

The impact of professional development on the teaching of problem solving in mathematics: A Social Learning Theory perspective

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Teachers' professional development (PD) has been described as an 'unsolved problem', particularly where there is an expectation to change teaching practices from teacher-centred orthodoxies to more student-centred approaches. This paper considers PD that has been designed to support the teaching of problem solving in secondary classes. One of the main problems in PD design and research has been identified as the limitations of existing professional learning theory. To respond to this, the research reported in this paper is intended to contribute to the theorisation of PD. I will present a case study of one teacher – taken from a larger multiple case study – as they take part in a programme of school-based PD. Social learning theory (SLT) is used to analyse and explain the learning processes as a result of participation in the PD programme. This reveals that SLT provides a useful theoretical approach. As a result, I suggest the approach could be used more extensively in professional learning and PD, to understand, evaluate and develop programmes more effectively.

Key words: professional development; PD; CPD; problem solving; inquiry-based learning.

Introduction

The new National Curriculum for England, which comes into effect from September 2014, features problem-solving as one of the aims for teaching and learning in mathematics: "The National Curriculum for mathematics aims to ensure that all pupils can solve problems by applying mathematics to a variety of routine and non-routine problems ..." (DfE, 2013: 3). Across Europe there has also been considerable interest, at policy level, in developing inquiry-based learning approaches in the teaching of STEM subjects (Wake and Burkhardt, 2013). Problem-solving and inquiry-based approaches involve students collaboratively working on complex and unfamiliar problems where, according to Schoenfeld (1992), the methods to use are not obvious or there may be a choice of different methods.

There are two main arguments for the wider use of these approaches, which I will refer to as *student-centred problem solving* as a pedagogic approach. First, there is an economic argument: developing transferrable and flexible skills is necessary in an increasingly complex and mathematically formatted world (Skovsmose, 2008). Second, there is the issue of student engagement, but this has also been argued to have economic consequences. It is suggested that *student-centred problem solving* approaches are more engaging (Martino and Zan, 2010), this can lead to higher take-up of STEM subjects in more advanced study (Rocard, 2007).

At policy level then, there is an interest in student-centred problem solving orientations. However, there is strong indication that teaching in secondary schools in England is predominantly traditional, teacher-led and focussed on teaching methods (Ofsted, 2008; 2012). It is also been suggested that attempts to reform extant practices

through professional development have not been successful (Borko, 2004; Guskey and Huberman, 1995). This has been attributed to under-developed theory in the field of professional learning (Opfer and Pedder, 2011).

This paper addresses these issues by presenting an aspect of the research and evaluation of a PD solution (Bowland, 2008). The PD was designed to support teachers implement *student-centred problem-solving* approaches in their teaching. It was also designed to be used, by departments, without external expertise.

In this research, I use a theoretical approach to understanding PD and professional learning that has not, until now, been used in the context of teachers' professional learning. The theory used is based on social learning theory (SLT) (Bandura, 1977). I illustrate its affordances by considering the case of a teacher who participated in the wider PD project and evaluation. From this I will demonstrate the power of this theoretical approach and its potential in the design, development and evaluation of professional development. In so doing, I attempt to offer a theoretical approach that counters the criticism aimed at extant theories used in professional development and professional learning.

The research question for this study is: How effective is SLT in accounting for teachers' professional learning in the context of a PD programme? For this I will consider the case of a single teacher who was a participant in a wider study.

Social Learning Theory

Social learning theory (SLT) or social cognitive theory represents a theoretical and research pathway that began in the latter part of the nineteenth century and has developed and grown subsequently. The originators of the ideas in SLT have been attributed to William James and then developed this century by Millar and Dollard and, through the latter part of the last century, by Albert Bandura (1977; 1986; 1997). The key features of SLT are:

- *Observational learning* – learning takes place by observing behaviour directly; or by using guides or principles for action and adapting them.
- *Self-efficacy* – the belief an individual has that they will be successful in any given endeavour or course of action.
- *Reciprocal triadic determinism* – this is the inter relatedness between individual thinking and beliefs, the social context and individual behaviour. These three components, in SLT, are reciprocally influencing.

SLT affords a number of advantages and facilities in respect to teachers' professional learning. One of which is the way learning is conceptualised and this, as I will explain, satisfies criteria identified in the literature. Sfard (1998) argues the equal importance of 'two metaphors' for learning; which are, individual, cognitively-oriented knowledge *acquisition* conceptualisations *and* social and participatory conceptualisations of learning. Borko (2004) suggests this is also true for teachers' professional development and professional learning. She refers to the theorisation of professional learning that draws on both metaphors as a *situative* approach. This is consistent with *reciprocal triadic determinism* in SLT.

