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ABSTRACT

A collaborative research study was designed to facilitate, at the local school level, a mathematics teacher's development of a "constructivist" pedagogy. This paper discusses the nature and influence of the teacher's professional beliefs on his attempts to create a classroom learning environment congruent with the principles of a constructivist epistemology. Cognitive perturbation is considered an important part of the process of reshaping the teacher's conception of his classroom role. The teacher designed and implemented constructivist teaching strategies. However, the narrow scope of these innovations highlighted the significant role of the teacher's established positivist epistemology in determining boundary conditions for conceptual change. In a constructivist epistemology cognitive perturbation facilitates a learner's reconstruction of his/her ways of interpreting experiences. It is an important pedagogical focus for teachers who wish to influence their students' conceptual development. This study found that teacher beliefs moderate cognitive perturbation and, subsequently, restrict the nature and scope of the teacher's conceptual and practical classroom changes. (Author)

THE INFLUENCE OF TEACHER BELIEFS ON CONSTRUCTIVIST TEACHING PRACTICES

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ABSTRACT

A collaborative research study was designed to facilitate, at the local school-level, a mathematics teacher's development of a "constructivist" pedagogy. This paper discusses the nature and influence of the teacher's professional beliefs on his attempts to create a classroom learning environment congruent with the principles of a constructivist epistemology. Cognitive perturbation was an important part of the process of reshaping the teachers' conception of his classroom role. He designed and implemented "constructivist" teaching strategies. However, the narrow scope of these innovations highlighted the significant role of the teacher's established positivist epistemology in determining boundary conditions for conceptual change. In a constructivist epistemology cognitive perturbation facilitates a learner's reconstruction of their ways of interpreting their experiences. It is an important pedagogical focus for teachers who wish to influence their students' conceptual development. This study found that teacher beliefs moderate cognitive perturbation and, subsequently, restrict the nature and scope of teacher conceptual and practical classroom changes.

INTRODUCTION

A "transmission model" of the teaching-learning process underpins the traditionally teacher-centred, didactic approach to teaching school mathematics and science. Students are expected to "receive" an accurate version of the teacher's mathematical or scientific knowledge, provided that they pay close attention to the teacher's expositions of the logical structure of the subject. Failure on the part of a student to faithfully reproduce a valid version of the "received" knowledge is attributed to various causes, chief amongst which are that the student is deficient in important learning abilities or effort.

The transmission approach has been extensively criticised for its association with student underachievement, most noteably by Romberg & Carpenter (1986) in a major review of the teaching and learning of mathematics. Alternative approaches which emphasis teaching for conceptual development are being widely promoted (Prawat, 1989). However, without an understanding of the epistemological assumptions underpinning the transmission approach it is unlikely that teacher educators will be able to successfully facilitate the necessary teacher conceptual change.

The history and philosophy of science is providing science educators with a better understanding of the nature of knowledge development, and with an alternative epistemology that addresses many of the issues of the conceptual change process. Nussbaum (1989) looked to the philosophy of science for an historical analogy with the conceptual change process experienced by scientists. He argued that the Empiricist-Positivist and Rationalist views that knowledge is "discovered" by scientists and can be described in "absolutist" terms are philosophically untenable. In rejecting these views, he argued in favour of "Constructivism" which views scientific knowledge as the personal constructions of scientists based on their existing theories and social influences. Nussbaum argued further that the constructivist view of knowledge development applies also to students of school science, and that a constructivist pedagogy would focus on students' existing knowledge as a starting point for conceptual change teaching.

Glasersfeld (1989) referred also to the history and philosophy of science, especially the theories of Kuhn (1970), and argued against the "traditional epistemological paradigm" which promotes an "observer-independent world-in-itself" of immutable, objective scientific truths which teachers of science believe they can "transfer" to their students in their linguistic communications. He regards students and scientists to be engaged in parallel activities of "constructing a relatively reliable and coherent model of their individual experiential worlds" (Glasersfeld, 1989, p 138). Glasersfeld's constructivism is elaborated in terms of an analogy with the adaptive functioning of a biological organism, and draws heavily on the theories of Piaget to provide a model of cognitive functioning in students of school science and mathematics.

