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Student teachers meaningful learning of mathematical modelling via design-based research

1. Linking design-based research and learning mathematical modelling

The inclusion of real-life examples and applications is regarded as an essential component in mathematics curricula worldwide. It largely depends on mathematics teachers who are well-prepared to teach mathematical modelling. Thus, two primary directives provided a stimulus for this study. Firstly, student teachers require adequate preparation in respect of their 'knowledge-in-action' of mathematical modelling. This includes competencies both as modellers themselves and as facilitators of modelling activities (compare Blum, 2015; Ng, 2013). Secondly, mathematical modelling has a positive influence on the teaching and learning of mathematics and on its inclusion in (and desires of) the current South African (SA) mathematics curriculum (CAPS) (compare Department of Basic Education, 2011). These two directives are not only limited to the SA context but are also relevant for a German context where the professional development of future teachers is well established (compare Blum & Borromeo Ferri, 2016).

The design-based research (DBR) approach selected for this study was based on an in-depth literature review, on the researchers' personal experience, and on ideas from other practitioners. The study was conducted over three phases (including eight micro cycles describing the design step-by-step and a macro cycle with the idea to yield contextually-sensitive design principles that might be suitable in further studies or in other contexts), focusing firstly on relevance, guided by a needs analysis (micro cycles 1 – 3), secondly on consistency and practicality via the design and implementation of two iterations (micro cycles 4 – 7), and lastly on effectiveness by means of reflective analysis and evaluation (micro cycles 7 continued & 8) (view Figure 1 from Durandt, 2018, p. 64). DBR linked particularly well with the learning of mathematical modelling as it is a flexible methodology aimed at improving practices through iterative cycles (analysis, design, development, and implementation via interventions). Furthermore, it focuses on the collaboration between researchers and practitioners with the intention to extend and identify new design possibilities. Some key characteristics of DBR, which are widely agreed upon, provided a suitable validation for the methodology for the study: (i) DBR's authentic nature, (ii) its ability to generate design principles, (iii) the rigorous methodology used in such studies, (iv) the fragile, complex and 'messy' nature of the design, (v) its unique processes to transcend the

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local context, (vi) its ability to generate credible evidence and useful knowledge (e.g. compare Anderson & Shattuck, 2012).

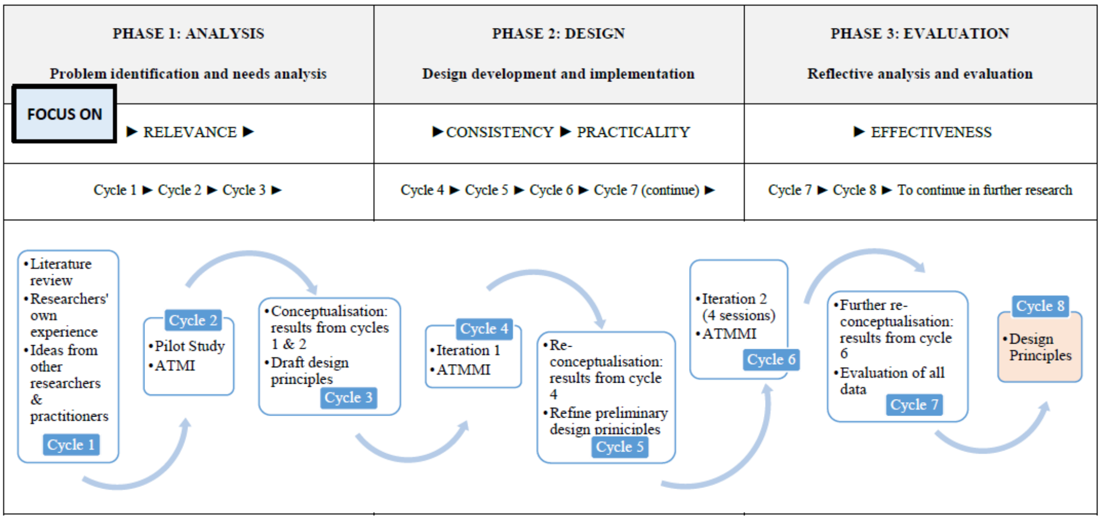

Fig.1: DBR process of the study

The design seemed suitable for exposing student teachers (both as modellers and as facilitators) to a well-planned set of modelling activities, while monitoring their development in modelling competencies and their change in attitude towards such activities over time. The broad research question was: What shortcomings and progression in student teachers’ learning experiences of mathematical modelling can be identified through a DBR study?

