Ready to teach? Reflections on a South African mathematics teacher education programme

Iben Maj Christiansen

Abstract

In this paper, I interrogate the extent to which a current mathematics teacher education programme at University of KwaZulu-Natal prepares teachers to teach well in the regional context. In order to determine which aspects to consider in the analysis, I draw on studies of factors correlated to learner achievement in South African primary schools. First, this suggests that the consideration of context should play a strong part in our teacher education. Second, it indicates that teacher actions most strongly linked to learning – deep representations, feedback guiding learning and challenging learners on their level – only occur occasionally in KwaZulu-Natal schools, and with limited opportunity to develop mathematical proficiency. The question I raise is to what extent we prepare teachers to teach in this way, and with awareness of the context. Third, I briefly consider what other, perhaps overlooked, competencies our teachers need.

In the light of Bernstein's recognition of the centrality of evaluation in the pedagogic device, I have analysed the exam papers in the programme. My analysis utilises a pragmatically compiled bag of tools. First, I distinguish between the knowledge categories in our programme: contextual knowledge, curriculum knowledge, content knowledge, pedagogic content knowledge, and general pedagogical knowledge. Next, I explore the extent to which specialised knowledge is foregrounded in our programme, drawing on Maton's distinction between a knowledge and a knower legitimisation code. Third, by distinguishing the semantic gravity of the course content, I aim to identify how theoretical or decontextualised knowledge is linked to the practice of mathematics teaching. This enables me to consider the extent to which the programmes favour cumulative or segmented learning.

My findings indicate that the programme is strongly founded in a knowledge code, and that it covers all of the five aforementioned knowledge domains, but it needs further exploration how well these are linked within and across courses, thus providing cumulative learning. Teaching for deep representations is strongly reflected in the exam papers, both in the content knowledge and the pedagogical content knowledge components, but there is virtually no indication that providing appropriate challenges to learners is important. While students are tested on their recognition and realisation of assessing learners' level of understanding, this is not utilised in teaching students to provide appropriate feedback, nor is it used to inform the design of activities which can cater for a classroom with learners of mixed ability or varying levels of current understanding. Furthermore, there is no assessment of the teachers' preparedness to teach for adaptive reasoning. In that respect, the programme appears not to prepare the students adequately for quality teaching. I discuss whether this knowledge mix and what is *not* taught can be seen as having an implicit student in mind, thus limiting access to relevant teacher competencies for some students.

Introduction

One assumption behind this paper is that teaching is facilitation and organisation of systematic learning (Morrow,1999) of specialised knowledge and specialised gazes on the world. A second assumption is that teacher education should prepare teachers to teach in schools, in terms of furthering their (1) professional knowledge, (2) professional practice and (3) professional engagement (Ingvarson, Beavis, and Kleinhenz, 2007). This implies (1i) knowledge about content and how to teach it, (1ii) knowledge about students and how they learn, (2i) curriculum, (2ii), classroom management, (2iii) assessment, (3i) reflecting on teaching, and (3ii) work with parents and others (*ibid.*).

By interrogating which factors are most related to learner performance according to international studies (next section), and regional/South African studies (subsequent section), questions to be considered in our teacher education programmes are formulated. Yet before I go there, I want to engage some issues of the aforementioned assumption.

Of course, how the first assumption above is interpreted is a crucial and critical issue. If it is taken in its narrowest form, it could be assumed to mean focusing on providing teachers with the content knowledge they will teach, and with a set of routines for transmitting it. In its broadest form, it could be taken to mean that teachers should be prepared to unpack the educational system and its positioning strategies, the psychology of the classroom, the recontextualisation of knowledge, and so forth, and be able to constantly reflect on and adjust their teaching accordingly – a critical stance perspective (Ainley and Luntley, 2007; Cochran-Smith and Lytle, 1999; Hiebert, Morris, Berk, and Jansen, 2007). In my claim that teaching is facilitation and organisation of systematic learning, I am driven to foreground providing learners with access to specialised knowledge above the critical stance. This does not reflect my own position as much as recognition of the need to start somewhere, also considering that learning to teach from a critical stance may be too great a leap from our current situation (cf. Beeby, 1966). Yet it is a dimension which should be considered, and I will do so elsewhere.

There are obvious methodological as well as educational problems with attempting to assess learning by measuring performance through large scale tests. It is, however, the only measure we have which allows statistical comparisons and correlations with background factors. Smaller scale studies are obviously useful in exploring the causal relationships reflected in correlations and in considering competence rather than performance. In this paper, I have consciously and pragmatically taken the simplistic view and discuss effectiveness of teaching in terms of impact on learner performance, despite being aware of the shortcomings.[1]

Another issue is the extent to which teachers should be able to critically engage the selection of content to teach. As sociologists of education have emphasised repeatedly, it is not arbitrary what counts as knowledge (or art), and the selection of content to teach is itself a highly contested area, as is the extent to which the teacher should be a change agent (Liston and Zeichner, 1987). Again, it would be too far reaching to engage that in what remains a first investigation of a programme.

The exploration, and with it this paper, draws on a series of analytical tools. Some of these are drawn from work which assumes a sociological sensitivity to educational issues, and addresses positioning in relation to different types of knowledge. Others are based on existing and widely accepted (though also widely contested) categorisations of teacher knowledge linked to statistical analysis of which teacher actions impact on learner performance. In one respect, they are brought together in a way which can only be defended from a perspective of perspective pluralism (Skovsmose, 1990) or a claim to complementarity, in the same sense that descriptions of an electron as a particle or a wave are complementary. In another respect, what unifies them in this study is the extent to which they select, reproduce and position student teachers to do the same to their learners.

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1 Such as ignoring more formative elements of teaching, or reducing the effect of caring relationships and the cumulative effect of learning which tends to disguise the work of previous teachers – a factor not often considered in impact studies. See (Lingard, Hayes, and Mills, 2003) for a discussion of related points.

Factors related to learner performance according to international studies

International impact studies, most of which have been conducted in more developed contexts, indicate which factors explain differences in learner performance. Hattie and colleagues' summary of such studies suggest that learners' aptitude/ability account for half of the difference in performance; school, home, peers and the principal for about 20%; and the teacher for 30% (Hattie, 2003). The obvious problem with this list is not separating out socio-economic background. "The school is in fact the institution which, by its positively irreproachable verdicts, transforms socially conditioned inequalities in matters of culture into inequalities of success, interpreted as inequalities of talent, which are also inequalities of merit." (Bourdieu and Darbel, 1969/1991, p.111). Hattie only addresses this by saying that "the major effects of the home are already accounted for by the attributes of the student" (Hattie, 2003, p.2).

