The Family Maths Programme
Developing Inquiry-based Teaching

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Abstract

This qualitative and quantitative empirical study of 39 facilitators investigates the extent to which the Family Maths professional development programme offered by the Nelson Mandela Metropolitan University develops facilitators' ability to implement inquiry-based teaching and learning. The facilitators' inquiry beliefs and ability to implement inquiry learning was measured by means of questionnaires, observation schedules and interviews. Data generated by the study reveal that both the facilitators' understanding and practice of inquiry improved as they progressed through the novice, intermediate and veteran categories of the Family Maths professional development programme

Introduction

The Family Maths programme was conceptualised and designed at the University of California, Berkeley during the late 1970s (Kreinberg, 1989) and has been adopted by a number of countries around the world. Examples of these countries include Canada, Australia, New Zealand, South Africa, Sweden, Costa Rica, and Puerto Rico (Thompson, 2005). The overall aims of the intervention programme are to redress inequalities in the schooling system, to dispel negativity towards mathematics, to make school mathematics relevant to learners in the world in which they live and learn and to promote an inquiry-based approach to teaching and learning (Damerow, Dunkley, Nevres, & Werry, 1984; Thompson & Mayfield-Ingram, 1998).

Since the new South African dispensation of 1994, recently revised National Curriculum Statements have aimed at transforming heavily entrenched, traditional approaches and replacing them with a new vision for education based on the introduction of Outcomes-Based Education. The Family Maths programme, as offered in South Africa by the Nelson Mandela Metropolitan University, not only attempts to support the transformative education practices targeted by the department of education, but also to extend them beyond the school walls to the community at large. This empirical study was undertaken in an attempt to determine the extent to which this programme is able to develop inquiry learning practices and skills in Family Maths facilitators.

Design

The research undertaken was an empirical study of 39 facilitators, all participants on the Family Maths professional development programme, who represented novice (less than one year's participation), intermediate (one to two years' participation) and veteran (more than two years' participation) categories. The participants were predominantly in-service teachers and teacher educators in the Departments of Education in the Western and Eastern Cape, South Africa. The findings were triangulated by comparing the data generated by both qualitative and quantitative methods, which included a questionnaire, two observation instruments and an interview protocol.

Firstly, the *Facilitators' Inquiry Learning Belief System Questionnaire* was used to measure the participants' inquiry beliefs and understandings of aspects of the inquiry process while their ability to implement inquiry learning was measured by using observation schedules, viz. Brophy and Good's *Workshop Interaction Coding System Observation Instrument* which measures the extent to which the facilitators use inquiry verbal feedback techniques during interactions with participants and a *Workshop*

Observation Instrument which measured the facilitators' ability to capture and focus participants' attention on critical parts of the problem solving process.

Semi-structured *interviews* with facilitators using standardised, open-ended questions allowed us opportunities to use probing questions to obtain response clarity and additional information from the interviewees. Quantitative statistical data were generated from the facilitator inquiry learning belief system questionnaire (n=88) and the workshop observation instrument (n=39). These data were analysed and subjected to analysis of variance (ANOVA) techniques to provide descriptive and inferential statistics. Comparisons were made of statistically significant mean facilitator scores across the three categories of facilitators in each of the three stages of the inquiry process. Quantitative data were generated from the workshop interaction coding system instrument (n=39) and qualitative data were generated through the semi-structured interview schedules (n=39). These data were analysed and classified according to broad categories to provide descriptive and inferential statistics.

Results
Data analysis of the belief questionnaire, workshop observations and semi-structured interviews with facilitators indicated that their inquiry beliefs and practices improved over time as they progressed from novice to veteran category.

Belief as measured by questionnaires
Analysis of the mean scores of the data generated by the four-point scale beliefs questionnaire revealed a statistically significant difference between the three groups of facilitators in terms of engaging participants in problem situations, allowing participants to explore the concept, and encouraging participants to explain the concepts and define mathematical terms. In each case the scores increased from novice to intermediate to veteran.

Teacher practice as measured by observations
The data generated by means of the *workshop observation schedule* were analysed statistically to provide descriptive and inferential statistics. The mean scores for each criterion were calculated and comparison of the mean scores of the three facilitator categories suggested a progression in both understanding and implementation of inquiry learning strategies as they proceeded through the two-year Family Maths facilitator professional development programme.

No statistically significant differences were recorded for a number of criteria observed during the workshops, indicating that levels of competence regarding these criteria were similar for all facilitators. However, comparison of the mean scores still suggests that progression is made as facilitators proceed from novice through to veteran category.

The probability levels of confidence for the criteria that were statistically significantly different and suggest a progression in understanding and implementation of inquiry learning strategies as facilitators proceed through the sequence of stages of novice, intermediate and veteran categories.

Step 1:   Engages the participants
During this stage the facilitators were expected to introduce activities that engaged learners and parents with a problem or phenomenon. As such, the 'Step 1' section of the workshop observation instrument attempted to identify the degree to which the facilitator engaged the participants in the problem solving activity according to specific criteria, such as 'creates a relaxed environment', 'encourages student autonomy', 'uses manipulative and physical materials', 'familiarises self with participants

understanding', 'encourages participants' discussion' and 'nurtures participants' natural curiosity'. For each of these criteria the facilitators' mean scores increased from novice to intermediate to veteran.

