BUILDING ON USING THE STRENGTHS OF MATHEMATICS TEACHER EDUCATION IN SOUTH AFRICA

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ABSTRACT:

Mathematics education in South Africa is under microscopic lens, as it is one of the cornerstone in producing skilled scientists and mathematicians the country’s economy and development needs. Lots of research done has revealed the poor teaching practices students are exposed to in previously disadvantaged schools. Inadequate content knowledge of mathematics teachers demonstrate has been claimed to be influential in the poor teaching practices. This paper then elicited the strengths South African mathematics teacher education possesses as a foundational place towards improvement. Surveys collected from five institutions that train mathematics teachers from Intermediate phase to FET phase were analysed to elicit the mathematics curriculum future teachers receive and attained in training. The findings revealed that South African curriculum on mathematics teacher education emphasises mostly professional training of teachers. Mathematics teacher training courses are very few leaving future teachers with limited knowledge for teaching mathematics.
INTRODUCTION:

Mathematics education in South Africa is under microscopic lens, as it is one of the cornerstone in producing skilled scientists, mathematicians, the country’s economy and development needs. Lots of research has revealed the poor teaching practices students are exposed to in previously disadvantaged schools (Brodie and Pournara 2005, van der Sandt & Niewoudt 2003 and Wessels 2008). Also, not having enough qualified mathematics teachers has been a contributing factor to the poor performance students demonstrate on mathematics tests. Inadequate content knowledge of mathematics teachers demonstrate has been claimed to be influential in the poor teaching practices (Mji and Makgato 2006; and Adler 2001). Most of the research points at teaching practices, multilingualism and shortage of teachers. Looking at the national challenges of poor literacy, little amount of time spent by teachers teaching and impact of HIV AIDS in the schooling system makes this challenge complex. The latter research has elicited lots of problems the education and mathematics education has. Little is known about the strengths that we can build on in mathematics education. This paper then aims to elicit the strengths South African mathematics teacher education possesses as a foundational place towards improvement. Surveys collected from five institutions that train mathematics teachers from Intermediate phase to FET phase will be analysed to elicit the mathematics curriculum future teachers receive in training. Secondly, future teacher surveys of the fourth years will also be analysed to measure two areas of development future teachers received. These two areas will be content knowledge and pedagogy content knowledge. This paper will highlight the relationships between curriculum presented to students with their content and
mathematical pedagogy knowledge. The paper aims to open discussion on mathematics teacher training towards standardizing mathematics curriculum for teacher education and to inform policy on how to build on towards successful teacher training of mathematics teachers in the country.

**Context:**

The five universities studied are not representing all teacher education institutions in South Africa however; they do represent the geographical landscape of the country. For example, out of the five institutions one is rural with students from rural, urban and semi-urban areas, the other four are all urban institutions although one of them is centralised to be accessible to rural, urban and semi-urban areas. Then the other three universities use sites that are within low socio economic background communities to reach mostly urban and semi-urban areas. The complexity of the enrolment in these universities is created by urbanisation that attracts many people from rural areas. The influx of rural people to the urban areas leads to all South African universities serving students from all diverse backgrounds in terms of rurality, urbanity, socio economic status, and ethnicity.

**Theoretical Framework:**

The debate about mathematics teacher education curriculum continues to grow because of the global challenges on student’s mathematics performance. Student’s dynamics are increasing as population diversify more and more. Shulman’s work has been leading on determining the three kinds of knowledge teachers need to become effective teachers. The content knowledge (CK), the pedagogical content knowledge (PCK), and the general pedagogical knowledge (GPK) are the three kinds of knowledge (Shulman 1986, 1987).
Mathematics Pedagogical content knowledge:

Adler & Davis (2006) describe Mathematics Pedagogic Content Knowledge (MPCK) as the “unpacking or decompressing” of mathematical ideas to elicit and engage learner’s thinking and reasoning (p.274). Prediger (2010) amplify this notion of unpacking or decompressing of mathematical ideas by stating that “it indicates a stronger intersection between subject-matter knowledge and pedagogical- content knowledge” (p.74). Schmidt et al. (2011); An et al. (2004) extend these descriptions to instructional planning knowledge, knowledge about how students’ learn, and the curricula knowledge. Adler & Davis (2006) assert that this knowledge is complex as it also involves cultural aspects of learning. Shulman (1987) confirms the latter by acknowledging that pedagogical content knowledge is inclusive of the knowledge for learners’ characteristics, educational context, values, philosophical and historical bases.