Hattie goes on to identify 16 characteristics of 'excellent' teachers, whose students perform better: they provide deep representations/content connections; a problem-solving stance to their work; they can anticipate, plan and improvise as required by the situation; are better at identifying important decisions; they are proficient at creating a learning classroom climate; have multidimensional perceptions of classroom situations; are more context-dependent; are more adept at monitoring and assessing students and provide more relevant feedback; are more adept at developing and testing hypotheses about learning and teaching; are more automatic; have high respect for students; are passionate; engage in enhancing learners' self-esteem and self-regulation; provide challenging tasks and goals for students; have positive influences on students' achievements; and enhance surface and deep learning.

Testing these in the USA, his paper claims that the three most important characteristics of teachers whose learners perform significantly better are: paying attention to deep representations, providing appropriate challenges to learners, and giving feedback which facilitates further learning. If teacher education is to take these findings seriously, it seems reasonable that these are the elements of teaching for which we should prepare our students. However, how does this relate to the other 70% of what impacts on learner performance, and how may the weighting of the factors be different in a developing context?

What furthers learning most in South Africa?

There have been numerous studies engaging which factors are most strongly correlated with learner performance. Most recently, I have been involved in a medium scale study of grade 6 teaching and learning in one South African province.[2] Such studies must all be seen in the context of the very low achievement of the majority of South African learners as indicated by the TIMSS and other studies. In the SACMEQ[3] III study (Hungi, Makuwa, Ross, Saito, Dolata and Van Cappelle *et al*., 2010), 44% of the learners in the province were found to operate on pre-numeracy or emergent numeracy levels, and this applied to even more of the learners in our study. The average score on the learner test in our study, which mostly consisted of grade 5 content, was just over 25% correct. All of this clearly indicates that the learners are operating far below grade level. Misconceptions are common (Christiansen and Aungamuthu, 2012).

The SACMEQ II study found substantial variations amongst schools in South Africa (SACMEQ II, 2010). This is in agreement with the findings from our own study which indicates that approximately 44% of the explainable variation in learner test performance can be attributed to differences between the classes, and since in most cases only one class from each school was included in the dataset, to differences between the schools. It appears to be a stronger factor than individual socio-economic status (Spaull, 2011; Van der Berg, Burger, Burger, De Vos, Du Rand and Gustafsson *et al*., 2011), and our data also support this. This is clearly a consequence of the Apartheid system with its segregated population groups, where less educated teachers often teach in poorly equipped schools in poor communities.

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2 While this was using the same instruments as the greater study headed by Carnoy and Chisholm (Carnoy, Chisholm, and *et al*., 2008), the study was undertaken independently, as part of a project under the KwaZulu-Natal treasury headed by Wayne Hugo and Volker Wedekind.

3 SACMEQ is the *Southern and Eastern Africa Consortium for Monitoring Educational Quality*, and it is a network of Ministries of Education. SACMEQ undertakes research to monitor, evaluate and inform improvements in education in the region. In 2007, data were collected in grade 6 classes to determine literacy and numeracy levels. Learners were selected in two tiered random process, first choosing schools and then learners, resulting in a sample of 9071 learners from South Africa. Some findings in this paper is from the previous SACMEQ study, three years earlier.

So while Hattie's (2003) comprehensive summary of the international literature indicates that the home factor is more important than the school location, the situation in South Africa may be opposite. While this could simply be because socio-economic status of the home is strongly linked to location, changing school appears to impact strongly on achievement (Van der Berg, *et al*., 2011).

There are other important factors. One of these is language. This has been discussed extensively elsewhere (Setati, Chitera, and Essien, 2009), so for here it suffices to say that our research in the province indicates that learner misconceptions are more prevalent in African home language learners (Christiansen and Aungamuthi, 2012); and indeed it makes sense that basic interpersonal communication skills (BICS) in a second or third language does not imply the cognitive academic language proficiency (CALP) required to learn equally well from instruction in this language (Essien and Setati, 2007; Gerber, Engelbrecht, Harding, and Rogan, 2005; Setati, *et al*., 2009).

That the school factor is very influential does not mean that the home situation does not matter. In our study, we also found that the amount of reading material the learners reported having in the home, having been read to as a child, reading at home, as well as who was their primary caretaker[4] had significant effect on test scores. The latter was also significantly related to the educational level of the caretaker. Preschool education is another factor which correlates with learner performance (Spaull, 2011).

Aspects of teaching linked to learner performance

Within the school, more related to the teaching, important achievement factors appear to be: discipline/classroom management, feedback, frequency

[4] With fellow siblings and grandmothers as caretakers being associated with lower performance.

of homework, feeling secure/safe in and around the school,[5] curriculum coverage, and presence of questions of high cognitive demand, while choice teaching methods such as direct instruction versus guided learning are less important– all according to our own study and others (Reeves, 2005; Spaull, 2011; Van der Berg, *et al*., 2011). For reading, the availability of textbooks also makes a difference, but this does not apply to mathematics textbooks (Spaull, 2011).

So while a recent report states that "poor performance of teachers is a major reason for the poor performance of the South African schooling system" (Centre for Development and Enterprise, 2011, p.27), not only is this putting too much of the responsibility on teachers given the impact of previously mentioned factors, it must also be understood which performance aspects of teaching are most important. There are also indications that interventions in poorer schools do not have much, if any, impact – some schools do not manage to turn resources into an educational advantage, and the teachers' content and pedagogical content knowledge has less impact the more disadvantaged the school is (personal communication regarding a review of school interventions, Paul Hobden). Along the same lines, strong Kenyan learners improved their performance substantially when they were given textbooks, whereas the same did not apply to weak or even average learners (Glewwe, Kremer, and Moulin, 1998).

To deepen our understanding of this, we engaged detailed analysis of the video recordings of teaching in our study. The study focused on grade 6 teaching and learning, at 39 schools chosen through stratified random sampling within one district in KwaZulu-Natal. A full set of data from a school consisted in a teacher questionnaire and a teacher test on content knowledge and some pedagogical content knowledge (PCK), a learner questionnaire, a learner test from the start of grade 6, a learner test from the

5 In our study, learners not feeling safe in school was statistically significant in relation to their test scores. 39% of the learners in the final sample, ie learners who sat for both tests, were sometimes scared of being hurt by other learners, and 4% often; 36% were sometimes scared of being hurt by a teacher in the school, and 4% often. An alarming number of learners do not feel safe in the school environment. Violence amongst learners and by teachers may not be uncommon, but learners also fear violence from the surrounding community, such as rape or abduction on the road to and from school; in our study, 36% sometimes felt scared of being hurt by someone from outside the school, 7% often. This is likely why a solid demarcation of the school area is one of the characteristics of resilient schools (Christie, 2001).

end of grade 6, a principal questionnaire, a video recording of a lesson in each grade 6 class, and a sample of learner workbooks to give some indication of curriculum coverage. As the data collection was difficult, we did not always get a full set of data from all schools, which limits the validity of our study. Yet the preliminary analysis indicates some issues for concern. And these made us ask how great a factor the teacher is in South African learner achievement, and what aspects of teaching and teacher knowledge seem to matter the most. All of this would inform what we foreground in our teacher education programmes.

