pedagogical framework describing three categories of teaching was developed that separated lecturing, student problem solving (in groups or individually) and whole class discussion of physics knowledge and problems. Coding in Nvivo identified amount of time spent on each category. A thematic analysis was also carried out for each lesson comparing intended curriculum with knowledge level exhibited in teaching PSTs received and to examine how teacher educators adjusted to PSTs' learning needs. To ensure validity and reliability data were analysed independently by two researchers and results discussed by five research team members. All five researchers visited classrooms and observed teaching first hand.

Data were collected in accordance with ethical procedures defined by the British Educational Research Association (BERA, 2011). The study was granted ethical approval by Durham University School of Education Ethics Committee.

The sample

The paper reports data collected in 2015-16 from final year pre-service teachers (PSTs, Table 1) undertaking primary physics diploma programmes at four purposefully selected CTEs offering physics teacher education in the Addis Ababa, Amhara and SNNP regions. Focusing on the final year of study permits an estimate of the level of knowledge newly-qualified teachers possess on leaving CTEs and starting their teaching careers.

Table 1 shows most PSTs (70.8 %) entered teacher education from Grade 10, that is, the minimum level. They are about 20 years old and most are male. PSTs' age is over the expected age for Grade 10 (16 years) due to their varied school attendance pattern and repeating years of education. After grade 10, when data were collected PSTs have received further three years of physics education, so may be assumed to have improved their level of conceptual knowledge to be comparable with that of international students in their last year of compulsory secondary education. Relatively more female PSTs entered the teacher education programme from Grade 12 than male students. Socio-cultural factors play a role in girls' accessing education (UNESCO, 2012). Hence, female PSTs may be less inclined to attend university, perhaps for family or gender-biased reasons, so are directed towards CTEs.

[INSERT TABLE 1 ABOUT HERE]

Table 1 gives the total number of PSTs involved in the study. Not all PSTs responded to the same items, as indicated in the description of the tests. Hence, N values in data tables vary.

Findings

Attained Physics Curriculum

Table 2 gives scores obtained by Ethiopian PSTs who responded to the knowledge test (based on Population 2 TIMSS questions) at the beginning and end of their final academic year. Scores are split by PSTs' entry point into the diploma programme; sub-cohorts inevitably differ in size due to factors (discussed above) that impact recruitment. All PSTs scores were slightly lower at the end of the year, which was surprising. Although this may be due to assessment fatigue, this indicates that the physics education received during teacher education did not promote a significant increase in PSTs' performance on this test. Those who entered from Grade 12 achieved consistently higher scores than those entering from Grade 10 and the gap between sub-cohorts widened over time. Differences between the sub-cohort scores are statistically significant ($p<0.001$). [INSERT TABLE 2 ABOUT HERE]

Table 3 presents raw scores of PSTs responding to specialist topic question sets. Most gave correct responses to fewer than two items (of six) correct in any test, so exhibit raw scores of less than 2. Respondents with Grade 12 backgrounds score consistently higher than those entering from Grade 10. Some topics exhibit score patterns in which end of the year results are lower than those obtained at the beginning.

[INSERT TABLE 3 ABOUT HERE]

Together, these data illustrate that PSTs demonstrate relatively poor knowledge levels about general physics items on entry to teacher education. As may be expected, Grade 12 level of education seems to confer better knowledge on PSTs than Grade 10. Next we compare PSTs' level of knowledge at the start of their final academic year with published TIMSS scores. Figure 1 compares Ethiopian PSTs' responses on specialist items in Electricity (Fig. 1) with those of international 13-year-olds who responded to the same items presented in the TIMSS test instrument. *TIMSS Highest* and *TIMSS Lowest* represent the highest and lowest scores on each item respectively. *TIMSS Average* represents the mean score for school students in all nations taking the test. Figure 2 shows the Ethiopian PSTs' responses split by the level of pre-entry education they had received. Figure 3 compares PSTs' responses for three items on Sound Waves to those of TIMSS respondents. [INSERT FIGURES 1, 2 AND 3 ABOUT HERE]