The inadequacies of the epistemological underpinnings of the pedagogy have been highlighted and challenged, and a viable alternative has been presented. The major problems now facing science and mathematics teacher educators are those of elaborating a viable constructivist pedagogy and constructing professional development models to facilitate major conceptual change in teachers. Constructivism requires that teachers' existing knowledge and practices be the starting point for a socially negotiated process of conceptual change. This paper reports on the findings of a case study of a teacher of secondary school mathematics who engaged in collaborative research to develop a constructivist classroom learning environment. The specific focus of this paper is on the influence of the teacher's beliefs in the conceptual change process.

INTERPRETIVE FRAMEWORK

Constructivist Epistemology

The constructivist nature of cognitive development has been recognised for some time (Piaget, 1970, 1971), and has recently received renewed attention by science educators investigating the role of students' conceptions of everyday phenomena in their learning of school science (Driver & Easley, 1978; Gilbert & Watts, 1983). Also, mathematics educators have begun to focus on the implications of a constructivist approach for improving the learning experiences of students in mathematics classrooms (Resnick, 1980, 1987; Novak, 1986; Cobb, 1987; Steffe, 1988).

A constructivist epistemology has been elaborated by Glasersfeld (1981, 1987, 1988, 1989) as a model of knowledge development in which knowledge is internally generated within the mind of the knower. Knowledge cannot be separated from the knower; it does not exist as an independent commodity that can be transferred from one knower (i.e., a teacher) to another (i.e. a learner). Neither does knowledge reside in the written or spoken words of the linguistic communications process. Teachers do not "convey" meaning in their dialogue with students. Rather, dialogue can focus student's thinking on their existing knowledge, but only if they are able to make meaning from the visual and auditory stimulation they are receiving. "...language becomes a means of constraining and thus orienting the student's conceptual construction" (Glasersfeld, 1989). Mathematical or scientific knowledge is a subjective cognitive construction that is used by the individual to interpret and predict personal experiences of the "real" world which exists in an unattainable state beyond the barrier of the senses.

In the same way that scientists' "observations" are predetermined by their theories, students' existing knowledge shapes their expectations and interpretations of their experiences of the "concrete" or "abstract" world. The extent to which prior knowledge and experiences differ from student to student determines the extent to which a range of different interpretations of the same classroom event is generated amongst a group of students. Thus it makes little sense for a teacher to expect a group of students to construct identical viable knowledge in response to the same set of learning activites.

An important constructivist concern is for the viability of an individual's mathematical or scientific knowledge. Viability is a qualitative measure of the extent to which the individual is satisfied with the fruitfulness of their knowledge in making sense of, or understanding, their own experiences. This knowledge is neither "true" nor "false" in relation to its role in enabling the individual to make sense of their experiences of their perceived world. The issue of the viability of individual knowledge often is overlooked by teachers whose main concern is the match between their own knowledge and that of their students. This "objectivist" perception of truth promotes an "iconic" conception of knowledge (Glasersfeld, 1989) which focuses on students production of "correct" symbolic replicas of the teacher's symbolic representations of his or her knowledge. Thus a "positivist" epistemology emphasises the authority of the teacher and disempowers the student from evaluating the viability of their own knowledge. As a consequence, students may retain their own viable interpretations of an event which has been interpreted very differently by the scientific or mathematical community, and simply reproduce "correct" but personally meaningless replicas for the teacher.