The video recordings were analysed for the practical PCK displayed, in particular the extent to which the teacher linked to prior knowledge, encouraged longitudinal coherence, showed more than one approach to a problem type, and identified and addressed errors or misconceptions (Ramdhany, 2010). They were also analysed for the extent to which teachers provided opportunities to develop mathematical proficiency[6] (Ally, 2012). All of these factors were then related to the teachers' test scores and the learners' achievement. I will briefly discuss the findings, as they informed the formulation of questions for the interrogation which informed this paper.

The teachers generally performed poorly on the test they were given. Though we only had both questionnaires and tests from 34 teachers, we tried to see if there was any significant difference in performance on the test depending on educational levels: the ANOVA showed no significant difference between teachers with a formal and no formal teacher qualification, respectively. This agrees with the finding from the SACMEQ study which showed that only about 6% of the variation in teachers' scores on a learner test was related to qualifications.

Teacher content knowledge is often considered crucial, but the studies indicate that it accounts for little of the variance in learner performance. For instance, an analysis of the SACMEQ III data indicates that a 100 point – or roughly one standard deviation – improvement in teacher score only raises

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6 The notion of mathematical proficiency contains five dimensions: conceptual understanding, procedural fluency, adaptive reasoning, productive disposition and strategic competence (Kilpatrick, Swafford, and Findell, 2001). Ally distinguishes between mathematical proficiency, which focuses on the learning, and opportunities to develop mathematical proficiency (OTDMP), which focuses on teaching. Further development of indicators of levels of OTDMP is needed, but the approach looks promising.

learner scores by 4.8 points; and this impact is much smaller in the poorer quintiles of schools (Spaull, 2011).

There were differences in the extent to which the teaching displayed practical PCK, and the teachers who displayed more PCK were more likely to have a professional teaching qualification or an academic qualification, but the results were not statistically significant (Ramdhany, 2010, p.65). More depressing, there was no significant difference in learner achievement gains from test 1 to test 2 between the teachers who displayed more PCK and those who displayed less (Ramdhany, 2010, p. 65). This is not necessarily the case in other contexts. Thus, a German study found that "when their mathematics achievement in grade 9 was kept constant, students taught by teachers with higher PCK scores performed significantly better in mathematics in grade 10" (Krauss and Blum, forthcoming). Thus it remains to be seen if pedagogical content knowledge matters more in high performing South African schools, where learners have attained a basic level of comprehension and competency – and are not hungry or in other ways struggling to have their basic needs met.

All in all, the opportunities to develop mathematical proficiency in the classes in our study were limited: only in half of the 30 classrooms from which videos were coded for this aspect, was conceptual understanding facilitated, and in 76% of these cases, a concept was simply stated or learners' attention directed to it. In the remaining 24% of the cases, a concept was formulated through discussion or demonstration and mathematically supported by teachers or learners (Ally, 2012). Only in about a third of the cases were opportunities provided which clearly clarified the concept with explicit links made to other concepts (Ally, 2012). This is not the best quality of teaching, if I go by the claim by Hattie that 'deep representations' is central to good teaching, as well as the stressing of conceptual understanding in much mathematics education literature from the past decades.[7] We did find a significant correlation (at the 5% level) between the highest secondary school qualification obtained by the teachers, and the extent to which they provided their learners with the opportunity to develop mathematical proficiency, in particular conceptual understanding. There was some indication that there was a correlation between learner achievement gains and the opportunity to develop adaptive reasoning yet this is not a reliable correlation since this

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7 This of course should not be taken to mean that conceptual understanding should be pursued without procedural fluency etc. though this perception may be prevalent (Bossé and Bahr, 2008).

strand was only evident in 9 lessons in the study (Ally, 2012). Yet, this result is in agreement with the claim by Kilpatrick et al, that adaptive reasoning is "the glue that holds everything together" (Kilpatrick, *et al*., 2001, p. 129).

While this seems to indicate that teacher education does not make much difference in South Africa, we must remember – besides the validity issue from the small number of teachers who actually provided us with all the relevant data – the role of the contextual factors mentioned above. Thus, it appears that school location and home factors matter much more in South Africa than in the studies to which Hattie refers, while teaching quality is generally questionable and therefore the impact of this factor is dwarfed by the general conditions of schooling and living in most of our communities.

What does this mean to mathematics teacher education? I engaged our local programme as a case.

Questions for the local teacher education programme

The Post Graduate Certificate in Education (PGCE) is a one-year post-graduate teaching qualification. Students with a bachelor's degree are accepted into the programme if they meet the entry requirements for their desired disciplinary specialisation. For mathematics teachers up to grade 9, this means having completed more than one course of first year university mathematics, and for teachers for grade 10–12, some second year university mathematics is required. The entry requirements are lower than in many programmes internationally, and this must be seen in the light of the severe national shortage of teachers of mathematics.

The programme comprises eight courses: 3 general education courses, 2 practical courses spent in schools ('teaching practice'), and 3 courses specific to their choice of discipline (teaching specialisations). There are two mathematics education courses available, one for grade 7–9, and one for grade 10–12. Both have as their stated purpose to equip the students with PCK for teaching the content specified by the national curriculum.

The discussion of what South African teachers need seems to indicate that they must be prepared to deal with the broader context to further the resilience of the school (Christie, 2001), which may imply taking some form of teacher leadership role and extending the teaching to include a stronger ethics of care (Grant, Jasson, and Lawrence, 2010). In the context of literacy in pre-school, Prinsloo and Stein go as far as to suggest that growing a vegetable garden is part of literacy education (Prinsloo and Stein, 2004). In any case, it is important that new teachers understand these issues and their impact on education. Thus, I was interested in seeing to what extent contextual issues were engaged in our PGCE programme.

For teacher education to counter the low educational achievement of our learners, it is important that its recognition and realisation rules are within specialised knowledge, not allowing students to rely first and foremost on their beliefs, past experiences, etc. For this purpose, I engaged the extent to which our teacher education programmes reflect a knowledge legitimation code (Maton, 2006), where claims to legitimacy are situated within the epistemic rather than the social relation – discussed further in the section on analytical tools. Yet students must be provided access into specialised knowledge, and thus it was important to consider how theory and practice were related in the courses. I did so by considering the semantic gravity of the course (Maton, 2009).

Next, I interrogated the extent to which the content of the courses reflected the indicators of good teaching outlined by Hattie (Hattie, 2003), and how this related to the context just outlined. Seeing that opportunity to develop adaptive reasoning may be linked to learner achievement gains, I also looked for the extent to which preparation for this was foregrounded in our programme.