These data illustrate an erratic pattern. In Figure 3, PST Grade 12 sub-cohort scores higher than the highest scoring nation in TIMSS on Item 1, yet on Item 3, their score is below the international average. Although these data represent a relatively crude measure, these figures suggest that level of knowledge among Ethiopian PSTs attained from their school education and evidenced at the start of their third year of study is approximately equal to that of the international average for 13 year olds responding to the same items in TIMSS. [INSERT TABLE 4 ABOUT HERE]

Table 4 compares Ethiopian PSTs' scores on all test items with the TIMSS mean score. PSTs scores were higher than the TIMSS international average where Population 2 questions were used (Electricity, Thermodynamics, Pressure). For the remaining four topics for which Population 3 questions were used Ethiopian PSTs scored below the TIMSS average. Data are split by sub-cohort: those with Grade 12 education scored higher than those who left school after Grade 10 in all topics. Nevertheless, the response pattern is consistent for both groups. ***Intended Physics Curriculum for Grades 5 – 8 Teacher Education***

Results are presented in Table 5. These indicate that the linear Diploma programme includes physics courses that comprise a total of 110 learning objectives.

[INSERT TABLE 5 ABOUT HERE]

Over 80% of learning objectives are at the Grades 11-12 level. This means learning objectives typically refer to physics laws, models and theories, not every-day phenomena and practical applications. For example, there are requirements to "state and explain the law of conservation of linear momentum" and "distinguish between conservative and dissipative forces" when solving problems. Some learning objectives, such as "computing impedances and reactances in ac circuits", are characteristic of university undergraduate programmes. These involve mathematics with, for example, students learning to "perform vector multiplication easily" and "solving problems using calculus". In experimental courses, emphasis is placed on students "developing skills of using electrical measuring instruments" and "estimating uncertainty in experiments". These objectives, while aspirational, are above the level of knowledge PSTs demonstrate. Thus, the intended teacher education curriculum seems out of step with the knowledge of recruits into teaching, but clearly sets high expectations for their attainment by the end of their teacher education programmes.

Implemented Physics Curriculum

Originally, the intention was to code classroom teaching using the framework devised for analysis of the intended curriculum. However, the process of gathering these data prompted changes to this plan. By the time the lessons were recorded, researchers had analysed PSTs' physics knowledge test data. This revealed the level of knowledge of most PSTs was equivalent to international 13-year-olds (TIMSS, 2013). In contrast, the lessons they were taught featured advanced physics knowledge. Thus, researchers' attention turned towards how CTE lecturers bridged the gap between PSTs' physics knowledge and the higher level expected by the curriculum. Their teaching strategies and the knowledge level expected of PSTs were noted. Evidence relating to PSTs' level of knowledge is best demonstrated by the intensive use of mathematics. All lessons focused on establishing and manipulating mathematical formulae to express physics knowledge. Qualitative discussion of physics phenomena, typical of teaching Grades 8 to 10 and Grades 11 - 12 was almost completely absent. Furthermore, some observed lessons involved mathematics common to undergraduate physics. For example, integral mathematics was applied to describe work done by a variable force in mechanics. Lecturers introduced a physics topic by writing a mathematical formula on the blackboard then continued by manipulating this formula. A reason for this was reliance on textbooks, which were used extensively by lecturers as sources for their examples and problems. [INSERT TABLE 6 ABOUT HERE]