General Pedagogical knowledge (GPK):

This knowledge is not subject specific but general to teaching. It provides teachers with classroom management skills, psychological and philosophical aspects of teaching and learning. This knowledge is the core knowledge for all teachers.

Recent investigations on mathematics teacher knowledge revealed importance of mathematics pedagogical content knowledge. Prediger (2010); Stylianides and Ball (2008) studies support this proposal by revealing that teachers needed knowledge about the content taught thoughtfully and overtly. The mathematics knowledge was not enough on its own but the mathematics pedagogical knowledge was demanded in both studies. Turnuklu & Yesildere (2007) studied 45 future primary teachers competency of MPCK in Turkey, their findings indicated that in-depth understanding of mathematics content knowledge was not enough to teach mathematics but connections of
Mathematics content knowledge and mathematics pedagogical knowledge were observed.

**Mathematics content knowledge (MCK):**

MCK refers to knowledge of mathematics topics (Schmidt et al. 2011). Regarding teacher education these are the mathematics topics taught at the level the teacher is trained to teach. This knowledge is revealed as the strong foundation that top performing countries in TIMSS strengthen in their mathematics teacher training (Schmidt et al 2011).

The latest research compared high performing countries on eighth grade TIMSS to the lowest performing countries using mathematics pedagogical content knowledge and mathematics content knowledge as indicators for effective teaching. The results revealed that future teacher knowledge varied tremendously between high performing countries and low performing countries than the students’ knowledge. Future teachers’ mathematical content knowledge scores were significantly poor at primary level indicating lack of basic knowledge (Hsieh, et al. 2011). Reflecting on courses taken by teachers Schmidt, et al. (2011) revealed that mathematics content knowledge courses taken vary widely amongst countries. Lower secondary teachers of high performing countries take more mathematics content knowledge courses that the lower performing countries while there is no significant difference on the mathematics pedagogy courses for elementary level. According to this study top achieving countries take more courses in their mathematics teacher training that include mathematics opposed to general pedagogy in lower secondary schools. In describing the knowledge needed for teaching mathematics Hsieh et al. (2011) and Schmidt et al (2011) indicated mathematical content knowledge as the emphasis of the top achieving countries compared to mathematics pedagogical knowledge that has been proposed by (Shulman 1987; Prediger
2010; Stylianides and Ball 2008). Blömeke et al. (2011) compared mathematical content knowledge scores of high performing countries with their mathematics pedagogical knowledge scores and discovered that the mathematics content knowledge scores are higher than the mathematical pedagogical knowledge scores. In addition, lower performing countries were pulled up as performing better in mathematics pedagogical knowledge including the United States however, their students’ mathematical performance on TIMSS was lower. These results challenge the ongoing debate of the kind of knowledge needed for effective teaching of mathematics. The intertwined variables that make the mathematics pedagogical knowledge and the mathematical content knowledge need more investigation. For example, the five top performing countries had mean scores of 623 Taiwan, 590 Singapore, 543 Switzerland, 535 Russia, and 528 Thailand on MCK with an overall average score of 500, then their MCPK scores changed the order by having Singapore on top with 593, Taiwan 592, Norway 545, US 544, Switzerland 537 with an overall average score of 500. Russia that was on the 4th place in MCK is on the 6th place in MCPK, with Norway and US pulled up by the MCK to the top 5 however their students’ performance on TIMSS is lower, Thailand was pulled down to the 7th place (Blömeke et al. 2011). These results support strong MCK for teachers for better student performance; however the MCPK plays a significant role on student performance too. The latter has weaker support in these findings. Hence the need for more studies with relevant methodologies in testing the relationship between student performance and teacher MCK, and teacher MCPK. This paper does not bring any improvement to these studies as it reports results that are part of the MT21 study using the same methodology. However, this paper reflects on the curriculum for
mathematics teacher education of South Africa and uses it as the foundational base for further development.

