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The impact of a professional development programme on the practices and beliefs of numeracy teachers

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This article describes some outcomes of a nine-month design-based research study into the professional development of 24 numeracy teachers with post-16 learners. Teachers analysed research-based principles for teaching, and engaged in a design-research process by testing and refining teaching activities to embody these principles. Data from questionnaires, interviews and classroom observations suggest that many of the teachers' practices and beliefs were profoundly affected. Practices became less transmission-oriented and teachers began to create new, collaborative learning environments where students were challenged to confront difficulties and take on more active classroom roles. Changes in beliefs regarding mathematics, learning and teaching are also described and discussed.

Keywords: numeracy; mathematics; basic skills; professional development; post-16

Introduction

Each year, teachers working in the Skills for Life (SfL) sector of adult basic skills spend, on average, about five days engaging in activities designed to promote their continuing professional development (CPD) (Cara et al. 2008). Indeed, it is a legal requirement that all teachers working in the post-compulsory sector must undertake at least 30 hours of CPD per year on a pro-rata basis (IfL 2007). The regulations specify the nature of this CPD only broadly – it involves 'any activity undertaken by him [the teacher] for the purposes of updating his knowledge of the subjects he teaches or developing his teaching skills' (Rammell 2007). This permits a wide range of activity, from local, in-house, informal and opportunistic to national, external, formal and carefully planned. The provision and quality of CPD is therefore uneven, and its effectiveness unknown. To date there is no coherent national strategy for ensuring that CPD has a positive effect on teaching and learning.

In this article we consider a cost-effective CPD programme that challenges teachers' practices and beliefs and which provides a replicable model that

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others may find useful. It combines many features recommended by researchers: it is sustained over time (Cohen and Hill 1998); it is related to the local context in which the teachers operate (Cobb et al. 2003); it involves teachers in active and collective participation (Garet et al. 1999); it focuses on developing teachers' knowledge of the content, the pedagogy and the underlying principles (Hammerness et al. 2005); and it offers continuing support for teachers in translating new ideas into everyday practice (Lee and Wiliam 2005).

This CPD programme was held on six days, spread over nine months, with 24 teachers working in the Skills for Life (SfL) sector of adult basic skills. The purpose was to explore collaborative ways of teaching and learning numeracy. The need for such a course is clear. Since 2001, these teachers had been expected to 'map' a core curriculum divided into five 'levels' onto individualised student learning plans. This requirement had encouraged them to fragment mathematics into discrete skills that could be then 'transmitted' to students through explanation and demonstration. The dominant mode of learning was therefore individualised, with learners working through practice worksheets (Coben et al. 2007). This approach does not promote robust, transferable learning that endures over time and does not produce knowledge and skills that can be used in non-routine situations outside the classroom (Ofsted 2006; Swan 2006a). Transmission approaches are also associated with increased drop-out rates in more demanding post-16 mathematics courses (Williams et al. 2008). Our professional development programme was designed to challenge this state of affairs. It encouraged teachers to explore teaching approaches that require students to work collaboratively, discuss and explain ideas, challenge and teach one another, create questions for each other to solve, and to share methods and results. The twin aims were to develop a *more 'connected', 'challenging'* approach to teaching, and to help students adopt *more active approaches towards learning*. This programme and associated resources were given the title 'Thinking through Mathematics' (TTM) (Swan and Wall 2007). TTM formed part of a larger ongoing project commissioned by the National Research and Development Centre for adult literacy and numeracy (NRDC), called 'Maths4Life' (www.ncetm.org.uk). TTM built on many years of research in the further education (FE) sector (Swan 2006b) and drew on the work of an earlier project commissioned by the government called 'Improving Learning in Mathematics' (ILM) (DfES 2005). Whereas ILM focused on teaching mainstream and advanced mathematics classes (Levels 2 and 3),[1] TTM was designed to address the very different contexts and requirements of those teaching adult numeracy at Level 1 and below.

The organisations, teachers and courses involved

Participation in the programme was by invitation. Twenty-four teachers (six men, 18 women) were invited from 12 organisations: seven further education

colleges; one drugs reintegration centre; one private training company; one sixth form college and two local authority adult education centres. A condition of participation was that the teachers would ensure that the senior management in each organisation would support them by giving them flexibility to adapt their schemes of work.