Table 6 summarises the type of activities observed in the lessons. PSTs engaged in problem solving is labelled *group work*, because during these times they were encouraged to work with one or more peers. *Class dialogue* means an exchange of questions and answers between PSTs and their lecturer. Questions directed to the whole group without expecting a specific student to answer were not coded as dialogue. Time spent by the lecturer explaining an answer to a problem following questions and answers with PSTs was included as dialogue. The eight lessons illustrate three types of teaching PSTs received. Lessons 1 and 2 involve a higher proportion of interaction in terms of PSTs or the lecturer asking questions. This seemed to be influenced by classroom context as only ten PSTs were present, most of whom entered the programme from Grade 12. Lecturer-PST dialogue revealed misconceptions that remained unresolved because the lecturer adopted a mathematical rather than a conceptual focus. In Lesson 1, for example, a particle model was used to explain heat conduction and convection. PSTs struggled to understand this model, but the lecturer focused on establishing a mathematical expression for heat transfer. This meant PSTs' conceptual difficulties remained. The second teaching type, found in Lessons 3 and 4, utilised less time on lecturing and more on problem solving. PSTs had ample time to solve problems and solutions were explained afterwards. Occasionally a male student (no female students were invited) was asked to present his solution to the problem on the blackboard. Lessons 5 to 8 exemplify a third teaching type, in which no time is spent on dialogue. These were didactic lessons in which the lecturer presented content from the textbook. In two of these lessons, PSTs solved problems for short periods, and no summaries involving whole class dialogue were included. A general observation was that lecturer-PST dialogue involved only a small number of PSTs, while the majority remained silent. Dialogue was targeted at the "best" PSTs and rarely or never included "weaker" colleagues.

Discussion

The paper analyses Ethiopian pre-service physics teachers' conceptual knowledge, showing that teacher education programmes recruit candidates with weak conceptual understanding. Despite receiving specialist physics teaching from CTE lecturers, attained curriculum analysis shows that PSTs training to teach Grades 5 to 8 leave their programmes with physics knowledge equivalent to the TIMSS international mean characteristic of Grade 8 students. These findings add weight to international studies including Sadler, Sonnert, Coyle, Cook-Smith and Miller (2013) and Baumert, Kunter, Blum, Brunner, et al (2010) who report that the gap between lower and upper level entry profiles is maintained throughout teacher education and beyond. This inadequate learning progress reflects PSTs' low grade entry profile (Kleickmann, Richter, Kunter and Elsner, et al, 2013) among other factors. The intended curriculum expects PSTs to learn physics at a level typical of Grade 12 or higher. This creates a significant challenge for teacher educators. However, observations of the implemented curriculum found almost no adaption to PSTs' low entry knowledge level. Lecturers keep strictly to the intended curriculum, presenting physics as if PSTs are able to master advanced knowledge without direct assistance. The outcome is that PSTs exhibit low or no learning gains in their final academic year, so complete leaving education with much lower knowledge levels than the intended curriculum suggests.

Two notable observations of the teaching PSTs receive are absence of conceptual discussions and extensive use of mathematics. This approach is typical of undergraduate level physics teaching in many high-income nations. The lack of conceptual discussion is not a fault of the intended curriculum, but caused by classroom pedagogy. Lecturers lack exposure to any tradition or experience of engaging in debates when PSTs ask "naïve" questions about basic physics concepts. Although curriculum documents emphasise mathematics, this focus is intensified when operationalised into lectures, becoming a route to delivery via over-reliance on a textbook. The findings parallel those relating to secondary education in Ethiopia, which is described as "academically demanding and closely tied to university entry requirements" (Joshi & Verspoor, 2013, p. 59). Joshi and Verspoor (2013) show that the Ethiopian Grade 10 curriculum is equivalent to that of grade 11 and 12 in the US and UK. What we observe, in other words, is an academic culture with high demands for teacher education and the Ethiopian school system. This culture developed when education was aimed for elite students and has not adapted to accommodate recent reforms towards mass education. This study reveals a significant mismatch between curriculum demands and PSTs' needs. This is problematic for lecturers in teacher education to handle, leading to teachers poorly equipped to teach, which in turn generates poor attainment among school students.