In order to facilitate a modification to a student's existing knowledge the student will need to experience a perturbation in relation to their perception of the viability of their knowledge, rather than be told that their knowledge is not valid according to some external criterion about which th have no knowledge. Thus it makes little sense for a teacher to expect students to undertake conceptual change in response to external indications about the "wrongness" of their existing knowledge. Knowledge growth for dealing with novel situations (e.g., problem identification and solving) requires perturbations in relation to some expected result. Structured social interactions amongst students and teachers can provide a ready source of cognitive perturbation which can be the focus of negotiation and consensus building.
In a constructivist epistemology, negotiation is an important process leading to consensus about the social value of an individual's knowledge. This process is undertaken within the scientific community (Kuhn, 1962) and has an equally important role in the classroom. It not only helps the individual student to reflect on, and evaluate, the viability of their knowledge for meaningfully organising their experiences, but provides also an opportunity to test its compatibility with that of significant others in personally meaningful circumstances. Perceived incompatibility provokes cognitive perturbations and provides a meaningful context for self-organized reconstruction, or adaptation, of an individual's knowledge. Perceived compatibility strengthens cognitive equilibrium and the perception of the viability of an individual's knowledge. Negotiation and consensus building are important activities for the cognitively self-regulating learner. Self-regulation within both social

and cognitive contexts are the keys to the development of the individual student's ability and self-motivation to modify their own knowledge.

There are important implications of a constructivist epistemology for the teaching and learning of mathematics and science. "The teacher's role will no longer be to dispense "truth" but rather to help and guide the student in the conceptual organization of certain areas of experience." (Glasersfeld, 1983). Teachers become builders and testers of the viability of their own conceptual models of their students' knowledge construction processes. They utilise their knowledge to provide learning opportunities that induce cognitive perturbations and reflective thinking in students, and promote student negotiation and consensus building. Rather than teachers telling students about "the" mathematical or scientific interpretations of the world, teachers provide opportunities for students to evaluate the viability of their own mathematical or scientific interpretations, and to reconstruct them should they experience lack of viability. Although the teaching goal might be for students to construct knowledge that is compatible with the consensual knowledge of the scientific or mathematics community, teachers' concerns are for the viability, rather than the valididty, of student knowledge.

Teacher Beliefs

However, a shift to a constructivist epistemology is not an event that can be achieved overnight. It requires teachers to reconceptualise their roles, develop new teaching practices, and abandon well-established and seemingly successful practices. This is far from being a simple task. Research on teacher thinking (Nespor, 1987; Clark & Peterson, 1986; Eisenhart et al, 1988) has demonstrated that teachers' theories and beliefs about the teaching-learning process play an important part in determining the nature of their roles in the classroom, and directly affect many aspects of their professional work, including lesson planning and the decisions they make during classroom interactions with students.

Teachers' beliefs about the nature of the curriculum influence the nature and scope of their curriculum reforms. Teachers whose curriculum interests are pr dominantly "technical" in nature (Kemmis & Fitzclarence, 1986) are likely to be concerned with reforms within the existing curriculum framework imposed by the state. They are likely to have a "determinist" belief that the curriculum and its associated problems are determined by the state and that the individual teacher cannot exert an influence over them. This belief can be compounded by a positivist belief that reifies the curriculum as a "real" object, rather than the subject of socially negotiated knowledge amongst the members of the educational community.

These beliefs can result in teachers perceiving their classroom roles as predetermined for the faithful reproduction of the "real" curriculum, with little concern for adaptations to local circumstances. Their classroom learning environments are likely to be characterised by: a "managerialist" teacher concern with delivering the syllabus and controlling students' interactions with it, rather than facilitating student participation in negotiating the nature of their learning activities; a "scientistic" teacher-directed discourse that assumes an unquestioning acceptance of the syllabus, rather than challenging its assumptions, values, and implications; and teacher-set "instrumental work", of a production line nature, in which compliant students exchange performance for grades, rather than engage in collaborative, critical inquiry.

Teachers' beliefs may be explicit and readily articulated. For example, student success or failure often is attributed by teachers to student characteristics, chance, or the quality of teaching, depending on the teacher's belief about the causes of student behaviour (Clark & Peterson, 1986). Although teachers' implicit beliefs are only partially articulated, they underpin the largely subconcious teaching routines developed over time by experienced teachers (Tobin & Espinet, 1987).