The backgrounds, attitudes, experience and qualifications of these teachers also varied considerably. Some were nominated to take part by their organisations and appeared less than fully committed to the project. Nine worked full time and the remainder were employed on a part-time or fractional basis. Professional experience ranged from under a year to 29 years (mean 6.5 years). Three held a degree in mathematics as their highest mathematical qualification, while two had not achieved a mathematics qualification at GCSE/O level. Eleven had gained a Level 4 subject-specific teaching qualification in numeracy.[2]

The numeracy courses represented were diverse. The majority catered for more than one level of the National Qualifications Framework (NQF), and over half contained learners working between Entry Level 2 and Level 1. The length of courses ranged between three months and nine months (September to June), and teaching sessions varied from 45 minutes to three hours. While most of the numeracy provision was discrete and stand-alone, two classes were embedded in other courses. Over one third of the programmes were held on a 'roll-on, roll-off' basis, with learners joining and leaving the course at different points, and this caused problems of continuity. Learners were predominantly female and White British. One third of the classes were composed of 16–19-year-olds, and the average number of learners attending each class was eight.

The programme

Teachers attended from four to six of the one-day professional development meetings, which were designed to challenge existing practices and beliefs by investigating how teachers might incorporate the following pedagogical principles into their teaching:

- **Build on learners' pre-existing knowledge** by developing formative assessment techniques (Black and Wiliam 1998; Black, Wiliam, and Assessment Reform Group 1999; Black et al. 2003);
- **Expose and discuss common misconceptions** (Bell et al. 1985; Bell 1993; Askew and Wiliam 1995);
- **Use higher-order questions** that promote explanation, application and synthesis rather than mere recall (Askew and Wiliam 1995; Watson and Mason 1998);
- **Use cooperative small-group work** that encourages critical, constructive discussion (with group accountability and shared goals), rather than

argumentation or uncritical acceptance (Mercer 1995; Boaler 2004; Alexander 2006);
- **Encourage reasoning rather than 'getting answers'**; replacing an emphasis on 'coverage' with an emphasis on learning;
- **Use rich, collaborative tasks** that are accessible, extendable, and encourage decision making and creativity (Ahmed 1987);
- **Create connections between topics**, so that students do not see mathematics as a set of unrelated tricks and techniques to be memorised.

These principles, which were subsequently endorsed and expanded via national consultation (Swan 2007), were introduced to teachers using the following four-stage procedure (Swan 2009):

(1) Existing values, beliefs and practices were recognised. We invited teachers to describe the situations in which they worked, and elicited their existing values and beliefs about mathematics, teaching and learning, and their classroom practices.
(2) Contrasting practices were offered and analysed. Through working on classroom tasks, then watching their use on video, teachers were confronted with practices that contrasted with their own. They discussed the principles underpinning these (described above). These provided 'challenge' or 'conflict'. We discussed common objections to these ways of working.
(3) Teachers were encouraged to suspend disbelief and adopt new practices. Teachers were encouraged to try out new classroom activities using prepared classroom resources. They were offered a mentor and a network of support as they did this.
(4) Teachers were given time to reflect on their new experiences. After trying out the activities, teachers were invited to meet together to share their classroom experiences and discuss the pedagogical implications. They were explicitly encouraged to reflect on the growth of new beliefs. They suggested new tasks and revisions to existing tasks.

The teachers were thus involved in an iterative, design-research process (Kelly 2003; Swan 2006a; van den Akker, McKenney, and Nieveen 2006). Research and design were interwoven – the teaching approaches and activities were iteratively modified and developed in the light of the emerging issues and findings, and the revised versions were observed in use to generate new research findings. In total, a collection of 29 discussion-based mathematical activities were created. The activities were categorised into five 'types' that encourage distinct ways of thinking and learning (Table 1). Examples of the activities are provided in Swain and Swan (2007) and the complete set has been subsequently published and distributed to all adult numeracy teachers (Swan and Wall 2007).

Table 1. Types of task devised and modified with the teachers.