Comparing the current study to international trends suggests Ethiopia has missed out on two types of curriculum reform that have impacted science education elsewhere. In the 1980s, aided by developments in cognitive psychology, school curricula became more closely adapted to meet students' intellectual needs and abilities. For example, Shayer & Adey (1981) applied Piaget's (1952) cognitive theory to science curricula, showing that some required levels of cognitive ability far above that of the average student, making examinations inaccessible to all but an elite group. They advocated matching intellectual demands of the curriculum with students' approximate age-related development. Subsequently, abstract learning outcomes were redistributed from lower to higher age groups, allowing potentially a higher proportion of students to be able to access these ideas as curricula developed understanding of complex ideas progressively. Later, attention turned towards conceptual understanding, because surveys documented students learned to solve problems mathematically but not conceptually (Hewson, 1981). Curricula and teaching focused on helping students' conceptual change from naïve pre-conceptualisations to required textbook-conceptualisations of science phenomena. The second reform aimed for science education for all (Association for Science Education, ASE, 1979; American Association for the Advancement of Science, 1989). Discussion documents showed that school curricula prepared students for further studies, but did not adequately prepare them for everyday needs and citizenship (Millar & Osborne, 1998).

Research outcomes in the Ethiopian context demonstrate absence of evidence for both reforms in revisions of science curricula. Learning outcomes remain highly abstract, particularly relating to PSTs' levels of knowledge prior to and during teacher education. The physics they learn is inadequate and inappropriate for preparing Grade 5 to 8 students aged 11 – 14 for any other aims than further studies in physics. Data presented here provide evidence for ways in which Ethiopian teacher education can be improved, creating a more appropriate balance between intended, implemented and attained curricula. Although examples are not always directly transferable between cultures, PSTs in the Linear Teacher Education Programme are learning the same physics concepts as those taught elsewhere. The crucial issue is how best to address the gap between PSTs' incoming knowledge and the requirements of the teacher education programme. At present CTEs and their lecturers are under pressure to fulfil Government targets for the number of trained teachers. In practice, this means the mismatch between intended and attained curricula is often concealed. Only by openly documenting the problem and engaging those working in pre-service teacher education in finding solutions can progress be made. At present, an implication arising is that the current generation of Ethiopian primary children is being taught physics by teachers

with limited physics knowledge and no prospects for improving this. This situation perpetuates the cycle of poor attainment outlined in the introduction.
Catching up with the second reform, scientific literacy makes further challenging demands. Ethiopia can draw on international developments, since the same type of debate is needed here as in other nations. A debate is required throughout the whole education system about the balance between "education for all" and preparing a small group of students for further studies. This should be followed by analysis of each subject area, highlighting essential aspects required for citizenship and everyday needs. Teacher education should build its curriculum on the outcome of this debate and analysis.

Overall, this study reveals serious gaps between the intended, delivered, and attained curricula in terms of PSTs' knowledge levels and CTE lecturers' practice. This gap is detrimental to the generation currently attending Ethiopian schools and the achievement of the country's high aspirations of aligning with low-middle-income countries in the near future. A key proposal is reconsideration of the intended teacher education curriculum with a view to ensuring that the system produces teachers with highest efficacy levels capable of delivering enhanced student achievements.

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Per Kind, the original Principal Investigator, died on 1st October 2017. His inspiration for and work on the project is remembered through this publication and in Ethiopia.

Declaration of interests

No conflicts of interest or financial benefits from undertaking the research are reported by any of the authors.

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Figure 1: Comparison of Ethiopian PSTs' correct responses levels to three Electricity items with those of the TIMSS highest, lowest and mean values

