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TOWARDS SYNERGY OF SCHOLARLY AND CRAFT KNOWLEDGE

Abstract

This paper outlines a conception of research in mathematics education intended to strengthen its contribution to the development of professional knowledge for mathematics teaching. It examines processes of knowledge creation within the practices of researching and teaching, by considering two projects concerned with the teaching of mathematics in elementary school. The first project illustrates an approach to eliciting and codifying craft knowledge; the second, an approach to contextualising and activating scholarly knowledge. These examples point to a dialogic cycle in which knowledge creation within the practices of researching and teaching becomes more co-ordinated, and knowledge conversion from one practice to the other is encouraged. In one phase of this cycle, scholarly knowledge is contextualised and activated within teaching thus stimulating adaptation and construction of craft knowledge. In the complementary phase, craft knowledge is elicited and codified through researching, stimulating adaptation and construction of scholarly knowledge. Studies report important reciprocal benefits of sustained interaction of this type between researchers and teachers and between researching and teaching. Such approaches point to a much higher degree of interactivity between educational research, classroom teaching, and teacher education than is currently typical.

Introduction

A recent ICMI study suggests that ‘mathematics education as a research domain’ is still engaged in ‘a search for identity’ (SIERPINSKA & KILPATRICK, 1998). In particular, while most contributors to the study see the development of knowledge and resources to support the teaching and learning of mathematics as an important goal, there is widespread disappointment with what the field has been able to achieve in this respect.

This presentation will examine how the profession of teaching can draw both on scholarly knowledge created within the practice of researching, and on craft knowledge created within the practice of teaching. Specifically, it will outline how synergy can be fostered between these practices by coupling their distinctive processes of knowledge creation.

Scholarly knowledge and craft knowledge

Models of teacher education within universities tend to assume the role of scholarly knowledge in providing theoretical foundations for practical actions. BIEHLER (1994) identifies two predominant views of the didactics of mathematics: first, as an endeavour bridging the gap between theoretical knowledge from ‘fundamental’ disciplines - such as mathematics and psychology - and the practice of mathematics teaching; or second, as constituting the ‘basic science’ for mathematics teaching itself. WITTMANN (1995) criticises the first viewpoint on the grounds that it leads to the problems and tasks of mathematics education being tackled only insofar as they are accessible to the concerns and methods of the foundation disciplines. He advocates a strong version of the second position, conceiving mathematics education as a ‘design science’ in its own right, directly concerned with the constructive development of knowledge and resources to support and transform mathematics teaching.

Other critiques have challenged the ‘theory into practice’ assumptions of conventional models of teacher education. STEINBRING (1994) argues that the reality of everyday teaching can only be influenced indirectly by didactical research. Teaching practices are strongly framed by more immediate institutional conditions, specifically by a distinctive epistemology of school mathematics. From this perspective, the relationship between researching and teaching, between ‘theory’ and ‘practice’, is one of exchange and feedback between two relatively independent social domains, each construing and mediating mathematical knowledge in its own fashion. From another perspective, ZEICHNER (1994) decries a general lack of respect for the craft knowledge of good teachers on the part of educational researchers who see fit to define a knowledge base for teaching without taking account of the expertise of teachers.

‘Craft knowledge’ refers to the professional knowledge which teachers bring to bear in their day-to-day classroom teaching. It is action-oriented knowledge which is not generally made explicit by them; knowledge which they may indeed find difficult to articulate, or which they may even be unaware of using. Through experimenting and problem solving in the course of teaching, and through re-presenting their teaching and reflecting on it, teachers develop such craft knowledge. Within teaching itself, then, there is an important process of knowledge creation.

This process may also incorporate knowledge conversion. Through contextualising and activating scholarly knowledge within teaching, it can be brought to contribute to the development of craft knowledge.

> ‘From a cognitive point of view, professional knowledge is developed as a product of professional action, and it establishes itself through work and performance in the profession, not merely through accumulation of theoretical knowledge, but through the integration, tuning and restructuring of theoretical knowledge to the demands of practical situations and constraints.’ (BROMME & TILLEMA, 1995: 262)

Moreover, knowledge conversion can proceed in the opposite direction. By eliciting and codifying craft knowledge, it can be brought to contribute to the development of scholarly knowledge.

I propose to exemplify and examine these processes of knowledge creation and conversion by considering two projects concerned with the teaching of mathematics in elementary school. The first illustrates an approach to eliciting and codifying craft knowledge; the second, an approach to contextualising and activating scholarly knowledge.

