Pre-service teachers' mathematics profiles and the influence thereof on their instructional behaviour

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Abstract

In this paper the notion of "mathematics profiles" and "instructional behaviour profiles is introduced. A brief explanation of what these profiles are and how they were constructed and represented for pre-service mathematics teachers is provided. An example of one of the participants' profiles is included as an example. The influence of the pre-service teachers' mathematics profiles on their instructional behaviour is then discussed. This is done with regard to using the mathematics profiles as a potential tool to optimise the development of pre-service mathematics teachers' instructional behaviour towards a more reform-oriented approach.

Introduction

How does one mathematically determine whether the gradient of a straight line is positive or negative? I asked this of a mathematics student teacher I was observing and was surprised that he could provide no mathematical explanation. Instead he explained that a positive gradient could be recognised by the fact that if you were walking along the line, it would be like walking up a mountain so you would feel really positive. On the other hand the negative gradient or slope is like coming down a mountain and one usually feels negative coming down a mountain. He confessed that he relied mainly on memorisation to explain mathematical concepts.

This is one of many similar examples where mathematics is endorsed as a process of rote memorisation rather than a discipline requiring understanding. During my role as a mathematics methodologist (or specialisation lecturer), I became increasingly frustrated and concerned at the low level of content knowledge as well as teaching and learning strategies being demonstrated by pre-service mathematics students during such practical teaching periods. Despite the global reform being initiated in mathematics education, the students continued to demonstrate a traditional and rote learning approach to teaching mathematics with only superficial motions towards a more constructivist paradigm. With their own experiences of mathematics teaching at school most likely being limited to a traditional approach, and the lack of deep change occurring in most schools they would end up teaching in, I began to wonder how we can most effectively achieve the reform in pedagogy we are aiming towards. And how much of this may be dependent on the mathematical content knowledge or what I have since come to term the "mathematics profile" of teachers.

Using the literature, I identified important components or indicators of content knowledge (subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs about the teaching and learning of mathematics) and used data from the final portfolios of seven students[1] in a one-year Post Graduate Certificate in Education (PGCE)[2] programme to compile mathematics profiles for each student and analyse the influence thereof on their resulting instructional behaviour.

Conceptual framework

The research was conducted from within a social constructivist paradigm. Ernest (1991, 1998) suggests social constructivism as a philosophy of mathematics and discusses it also as a philosophy of mathematics education. Through this lens mathematics is viewed as a social construction and knowledge is a result of a process of coming to know including processes leading to the justification of mathematical knowledge

The two main constructs in the study were the mathematics profiles and the instructional behaviour of the participants. The mathematics profile construct was determined with respect to four components, namely, subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs about the teaching and learning of mathematics. The instructional behaviour construct was studied with regard to participants' use of a traditional versus reform approach to teaching, and whether learners were afforded an authoritarian versus democratic style of learning.

The conceptual framework draws extensively on the work of Ernest (1988, 1991, 1998) in analysing the two main constructs of mathematics profiles and instructional behaviour. However, where there was not sufficient literature in Ernest's work, the conceptual framework was supplemented by other authors such as Ball (1988, 1990, 1991) for the subject matter component, Shulman (1986) and Veal and MaKinster (2001) for the pedagogical content knowledge component, Thompson (1984, 1992) for

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[1] These students were not all enrolled for the course in the same year. One of the students completed the course in 2006, two of the students completed the course in 2007 and the other four completed it in 2008.

[2] This is a post graduate certificate that students enrol for once they have obtained an initial Bachelor's degree in order to qualify as teachers.

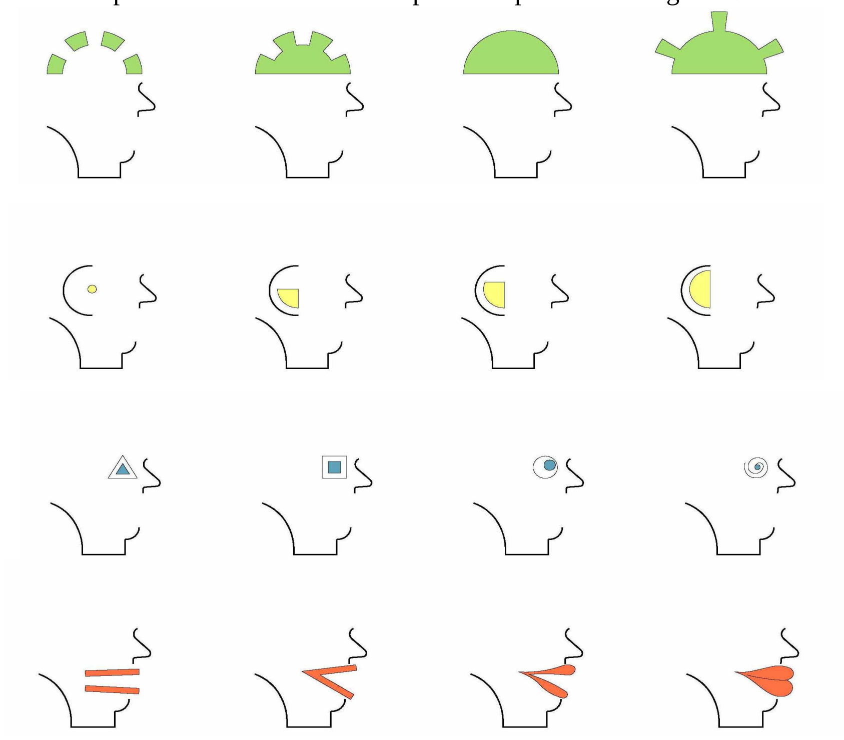
the conceptions component and Goldin (2002), Boaler (2004) and Davis (1997) to inform the instructional behaviour analyses.