Ethiopian PSTs N=325

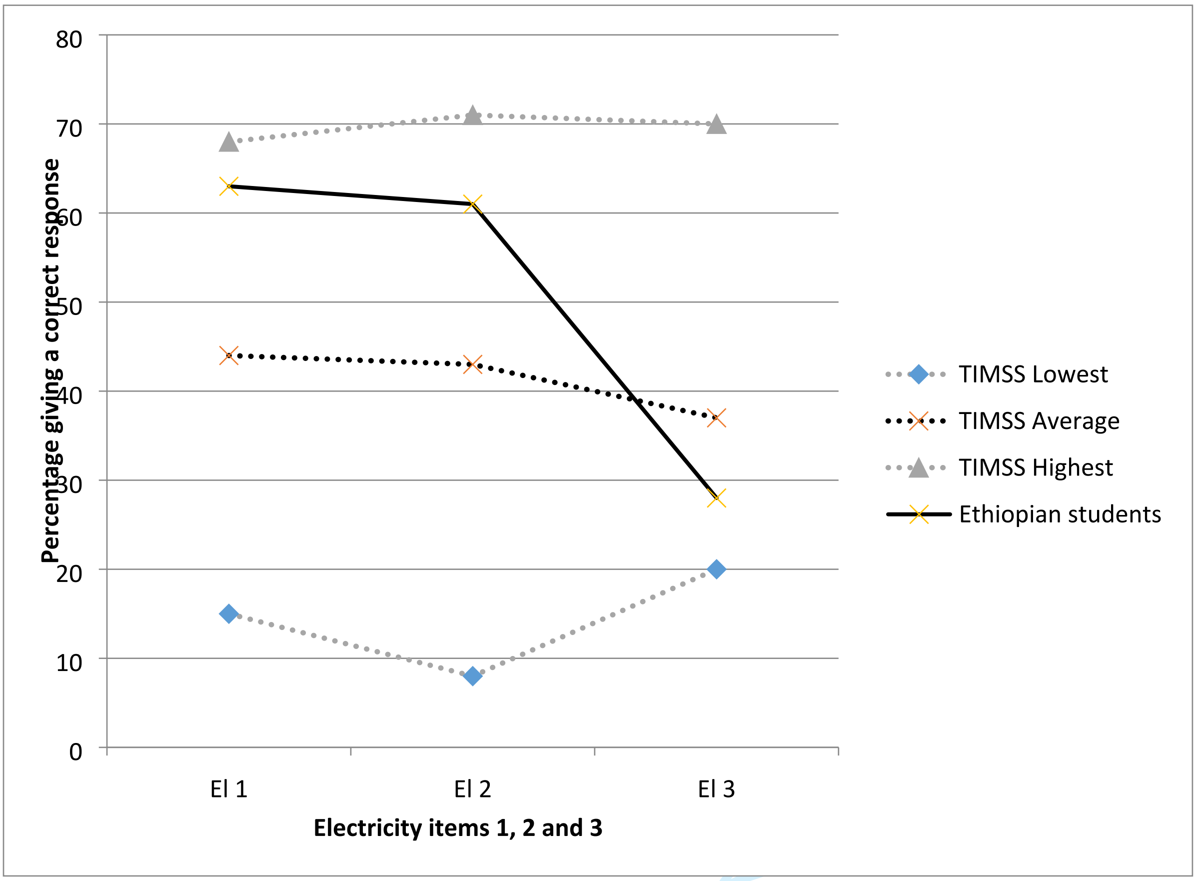

Figure 2: Correct response levels given by Ethiopian PSTs entering teacher education post-Grades 10 and 12 compared to TIMSS highest, lowest and average scores