Eliciting and codifying craft knowledge: the example of interactive direct instruction

A programme of research which has demonstrated the possibilities of eliciting and codifying the craft knowledge of teachers has been conducted by LEINHARDT, PUTNAM, STEIN & BAXTER (1991), employing more generic concepts and methods developed by cognitive scientists to investigate expertise. Teachers were identified as ‘experts’ on the basis of their consistency in producing both high gains in student achievement and high levels of final achievement. Their instruction was analysed by observing them in action in the classroom, and by interviewing them to elicit underlying thinking.

This led to a conceptualisation of teachers’ pedagogical knowledge and reasoning in terms of constructs of ‘script’, ‘agenda’ and ‘explanation’. A teacher’s ‘script’ for a particular curricular topic is a loosely ordered repertoire of goals, tasks and actions, continually developed and refined over time. It incorporates sequences of action and argumentation, relevant representations and explanations, and markers for anticipated student difficulties. The most important feature of a script is the way in which it acts as an organising structure, co-ordinating knowledge of subject and pedagogy with reasoning about actions and goals, thus underpinning the efficient and cohesive planning and development of lessons.

Such a script provides a matrix of knowledge supporting the setting of a lesson ‘agenda’ i.e. a mental plan including lesson goals, actions through which these goals can be achieved, expectations about the sequencing of actions through the lesson, and important decision points within the lesson. The agendas of these expert teachers showed developed instructional logic and smooth flow; they took account of students’ actions and reasoning, and sought evidence of these.

A crucial element of any script is its ‘explanation’ of a new idea. This involves systematically organising students’ experiences so as to help them construct a meaningful understanding of the concept or procedure. It includes appropriate verbalisation and demonstration by the teacher - or the management of such contributions from students - in support of this goal. A model of the different elements which contributed to the effectiveness of the explanations of expert teachers included:

- anticipation of prerequisite ideas and skills,
- motivation of the new idea,
- specification of its conditions of use,
- principled legitimisation of the new idea,
- completion of the explanation, and
- integration of different elements.

However, an unexpected finding concerned the way in which these expert teachers attended to the thinking of students.

> ‘[Teachers] did build models, but in different ways than we had anticipated. Teachers seem to construct flags for themselves that signal material which will cause difficulty as it is being learned, and then they adjust their teaching of the topic in response to those flags or to past successes. They seem to diagnose their teaching and its cycle rather than diagnosing the mental representation of a particular student. A major goal of teaching seems to be to move through a script, making only modest adjustments on-line in response to unique student needs.’ (LEINHARDT, 1988a: 51-52)

Leinhardt has suggested that other forms of teaching need to be studied:

> ‘Although our experts have been shown to be responsive and supportive of student efforts to learn key concepts and procedures, the content, method, and direction of their lessons are situated primarily with the teacher. Cognitively-based learning theories, however, suggest that it is pedagogically sound and cognitively necessary for students to have a role in determining the method and direction of their own learning. A key feature of [future] studies will be the distinction between the explanations that are essentially designed by teachers in advance, and those which students play an active role in constructing during classroom dialogue.’ (LEINHARDT et al., 1991: 111)

However, conducting such studies is problematic if teachers have not already developed such pedagogical models. The development of qualitatively new forms of pedagogy calls for some form of intervention.

Contextualising and activating scholarly knowledge: the example of cognitively guided instruction

Another programme of research has addressed this issue by seeking to contextualise and activate scholarly knowledge as a resource for the development of teaching. The Cognitively Guided Instruction (CGI) project focused on developing teachers' knowledge of a research-based model of arithmetic word problems and the strategies that children use to solve them (PETERSON, FENNEMA & CARPENTER, 1991). However the researchers emphasised to teachers that they themselves were best placed to make informed decisions about how to use research-based knowledge in their own classrooms.

Nevertheless, the researchers acknowledge some influence on teachers:

> 'We do not believe that we did not influence directly what teachers did in classrooms. The mathematical content we showed and discussed with them was based almost exclusively on word problems. The videotapes were of individual interviewers asking a child to solve word problems, waiting while the child solved the problem, and asking questions such as 'How did you get that answer?' or 'Could you show me what you did?' Teachers were encouraged to ask children to solve word problems and ascertain how the problems were solved.' (FENNEMA, CARPENTER, FRANKE, LEVI, JACOBS & EMPSON, 1996: 408-409)

An experimental study of the impact of the original CGI intervention found that it did indeed lead to teaching which placed more emphasis on building upon students' thinking (CARPENTER, FENNEMA, PETERSON, CHIANG, & LOEF, 1989). In particular, in aggregate terms across CGI classes, more time was spent talking about problems and discussing alternative solutions. Teachers listened more frequently to students' accounts of their problem solving and allowed students to explore a variety of solution strategies for a problem. Consequently students performed better on measures not just of complex problem solving but of number-fact knowledge.

