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ABSTRACT

In this paper the development of science pedagogical content knowledge (PCK) in elementary teachers is considered, with a particular focus on beginning teachers. Explored is a conceptualization of the development of science pedagogical content knowledge in elementary teachers which emerged from two studies. The first examined the science teaching practices of beginning elementary teachers, while the second explored elementary teachers' understanding and use of "activities that work" in science. The paper emerged from consideration of how some elementary teachers in our studies, who lack science content knowledge, generate PCK to enable them to teach science. The main tenet of the model of PCK development is that "activities that work" become a substitute for science content knowledge and PCK. A number of implications for elementary science curriculum emerge from this understanding, such as considerations for preservice teacher education science courses and the nature of the elementary science curriculum. (Contains 40 references.) (ASK)

How do Beginning Elementary Teachers Cope with Science: Development of Pedagogical Content Knowledge in Science

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Knowledge in Science

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Abstract

In this paper we consider the development of science pedagogical content knowledge in elementary teachers, with a particular focus on beginning teachers. We explore a conceptualisation of the development of science pedagogical content knowledge in elementary teachers which emerged from two studies. The first examined the science teaching practices of beginning elementary teachers, while the second explored elementary teachersí understanding and use of "activities that work" in science. The paper emerged from consideration of how some elementary teachers in our studies, who lack science content knowledge, generate PCK to enable them to teach science. The main tenet of our model of PCK development is that "activities that work" become a substitute for science content knowledge and PCK. A number of implications for elementary science curriculum emerge from this understanding, such as considerations for preservice teacher education science courses and the nature of the elementary science curriculum.

Introduction

A recurring theme in much of the literature about elementary science education in Australia and other countries has been the degree of preparedness and apparent reluctance of many teachers to teach science (e.g. Abell & Roth, 1992; Appleton, 1977; 1995; Department of Employment, Education & Training, 1989; Harlen, 1997; Mellado, Blanco, & Ruiz, 1998; Smith & Neale, 1991). The essence of these and other reports is that significant numbers of elementary teachers avoid teaching science, are not knowledgeable about science, and lack confidence to teach it. There are consequent concerns about the quality of education available to elementary school students (e.g. Australian Foundation for Science, 1991). It was within this context that we were studying aspects of elementary teachersí science teaching (Appleton & Kindt, 1998b; 1999). As we analysed the data from a second study (report in preparation), we were given cause to reflect upon and reexamine the data from our first study in terms of the construct of Pedagogical Content Knowledge (PCK) (Shulman, 1986; 1987). Our reflection led to new insights, for us, regarding the nature of PCK in science, for many elementary teachers, which is the subject of this report.

In this paper, we shall therefore provide a background picture of reported difficulties for teachers in elementary science education, a summary of the construct of PCK, a brief description of the studies which contextualised this report, an explanation of our insights into PCK in science for elementary teachers, and what we see are some implications for elementary science education and the preparation of elementary teachers.

Teachers and Elementary Science Education

As this report was developed within the Australian context, we refer mainly to Australian studies, though parallel studies from other countries can be found. Since the introduction of science (as opposed to "nature study") to the elementary curriculum in Australia thirty to forty years ago, surveys of science teaching have revealed that many elementary teachers do not teach science, and frequently when it is taught, strategies used tend to be teacher discussions, explanation, watching science television shows, library research, and teacher demonstrations (Australian Science, Technology and Engineering Council, 1997; Department of Employment, Education & Training, 1989; Symington, 1974; Varley, 1975). While a number of factors such as lack of equipment have been cited as reasons for this, there is overwhelming evidence that a major contributing factor is the tendency for elementary teachers to have poor science background knowledge, and to lack confidence in teaching science. This was identified long ago by Varley (1975) and Symington (1974), and has been consistently reported since (e.g. Appleton, 1991; Australian Foundation for Science, 1991; Australian Science, Technology and Engineering Council, 1997; Department of Employment,