The issue of *how* to convey these issues to the students were not considered presently.[8]

Analytical tools

In the study, I operationalised a number of coding systems. First, I considered

8 There is much input on this, see for instance (Adler and Davis, 2006; Artzt, 1999; Jaworski and Wood, 1999; Langford and Huntley, 1999; Liston and Zeichner, 1987; Lloyd, 1999; Nakanishi, undated; Ohtani, 2003; Parker and Adler, 2012; Rayner, Pitsolantis, and Osana, 2009; Schifter, 1998; Yang and Leung, 2011). In the South African context, a refreshing perspective is still delivered by (Breen, 1991/2).

five knowledge domains: Contextual knowledge including knowledge of learners' background; curriculum issues, including meta-questions regarding the nature of teacher knowledge and questions regarding the overall purposes and goals of education; content knowledge; PCK; and general pedagogical knowledge. Other contributions to this issue have discussed the problems of identifying the knowledge domain of a task or question, in particular in relation to PCK (Adler and Patahuddin, forthcoming; Krauss and Blum, forthcoming). In order to work around this problem, in a pragmatic way given the preliminary nature of this study, I did this by working with some more clearly demarcated sub-categories. Another consideration was that, unlike the questions discussed by (Adler and Patahuddin, forthcoming), the tasks comprising the data in this study did not have to address one knowledge domain only, so it was possible for a question to fall within more than one category or sub-category.

Content knowledge was separated into three categories, namely declarative (conceptual), procedural, and 'doing mathematics' (Stein, Smith, Henningsen, and Silver, 2000). Some of Hattie's (2003) 16 characteristics of excellent teachers would be hard to assess outside of the practice of the classroom, but I felt that nine of them could, and these were then grouped either as PCK or as pedagogical knowledge. Thus, PCK was given five sub-categories:[9] assessing and giving feedback; deep representations including linking to other content; focusing on key aspects of teaching; challenging the learners; and focusing on deep rather than surface learning. Likewise, pedagogic knowledge was distinguished as: facilitating a classroom culture conducive to learning; furthering a multi-dimensional understanding of the classroom; having a pedagogical repertoire with more than one informed approach; and adapting a problematising strand where more information is sought before making a teaching decision. These sub-categories were also not mutually exclusive.

Second, I focused on legitimisation of knowledge. As has been pointed out by Adler and colleagues, the way knowledge is legitimised in education can be revealing. For instance, (Parker and Adler, 2012) found that a mathematics lecturer legitimised content knowledge by referring to mathematics, but knowledge about teaching was legitimised with reference to mathematics, the

9 This does not imply that these are necessarily the best descriptors or indicators of PCK, nor that they are exhaustive. I used them because they are important factors determined in Hattie's work, and because they relate well to previous work on the nature of PCK, which I will not go into here.

lecturer's personal experiences, etc. Working with examination papers does not allow me to follow Parker and Adler's method. I turn instead to Maton, who is interested in the legitimisations of knowledge. He postulates that "knowledge comprises both sociological and epistemological forms of power" (Maton, 2000, p.149), and "knowledge claims are simultaneously claims to knowledge *of the world* and *by authors*" (ibidem, p. 154, italics in original). Two modes of legitimation are worked with, a 'knowledge mode,' and a 'knower mode'. In the knowledge mode, the epistemic relation, the knowledge, is foregrounded. In the knower mode, knowledge is more specialised by its social relations, whether it is who you are or your particular cultivated gaze on the world that counts. To distinguish the legitimation code, I drew on the analytical categories presented by Chen, Maton and Bennett (2011). They distinguish between four:

- knowledge code (ER+, SR–), where possession of specialised knowledge, procedures or skills is emphasised as the basis of achievement and the dispositions of actors are considered less significant;

- knower code (ER–, SR+), where the dispositions of actors are emphasised and specialist knowledge or skills are downplayed. These dispositions may be considered innate or natural (e.g. notions of 'genius'), cultivated (e.g. an artistic sensibility developed through immersion in great works), or socially based (e.g. a specific gender);

- elite code (ER+, SR+), where achievement is based on having both specialist knowledge and being the right kind of knower; and,

- relativist code (ER–, SR–), where neither specialist knowledge nor particular dispositions are important (Chen, *et al*., 2011, pp.131–132).

The third tool for analysis engaged the extent to which knowledge in our programme was context dependent or abstract. Whereas Bernstein made a distinction between horizontal and vertical discourses in the knowledge production sphere (Bernstein, 1999), Maton is also interested in the reproduction of knowledge and employs a more graduated measure which will allow him to see if a curriculum favours segmented or cumulative learning (Maton, 2009). One measure which assists in this is semantic density, which indicates the extent to which meaning depends on context – weaker semantic gravity is associated with vertical discourse and more context independence, stronger semantic gravity with horizontal discourse and more context dependence (*ibid.*). As Dowling discusses, it is necessary to start from less specialised knowledge to gain access to the specialised, and the specialised can then be applied (Dowling, 1998). In other words, there will be a gradual decrease of context dependence as learners move from the everyday into mathematics, and then an increase in contextualisation as mathematics is applied. Maton has picked up on the move towards more abstraction in his 2009 paper, which develops categories of analysis for abstraction. He does not have a similar set of categories for when students are asked to apply more decontextualised knowledge. I therefore developed 6 categories for abstracting and 6 for applying, paired according to increasing degree of decontextualisation. I also added a category for entirely decontextualised, that is, theoretical, knowledge. The coding categories are shown in the appendix, which also compares them to Maton's categories, the extended Bloom's taxonomy (Anderson, 2005; Anderson and Krathwohl, 2001), and (Hatton and Smith, 1995)'s types of reflection in teacher education.

Method

The current results are from the first, exploratory phase of the study only. For the purpose of interrogating the extent to which we prepare teachers appropriately for teaching mathematics in the South African context, I decided to start by interrogating the evaluative rules of the PGCE maths programmes, starting with what the exam papers imply are core knowledge areas and competencies. All papers from the three general education courses (610, 620 and 630) and from the two mathematics education courses (GET for up to grade 9 and FET for grade 10–12) were coded in NVivo 9. When comparing the exam papers, the mark allocation was taken into account. This was challenged by the fact that all but one paper allowed students to choose between questions, however I felt that the entire paper had to be considered in determining the knowledge legitimised in the programme.

Firstly, all questions were coded for their knowledge domain and sub-categories, as previously listed. These codes were not exclusive, as one exam question could relate to several categories.