However, given the researchers' open stance on the operationalisation of 'cognitively guided instruction', important enigmas remained, particularly about how teachers were making use of knowledge of children's thinking within their teaching. A case study examined one exceptional teacher:

> 'who made intensive use of the [research-based model] as she made instructional decisions.. More than most of the other teachers, she was able to identify the problem types, their relative difficulty, and their related solution strategies. She was able to correctly identify which problems children in her room could solve and which solution strategies they would use.' (FENNEMA et al., 1993: 560, 563)

On probing, the researchers were surprised by what they found:

> '[I]n our belief, children would be given slightly more challenging problems than they had successfully solved, and they would be encouraged to use more sophisticated solution strategies by teachers either manipulating the number size or problem complexity. The hierarchy of problem types and solution strategies would be used systematically to make both daily and long-term instructional decisions. [This teacher] did not do what we had anticipated. Although at times she made use of the specifics of the hierarchy.. we were unable to identify any systematic way in which she selected

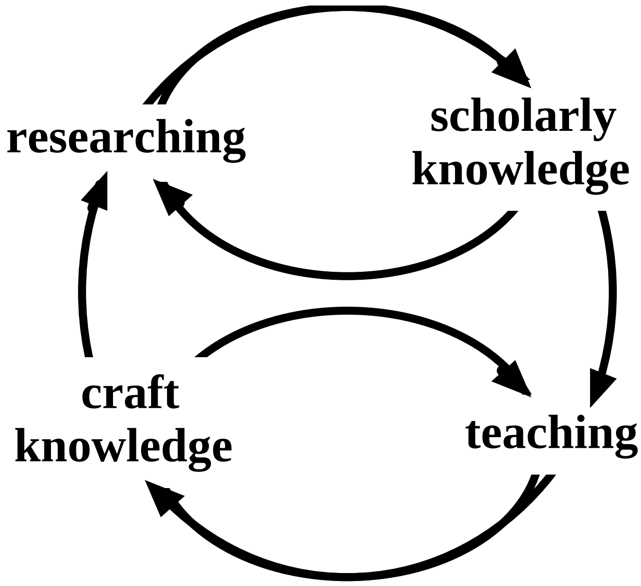
> problems.. Instead, she used the knowledge about problem types to dramatically broaden the scope of her curriculum and her expectations of children. She used all problem types from almost the first week of school, and children in her class had many opportunities to solve all types of problems using whatever solution strategy they chose.' (FENNEMA et al., 1993: 578)

As with interactive direct instruction, then so with cognitively guided instruction. The pedagogies developed by expert teachers proved different in important respects from those anticipated by researchers. In particular, in both cases, the way in which teachers made use of knowledge of children's thinking was tailored to collectivised, rather than individualised, models of teaching and learning. As Bromme notes:

> 'The categorical unit 'whole class' is rather neglected in theories on mathematical education, the focus being more on the individual student as a categorical unit of perceiving and thinking. Therefore teachers have to develop their own concepts about the class as a unit, and it is not by chance that the notion of 'the class' as an individual unit is an important element of teachers' professional slang.' (BROMME, 1994: 85)

A dialogic cycle of knowledge creation: coupling the construction and conversion of scholarly and craft knowledge

These collaborative research programmes point towards a dialogic cycle in which knowledge creation within the practices of researching and teaching becomes more co-ordinated, and knowledge conversion from one practice to the other is encouraged. In one phase of this cycle, scholarly knowledge is contextualised and activated within teaching, stimulating adaptation and construction of craft knowledge. In the complementary phase, craft knowledge is elicited and codified through researching, stimulating adaptation and construction of scholarly knowledge. In both phases, conversion involves the filtering and reformulating of knowledge. Only certain derivatives of scholarly knowledge will prove capable of being incorporated productively within craft knowledge; equally, only some derivatives of craft knowledge will prove able to be fruitfully appropriated as scholarly knowledge.