Classifying mathematical objects	Learners devise their own classifications for mathematical objects (e.g. shapes, numbers, symbols), and/or apply classifications devised by others. In doing this, they learn to discriminate carefully and recognise the properties of objects. They also develop mathematical language and definitions.
Interpreting multiple representations	Learners work together matching cards that show alternative representations of the same mathematical idea (e.g. words, pictures, symbols). They draw links between representations and develop new mental images for concepts.
Evaluating mathematical statements	Learners are given statements and are asked to decide upon their validity. (E.g. "Max gets a 10% pay rise, Mary gets a 5% pay rise, so Max gets the bigger pay rise".) When are they true? When are they false? Learners suggest their own examples and counterexamples.
Creating and solving problems	Learners are asked to devise their own problems for other learners to solve, using given constraints. When the 'solver' becomes stuck, the problem 'creators' take on the role of teacher and explainer. These activities exemplify the 'doing' and 'undoing' processes of mathematics.
Analysing reasoning and solutions	Learners compare different methods for doing a problem, organise solutions and/or diagnose the causes of errors in solutions. They begin to recognise that there are alternative pathways through a problem, and develop their own chains of reasoning.

Methods of data collection

In order to evaluate the effects of the programme, quantitative and qualitative data were collected. These came from two sources: teachers' views were obtained through questionnaires, interviews and unstructured oral feedback given during the professional development meetings; and teachers' practices were observed first hand by 11 researchers. In total, 49 semi-structured teacher interviews and 110 classroom observations were carried out, and each teacher was observed between three and six times. In addition to this, further data was collected from around 200 learners to assist in validating the accounts. Below, we consider how teachers' beliefs and practices evolved over the course of the project.

The impact on teachers

Interpretations of the project

In a companion article (Swain and Swan 2009), we describe how the teachers only gradually came to realise the profound nature of the challenges with which they had been presented. Teachers' comprehension of the underlying

principles evolved gradually and, particularly during the early stages, some teachers appeared to interpret them in a partial or superficial way. At least six of the teachers claimed that they were already using teaching approaches that were compatible with the principles before the project began, and two teachers retained this view at the end. Alternative interpretations of terms such as 'discussion' and 'talk'; 'working collaboratively' and 'group work'; and 'mistakes' and 'misconceptions' meant that some teachers thought they were using the principles when our classroom observers did not. In addition, a few teachers had low expectations of their learners and a 'protective' attitude towards them. This meant that some did not always want to challenge learners in the way the teaching approaches intended.

Changes in practices

We asked teachers to reflect on their own practices both at the beginning and at the end of the project (17 of the teachers completed both questionnaires). This was compared with data obtained from lesson observations. Teachers were asked to rate the relative frequency of 28 teaching behaviours using a five-point scale (Figure 1).

On the pre-questionnaire, teachers rated themselves as student-centred in orientation. They saw themselves as enabling students to work collaboratively, discussing ideas and mistakes, and addressing individual needs. They said that they did not tend to restrict themselves to single methods, hurry learners or closely follow textbooks or worksheets. They still, however, showed some characteristics of teacher-centred approaches, such as a frequent tendency to carefully structure and simplify work for students, so that students could begin with easy questions and gradually work up to harder ones. These responses are to some extent a reflection of the fact that these teachers had small classes and were forced to deal with more severe learning difficulties (including reading difficulties, so textbooks would be less appropriate). Their response to difficulties, that may be perceived as caring, was to simplify the intellectual demands made on students. It should also be noted, however, that the students' perceptions were that their teachers were rather more teacher-centred than these results would indicate.

On the post-questionnaire, teachers reported substantial changes to their practices that made them considerably more learner-centred. In fact, every practice occurring more than half the time on average may be considered to be learner-centred, with the exception of one: they still had a tendency to start with easy questions, but not nearly so much as before. Many now saw the value in challenging learners. The greatest increases in emphasis may also all be described as learner-centred behaviours. Almost all of the teachers, however, reported that there had been pressures and constraints that had prevented them from using the activities in optimal ways. One factor that hindered the implementation of the principles for some teachers was the