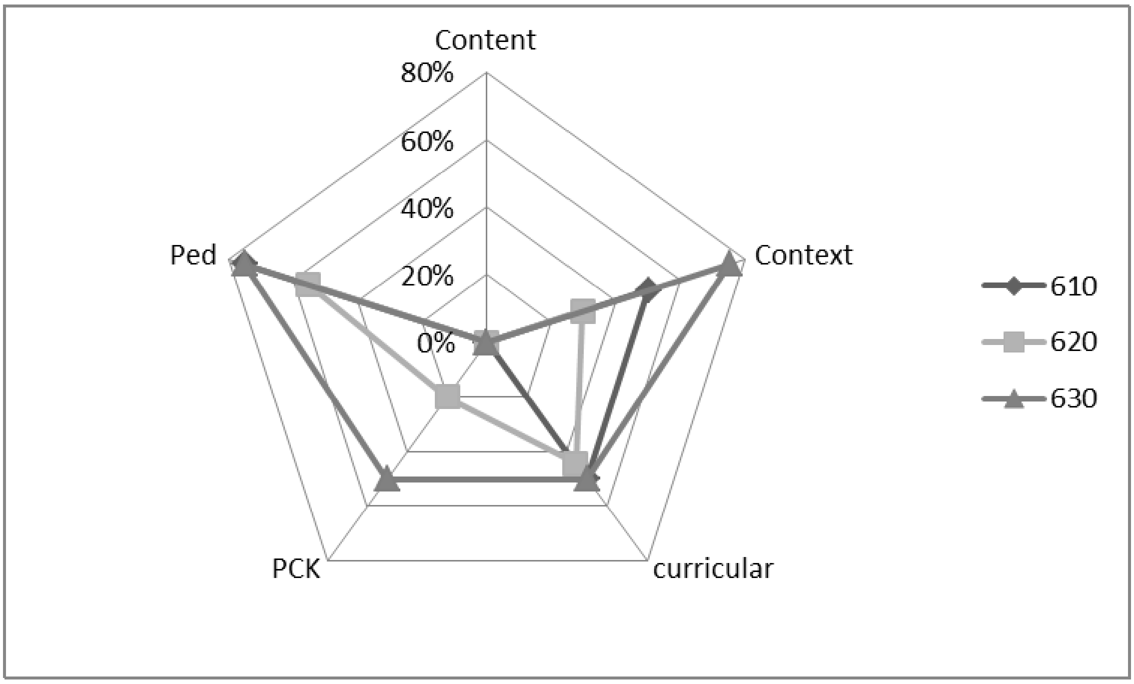
To determine the legitimation code of a question, an exam question was coded as dominated by a knowledge code when specialised knowledge was clearly required to answer the question, even if there was some allowance for a social gaze with reference to students' experiences, beliefs and attitudes not informed by specialised knowledge. An exam question was coded as being within an elite code when students were asked to engage their beliefs, experiences etc. in the light of specialised knowledge or vice versa. Finally, the knower code was used when students were asked for their individual beliefs and opinions with little or no indication that specialised knowledge must be engaged. These codes were mutually exclusive.

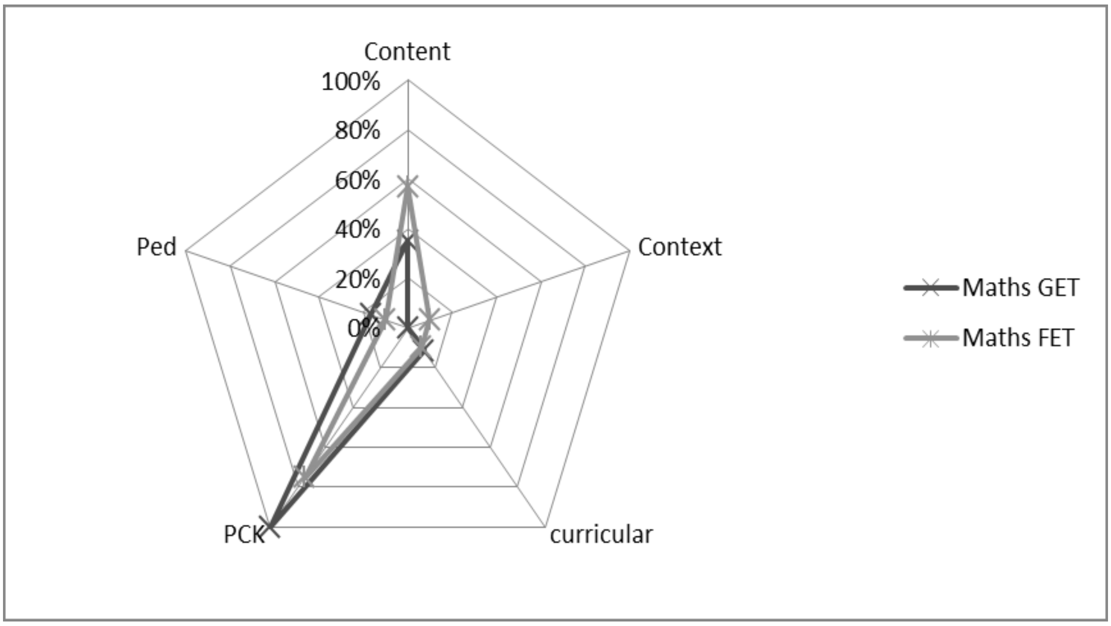
Finally, each question was coded for its degree of semantic gravity, and next for whether it encouraged students to abstract (weaken semantic gravity) or apply (strengthen semantic gravity).

Findings

It was not unexpected that the knowledge categories assessed strongly depend on whether the course is a general education course or mathematics education course, with the latter foregrounding PCK and mathematical knowledge for teaching:

Figure 1: The five knowledge dimensions in the courses in the programme. Figure 1a shows the knowledge dimensions in the general education courses; Figure 1b the knowledge dimensions in the mathematics education courses.