However, cognitively-oriented and participatory theories have come to represent two distinct strands of research in professional development, mathematics education and educational research. It has been argued that these two approaches are

too distinct; they have separate philosophical underpinnings and are incompatible. It is not possible, therefore, to unite the two to develop a genuinely *situative* analysis as suggested by Borko (see, for example, Greeno, 1997). However, SLT arrives from a different tradition and implicitly takes a *situative* perspective on learning. Individual acquisition is captured in the construct of self-efficacy and the participatory aspect reflected in SLT's reciprocal determinism. So let us turn to the key concepts and structures in Bandura's formulation of SLT.

A central tenet of SLT is observational learning. While this may suggest replication or mimicry, the mechanisms of observational learning within SLT involve a process through which novel behaviours are formed. That is, an observer can watch somebody's behaviour and consciously adapt and develop what has been observed and subsequently behave in a way that is related to what was observed but has been transformed and developed by the observer.

The processes by which novel behaviours are formed are regulated through self-efficacy. Self-efficacy represents the belief an individual has in their ability to achieve certain levels of attainment using a particular approach or behaviour in a particular domain (Bandura, 1997). For example, an individual will observe a set of behaviours in a situation or context and then adapt them to a form consistent with what they believe they will be effective. If, as in the context of teaching, existing behaviours (practices) are dominated by norms and expected routines then lower levels of efficacy would result in the implementation of behaviours that are similar to existing approaches. Higher levels of efficacy may prompt the introduction of more novel approaches.

Self-efficacy reflects individual cognitive aspects such as underlying knowledge as well as affective aspects such as confidence, motivation and 'underlying skill' (Bandura, 1997). Self-efficacy combined with observational learning provides a *situated* or *participatory* component through which behaviours are observed and self-regulated. In the context of a school, the self-regulating processes of modelled behaviour serve to 'conservatise' teachers' practices. High levels of efficacy are required by individual teachers to implement and sustain practices that vary from the orthodox routines and organisation of teaching.

Methods

This study uses a case study approach as characterised by Yin (2009). In this paper I will present the analysis of a single case, that of Imran (pseudonym), as he participated in a PD programme run by his department, and then, as he attempted to implement *student-centred problem-solving* in one of his classes.

The PD was designed to support the teaching of *student-centred problem solving*. The programme involved two cycles of PD sessions, each with an hour-long *introductory* session: an *into-the-classroom* phase – where teachers 'try out' the ideas presented in the introductory session – finally there is a *follow-up* session in which the department meets for an hour to reflect on their experiences in teaching the approaches suggested in the *introductory* session. In Imran's school the sessions were led by the head of mathematics, the materials provided detailed instructions and resources to run the PD sessions.

The PD materials, developed by the Shell Centre team at the University of Nottingham, were originally released as part of the Bowland materials (Bowland, 2008). There are seven PD modules in all, two of these were used for the two cycles of PD sessions described above. The modules, as well as having a general emphasis

on teaching using a student-centred problem-solving approach, each have a more specific pedagogical focus. The modules used in Imran's school focussed on *Questioning and reasoning* and *Involving pupils in peer and self-assessment*.

Imran was selected for the case study in this paper as he appeared to illustrate the challenges teachers face in adopting new approaches in teaching. That is, he explained that his teaching was traditional, with an emphasis on teaching methods and presenting students with extensive opportunity to practise with textbook- or worksheet-based exercises. He taught in a way consistent with the norms of practice described above. It was assumed that Imran is representative of many teachers who generally teach mathematics using a teacher-centred approach. And so, it is likely that the exploration of Imran's attempts to develop and potentially change his approach serves to investigate the efficacy of SLT in the context of professional learning.

Data collection included questionnaires administered to all teachers before and after the programme; the observation of PD sessions and lessons; and interviews with the PD leaders, heads of departments, after the PD sessions. There were also interviews with teachers after each observed lessons. Imran was observed on five occasions through the project, two of the observations involved the *into-the-classroom* phase of the PD. Teachers were asked to teach a 'problem solving' lesson in each of the observed lessons. This was in order to understand how teachers developed in their teaching of student-centred problem solving through the project.