Education & Training, 1989; Varley, 1975). For instance, elementary teachers (including preservice teachers) tend to have little science content knowledge in the physical sciences (e.g. Appleton, 1991; Varley, 1975) and particularly lack self-confidence in teaching these (Appleton, 1991; Ginns & Watters, 1994). Hope and Townsend (1983) found that preservice teachers tend to hold similar misconceptions in science to their students, and Symington and Hayes (1989) noted how preservice teachers avoided acquiring the science background knowledge when preparing science lessons. When teachers lack confidence to teach science, they tend to use teaching strategies which allow them to maintain control of the classroom knowledge flow, but which are not appropriate ways of engaging students in science (Symington, 1980).

An intuitive response to these difficulties has been to increase the amount of science content in preservice programs (Department of Employment, Education & Training, 1989), but there is evidence to suggest that this does not necessarily lead to the desired changes (e.g. (Skamp, 1989; 1997). On the other hand, some success has been reported in both preservice and inservice settings where the science content is dealt with in non-traditional ways (Jane, Martin, & Tytler, 1991; Walsh & Lynch, 1985), or in a pedagogical context with strong foci on student misconceptions, constructivist views of learning, and gender equity (Hardy, Bearlin, & Kirkwood, 1990; Napper & Crawford, 1990). The trend in these reports about science content background knowledge and pedagogical contexts can be further illuminated by the construct of Pedagogical Content Knowledge.

Pedagogical Content Knowledge

Just over a decade ago, Lee Shulman suggested the notion of Pedagogical Content Knowledge (Shulman, 1986; 1987), one of seven suggested knowledge bases required for teaching. He suggested PCK was different from content knowledge and knowledge of general pedagogy, rather consisting of representations of subject matter, student conceptions, and understandings of specific learning difficulties (van Driel, Verloop, & de Vos, 1998). In a sense, it was knowledge of how to teach specific content in specific contexts ó a form of knowledge in action (Mellado et al., 1998). Grossman (1990) suggested there were four central components to pedagogical content knowledge: knowledge and beliefs about purpose, knowledge of studentsí conceptions, curricular knowledge, and knowledge of instructional strategies. Cochran, DeRuiter, and King (1993) proposed a similar set of four components which they preferred to call pedagogical content knowing (PCKg): knowledge of students, knowledge of environmental contexts, knowledge of pedagogy, and knowledge of subject matter. Based on that work, Cochran and Holder (Cochran & Holder, 1998; Holder & Cochran, 1998) have identified further fine-grained detail for each of these components, and shown how they are interrelated, although there is a degree of overlap in the detail. This suggests that further differentiation of the construct may not be helpful in developing a deeper understanding of pedagogical content knowledge.

Sources of PCK, according to Grossman (1990), are classroom observation ó as a student and during preservice teacher education; studies in science; teacher education programs; and personal classroom experience. For beginning elementary teachers, we would add to that list, recommendations from trusted colleagues (Appleton & Kindt, 1999).

We note in the literature that reports of PCK development tend to be dominated by secondary contexts. Our experience with elementary teachers, and reports of PCK development in elementary teachers (such as Smith & Neale, 1991) lead us to consider that PCK and PCK development for these groups of teachers may differ. For instance, Bell, Veal, and Tippins (1998) proposed a hierarchy of PCK, based on work with secondary physics teachers. They identified a broad base of *science* PCK, specific *discipline* PCK (say physics), and specific *topic* PCK (say electric circuits). They saw specific discipline PCK as emerging from repeated experiences of teaching specific topic PCK. While this may be so for secondary teachers, most elementary teachers would work from general science PCK (e.g. that science should be activity-based) and with specific topic PCK, but would rarely achieve specific discipline PCK. Further, secondary teachers would tend to develop specific discipline PCK in their own discipline speciality, and may find their PCK for teaching out of their discipline problematic. Chan (1998), for instance, reported the misconceptions about selected biology topics held by scientists with Ph Ds in physics; hence highly qualified teachers in one discipline will not necessarily develop effective PCK for other disciplines.