2. Research design

As part of their formal education, a sample of 55 third year mathematics student teachers, arranged in ten comparable groups by using purposive sampling procedures, were exposed to a series of modelling activities over two iterations (view Figure 1). Mixed data was collected in cycle 2 (the pilot study that consisted of one session), cycle 4 (iteration 1 that consisted of 1 session), and in cycle 6 (iteration 2 that consisted of four sessions). During each cycle participants were exposed to modelling activities, for example solving a Traffic Flow task (for task details see Durandt, 2018). These activities ranged from mathematical application tasks to real-life open-ended modelling tasks with substantial modelling demand. Participants were expected to work their way through the modelling cycle and record their work on a predesigned worksheet. In groups, they participated in discussions, reflected on their own and others’ work, prepared posters and presented their proposed solutions. Each data collection cycle (2, 4 & 6) was followed by a cycle where the results were conceptualised and draft design principles identified, and refined. The implementation of all activities was according to plan, including control measures (e.g. taking fieldnotes).

3. Test instruments and methodology of the study

During the DBR phases, rich data were collected via a selection of qualitative instruments (including a predesigned worksheet, reflective homework activity, report, presentation/poster, grading form, field notes and an open-ended questionnaire), and the Attitudes Towards Mathematical Modelling (ATMMI) instrument. Data were collected individually and in groups. All qualitative data collection instruments were carefully designed at the end of micro cycles 1, 3 and 5. Students' worksheets were marked according to a framework deduced from relevant literature and compared through the cycles. Both conventional and directed content analysis methods were used to analyse the data and trustworthiness of findings were confirmed. The ATMMI (adapted from Schackow, 2005) is a locally tested instrument to gain information regarding student teachers' attitudes towards mathematical modelling. The instrument consists of 40 Likert-scale items grouped in four dimensions: enjoyment, value, self-confidence and motivation. Data was collected at the end of iteration 1 (cycle 4) and at the end of iteration 2 (cycle 6). The Statistical Software Package for the social sciences (SPSS, version 24) was used to analyse the data. Internal consistency was confirmed by acceptable Cronbach's alpha coefficients (in all sub-scales > .8). The one-sample t-test was used to evaluate the effectiveness of the series of mathematical modelling activities on student teachers' attitudinal scores.

4. Results of the study

A conceptualisation of findings at the end of micro cycles 3, 5 and 7 resulted in the development of a set of practice-based design principles, grouped according to: Cluster 1, with an emphasis on developing competencies; Cluster 2, with an emphasis on building perceptions; and Cluster 3, with an emphasis on providing resources and opportunities. The design principles in these clusters intend to give a possible solution to the challenge participants experienced throughout the intervention. They showed shortcomings regarding mathematical modelling competencies and had predetermined ideas about mathematics. They require opportunities to build positive perceptions about mathematical modelling as well as sufficient resources and opportunities throughout their formal tertiary education to participate regularly in modelling activities. Participants showed substantial progression – they expanded their mathematical pedagogical content knowledge regarding modelling (e.g. showed an improved understanding of the modelling cycle), improved as modellers (e.g. creating a mathematical model from the real-world situation), and showed positive changes in all attitudinal aspects and even significant positive changes in enjoyment and motivation towards modelling activities.

5. Discussion and perspectives

The pragmatic approach chosen for this study resulted in rich data shedding light on student teachers' shortcomings and progression in modelling competency and their positive attitudinal experiences, similar to the results of other studies (e.g. Anhalt & Cortez, 2016), but also contradicting some findings from Kreckler (2017). Both the approach and the findings of this study could support the international discussion. DBR guides theory development but usually takes place to its full capacity through several iterations and this study could thus be further developed through more iterations. Additionally, a narrower lens on aspects of mathematical modelling (e.g. reflective activities) could enhance metacognitive development.

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