**Mathematics teacher education research in South Africa:**

Poor mathematical performance of South African students has been related to inadequate teaching practices as one of the major factors that impact the students’ performance. South African history of inequality continues to dominate education reflecting the in-depth of the scars Apartheid caused (Adler 2006). One major means of addressing this challenge a QUANTUM project led by Adler aimed at developing a research based model for mathematics teacher education that is appropriate to the South African context. The findings generated in this project revealed that South African mathematics teacher education varies in different institutions tremendously (Adler 2005). Also the mathematics for teaching (MtF) in Adler’s language is not well prepared, there are attempts in the curriculum but the assessments are dominated by procedures (Adler and Davis 2006). On the other hand, case study work from this project indicates that the context determine the kind of pedagogy needed (Adler and Hullet 2008).

**RESEARCH DESIGN:**

This paper reports data from an MT21 international study funded by NSF. This paper only reports the relationship between the curriculum teachers receive in the 5 South African institutions and their exit knowledge. Therefore this paper focused on the future teachers who are in their 4th year of study in both General Education Training (GET) covering grades 4-9 and Further Education Training (FET) covering grades 10-12 phases. Out of 530 4th year future teachers enrolled across the five institutions, 346 filled in the surveys. Data was collected by administering two surveys that are (1) future teacher survey and (2) institutional survey.
Future teacher survey:

MT21 future teacher survey collected data on four main parts. The topics were demographics and academic background of the student, academic programme learning opportunities the student is exposed to, students’ beliefs and perspectives on schooling, teaching and learning, and student knowledge related to teaching junior secondary school mathematics. This paper focuses only on student knowledge related to teaching of mathematics from the future teacher survey.

Institutional survey:

MT21 institutional survey was lengthy and thorough. It gathered programme specific information about entrance requirements, student recruitment, course and practical school experience requirements, typical course topic electives, self-perceived relative programme strengths, and recent or anticipated reforms. This paper focuses on the curriculum prepared for mathematics teacher education from this data.

Data analysis

MT21 developed eight achievement scales for the test items administered to future teachers. The achievement items covered mathematical topics covered in the lower and higher secondary education. The identified mathematical topics used were informed by the TIMSS items (Schmidt et al 2001). The identified topics include algebra, functions, number, geometry and statistics. The topics were at the secondary level with deep understanding that Ball and Bass (2003), Adler and Davis (2006) describe in defining knowledge for teaching mathematics. Out of the eight scales, five focussed on mathematics knowledge of the five identified topics, three focussed on the mathematics pedagogy. A Rasch model was used to obtain scale scores based on items classification. Mathematics and Mathematics pedagogy together had 15 dimensions. Then the scaled score were
calculated from the Rasch scores refer to the MT21 international report.

**FINDINGS:**

The curriculum offered by the five institutions is displayed to give a summarised picture of mathematics teacher training.

**Table 1: Course taking in the five institutions of South Africa**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Number of Maths content courses</th>
<th>Number of Maths Method courses</th>
<th>Number of Education modules and general pedagogy</th>
<th>Number of other courses taken</th>
<th>Total number of courses taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>A FET</td>
<td>11</td>
<td>3</td>
<td>11</td>
<td>19</td>
<td>33</td>
</tr>
<tr>
<td>GET</td>
<td>0</td>
<td>3</td>
<td>17</td>
<td>12</td>
<td>32</td>
</tr>
<tr>
<td>B FET</td>
<td>5</td>
<td>3</td>
<td>14</td>
<td>12</td>
<td>34</td>
</tr>
<tr>
<td>GET</td>
<td>2</td>
<td>6</td>
<td>13</td>
<td>6</td>
<td>27</td>
</tr>
<tr>
<td>C FET</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>GET</td>
<td>0</td>
<td>4</td>
<td>8</td>
<td>22</td>
<td>34</td>
</tr>
<tr>
<td>D FET</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>12</td>
<td>32</td>
</tr>
<tr>
<td>GET</td>
<td>5</td>
<td>4</td>
<td>14</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td>E FET</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>GET</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>25</td>
<td>43</td>
</tr>
<tr>
<td>Average FET</td>
<td>5</td>
<td>1.2</td>
<td>11.4</td>
<td>15</td>
<td>30.4</td>
</tr>
<tr>
<td>GET</td>
<td>2.5</td>
<td>4.7</td>
<td>11.6</td>
<td>15.2</td>
<td>34</td>
</tr>
</tbody>
</table>