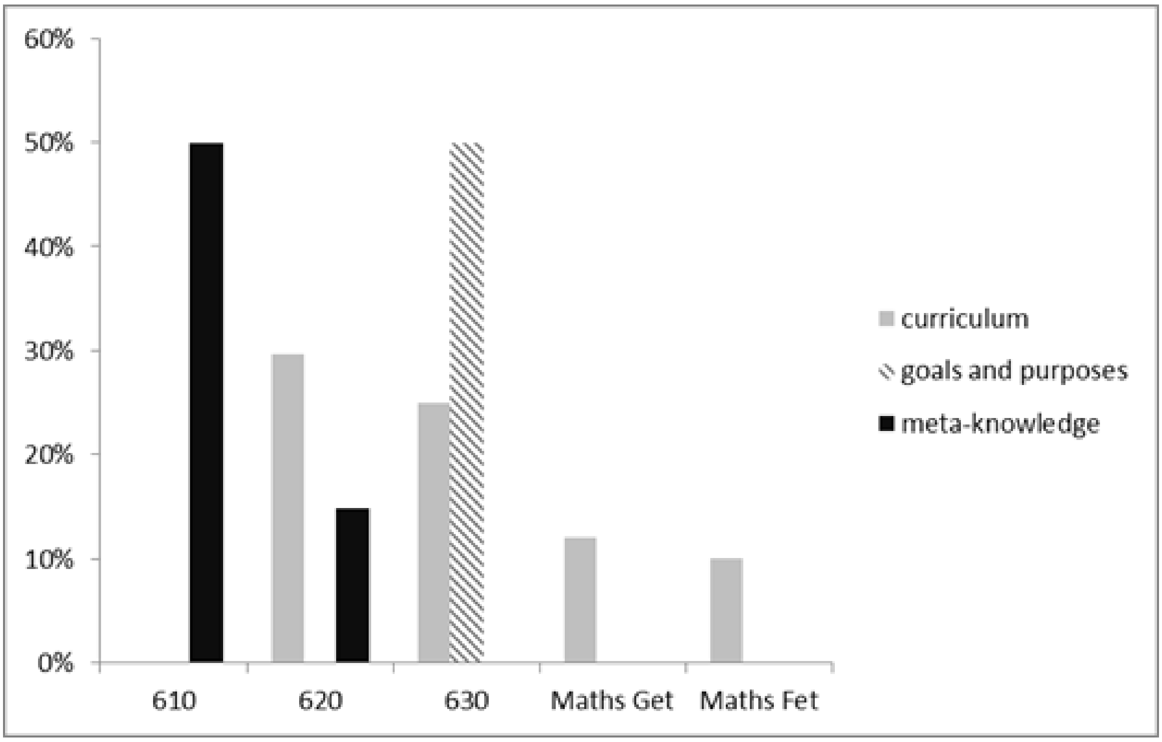




It is unclear how integrated the knowledge dimensions should ideally be, but in my view students would benefit from leaving their teaching education with a coherent message about what is important in teaching. It warrants further interrogation about the extent to which the programme as a whole achieves this, across the knowledge domains. As discussed earlier, the broader context of education in South Africa has an immense impact on the teaching-learning situation, and appears to be well addressed in the general education courses, but only figures in passing in one of the two mathematics education examination papers. I need to interrogate further the extent to which the issues showing up in our grade 6 study correspond to what is engaged in the courses, for instance if engaging issues of leadership, language, relating to the home, etc. are addressed. If contextual issues are engaged in too decontextualised or general ways, students may not develop practical skills in handling the situation in struggling schools. Indeed, one student said that the university trains student teachers for 'A schools', but force them to also teach in 'B schools' (Mari van Wyk, presentation to faculty, November 2011).

The curriculum also appears more taken for granted in the mathematics education examinations, which do not engage the goals of education at all:

Figure 2: The percentage of questions in the five exam papers which engaged with three sub-categories of curricular issues in the five courses in the programme: unpacking the curriculum, engaging goals and purposes for mathematics education, and meta-knowledge about what teachers should know and be able to do.



Thus, the mathematics courses appear detached from the broader context. In itself, this is not a problem – clearly, it facilitates specialised knowledge in mathematics and the PCK of mathematics – but the programme as a whole needs to be clearer on whether there are benefits to making links between knowledge domains and if so how this is best accomplished.

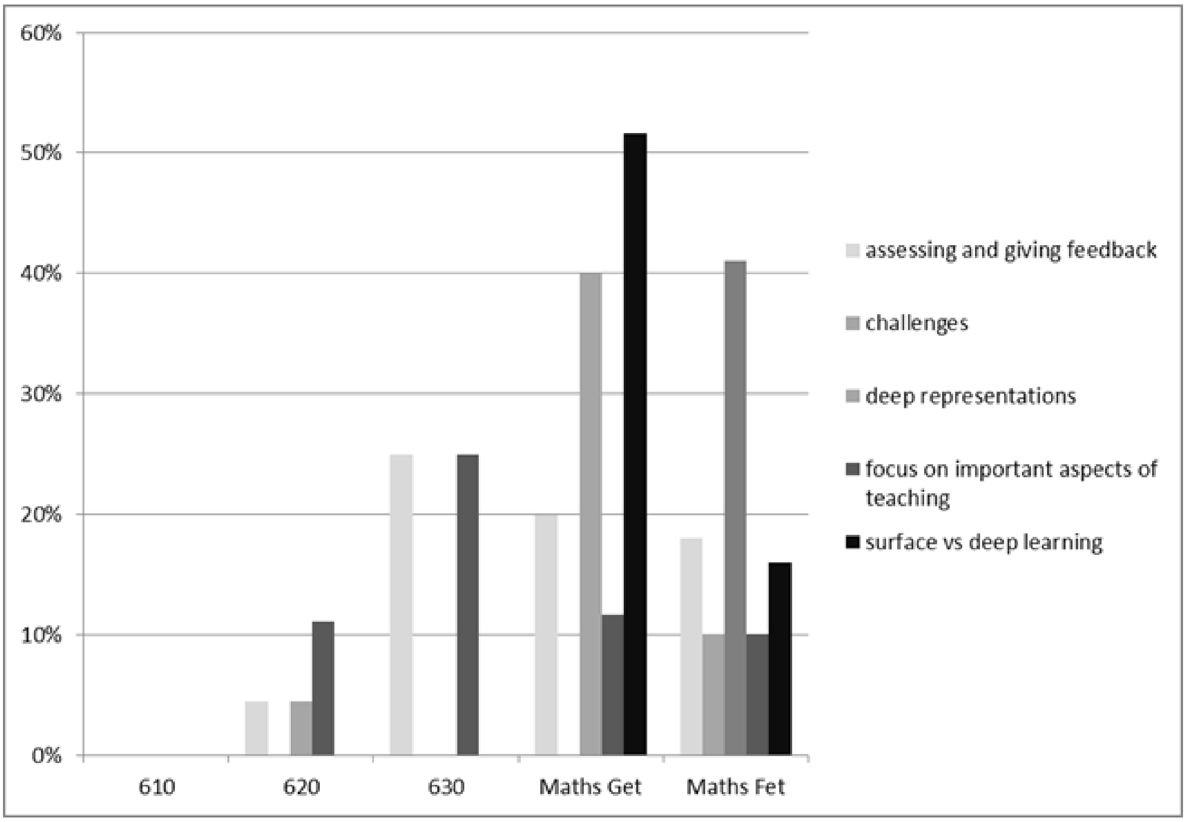
Looking at questions across the papers which had been coded within more than one knowledge domain, I looked at the frequency of overlapping codes (see Table 1). It was clear that content knowledge was most likely to occur in the same question as PCK, that contextual knowledge was overlapping most with curriculum issues and general pedagogy, and that pedagogical content knowledge occurred more often together with PCK. This indicates a decent degree of connections, but the nature of these must be further investigated.

Table 1: Frequency of overlaps of knowledge categories in the five courses. PCK and content knowledge were both assessed in 10 questions.