Ethiopian PSTs N=325

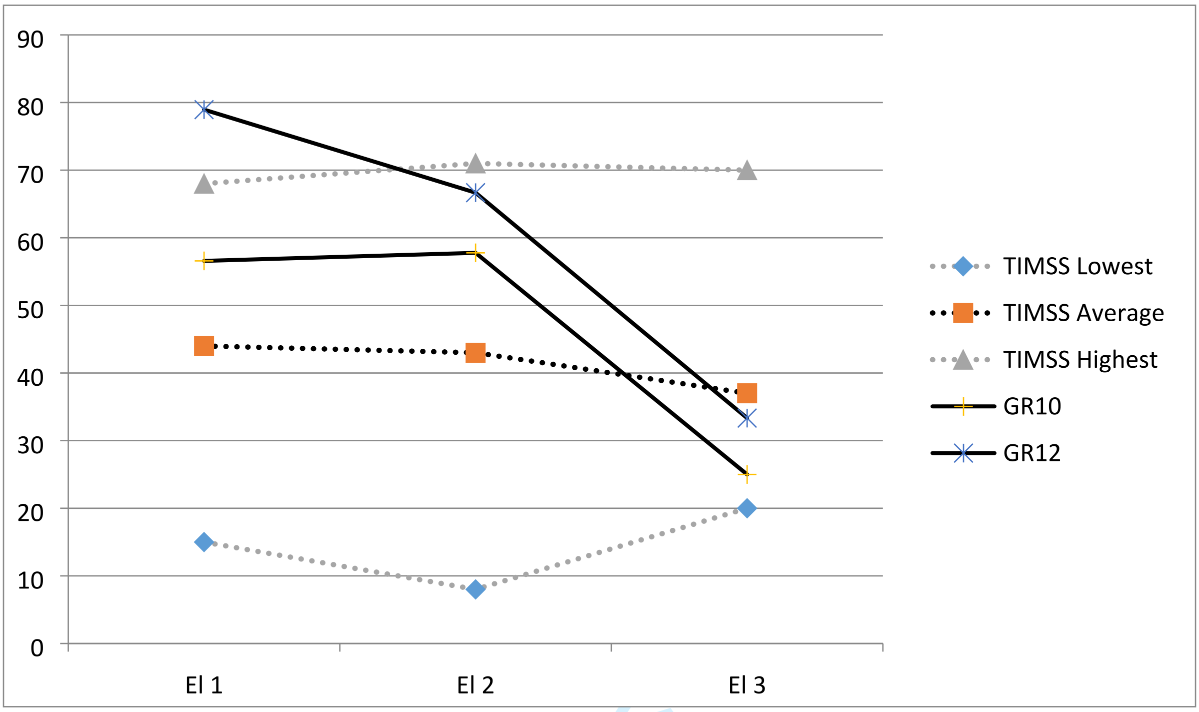

Figure 3: Comparison of Ethiopian PSTs' correct responses levels to three Sound Waves items with those of the TIMSS highest, lowest and mean values