Table 1 presents the curriculum future teachers are exposed to in the five institutions. The diversity of the programmes across the five institutions supports Adler’s (2005) observation on QUANTUM project that South African mathematics education is complex and diverse amongst institutions. The emphasis is clearly of teaching profession than mathematics teaching profession. The average for education modules for both FET and GET programme is 11 courses versus an average of 1 course for FET mathematics pedagogy and an average of 5 courses for GET programme. FET favours
Mathematics content knowledge at an average 5 courses against 2.5 GET, while GET favours mathematics pedagogic knowledge than content knowledge at an average of 4.1 courses against 1.2 for FET. Generally, mathematics teacher training is not in favour of strengthening the mathematics knowledge and the mathematics pedagogic knowledge.

**Mathematics Knowledge**

Figure 1: Grouped Percentile Distribution of Mathematics Knowledge Scale Scores for all five institutions together.
Figure 2: Grouped Percentile Distribution of Mathematics Pedagogical Knowledge of five institutions
Grouped results of the five institutions:
Mathematics Knowledge: The overall differences between the two programmes from the five institution was statistical significant (p<.001). Figure 3 reveals that algebra and functions have greater difference compared to other topics. In general FET future teachers demonstrate stronger knowledge of mathematics.

Figure 3: Mean Level Performance on the Mathematics Knowledge Scale Scores of the two programmes

![Mathematics Knowledge Scale scores](image)

The graph shows that FET and GET future teachers demonstrate strong knowledge of number followed by functions for FET and data and probability for GET future teachers. The curriculum distribution of the FET group in the five institutions is reflected on the mathematics knowledge of the future teachers that favour FET students than GET.

Mathematics Pedagogy Knowledge
Mathematics pedagogy item did not only focus on mathematics knowledge but on how students reason mathematically and what are their common misconceptions. The three scaled scores reflect knowledge of the lower secondary curriculum, how students think and learn mathematics and instructional approaches for teaching particular mathematics topics refer to Figure 3. The difference between the two programs
was statistical significant \((p < .000)\). Figure 4 present the results of the three scales. FET future teachers scored higher on curriculum and teaching however, GET scored higher on the knowledge of students. The performance can be traced back on the number of courses taken by GET students on mathematics pedagogy that are higher than the FET.

**Figure 4: Mean Level Performance on the Mathematics Pedagogical Scale Scores**

<table>
<thead>
<tr>
<th>Mathematics Pedagogical Scale Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>GET</td>
</tr>
<tr>
<td>FET</td>
</tr>
</tbody>
</table>

**DISCUSSION:**

The findings of this study highlight two possibilities in improving mathematics teacher training in South African institutions. The first possibility is standardization of mathematics teacher education concerning a need for a rigorous curriculum and more emphasis on mathematics and mathematics pedagogy courses. The curriculum offered by the five studied institution indicate a weakness on the course intake for training mathematics teacher education. The strength of the programmes is on developing the teaching profession generally. The second possibility is revealed by the better performance of GET teachers on understanding students that reflects relationships between more mathematics methods courses and knowledge of students.
Developing this strength more on GET and transferring the practice to the FET future teachers will be of high benefits to the mathematics teacher education. Respectively the mathematical knowledge demonstrated by FET future teachers who take more mathematics courses than GET students who sometimes do not take any mathematics courses indicate a possibility for development. The findings of this study as well as the QUANTUM project reveal that mathematics education in South African institutions is varied. There is still lack of empirical evidence that could describe mathematics teacher education in South Africa due to lack of participation to studies like this and due to the historical nature of higher education in developing curriculum that depends on academics own discretion. As Adler argued, more research is needed in this field for South Africa to be able to work with it’s mathematics education crisis.

This paper therefore recommends revisiting of the curriculum for mathematics teacher education using the research on South African mathematics education as the basis for our context as foundation. Also, the policies on education need to give attention to mathematics education within the context of education. Mathematics teacher education demands its own policies and curriculum when comparing to the international community especially leading countries in TIMSS. Increasing the number of mathematics courses and mathematics pedagogy courses students take would be a starting point for growth.

REFERENCES:


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