Methodology

A qualitative case study design was used as the research methodology for this exploration. The case study was carried out retrospectively or post-hoc, in that the data set was only analysed once the students had completed their PGCE course. A slightly alternative data collection technique was used in this qualitative approach in that interviews were not conducted with any of the participants. The final portfolios that participants handed in were the main source of data. This means that the participants themselves initially selected the "data" they chose to present. I then did the first data reduction in selecting reflections and other entries from participants' portfolios to compile participant reflections. These were taken directly from the portfolios and written in the voice of each participant. The second data reduction was done in writing the researcher reflections. These reflections were written as a response to the participant reflections based on my experiences and assessments of the participants as their specialisation lecturer. In the third data reduction, the participant and researcher reflections were deductively analysed using the relevant categories discussed in the literature. This analysis was then presented visually displaying an initial and final mathematics profile for each participant and placing each of these in a sub-quadrant on the instructional behaviour Cartesian plane. This plane was made up of the traditional/reform teaching continuum (x-axis) and authoritarian/democratic learning continuum (y-axis). These visual representations facilitated the cross-case comparison.

Presentation of data

As indicated in the methodology, participant reflections, researcher reflections and visual representations of the mathematics profiles and instructional behaviour of participants were used in presenting and analysing the data. For the scope of this paper, a visual representation of the profiles of only one of the participants is provided (Barnes, 2009). A summary and brief explanation of each of the categories of the components of the mathematics profile is provided in Figure 1.



Category 1 2 3 4

Figure 1 Illustration of the four categories of each component of the mathematics profile

The *head* of the face represents the *subject matter knowledge*. In the visual representation, the category on the extreme left indicates obvious and fundamental conceptual gaps in the participant's subject matter knowledge. In the second category, less fundamental conceptual gaps were evident with some relational coherence of the content. The third category indicates that the subject matter knowledge appeared sufficient with no gaps evident in terms of errors or lack of mathematical understanding observed during the course of the year. The final category on the right depicts subject matter knowledge that is not only relational but also able to extend into other learning areas where necessary.

The *ear* depicts the pedagogical content knowledge. Reasons for this include that much of the pedagogical content knowledge of a student teacher is taken in by what they hear in class at university and what they heard at school. A large part of this in their own teaching practice is their ability to hear the learners, their errors, their thinking and where they are at in their thinking. The category on the far left indicates an incomplete pedagogical content knowledge for a pre-service teacher. The categories towards the right of the continuum show varying levels increased pedagogical content knowledge.

The *eye* illustrates each participant's view or conceptions of mathematics (for obvious reasons). The varying shape of the eye in the four categories indicates a movement from seeing mathematics in its absolutist form as a limited, rigid, structured and rule-bound subject on the far left category to a more dynamic, interrelated and continually evolving subject that is more in line with the constructivist/problem-solving view as expressed by Ernest (1991), in the category on the far right.

Finally, the *mouth* represents the beliefs about the teaching and learning of mathematics that each participant verbalised or expressed. In differentiating between these belief categories, the role of the teacher can be either a transmitter on the far left, instructor, explainer or a facilitator on the far right of the continuum. A transmitter is a device that transmits specific information or signals to "passive receptors" or receivers that receive the signal but do not transmit back. When a transmitter sends out a signal to a transceiver though, the transceiver sends back information. In my view the teacher in the role of the transmitter believes the teacher is an expositor and although they are aware of the learners in the classroom, they talk to them as passive receptors without expecting input. The instructor and the explainer, however, both view the learner as a transceiver that they expect to be more active and communicate with them. The difference though is that the instructor demands a much lower level of input and response from the learner than the explainer, who tends to require responses that demonstrate understanding. Finally, the facilitator has the fuller, closed lips indicating that, similar to the explainer, they also expect learners to communicate their understanding and in my view, they see learners not only as transceivers but as decoders. Facilitators therefore tend to continually demand more high-level mathematical reasoning and facilitate discussions that elicit this. In such cases, the learners are supported to do more of the thinking and construction of knowledge with the facilitator guiding the process (hence the closed mouth in the visual representation).