	Content knowledge	Contextual knowledge	Curriculum issues	PCK	Pedagogic knowledge
Content knowledge	–	0	1	10	0
Contextual knowledge	0	–	7	1	3
Curriculum issues	1	7	–	3	2
PCK	10	1	3	–	9
Pedagogic knowledge	0	3	2	9	–

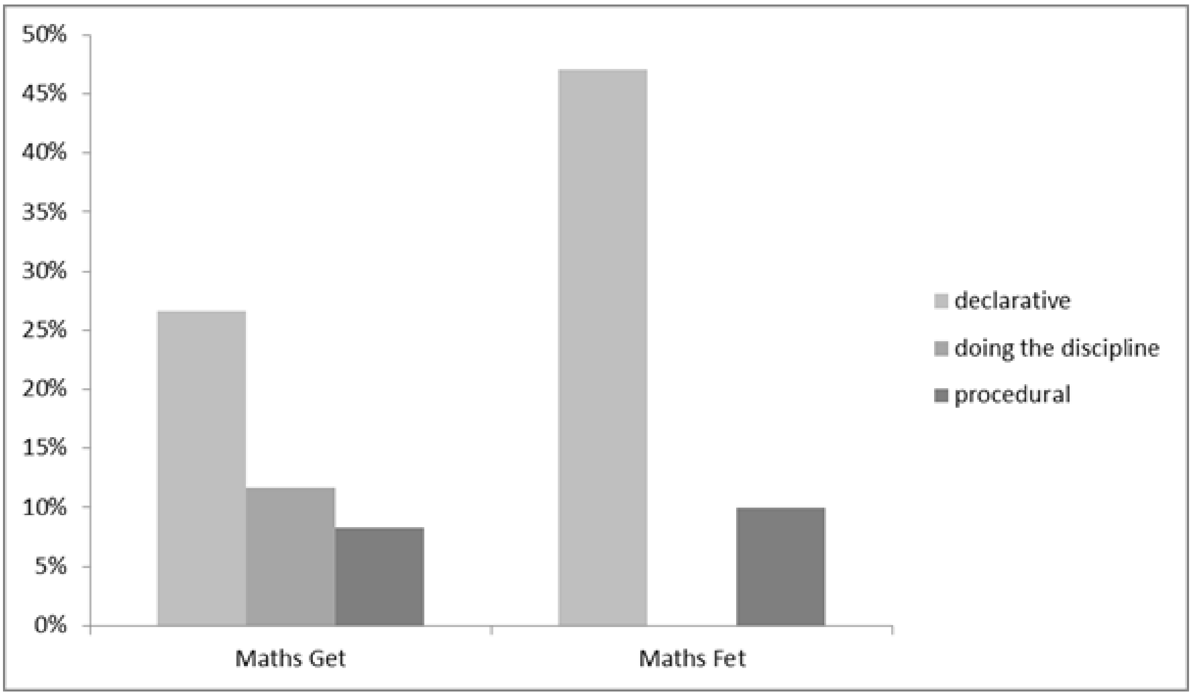
When it came to PCK, the mathematics education courses covered a broader range of aspects, though not with equal emphasis:

Figure 3: Frequency of the sub-categories of PCK in the five courses



From the perspective of Hattie's findings (2003) and in the light of the limited extent to which opportunities to develop conceptual understanding were found in our grade 6 classrooms, it is comforting to me to see the strong emphasis on deep representation in the two content courses. Yet, the absence of this dimension in the general education courses is ground for concern – where it could have been engaged in a more decontextualised way as a priority. The focus on the conceptual dimension was also clear in the mathematics for teaching courses, whereas it appears that the engagement with the one opportunity to engage in deriving a formula was limited to considering how to show this to learners, and thus did not appear to stress that teaching mathematics can include providing opportunities to develop adaptive reasoning:

Figure 4: The types of content knowledge assessed for in the two mathematics education modules in the programme



Returning to PCK, the second of the three most important types of teacher action, according to Hattie, is assessing and giving feedback, and this aspect is addressed in the general education courses, increasing with each course, and also assessed in the mathematics education courses. However, a more detailed reading of the exam questions indicates that questions in this category focus on identifying learners' level of understanding and not on how to give appropriate feedback. Only one question in 630 asks "Bearing the theories in mind, describe how teachers in South Africa can help to facilitate . . ." and this does not assess the complex process of giving feedback in any substantial way (cf. Hattie and Timperley, 2007). Thus it is clear that in this crucial respect, we are failing in the preparation of our mathematics teachers. This is more reason for concern when I note that feedback in the observed grade 6 classrooms mostly is what has been called task feedback (Hattie and Timperley, 2007) – simply indicating if an answer is correct or incorrect – and often is tacit.

The third of Hattie's most important categories is challenging learners. This is also notably absent, with only the one mathematics education course assessing this aspect, and only in a very indirect way. This question reads:

> You want the learners to draw a histogram based on the data. You are thinking about whether you should give them the relevant intervals or ask them to group the data using their own choice of intervals. There are both several weak and several strong learners in the class. Discuss some advantages and disadvantages of each of the options.

The students are being asked to consider two options in relation to the mixed ability class, but there is certainly no explicit requirement that they consider how the task could be made to be challenging for the learners (albeit this consideration was discussed in the marking memorandum). Thus, there is no indication that the courses have engaged in preparing the students to teach large classes with learners of mixed ability, so that learning can happen for more learners irrespective of their current level. One intervention which took a strict mastery approach to mathematics learning in primary school (Schollar, 2008) indicates that such careful challenging of the learners on their current level can be highly beneficial. It is also a pressing issue in the light of the span of abilities in many South African classrooms, in particular in rural contexts. Thus, our teacher education programme seems to fall short in this respect as well.

With respect to pedagogical knowledge, I expected this to be more prevalent in the general education courses. It was noteworthy that the dimension of creating a classroom conducive to learning was not assessed in the mathematics education courses, which seems concerning to me as it detaches considerations of content learning from overall classroom environment. In this category, I included allowing learners to make mistakes, and with the vast body of research on learner misconceptions in mathematics education (Ben-Zvi and Garfield, 2004; Cuffel, 2009; Molina, Castro, and Castro, 2010; Walcott, Mohr, and Kastberg, 2009) as well as socio-mathematical norms (Cobb, 1991; Cobb and Bauersfeld, 1995), I find it highly surprising that this was not foregrounded in the assessment in the courses. Interestingly, general pedagogical skills which some of our students feel they have not adequately developed, are how to use textbooks and the chalkboard well (Mari van Wyk, presentation to faculty, November 2011). Yet textbooks are only effective learning resources if they, besides the content being appropriate and well organised, are used well. None of the questions in the exam papers engaged how to judge the quality of a textbook or even a task, though previous papers had asked students to determine the van Hiele geometrical level of tasks, for instance. One question asked students to identify to what extent a textbook task fell within the mathematics literacy[10] curriculum, but other than that, no questions examined students' ability to engage with teaching resources in any respect. It seems likely, then, that this is assumed to be a skill which students possess or develop, without explicit teaching, or that it is something they will 'pick up' while on teaching practice in schools.

With respect to the legitimation code, all courses were strongly dominated by either a knowledge or an elite code, with only the 610 course having a small occurrence of the knower code. Separating the knowledge code into a strong and a less strong knowledge code ('knowledge' for short in the table below), it appeared that the legitimation code varied somewhat with knowledge type:

Table 2: Number of exam questions coded as exhibiting knowledge or knower codes in the five knowledge categories across the courses in the programme

	Content knowledge	Contextual knowledge	Curriculum issues	PCK	Pedagogic knowledge
Strong knowledge	8	0	1	10	1
Knowledge	2	1	2	7	5
Elite codes	2	7	6	10	13
Knower	0	0	0	0	1

Thus, the content knowledge is dominated by a very strong knowledge legitimation code, which is perhaps expected given the nature of mathematics as a discipline. Pedagogical content knowledge is more strongly dominated by a knowledge code than pedagogical, context and curriculum knowledge. With the current crisis in education, this is in need of further exploration, because it would be problematic to assume that students develop a trained gaze as a teacher after just four years of teacher education, in particular if the gaze encouraged or assumed at university is at odds with the views of teaching students bring from their own experiences.