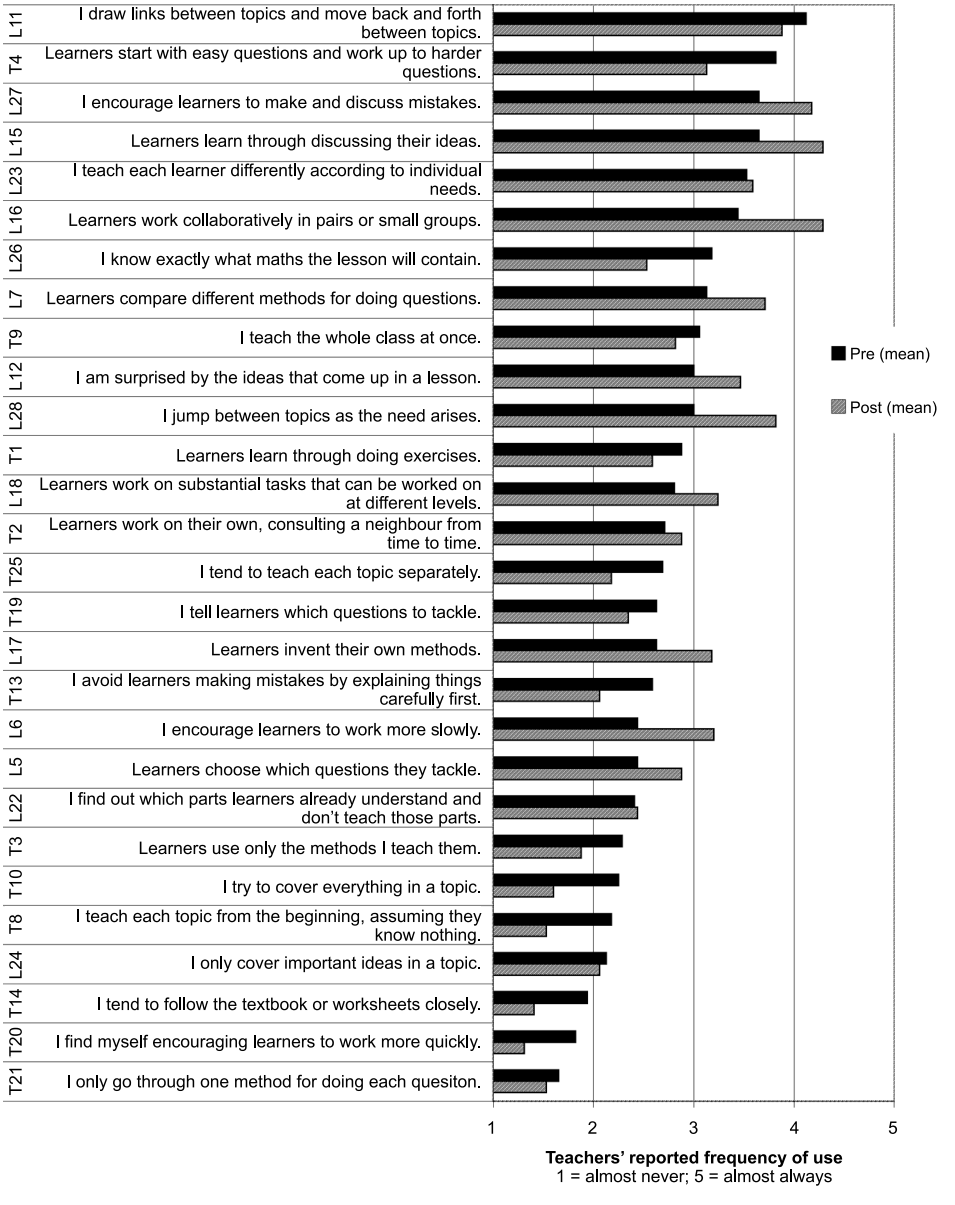

Figure 1. Teachers' self-reported changes in behaviour. (Teachers were asked to rate 28 practices on a five-point scale according to how common the practice was in their lessons [1= almost never, 2 = occasionally, 3 = half the time, 4 = most of the time, 5 = almost always]. The coding shows practices that are designated as predominantly either learner centred [L] or teacher centred [T]. Numbers after L and T show the position of the statement on the questionnaire. Mean ratings for each statement are shown for the 17 teachers who provided both pre- and post-questionnaire data.)

perceived pressure from senior management to prepare learners for accredited tests, and to map learning outcomes to particular content areas.

The data from direct classroom observation supported teachers' perceptions. Teachers and observers were in broad agreement that 18 of the 24 teachers had changed their practice towards becoming more learner-centred and that seven of these had introduced changes of a substantive and wide-ranging nature. Observers judged that the main ways teachers' practices changed was in terms of their organisation (with more group work), the classroom ethos (where learners were relaxed and felt less worried about making mistakes), and learners' practices (where learners were given more choices and encouraged to ask questions). The principles that the teachers found the easiest to introduce into their practice were 'rich, collaborative tasks', 'cooperative small group work' and 'asking higher-level questions'. They found the following principles more difficult to apply: 'exposing and discussing common misconceptions'; 'creating connections between topics'; 'building on knowledge learners already have'; and 'encourage reasoning rather than getting answers'.