Research has shown that changing teacher beliefs about their classroom roles can be as difficult as changing the viable concepts students construct to interpret their experiences of the world. Olson (1981, 1982) reported that implementation difficulties of an innovative student-centred science curriculum in England were due largely to teachers' established beliefs. Teachers were unwilling to abandon their "strong influence" on classroom events, and "translated" the innovative design into more famil[illegible] established practice in their attempts to overcome perceived dilemmas associated with their roles.

Research on student conceptual change in school science suggests that students be made aware of, and experience a sense of dissatisfaction with, their existing conceptualisation, and that the alternative concept will be constructed only if it is found to be "intelligibile", "plausibile" (Posner et al., 1982) and "fruitful" (Gunstone & Northfield, 1986, 1988). Similar suggestions for facilitating teacher conceptual change have been made by researchers. Teachers should be made aware of their "subjectively reasonable beliefs" or "practical arguments" (Fenstermacher 1986, 1979) that shape their established classroom practice; they should be engaged in a "dialectical approach" to curriculum development (Olson,1981; Kemmis & Fitzclarence, 1986); an alternative belief should be "made available" to replace the teacher's established belief (Nespor, 1987); a sound and convincing rationale for "adopting" a new belief must be provided and reiterated (Floden, 1985); and successful practice of the teacher's "new perspective" needs to be facilitated (Ruthven, 1987).

Constructivism provides also a methodological rationale for facilitating teacher conceptual change. It requires that teacher's existing knowledge and beliefs be the starting point for a socially negotiated process of conceptual change. A collaborative research relationship (Watt & Watt, 1982; Saphier, 1982; Kyle & McCutcheon, 1984), with a teacher-as-researcher focus, provides a context for the teacher to evaluate the viability of their pedagogical beliefs, knowledge and classroom actions. An interpretative research approach (Erickson, 1986) provides a means of interpreting qualitative classroom-based research data from a constructivist perspective, providing the teacher with "operative knowledge" (Glasersfeld, 1989) of constructivist epistemological principles.

METHODOLOGY

This paper reports on the findings of a study designed to investigate the nature and role of a teacher's professional beliefs during the process of his formulating and implementing a constructivist pedagogy.

A high school mathematics teacher and the author established a collaborative research relationship (Watt & Watt, 1982; Saphier, 1982; Kyle & McCutcheon, 1984) in which the teacher adopted the role of coresearcher. Collaboration occurred for an eight-week period in 1987, during which time 24 consecutive lessons in a Grade 12 mathematics class of 28 students were observed. In the following year the study involved observations of 12 consecutive lessons in a Grade 9 mathematics class of 30 students during a period of four weeks. The latter part of the study was conducted to determine the extent to which the conceptual and practical changes reported in the first year had been sustained.

The teacher's self-determined research role focused on developing an improved teaching practice that would directly benefit his mathematics class. He formulated the following research question: "How can the acquisition of mathematical knowledge by students be enhanced by specific teaching strategies?" The teacher documented his involvement in the study and reported his interpretation of the findings (Fleming, 1988).

The author attempted to facilitate the teacher's development of a constructivist epistemology and teaching style, and investigated the nature and role of the teacher's professional beliefs in relation to his changing classroom role. The collaborative approach provided opportunities to exemplify the process of learning inherent in a constructivist theory of knowledge development by enabling the teacher to become a learner of his own teaching (Fenstermacher, 1986).

During the study the author performed a number of key roles. He documented the teacher's classroom actions by employing an "interpretive" research approach (Erickson, 1986) which guided the daily collection and analysis of qualitative data from classroom observations, and teacher and student interviews. Data were recorded in fieldnotes, and first analyses were conducted immediately on return from each school visit. These analyses, or reflections, provided a focus for subsequent observations, and guided the verbal and written dialogue with the teacher.