We have raised this last issue to highlight the context of elementary teaching: few elementary teachers are science discipline specialists. They have mostly chosen humanities specialisations and can therefore be *expected* to have limited science content knowledge and science/discipline/topic PCK. Within this context, it should not be surprising that surveys have revealed problems with elementary science education. The same surveys that reveal problems, however, also show that some teachers do teach science, and teach it effectively. Further, not all of these teachers have specialised in science.

Our Research Focus

If PCK is a useful and valid construct, it consequently needs to explain why and how some teachers who are not science specialists have developed science and topic PCK sufficient to enable them to teach elementary science effectively. In particular, beginning teachers have limited science PCK (van Driel et al., 1998), so how do they cope?

The Research Studies on Which Our Views are Based

The first study which we undertook was an investigation of recent graduatesí practices in teaching elementary science as part of their beginning teaching experience, and influences on those practices. We interviewed and observed nine teachers located in a variety of schools and across most grade levels. Several aspects of this study have been reported elsewhere (Appleton & Kindt, 1998a; 1998b; 1999).

An expression used by many of the teachers which emerged from this study was "science activities that work." Although there were indications of what this expression meant to these beginning teachers, we undertook a second study to explore the notion more fully, with a wider sample of teachers. A further twenty teachers were interviewed, supplemented by a number of lesson observations, focusing on the notion of activities that work. The teachers again covered most grade levels, but this time ranged from a few yearsí experience to over twenty years of teaching. It was as we were analysing the data from this study that we became aware of the significance of activities that work for the development of science PCK for elementary teachers, particularly for beginning teachers. Since reports on the second study are still in preparation, we will draw mainly on material from the first study. Firstly, however, we shall clarify some aspects of what the beginning teachers meant by activities that work. Common themes were:

An activity that works "teaches" the required science content. That is, by engaging in the activity students should achieve any expected cognitive learning goals (such goals are often implicit, and are rarely stated explicitly by the teacher).

> **I didnít have to say a word and have to teach anything. It was visual and I think a lot of them learn by that visual aspect. (Mary)**
>
> **The kids are getting their success, getting their skills um and that. They enjoy doing it, like - itís not a chore. (Diane)**

The background science content for the activity is already known to the teacher, or is contained in the activity description.

> **If there was a concept that I wasnít sure about Iíd talk to [the teacher next door] about different ways how it was done, how she had done it in the past, and what worked for her, and I had some kind of background to go on. (Diane)**

An activity that works involves students, and is fun for them to do.

> And the [activities] that I found that the kids didnít really get involved in, I um got rid of those and [am] going to use some other ones. (Tom)

> Sometimes I feel that we didnít round up [that is, conclude] the lesson [satisfactorily] and[I think], "Gosh I did a bad job." But then I think, "Look at the fun they were having. They were you know pretty much motivated, pretty much there all the time." (Mary)

An activity that works has a predetermined, predictable outcome, though some experienced teachers did not share this view.

> You also know what will come out of the experiment at the other end of the day sort of thing, whereas last year like it was an experiment for me as well as for them [the children]. (Mary)

From this study, we gained the impression that activities that work were fun things which the students could do, got them involved, were fairly safe for the teacher in management and science content terms, were predictable in outcome, and would teach the students something without much teacher intervention.

Ways that Beginning Elementary Teachers Cope with Minimal PCK

Firstly, we need to highlight that there are a number of elementary teachers who have a fairly good knowledge of science content, and are very confident about teaching science. One of the beginning teachers in our first study, Amanda, belonged to this group. She had studied a number of science areas, felt very confident about teaching science, and enjoyed doing it. Such teachers should be able to construct PCK from their own knowledge base of the science content, other knowledge areas, and their own experience ó recognising that beginning teachers lack experience and may need other forms of support in developing PCK. However, we also point out that teachers with considerable expertise in one science discipline may well have difficulties with other science disciplines (Chan, 1998).