The semantic gravity of the courses varied somewhat, with the general education courses being more decontextualised from direct experience and the context of application of the knowledge. The relatively context dependent

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[10] Mathematics Literacy is a school subject in South Africa, for grades 10–12.

activity of providing examples of categories within given frameworks such as the Van Hiele levels dominated the mathematics education courses, with relatively weak semantic gravity tasks such as discussing/critiquing and generalising/combining being more prevalent in the general education courses. The five courses were almost entirely dominated by applying decontextualised knowledge, in contrast to abstracting general principles from contexts. This could be explained with reference to the professional orientation of teacher education programmes, but it remains an open question to what extent this is the best approach to learning relevant knowledge and competencies, as well as the best approach to assessing them. One way to engage this further is to see to what extent the mathematics of the mathematics education courses is being 'unpacked' (Adler and Davis, 2006), but I believe we need a similar notion for other knowledge domains.

Conclusion and discussion

In this explorative first phase of the study, I contrasted national/regional with international findings about factors most strongly correlated with learner performance. I used this to develop tentative indicators reflecting aims for our mathematics education programmes in preparing students to teach in South Africa. I also considered to what extent specialised knowledge was foregrounded in a PGCE programme, meaning that students do not rely on their own beliefs and experiences. In this phase, the evaluative rules of the UKZN PGCE programme were analysed in order to determine what knowledge is legitimised or valued in the programme.

It was found that the programme is strongly within a knowledge code, though with some space given for the students to relate their own experiences etc. even in the examination. The semantic gravity varies, but generally focuses on applying more decontextualised learning. It remains a question for further exploration if this would benefit from being supplemented by more work on abstracting and generalising.

The programme covers many relevant aspects, but it needs further exploration in terms of how well they are linked and to what extent they provide a connected and complete teacher education. In particular, it must be considered to what extent the contextual knowledge dimension is linked to the disciplinary and pedagogic practice of teachers or operates on a more general level.

With respect to pedagogical content knowledge in particular, I found that the programme strongly legitimises teaching for deep representations, and also addressed the assessment of learners, but offers little direction on how to challenge learners on their level, and on how to provide substantial and constructive feedback to learners. In addition, no attention was given to the development of skills related to provide learners with the opportunity to develop adaptive reasoning.

In addition, it was found that some aspects which may not have been considered by Hattie, who compared experienced and expert teachers, nonetheless could be crucial to include in a pre-service programme. In particular the issue of preparing students to use textbooks and other materials appropriately needs to be considered.

The overall approach of comparing what we teach in the teacher education programmes to what we find works in our schools is crucial, and the sub-categories of pedagogical knowledge and pedagogical content knowledge derived from Hattie's work are deemed promising, though they may need adjusting to reflect some taken-for-granted aspects. Bringing in Maton's modes of legitimation (knowledge and knower codes) assisted me in assessing the extent to which the courses relied on an implicit gaze or foregrounded the epistemic, and I think this provides a useful insight into our teacher education programmes. So did using semantic gravity, but it was more the direction of the move between high and low semantic gravity that provided a useful insight in the relation between theory and practice in the course, than being able to determine the semantic gravity itself.

All in all, this can only be the beginning of the development of a more powerful and theoretically coherent language of description with which to assess what we do in teacher education.

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Iben Maj Christiansen
School of Education
University of KwaZulu-Natal

christianseni@ukzn.ac.za

Appendix

Semantic gravity: degree of independence from context of direct experience or use	Allen's framework used by Maton, 2009 (about case studies)	Hatton & Smith, 1995 on reflection in teacher ed	Extended Bloom's taxonomy	Criteria for evaluating assessment tasks: what does the task require? What are the implicit recognition and realization rules?	
				Abstracting ('Up')	Applying ('down')
				Entirely abstract: Theoretical work only	
Weaker	**Abstraction**: Presents general principle or procedure to address wider or future practice		***Creating*** it the process of putting together elements to form something else, sometimes a new creation but it could also be the recreation of something that has been produced before	**Abstract**: Asks student to abstract a general principle from linking the issues of the question with information and in particular theory or theoretical concepts	**Expand**: asks student to relate theoretical concepts to each other in a principled way, for instance by drawing out a new aspect, but based on a specific context or class of contexts
	Generalisation: Present a general observation or draws generalize conclusion about issues and events *in* the case	**Contextualization of multiple viewpoints**: drawing on any of the possibilities below applied to situations as they are actually taking place	***Evaluating*** is the process of making judgements normally based on some kind of criteria or a set of standards	**Generalize**: Asks the student to combine the given fact and information from other sources in presenting a more generalized conclusion	**Combine**: asks student to link more than one theory to the situation of the question
	Judgement: Goes beyond representing or interpreting to offer a value judgement or claim	**Critical**: seeing as problematic, according to ethical criteria, the goals and practices of one's profession	***Analyzing*** is the ability to break down a problem into its parts and see how the parts interrelate and who you can use them together	**Critique**: Asks the student to make claims about a stated general issues reflected in a situation to which the question refers; discuss a number of given factors	**Discuss**: distinguish or compare concepts or theories or approaches, discuss conditions for something to be applied/implemented
	Interpretation: Seeks to explain a statement by interpreting information from the case or adding new info. May use litt or personal experience	**Dialogic**: weighing competing claims and viewpoints and exploring alternative solutions	***Applying*** is carrying out a procedure in a given situation, which is different from the knowledge of procedures spoken about earlier although the two are often linked as you need the knowledge of a procedure to apply it correctly	**Interpret**: Asks the student to explain the situation referred to in the question through reference to the literature	**Characterise:** describe, classify or characterize something using an existing framework
	Summarising description: Decriptive that summarises or synthesizes information from the case, but with no new info	**Descriptive**: seeking what is seen as 'best possible' practice	***Understanding*** is the process of constructing meaning from various sources of information	**Summarize**: Asks student to summarise key issues from her/his experience or from the specific situation referred to in the question	**Exemplify**: give specific informed/reasoned example of something within a stated category; explain how would carry out a specific principle in practice
stronger	**Reproductive description**: Reproduces information directly	**Technical**: drawn from a given theory base, but always interpreted in light of personal worries and previous experience	***Remembering*** is the process of retrieving knowledge from memories	**Describe**: Asks student to engage direct experience or to respond to a specific situation without reference to broader context or principles;	**Illustrate**: simply state an example of something