Facilitating Conceptual Change

In a constructivist epistemology cognitive perturbation performs a key role in the reconstruction of a learner's concepts. The author engaged the teacher in a process of critical inquiry, from a constructivist perspective, on his own teaching practice. The purpose was to enable the teacher to reflect on the extent to which the epistemological assumptions, reflected in his established teaching strategies, were compatible with facilitating the construction of students' mathematical knowledge. This process aimed to stimulate cognitive perturbation in the teacher, and was facilitated by providing the teacher with copies of daily fieldnotes which contained:

- analyses of classroom events, such as the nature and duration of teacher-dominated activities
- descriptions of student conceptions, learning difficulties, perceptions of the learning environment, and classroom activities
- questions that sought the teacher's explanation of selected aspects of his intentions, classroom behavior and expectations
- specific content-related teaching suggestions for facilitating the growth of the teacher's pedagogical content knowledge (Shulman, 1985, 1987).

The author further assisted with the teacher's epistemological reconstruction by engaging him in frequent critical dialogue, providing readings on constructivist theories of knowledge development from the educational research literature, and assisting the teacher to plan and evaluate innovative teaching strategies.

Measuring Conceptual Change

In addition to daily school-based discussions, the researcher conducted informal interviews with the teacher during the study; audio recordings were made and transcripts produced. A series of structured interviews was conducted shortly after the completion of the collaborative stage of the study in order to determine the nature of the teacher's implicit beliefs, especially those beliefs which had a major impact on the teacher's reconstructed classroom role and teaching practice. The articulation of implicit beliefs was expected to provide substantive evidence of the extent to which the teacher had developed a constructivist epistemology. Of particular interest to the author was the identification of beliefs that restricted the development of a constructivist pedagogy.

The structured interviews were modelled on the "repertory grid" technique for investigating teachers' implicit theories and beliefs about their classroom roles (Olson, 1980, 1981; Munby, 1984). This research method is based on the "personal construct theory" of Kelly (1955) and has been used to investigate how teachers construe their work in relation to a curriculum innovation. The method involved the elicitation from the teacher of a listing of teacher and student behavioral events that he would prefer to see taking place in an ideal version of his classroom, his grouping of the events into a two-dimensional matrix with numerical information about the strengths of the relationships between the individual elements and groupings, a factor analysis of the resultant grid, and an interview to identify the nature of the teacher's implicit professional beliefs represented by the factors.

The interview data were interpreted in conjunction with the observational fieldwork data and the teacher's report on the study (Fleming, 1988), and inferences about the teacher's professional beliefs were formulated. Metaphors were constructed as organisational devices to explain the relationships between sets of teacher beliefs and classroom actions (Lakoff & Johnson, 1980; Johnson, 1987). Inferences were further synthesised (Erickson,1986) and expressed in the form of assertions. The assertions about the teacher's beliefs accounted for both confirmatory and discrepant evidence obtained during the data collection activities.

FINDINGS

The Teacher

The main subject of the study was a male high school teacher of 13 years professional teaching experience. His major teaching areas were biology and physics which he had taught to all grades at the high school level. He had completed a university degree in biology with minor studies in chemistry and first-year mathematics and physics, but had not obtained a pre-service teacher education qualification. Prior to his current appointment he had taught in three other schools in the Perth area since graduating from university.

At the time of the study, he had been working in his current school for less than 18 months. He had been appointed to teach two-year university entrance courses in both physics and mathematics to senior classes. In his first year at the school he had commenced teaching the first year of a two-year mathematics course to a Grade 11 class. This was his first experience of teaching mathematics, apart from some private coaching. At the time of the study, he was teaching the second year of the mathematics course to a Grade 12 class which contained about a third of the students from the previous Grade 11 class. The study was conducted in that class.

Clearly, the teacher was teaching out of field. He was very inexperienced with the subject and was unfamiliar with most of the students in the class, but was, in other respects, an experienced high school teacher. Also, he was eager to improve his professional performance, and at the time of the study had enrolled as a part-time student in a postgraduate teacher education course.

The School.

The school was a long-established non-government institution funded largely by the Catholic Church. It is located on the outskirts of the Perth inner city metropolitan area and enrols only female students. The school provides a combination of academic and personal development programs for Grades 8 to 12.