When there are substantial gaps in teachersí science content knowledge, and they have very low self-confidence about teaching science, we suggest that the natural reaction for such beginning teachers is to avoid teaching science. The avoidance behaviour may be exhibited in several ways:

No science is taught at all

We did not observe this with the beginning teachers in our study, which is hardly surprising given that they were volunteers, inviting us to inspect their science teaching practices. However, surveys reveal that this does occur. In our experience, some teachers just do not teach science and bluff their way through with the school administration; others avoid science by arranging to "team teach" with a colleague, where they divide subject responsibilities between them and take turns with the two classes.

Postponing science

One of the beginning teachers, Katrina, admitted to constantly postponing starting science after initial difficulties with an early science class:

> Iím not really confident in science - the actual teaching of it. Like, some areas are sort of, the concepts are sort of [difficult]. I donít remember doing much of science when I was at school. In some of the areas I find, itís hard [to understand], you know. I just never was really confident teaching it and understanding all those different things so that was hard. The kids had done a lot of it and I was really just finding my feet at the beginning of the year anyway, and I was sort of focussing more on Language and Maths, which I shouldnít

> have been doing I know, but um it was just sort of pushed to the side a little bit. (Katrina)

Another form of postponing science which we noted was associated with timetable and curriculum pressures:

> Weíve had inservice days, with the tests and SBS [a trial outcomes-based math program], and I think Iíve only spent three days a week in class in the last three or four weeks, so science gets kicked. (Kim)

Fortuitous events are used

We also noted some of the beginning teachers claimed their science program was built around fortuitous events. While this may present opportune "teachable moments," we are inclined to think that most of a science program supposedly built around occasional fortuitous events is a form of avoidance. Diane explained to us that she had set science activities which she used, but "apart from set things, like if thereís something that happens or thereís something of interest we do it like incidentally and spontaneously as it happens."

Thematic teaching

Most of the beginning teachers claimed that they often taught using themes, and built the science into the theme where they could. While this is an effective means of making the curriculum meaningful for students, we noted that it could be a device to minimise the science being taught or to make it into something the teacher was more comfortable with.

> Sometimes I get more of an emphasis on science than at other times, like when we were talking about at the beginning of the year [the theme] *Themselves and Their Families* . And when it came to *Themselves* there was a lot of science. When they were talking about their families and their homes, that was more social studies. (Jill)

Activities that work are used as a basis for PCK

For beginning teachers who make some effort to teach science, we would suggest that *activities that work serve as a substitute for PCK in science* . These can take a few different forms, depending on the confidence level of the teacher, and the level of expertise they have with a variety of teaching strategies.

Activities based on strategies borrowed from other subjects. One form of activity that works is focused on some science topic, but the teaching strategies employed tend to be drawn from subjects such as language or social studies (Appleton & Kindt, 1998a; Harlen, 1997). In these activities, teaching strategies such as book research, writing reports or summaries, and class discussion predominate:

> I showed them the picture and they researched for information in the books and I read it to them and the Grade Oneís drew a picture and the Grade twoís did a [written] exercise. That has been the format for about ten lessons on ten different animals. (Joan)

We hasten to add that we are not implying that such strategies have no place in science lessons; but we also consider that other strategies should be included in a science program. Joan later reported how she had used other science activities which involved hands on investigations.

Katrina provided us with some insights into what happened to her in her first few weeks of teaching. As revealed in her comment above, she constantly postponed starting science, and concentrated on language, math, and social studies. We would suggest that as she acquired experience with these subjects, she built up specific pedagogical skills and PCK related to the teaching strategies common in those subjects. When the teacher felt she really must start teaching science, it would be a small step to move from a non-science topic for book research to a science topic. It would be a "safe" way to teach science because it would involve no great change in her current teaching practices, and would not require her to know about the science content, since the students would be expected to obtain all the required information from books or similar sources. For her, this would be a way of teaching science successfully, in that the students were actively involved, the class was managed with purposeful activity, and tangible outcomes such as summaries in studentsí science notebooks would be evident. Consequently, book research on selected science topics would become activities that work for her. As she gained experience in teaching science this way, she would build up a level of PCK in science very similar to that for other subjects.