The analysis of data involved a two-stage process in which data were first reduced and organised. The second stage featured a range of analytic approaches, involving the analysis of video recordings of PD sessions, observed lessons and interviews. Interviews with teachers were analysed and coded in order to identify the challenges teachers faced in teaching using the suggested approaches and the way in which they felt they had developed through the programme. These were compared and triangulated with interview responses from heads of departments and lesson observations. From this a case study report for each teacher was generated with a particular focus on the way in which s/he had developed through the programme. In the next section I will present an analysis of Imran's experience using SLT as the analytic framework.

Results

Imran had been teaching for about nine years at the time of this study. This was his third teaching post. He had been at the school two years. It is an average sized comprehensive school serving students in the 14-18 age range and located in a village outside of a city in central England. GCSE results were below the national average and pupils also made progress below the national average.

Imran described himself as a traditional teacher, although he indicated that he would like to try more problem solving and use more student discussion and collaboration in his lessons. The head of department, Deborah, had strongly encouraged Imran to be a participant in this study in order that he had the chance to develop his approach to using student-centred problem solving. Deborah had decided to do the PD modules on *Questioning and reasoning* and *involving pupils in peer and self-assessment*. Imran attended all sessions along with most other members of the department.

In terms of SLT, Imran's practice was consistent with the norms of school mathematics teaching. In order for his practice to change, then the PD would need to

help him develop self-efficacy in the suggested alternative approach. It would also need to provide observable 'models' of the suggested approach.

The head of the department described the department as having a core team of four teachers of which Deborah counted herself a member. This group had a particular interest and commitment to developing teaching and learning. Imran, although a valued member of the department, was peripheral to the 'core' group. Deborah also recognised Imran as a traditional teacher who found the behaviour of lower-attaining students challenging.

From an SLT perspective this suggested that there was an efficacious group of teachers in the department who were willing to experiment, work together and try things out. Imran, who was less efficacious in respect to his teaching, was on the periphery of this group. It is assumed he is less efficacious because he is less confident and motivated to try things out. This assumption is supported by the analysis of interviews and observations.

At the beginning of the project Imran explained how he teaches in a traditional way using exercises and worksheets having explained a method:

Most of the time we are doing [something like] SOH-CAH-TOA [mnemonic for trigonometry ratios] and they use it and apply it straight away.

The first lesson that was observed involved students working on two problems involving the optimisation of the volumes of two objects. In the interview afterwards Imran explained that the difference between the lesson and the way he usually taught was that he did not provide an explanation of how the problems should be solved at the beginning of the lesson. Imran had interpreted a problem solving lesson as much like a traditional lesson but not involving teacher exposition or an explanation of methods at the beginning of the lesson. Imran did not appear to be confident in handing over decision-making to the students. This is consistent with SLT, if more efficacious in respect to the teaching of problem solving it is likely that Imran would have given greater authority to the class.

In the second lesson, Imran was expected to use the ideas presented in the PD introductory session: the lesson planned in that session or the suggested lesson plan, to try out the student-centred problem solving approaches described in the PD. Like many of the teachers participating in the PD, Imran chose to use the tasks and adapt the model lesson plan included in the PD materials. This can be considered in terms of observational learning. Bandura extends observational learning to include, as well as the direct observation of behaviour, the use of 'guides' or 'principles for action' (Bandura, 1997). Here the lesson plan represents an observable behaviour. In addition, included in the PD materials and shown in PD sessions, are videos of lessons as examples. What is interesting from a SLT perspective is the way in which Imran uses and adapts the models.

The suggested lesson plan includes a brief introduction by the teacher and a few minutes for students to look at the problem individually. It is then suggested that the teacher collects ideas at the board before students work in groups for 20 minutes on the problem. This is followed by a whole-class discussion after which students are given further time to work on the problem. Finally, it is suggested, students present their solutions.

Planning and organising:
Aircraft turn-round time

Between landing and taking off, the following jobs need to be done on an aircraft.

	Job	Time needed
A	Get passengers out of the cabin and off the plane	10 minutes
B	Clean the cabin	20 minutes
C	Refuel the plane	40 minutes
D	Unload the baggage from the cargo hold beneath the plane	25 minutes
E	Get new passengers on the plane	25 minutes
F	Load the new baggage into the cargo hold	35 minutes
G	Do a final safety check before take-off	5 minutes



What is the shortest time needed to do all these jobs?