*Step 2:   Allows participants to explore the concept*
Step two of the National Science Education Standards (1996) model of inquiry instruction identifies the degree to which the facilitator allows participants to explore the concept of the problem solving activity according to specific criteria. Data generated by the workshop observation schedule also revealed a progressive increase from novice to veteran mean scores for the second step of inquiry learning.

Step 3:   Encourages participants to explain the concept and define the terms
Step three of the National Science Education Standards (1996) model identifies the degree to which the facilitator encourages participants to explain the concept and define the terms related to the problem solving activity, according to specific criteria. Data generated by the workshop observation schedule revealed a general increase in mean scores from novice to veteran facilitators for this step of inquiry learning.

Overall mean scores for practices observed
The total mean scores for the workshop observations in general, which includes the three steps of the NSES inquiry model focused on in this study, suggest a steady progression in the implementation skills of the facilitators on the Family Maths professional development programme as they advance through the sequential stages; from novice, to intermediate to veteran (see Figure 1).
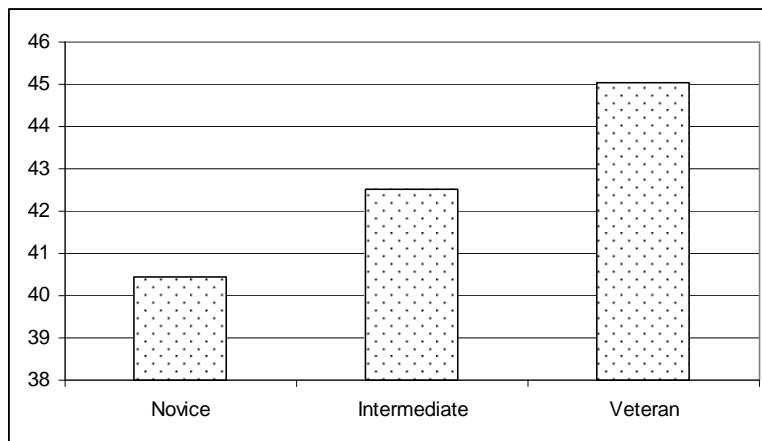
Facilitator Categories

Figure 1:   Overall mean scores (total) of novice, intermediate and veteran groups in terms of inquiry-based practice.

Analysis of variance
Statistical analyses (ANOVA) of the data generated by workshop observations reveal that there were statistically significant differences between the veteran, intermediate and novice groups in terms of 'encouraging and accepting student autonomy and student initiative', 'familiarising themselves with the participants understandings of concepts', 'encouraging participants to engage in discussion with the facilitator and one another', 'nurturing participants' natural curiosity', 'focusing and supporting inquiry while interacting with the participants', and 'giving participants opportunities to refine their

explanations and definitions'. In each case the veteran group scored the highest and the novice group the lowest.

The data generated indicate significantly different levels (between 95% and 99% levels of confidence) in the ability of facilitators to encourage and accept student autonomy and initiative as an important inquiry strategy as they progress through the two year Family Maths professional development programme. There is also a significant difference at the 95% level of confidence between the veterans and novices' ability to familiarise themselves with the participants' understandings of concepts. The veteran group of facilitators show a much higher level of competence in familiarising themselves with workshop participants' understanding of concepts than the novice group of facilitators.

The statistically significant difference in terms of the ability of facilitators to encourage and accept student autonomy and initiative, as well as encouraging participants to engage in discussion with the facilitator and one another are at the 99% and 95% levels of confidence between the veterans and novices and the intermediates and novices respectively. The data on the category 'nurturing participants' natural curiosity' shows a statistically significant difference between the veterans and the novices at the 95% level, while there is a similar level of confidence between the scores of the veteran and novice group in terms of 'focusing and supporting inquiry while interacting with the participants. The difference between the veterans and the novices in giving participants opportunities to refine their explanations and definitions is also significant at the 99% level of confidence.

Comparison of beliefs and practices

In all three categories of facilitators, viz. novice, intermediate and veteran, the novices show the least amount of understanding overall regarding inquiry learning (inquiry beliefs) and they also have the lowest rating with regard to implementation of inquiry learning strategies. The group of intermediate facilitators generally show a greater understanding than the novice group and also implement inquiry learning more effectively in the workshop situation. The veteran group of facilitators show the greatest understanding of inquiry learning and also show the greatest skill in the implementation of inquiry learning strategies.

Table 1 represents the mean scores for each of the categories, i.e., (i) encouraging the participants to engage, (ii) exploring the concepts and (iii) explaining the concepts and terms where the scores for both the beliefs and practices data are the sum of the average scores for each of the three steps (i.e., steps (i), (ii) and (iii) of inquiry learning) in order to accommodate the different group sizes and to allow direct comparisons and analysis of variance to be made (as opposed to the simple sum of scores shown in Figure 1).