"Hands on" activities that work

Several of the beginning teachers stated that they thought some hands on component was important in science. They tended to refer to activities that work as ones which include hands on activities or "experiments."

> Kids love to see colours [making rainbows] so thatís something thatís really popular and works really well. (Mary)

> [Activities are an important part] of my teaching, yeah. With grade one and two itís very much hands on and you have got to have a variety of activities. You canít expect them to sit and listen or sit and write and thatís the whole lesson. (Joan)

As noted above, beginning teachers build a repertoire of such activities that work from their own schooling in science; their preservice teacher education, including the practicum component; their own teaching experience, and from trusted colleagues. It is this repertoire of activities that serves as PCK in science for the teachers, since there is a set routine for each activity, and the science content is constrained to some manageable form.

> If I donít know [the subject material] that well then Iíll stick basically to the Sourcebook [official curriculum guide of science activities] and do what it tells me to do and go from there. (Mary)

Those teachers who already know the science content feel confident with such activities. Some teachers may have a limited knowledge of the science content, but feel that it is sufficient for them to get by with the activity, particularly if the lesson focus is moved onto process skills (Harlen, 1997). Those who do not know the content would expect the students to obtain it from the activity.

So, we would suggest that once teachers have used an activity a few times and are confident that it works, then that activity becomes part of the teachersí science PCK, even though there may be minimal science subject matter known to the teachers (Grimmett & MacKinnon, 1992). Mary provided some insights regarding this:

> But this [my second teaching] year like you feel confident this year, that you know more of what you want from the kids. You know more. You also know what will come out of the experiment at the other end of the day sort of thing; whereas last year like it was an experiment for me as well as for them, so youíre both experimenting at that point. (Mary)

Summary. Based on the above, we make the tentative assertion that activities that work can take two main forms for elementary teachers: activities that employ pedagogies derived from other subjects, and activities with a hands on emphasis. The beginning teachersí choice would depend, amongst other factors, on their level of confidence in teaching science and the repertoire of activities they have acquired (Appleton & Kindt, 1998a). We further suggest that, as part of a repertoire of activities that work, an activity can be used year after year, whenever the curriculum and contextual circumstances permit. Because it becomes part of the teachersí personal repertoire of teaching, it is unlikely to be abandoned unless there is a sudden dramatic failure in its use or there is a change of circumstances and a lack of resources.

Implications of using activities that work

For the implemented curriculum. A consequence substituting activities that work for PCK in science that the elementary science curriculum becomes fragmented ó a series of largely unrelated activities which probably contribute little to progressive conceptual development in students. Such a fragmented curriculum would tend to preclude the use of any but the most superficial strategies for achieving conceptual development emergent from contemporary constructivist ideas about learning (e.g. Wandersee, Mintzes, & Novak, 1994).

An approach which relies on activities that work, where the teacher hopes that activities will inherently "teach" those engaged in them, appears to be a distortion of discovery learning. There seems to be the assumption that if the activity is any good then students will learn whatever it is the activity is about, simply by doing it. Texts and curriculum materials which respond to this teacher-need without providing appropriate background knowledge of how the activities fit into a broader science conceptual map are a modern version of the "teacher-proof" curriculum programs which emerged during the 1960s.