Would it make any difference to this time if the people could get off more quickly (from the front and rear of the plane)?

Figure 1: Example task from PD materials

Imran adopted a similar structure when he attempted the lesson with his group. However, he made one substantial adaptation. In the lesson he used two of the problems from the PD session and used the suggested structure twice in the lesson. He halved the suggested times. He explained why he adapted the suggested lesson:

...when I look at these problems I tend to just adapt to my class, I won't particularly go with what's on the lesson plan. I would sort of adapt to my lesson.

In the first half of the lesson he used the aircraft turn-round problem. He introduced the problem and gave the class three minutes to consider the problem on their own. He opted not to collect ideas at the board, as suggested, but explained to students that they should think about how they write the answer down.

Imran stopped the class and questioned them about the effects of passengers leaving the aircraft from both the front and the rear. He presents this as a closed question but attempts to foster a whole-class discussion. However, it appears likely that he is not used to leading a more open-ended whole-class discussion.

It is clear that Imran has taken the ideas presented in the PD and adapted them in order to develop a lesson that he felt comfortable with. Imran explained in the post-lesson interview that he thought the tasks were too easy and this had prompted his decision to include the two tasks in the lesson. It was interesting that he did not ask the students to extend the tasks. It appeared that Imran preferred them to find a solution and then move on, rather than explore the situation in more depth. It is possible that Imran did not understand the aims of the PD that were to use student-centred problem solving approaches; his interpretation appeared to be that it was about getting answers in the context of more open-ended problems.

Furthermore, it seemed likely that Imran was concerned about transferring authority and decision-making to the students. As such he would have felt a loss of control. As a result of observing Imran for five lessons it seemed highly probable that the control issue was the most likely explanation for the adaptations Imran had made to the suggested approaches.

What appeared to be happening was that Imran wanted students to be 'busy' on the problem, allowing students space to explore may have challenged Imran in terms of managing behaviour or possibly in the mathematical questions that may have arisen. The character of the lesson involves short periods of group work with frequent interjections by the teacher.

In interview, Imran explained that he found it difficult to allow students more opportunity to think about and discuss problems and he attributed this to his own lack of confidence and experience in using student-centred approaches. Although over the course of the PD and through the lessons observed he felt he had become more comfortable with it, he still found it very difficult. He accounted for his reluctance in terms of 'not being confident enough' to give greater authority to the students.

Discussion

In the case presented, SLT provides a useful theoretical explanation for what was observed. From an SLT perspective Imran adapted the models and ideas suggested in the PD and this perhaps reflects the way in which teachers adapt and interpret reform ideas in order that they can reproduce an approach in the classroom that they feel is achievable and are comfortable with. In Imran's case the adaptations were sufficient to suggest that what he was implementing in his teaching was some way distant from the approach suggested in the PD. I would suggest this is quite common and would explain why so much reform-oriented PD does not result in fundamental changes to teaching.

It was pointed out at the beginning of the paper that a key assumption in this research is that teaching is predominantly traditional, teacher-centred and oriented towards teaching and learning methods. An explanation for this observation can be offered in terms of the practical demands of teaching day-to-day (see, for example, Cuban, 2009). A second related reason is related to the idea of teaching following 'cultural script' (Stigler and Hiebert, 1999). In sum, traditional teacher-centred teaching offers an approach that is manageable and economic in the school institutional context. At the same time it offers routines that students, parents and teachers have familiarity with.

Deviation from this norm represents a demand for many teachers. Imran, in this case study, illustrates how teachers respond to an expectation to teach using more student-centred approaches. He takes the modelled approach – in video or as a lesson plan – and modifies the approach to a format that he was comfortable with. Indeed, something that was more teacher-centred.

An analysis using SLT is useful in this respect because it offers a route to understanding the way in which reform attempts interact with existing practices, in schools as well as with the knowledge and beliefs of the teacher. It highlights the importance of the need for appropriate models, suggested-lesson plans, video examples and classroom activities. It also shows that it is important to consider the self-efficacy of teachers in respect to the implementation of the suggested approach. A final point is to consider how the PD supports the development of teachers' self-efficacy.

Concluding comment

In this paper I have illustrated how SLT can be used to explain both the professional learning and the constraints that teachers experience. I argue, based on the limitations of existing theory and the evidence of this case study, SLT has potential in improving the design, research and evaluation of PD and professional learning. This paper serves to illustrate and exemplify the use of the theory and hopefully prompt further research in this area.

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