Changes in teachers' beliefs

Teachers were asked at the beginning and end of the project: 'What are your current views on Mathematics, Learning and Teaching?' They were also asked to give each of nine statements a percentage weighting, so that the sum of the three percentages in each section totalled 100% (Table 2). They were also invited to add their own personal statements underneath. Their views were classified under three categories, *Transmission*, *Discovery* and *Connectionist* (Askew et al. 1997), as defined in Table 2. The mean of the three transmission statements was calculated and this was deemed an overall transmission weighting for that teacher. A similar calculation was made for the other two weightings. The results of the pre- and post-questionnaires are given in Figure 2. They show that teachers reported a significant movement away from a transmission/discovery orientations and a significant increase in the connectionist orientation. Teachers had thus begun to distance themselves from the view that mathematics is best learned through lectures and exercises and they had recognised limitations in students learning individually through worksheets. They were beginning to develop a *connectionist* orientation which recognises that mathematics is best learned through interpersonal activity and that students have prior knowledge (and misconceptions) which need to be recognised, made explicit and discussed. This orientation gets its name from the emphasis it places on making *connections* with students' prior knowledge and between mathematical topics.

Concluding remarks

These results suggest that a professional development programme, in which teachers introduce research-based principles into their practice and reflect on

Table 2. Beliefs about mathematics, teaching and learning.

Mathematics is..	
Transmission:	a given body of knowledge and standard procedures. A set of universal truths and rules which need to be conveyed to learners.
Discovery:	a creative subject in which the teacher should take a facilitating role, allowing learners to create their own concepts and methods.
Connectionist:	an interconnected body of ideas which the teacher and the learner create together through discussion.
Learning is..	
Transmission:	an individual activity based on watching, listening and imitating until fluency is attained.
Discovery:	an individual activity based on practical exploration and reflection.
Connectionist:	an interpersonal activity in which learners are challenged and arrive at understanding through discussion.
Teaching is..	
Transmission:	structuring a linear curriculum for the learners; giving verbal explanations and checking that these have been understood through practice questions; correcting misunderstandings when learners fail to 'grasp' what is taught.
Discovery:	assessing when a learner is ready to learn; providing a stimulating environment to facilitate exploration; and avoiding misunderstandings by the careful sequencing of experiences.
Connectionist:	a non-linear dialogue between teacher and learners in which meanings and connections are explored verbally. Misunderstandings are made explicit and worked on.

classroom outcomes, can effect significant changes in practices and beliefs. On a closer analysis, our results suggest that beliefs evolved along three trajectories: from transmission to discovery; from transmission to connectionist; and from discovery to connectionist. What seems to happen is that as teachers recognise the limitations of transmission methods, they move from a 'telling' role into a 'not telling' role. They recognise that they had previously not allowed learners to think for themselves, and react against this. They therefore stand back and begin to adopt a passive 'facilitating' discovery role rather than a proactive 'challenging' connectionist role. The danger is that teachers get stuck at this point and, as Askew illustrated in his study of numeracy teaching in primary schools (Askew et al. 1997), discovery teaching is often less effective than transmission teaching. The teachers who move beyond this discovery orientation towards a connectionist one, however, become more effective as they learn to listen to learners' reasoning, then actively engage them in collaborative, dialogic talk (Alexander 2006). They