Of considerable concern to us is that an approach to teaching primary science based on activities that work is probably antithetical to constructivist views of learning which permeate much of the science education literature. In an activities-that-work approach, the activities seem to be treated more like isolated experiments rather than investigations, and as such limit enquiry. The characteristic of many such activities having a predictable outcome makes them convergent in nature, and reinforces a view of science as knowing things and doing experiments ó views which are linked to positivist notions that there are answers to every problem in nature, and that such answers may be proved by experimentation. This tends to undermine the open ended, problematic, enquiry strategies more characteristic of constructivist-based approaches to teaching science. The dilemma, then, is that if teachers are oriented to an activities-that-work approach, this may not be readily reconciled with constructivist-based ways of teaching.

Something which we therefore think must be considered is whether there should be a move toward a minimal elementary science curriculum. By this we mean a highly restricted set of science learning outcomes and content areas. If the prescribed science learning outcomes and content are too broad, it becomes very difficult for many elementary teachers to have sufficient activities at hand to deal with what is required. If the requirements are more restricted, then sets of activities that work are more likely to be accumulated by teachers to meet the needs of the required curriculum. This suggestion is also related to the dilemma of depth versus breadth of coverage. We personally believe it is preferable to cover less content in depth with understanding than to cover more content superficially and with little understanding; but we also fully recognise the politicised nature of such curriculum decisions.

A final consideration about the elementary science curriculum which we would draw attention to is the perceived priority given to science. The beginning teachers in our first study perceived that the school system put science at a lower priority than many other subjects (Appleton & Kindt, 1999). While this perception could merely be a local effect, from our many years in elementary science education, we would say that this is a widespread belief based on system actions and priorities. For teachers to change their views about the relative importance of science in the elementary curriculum, they would need to see system priorities reflect this.

For teacher education programs. For a long time the poor state of science teaching in primary schools has been explained by assuming that most teachers have some shortcomings, or that they are recalcitrant or resistant to change. Teacher education programs have also received criticism (Department of Employment, Education & Training, 1989) for not preparing teachers adequately. The remedies suggested, such as more science content for preservice programs, have therefore emerged from a deficit view of teachers. While the suggested remedies may be what *are* needed to help teachers come to grips with science teaching (Harlen, 1997), the realities of the teachersí workplace and their attempts to cope with this have tended to go unacknowledged. The actions of many teachers, in the light of this analysis, we would consider to be perfectly reasonable given the circumstances in which they find themselves. On the other hand, it is essential that the needs of the students in having access to effective science education also be met.

Since a key need of beginning teachers is to have a repertoire of activities that work, a key component of teacher education programs should be to provide such a set. We would suggest that the most effective way of achieving this would be to deal with science content in a pedagogical context, where there is also a focus on student perceptions, and ways of dealing with those. Osborne (Osborne & Freyberg, 1985) suggested this years ago, but the significance of his suggestion seems to have been overlooked in many of the recommendations about teacher education for elementary science teaching. So, we suggest that a key characteristic of preservice science subjects should be to involve student teachers doing the science that they might be expected to teach, and understanding why the science they do "works" in both scientific and pedagogical senses. The student teachers could then collect a number of activities that work grouped as topics, and accompanied by explanatory notes. However, a note of caution: we have found in our own teaching that programs which focus on student teachers doing isolated activities from the elementary curriculum, do not necessarily improve their confidence in science teaching, and they tend to get bored. It is necessary to pitch the science at their level to maintain interest, and to use pedagogies that encourage their own learning (Hardy & Kirkwood, 1991; Jane et al., 1991; Walsh & Lynch, 1985).

Further, we feel constrained to comment on the popular move, at least in Australia, to increase science content in preservice programs by requiring education students to take more science subjects from (science) degree programs in the hope that they will gain increased self-confidence to teach science (Harlen, 1997) and hence more science subject matter which can be transformed into science PCK. However, there is emerging evidence that more science content of the sort normally offered within science degrees is of limited help to prospective elementary teachers (e.g. Skamp, 1989). Since there is evidence to suggest, as mentioned above, that science content is most meaningful to preservice education students when it is dealt with in an educational context (Hardy & Kirkwood, 1991; Skamp, 1989), science faculty who are not familiar with such contexts find it difficult to make the work relevant to education students.