Similarly to the approach applied to the development of the mathematics profiles, each of the traditional/reform and authoritarian/democratic learning continuums (each forming an axis of the Cartesian plane in Figure 2) was divided into four equal divisions. However, these are not differentiated into categories, but rather form four smaller sub-quadrants in each of the four main quadrants of the Cartesian plane. I purposefully avoided using numbers on the Cartesian plane so that this remains a representation of their changing instructional behaviour, as I see it, without attaching a value or measurement to it. An initial and final quadrant for each participant was derived according to their position on each of the traditional/reform teaching and autocratic/democratic learning continuums. Visual representations such as the example provided above were constructed for each of the seven participants in the study and these facilitated the cross-case comparison. Four main aspects emerged from the comparison.

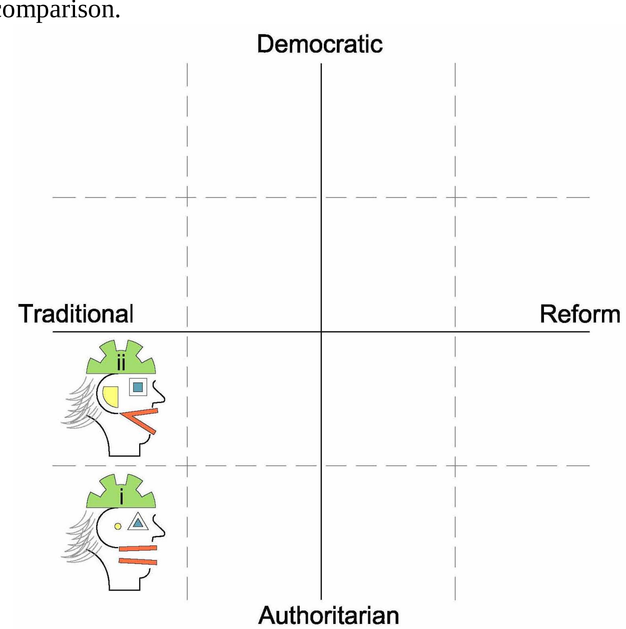


Figure 2 Example of a visual representation of a participants' changes in profiles

Firstly, the component of subject matter knowledge does appear to play an important part in enabling or constraining the changes in pre-service mathematics teachers' instructional behaviour. Secondly, I am suggesting that not just reflecting on one's practice/experiences but that the quality of these reflections may affect the extent of positive change pre-service teachers make in their instructional behaviour. Thirdly, I suspect that encouraging students to access and read more literature in the mathematics and mathematics education domain is something that could be considered developing and improving pre-service teachers' mathematics profiles, with particular reference to their conceptions and beliefs. Finally, it appears that an improvement in pre-service teachers' pedagogical content knowledge does not necessarily have the extent of influence on changing their instructional behaviour that was expected.

These four aspects have important implications for training mathematics teachers in the Further Education and Training Phase. As I reflected on the current intended outcomes and content of the PGCE course that forms the context for this study, I realised that we spend most of the year focusing on improving the pedagogical content knowledge of our students (both general and more domain specific) and on training them to approach teaching and learning in a more reform and democratic-orientated way. Research indicates that this type of approach to teaching and learning is more likely to result in independent and critical-thinking learners. However, the mathematics profile appears to have more of an influence on the instructional behaviour of students than I originally anticipated. As long as we continue trying to focus on training and changing the instructional behaviour of our students without considering their mathematics profiles, we will not be able to achieve our intended outcomes. I am therefore suggesting that evaluating students' initial mathematics profiles and then working to improve and expand the necessary components may be more effective in reforming students' instructional behaviour. The emphasis on improving pedagogical content knowledge without considering students' conceptions of mathematics and their beliefs about the teaching and learning of mathematics does not appear to enable this intended reform. The issue of how best to assist students who exhibit conceptual gaps in their subject matter knowledge also needs to be considered owing to the enabling or constraining impact of this component suggested in this study.

Conclusion

The results of the study indicated that the mathematics profile of a pre-service teacher of mathematics has a considerable influence on their resulting instructional behaviour. The visual representations suggest that the participants who made the most substantial changes in their mathematics profiles also made the most significant changes in their instructional behaviour. I am not trying to indicate a mathematical direct proportion here in that more changes in the mathematics profile imply more changes in the instructional behaviour. Rather I am fore-grounding the trend that the students with final mathematics profiles with components predominantly in the third or fourth category (see Figure 1) demonstrated the most movement in terms of their instructional behaviour. Students' whose final mathematics profiles were predominantly in Category 1 and/or 2 of each component similarly demonstrated the least movement in their instructional behaviour. This suggests that focusing on all of these components of the mathematics profile in teacher training is an important aspect in reforming pre-service teacher's instructional behaviour.

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