Huberman has pointed to some of the benefits to researchers and researching of ‘sustained interaction’ with teachers and teaching, ‘in which researchers defend their findings and.. practitioners dismiss them, transform them, or use them selectively and strategically in their own settings’ (HUBERMAN, 1993: 34). Reframing ideas in order to collaborate successfully with teachers appears to trigger a decentring process amongst researchers. In particular, it creates a need to address the counter examples, qualifications and outright challenges which arise as ideas are tested out by teachers and within teaching. In doing so, researchers are obliged to go outside the study at hand, to marshal a broader range of scholarly thinking and research experience related to these ideas, and to bring them to bear on these claimed anomalies. Clearly, too, sustained interaction can also make an important contribution to the professional development of teachers. Indeed an essential component of the dialogic cycle outlined above is development in the craft knowledge of participating teachers.

Pedagogical innovation and teacher development: the contributions of scholarly and craft knowledge

Challenging and changing teachers’ beliefs is often portrayed as providing the impetus for them to rethink teaching approaches and develop new teaching strategies. However, the CGI studies lend further support to previous investigations which have suggested that changes in pedagogy may be rather loosely coupled with, rather than directly induced by, changes in beliefs (FENNEMA et al., 1996). Moreover, without an appropriate renewal of craft knowledge, powerful factors act against change in pedagogy. Given that teachers already possess ‘a highly efficient collection of heuristics.. for the solution of very specific problems in teaching’, resistance to change on their part ‘should not.. be perceived as a form of stubborn ignorance or authoritarian rigidity but as a response to the consistency of the total situation and a desire to continue to employ expert-like solutions.’ (LEINHARDT, 1998b: 146)

Certainly, the importance of craft knowledge has often been underestimated within mathematics education reform. Rejection or reduction of innovative pedagogical forms are also encouraged by the rhetorical tendency to oppose ‘old’ and ‘new’:

> ‘The striking issue here, which has not been taken with sufficient seriousness.., [is the] handling [of] different educational practices in their didactical totality. How can, for instance, project work in mathematics support work with routine tasks, and how can work with routine tasks support project work?.. [N]othing shows teachers how to co-ordinate the ‘old’ and ‘new’ into a totality.’ (MELLIN-OLSEN, 1995: 152)

Conversely, where teachers do reject the ‘old’ in favour of the ‘new’, they must create new types of ‘script’ (in Leinhardt’s sense). Bauersfeld describes the form that initial attempts may take:

> ‘Convinced that there is no transmitting of knowledge, [such teachers] favour the belief that nothing should be taught that the students can find themselves. This swing from one extreme to another produces a manner of teaching that comes very near to the questioning technique of [the] famous computer program ‘Eliza’. They just take up the students’ doubted or incorrect utterance, and react by using the same words and shaping them into a question.’ (BAUERSFELD, 1998: 383)

Discussing CGI and the similar Integrating Mathematics Assessment (IMA) project, RHINE (1998) suggests that the influence of such projects may not be due primarily to their developing of teachers’ knowledge of cognitive models for specific topics, but simply because they lead teachers to value students’ thinking. Indeed a direct impact may result from teachers recontextualising questioning strategies from clinical interviewing to classroom teaching. Rhine quotes one of the IMA teachers: “All I remember about those videotapes is [the interviewer] asking the kids over and over again, ‘Why did you do it that way?’” (p. 28). Moreover, Rhine suggests that the example of CGI may be atypical, since ‘the experience of the IMA project indicates that similar concise models [of students’ thinking] may be difficult to achieve as content in higher grades becomes more complex’ (p.29). One could add that the circumstances of teaching also need to be taken into account. For example, it seems particularly feasible for teachers to build models of individual students’ thinking where they work with only one class over a whole school year, and where classes are relatively small in size and stable in composition.

The challenge remains, then, to develop and refine new forms of ‘script’, ‘agenda’ and ‘explanation’ through which teachers - and their students - can realise new pedagogical approaches. Such forms would be appropriate to different stages of mathematics learning, to differing institutional and classroom conditions, and to diverse cultural contexts. Equally, there is a need to develop ‘practical theorising’ approaches to teacher education and professional development in which ideas and methods, whether from scholarly or craft knowledge, are tested in practice in terms of the insight they provide into teaching and learning processes, and the support they offer in improving the quality of these processes (RUTHVEN, 2001).

This presentation has examined how the practice of research in mathematics education might be conceptualised and organised so as to strengthen its contribution to the development of professional knowledge for mathematics teaching. Elsewhere I have made reciprocal suggestions as to how the practice of teaching might be conceptualised and organised around the idea of ‘warranted practice’, so as to benefit from making fuller use of scholarly knowledge and research processes (RUTHVEN, 1999). Together, these suggestions point towards a much higher degree of interactivity between educational research, classroom teaching, and teacher education than is currently typical.

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