For elementary teaching. The first issue we feel compelled to raise is the appropriateness, given the ongoing evidence of difficulties in elementary science such as reported here, of having generalist teachers teach science. Others have made a case for specialist science teachers in the elementary school (e.g. Abell & Roth, 1992), which suggestion should receive due attention by education systems. In saying this, we fully recognise the political and fiscal implications for those systems. Having science specialist teachers would ensure that a regular science program was taught to all children. Hopefully the teachers selected as specialists would have an appropriate background in science with extensive science PCK. Arguments against having science specialists tend to focus on the consequent decontextualisation of science from the rest of the curriculum, the inability of a specialist teacher to get to know all of the children and their needs in large schools, and the resource implications for staffing, rooms, and equipment. There are also difficulties associated with staffing small schools and those which are geographically isolated.

We would also raise the issue of support for beginning teachers. The most helpful support reported by the teachers in our study was that of colleagues (Appleton & Kindt, 1999). The importance of colleagues or mentors to answer questions about science content, provide ideas for science pedagogical content knowledge, and be a general support for novice teachers has been well substantiated (Anderson & Mitchener, 1994). While such support appears important for beginning teachers who are already confident about teaching science, it appears to be crucial for those with less confidence. Our work (Appleton & Kindt, 1998a) suggests that, without the support and impetus provided by colleagues, some beginning teachers may adopt a habit of not teaching science which remains for a considerable time. In Australia, there are unfortunately few formal mentoring programs for beginning teachers generally, let alone in science. Any support found by beginning teachers tends to be serendipitous, and highly dependent on the local school circumstances. For a mentoring system to be put into place would require adequate resourcing and a commitment to this from education systems and school administrations.

A final comment is regarding professional development opportunities for elementary teachers. Beginning teachersí concerns are primarily for self and self-image as a teacher, rather than a focus on studentsí learning (Fuller, 1969). These concerns appear to be exacerbated when classroom management also becomes a difficulty, as it frequently does. Consequently, the level of effort and skill required by beginning teachers to teach science using a hands-on approach, let alone a constructivist-based approach, may not be achievable for many. The tendency therefore is to revert to authoritarian, teacher-directed approaches (Harlen, 1997; Symington, 1980). In this context, activities that work are seen to work partly because they engage students, in the sense that they keep students interested and quiet and consequently manage studentsí behaviour. Support for beginning teachers therefore needs to take these concerns and issues into account. The availability of mentors would address some of these issues, but other initiatives would also need to be considered. These might include some release time for beginning teachers, regular access to science advisors, or team teaching with a part-time teacher during lessons likely to include management problems. Unfortunately these all have significant cost implications which are unlikely to supported in the current climate of financial stringency.

Concluding Comments

For us, the realisation that the majority of elementary teachers may use activities that work as a substitute for Pedagogical Content Knowledge in science gave us a better appreciation of the complexities of teaching and of teacher knowledge. It also cast some doubt on the accepted views about the nature of PCK and the role of content knowledge in its construction. Do we err by assuming that activities that work can substitute for PCK, at least for beginning elementary teachers? If they are a substitute, do activities that work become, over time, an effective set of PCK for elementary teachers, even though there may be little science content associated with the activities?

Whether we like it or not, the teaching profession seems to self-select people for elementary teaching who tend to fear science rather than those who love it. In much of the literature, many elementary teachers are seen as deficient because of the difficulties they experience with science. We would rather take the perspective that many of these teachers are achieving well within the constraints in which they have to work. They have found that, by drawing on a set of activities that work, they can develop a form of, or substitute for, PCK that gets them by in science and provides some science learning for students. Often, they achieve this with little support from their school, school system, or from their teacher education programs. It behooves us as science educators to recognise the difficulties they experience and try to find ways of enhancing their efforts to teach science more effectively.

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