Ethiopian PSTs N= 131

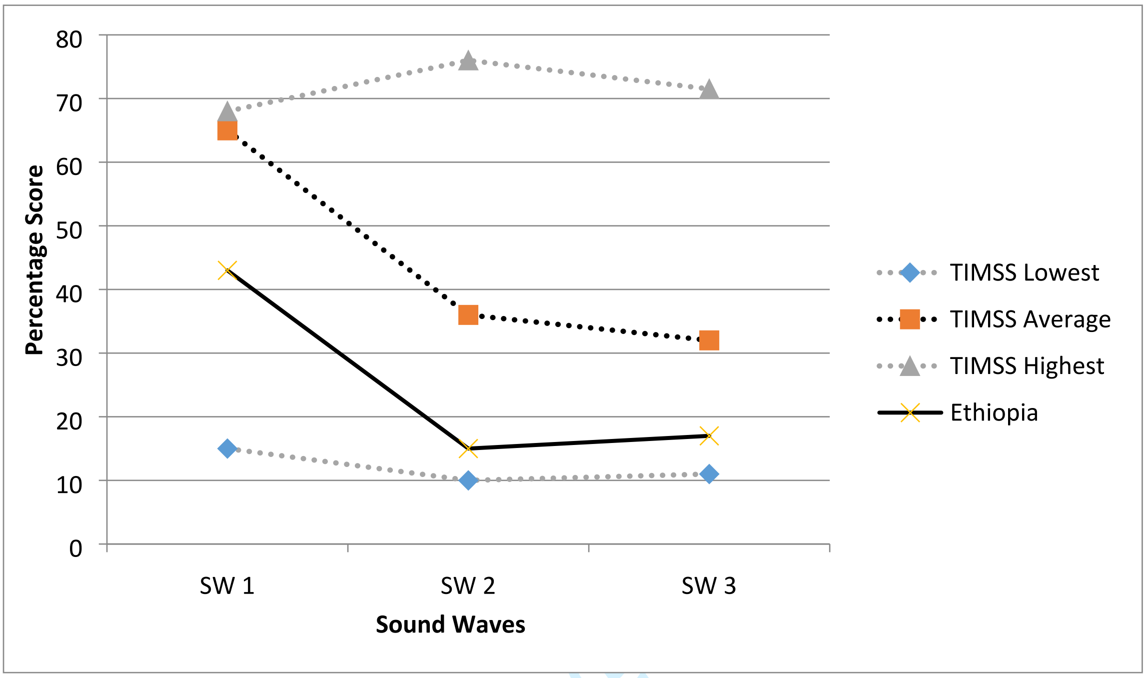

Table 1: PSTs' gender distribution and examination entry level

Entry level	Male No. (% of total)	Female No. (% of total)	Totals No. (% of total)
Grade 10 entrants	252 (55.9)	54 (12.0)	306 (67.9)
Grade 12 entrants	84 (18.6)	42 (9.3)	126 (27.9)
Entrant level missing	11 (2.4)	3 (0.7)	14 (3.1)
Gender missing	-	-	5 (1.1)
Totals	347 (76.9)	99 (21.9)	451

Table 2: Ethiopian PSTs' scores on general electricity items at the start and end of their final year of teacher education

PSTs' entry grades	Start of academic year			End of academic year	
	No.	Test score[1]	Standard Deviation	Test score	Standard Deviation
10	78	11.4	2.0	10.8	2.2
12	25	12.4	1.8	12.3	1.8
All	103	11.6	2.0	11.2	2.0

[1] Scores calculated as logit values in Winsteps, but rescaled to fit the number of items in the test. Each student responded to 18 items.

Table 3: Ethiopian Primary PSTs' raw scores on specialist physics items at the start and end of their final year of teacher education

Specialist topic	Entry Grade	No.	Start of Academic year: Raw Score[2]	Start of Academic year: Standard Deviation	End of Academic year: Raw Score	End of Academic year: Standard Deviation
Electromagnetism	10	78	1.18	0.98	1.14	0.99
	12	25	1.12	0.67	1.91	0.95
	All	**103**	**1.17**	**0.91**	**1.34**	**1.00**
Mechanics	10	46	1.15	0.97	1.45	0.98
	12	12	1.67	0.98	1.90	0.74
	All	**58**	**1.26**	**0.98**	**1.54**	**0.95**
Waves and Optics	10	54	1.11	0.82	1.24	0.77
	12	12	1.42	1.30	1.58	1.20
	All	**66**	**1.17**	**0.92**	**1.31**	**0.86**
Thermodynamics	10	49	1.27	0.88	0.94	0.96
	12	18	1.79	1.30	1.47	0.80
	All	**68**	**1.41**	**1.00**	**1.08**	**0.95**

[2] Raw Scores out of six points

Table 4: Ethiopian PSTs' scores on specialist physics items compared to TIMSS mean scores on entry to the teacher education programme

Ethiopian PSTs N=325

Topic	No. of Items	TIMSS Mean score	All Ethiopian PSTs	PSTs entering at Grade 10	PSTs entering at Grade 12
Electricity	3	41	**51**	46	60
Thermodynamics	5	47	**52**	50	58
Pressure	3	26	**30**	28	35
Energy	3	23	26	22	32
Force and Motion	2	30	25	23	28
Sound Waves	4	47	31	30	34
Optics	2	32	19	17	23
Grand Average		**35**	**33**	**31**	**38**

Table 5: Document analysis of the intended curriculum for physics pre-service teacher education

Dimension	Grades 8-10	Grades 11-12	Undergraduate	Totals
Investigating/Experimenting	4	14	1	19
Solving Problems	17	55	10	82
Using Mathematics	0	5	4	9
Total	**21**	**74**	**15**	**110**

Table 6: Characteristics of eight lessons observed in the Linear Teacher Education Programme

Lesson	Topic	PSTs entry grade		Lesson Time %			Language
		Grade 10 No.	Grade 12 No.	Lecturing	Group Work	Class Dialogue	
1	Thermodynamics	3	7	52.1	8.9	11.6	Amharic
2	Electromagnetism	3	7	66.2	9.8	25.7	Amharic
3	Electromagnetism	17	4	16.8	41.4	41.8	English
4	Electromagnetism	17	4	9.4	42.2	48.4	English
5	Electromagnetism	21	7	100	0	0	English
6	Mechanics	19	7	100	0	0	English
7	Electromagnetism	25	5	80.4	19.6	0	English
8	Thermodynamics	25	3	90.9	9.1	0	English