Table 1:   Comparison of facilitator mean scores with regard to inquiry learning belief versus practice

	Novice		Intermediate		Veteran	
	Belief	Practice	Belief	Practice	Belief	Practice
Engage	3.39	2.58	3.62	2.83	3.70	3.02
Explore	3.15	2.42	3.34	2.65	3.48	2.76
Explain	3.16	2.38	3.45	2.53	3.56	2.69
Sum of scores	9.70	7.38	10.41	8.01	10.74	8.47

A comparison of these sums of scores is depicted graphically in Figure 2.
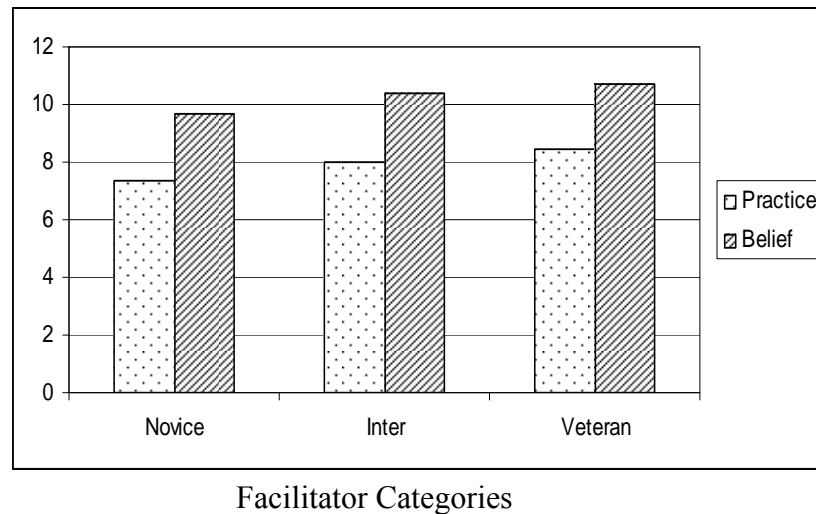

Facilitator Categories

Figure 2: Comparison of participating facilitators' beliefs and practice overall in terms of inquiry learning

In all categories of comparison (i.e. the difference between novice, intermediate and veteran practice vs belief scores) in Figure 2 the probability value is equal to or less than 0.05 ($p \leq 0.05$) and there is, therefore, a 95% level of confidence that the statistical differences between the mean scores of the belief system questionnaire and the workshop observation instrument scores are not due to chance in each case.

Facilitators' verbal responses measured by Workshop Interaction Coding System Instrument
The facilitators' verbal feedback techniques were measured using the *Brophy and Good Dyadic Interaction Coding System*. This instrument classifies answers, questions, clues and rephrasing of questions, and provides a coding sheet of which the facilitators' verbal feedback techniques are recorded. Analysis of these data revealed that, across all categories of facilitators, higher order responses of 'giving clues' and 'rephrasing questions' were more frequent responses by facilitators than merely 'repeating questions'. This was encouraging for the researcher as giving answers to participants is strongly discouraged in the Family Maths programme.

Interviews
The data generated via interviews were classified into broad categories and analysed within the framework of reviewed literature. The responses from facilitators of the intermediate and veteran groups intimated that the majority felt confident in terms of implementing inquiry learning as they believed that the Family Maths programme had been effective in developing their questioning skills and their ability to give meaningful clues. However, a large number of novice group facilitators felt that they had not mastered the skills of 'questioning' or 'giving clues' and would benefit by further training in this regard.

Most of the facilitators' from the intermediate and veteran categories acknowledged that inquiry-based learning had changed their way of teaching both in the workshop situation and in the classroom. A novice facilitator's response was "I still find it hard to move away from the teacher-centred approach". Responses from intermediate and veteran facilitators included "inquiry learning has changed my way

of teaching" and "inquiry-based learning has made me think differently about my own teaching strategies".

Discussion

The apparent disjuncture between the facilitators' beliefs and practices may be of concern to some. However, while some researchers have suggested that beliefs are a major force in affecting teaching practice (Schoenveld, 1992; Thompson, 1992); others believe that they are not (Hoyles, 1992). Skott (2001) maintains that mathematics teachers can hold simultaneously multiple, and possibly conflicting beliefs, about their practice in the course of classroom interaction.

Interview data support the questionnaire and observation data in that they all suggest that facilitators' perceptions, attitudes and abilities regarding inquiry learning all strengthened as they proceeded through the facilitator categories of the Family Maths programme. This type of development, with its emphasis on inquiry techniques and active engagement, is particularly important in the South African context during the implementation of the new national curricula which are underpinned by constructivist and inquiry-based approaches to meeting the curriculum outcomes via outcomes based education.

Conclusion

The findings of this study suggest that the Family Maths professional development programme, which is offered by the NMMU, can promote individual's ability to engage in multiple aspects of inquiry-based teaching and learning over the two years that it operates. In turn this implies that appropriately selected aspects of the approach may have the potential to assist in the design of other teacher development programmes engaged in the process of both dispelling negativity towards mathematics and making school mathematics more relevant to learners.

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