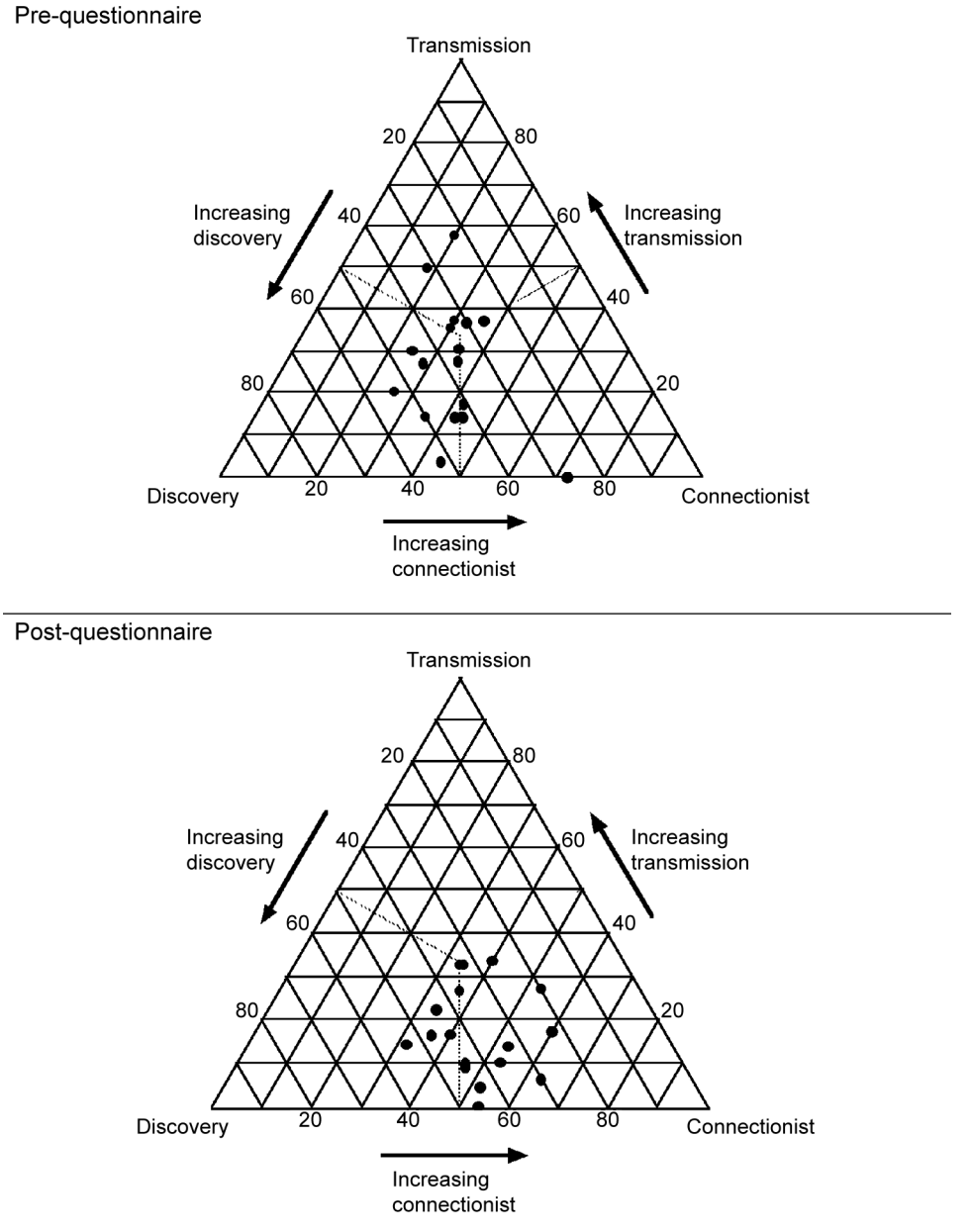

Figure 2. Triangular plots showing changes in orientation for each teacher. (Each point shows the mean weightings given to the three orientations by one teacher.)

challenge learners and stimulate thinking and reasoning without taking over. Whereas transmission teachers tend to begin each lesson with explanations and examples, the connectionist teacher offers these *after* learners have had time to think and discuss for themselves.

It might be assumed that in order to change a teacher's practice, one has to first change through persuasion his or her beliefs about teaching. Indeed, this forms the model of many pre-service and in-service professional development courses, where ideas and theories are propounded and illustrated. However, we would suggest that changes in beliefs are more likely to follow changes in practice, after the implementation of well-engineered, innovative methods, as processes and outcomes are discussed and reflected upon. Professional development, we suggest, will be made more effective by involving teachers in collaborative design-based research, in which teachers are encouraged to iteratively analyse, test, and refine classroom activities that exemplify research-based principles. This process, as well as being enjoyable for teachers, can bring about profound changes in their beliefs and practices. More research is needed to ascertain how enduring these changes in beliefs and practices will be, and how these new approaches are integrated into teaching routines in different contexts and with varying degrees of support.

Notes

1. In the National Qualifications Framework, Level 2 is equivalent to the top three grades at GCSE, and Level 3 to A level.
2. Level 4 has since become Level 5 in the professional standards introduced in 2007.

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