Each subject area in the school was administered by a specially appointed senior teacher whose role was to ensure that the subject syllabus was suitably implemented by the subject teachers in his/her department. The content of the Grades 11 and 12 syllabus was set by the Secondary Education Authority (S.E.A.), a State government organisation with responsibility for establishing university entrance courses and examinations. Teachers were required to ensure that students were well prepared to sit the S.E.A.'s university entrance examinations which are administered at the end of Grade 12. In addition, school policy requires a minimum delivery rate for the syllabus, in preparation for each of the school-based three-monthly summative "topic tests". The results of these examinations form the basis of the school-based assessment system.

Assertion 1: The teacher's established pedagogy was shaped largely by his technical curriculum interests and positivist epistemology.

At the commencement of the study the "technical" orientation of the teacher's beliefs about the nature of the curriculum (Habermas, 1974; Kemmiss & Fitzclarence, 1986) and his "positivist" epistemology (Nussbaum, 1989) shaped a largely teacher-centred learning environment. Mathematical knowledge was presented as an objectified commodity by a teacher whose main concerns were managerial: the efficient delivery of the syllabus content.

New mathematical knowledge was available to students who, metaphorically speaking, were able to closely follow the teacher on a voyage of discovery of the mathematical "world-out-there". The teaching focused on exposing the teacher's mathematical knowledge to the whole class. Knowledge development was promoted implicitly by the teacher's established pedagogy as the successful replication of the symbolic structures used to represent the teacher's knowledge. The authority of the teacher as expert knower was invoked to indicate the success of students' learning endeavours; a pedagogical focus on the validity of students' knowledge shaped teacher-student classroom relationships.

Teacher and Student Roles

The predominance of the teacher's technical curriculum interests was highlighted by his justification of the failure to learn of a large proportion of the class. Although he admitted that at least a third of the class was unable to cope with the pace of his whole class presentations, he believed this to be an inevitable consequence of there being insufficient class time to focus on these students. He defended this rationalisation with reference to the school mathematics department policy which required parallel classes to be "prepared" for common, six-weekly topic tests. The teacher's interpretation of this policy supported his belief in controlling student "progress" through the syllabus. His resultant pedagogical focus was fixed on the delivery of the syllabus. This teacher role assumed a higher priority than the creation of meaningful learning opportunities for many students.

The teacher's technical curriculum interests were strengthened by his belief in the existence of an inherent student characteristic that prevented some students from being academically successful. He believed that students failed to learn in his class because of their poor academic motivation, which he attributed to their elementary school experiences. He believed poor academic motivation to be a fixed trait which he could not influence. He did not perceive his role to include the enhancement of students' academic motivation. When pressed on this issue, the teacher revealed that he did not believe in "coercing" students to be more involved in classwork. Clearly, the teacher's interpretation of motivating students was limited to controlling their behavior, rather than to providing them with meaningful learning opportunities in which they could engage as self-regulated learners. The teacher's pedagogical focus was fixed on the syllabus, rather than on the students.

The teacher's positivist epistemology obscured the need for a more student-centred classroom learning environment. If mathematical knowledge exists independently of the knower, then the teacher's role is to manage the learner's exposure to it; in this case, exposure to the teacher's mathematical knowledge. Thus the teacher believed that his main classroom role was to "lead" students "step-by-step" through careful explanations of the logical structure of each new concept. Time was his chief concern. He was not prepared to "wait indefinitely" for students, and believed that he should "introduce" at least one new concept each lesson.

Lessons comprised teacher-directed, whole class instruction which included a high degree of teacher talk. The teacher gave lengthy verbal explanations of his mathematical knowledge, supported by hastily drawn and partly legible blackboard illustrations, but with little reference to the textbook. Students, implicitly, were expected to watch, listen, make sense and record notes: an activity which several students, who demonstrated remarkable foresight, criticised as "university lectures".

In practice, the teacher's classroom actions gave rise to a submissive, uncritical and compliant role for students who, implicitly, were expected to act as an interested audience for the recounting of the teacher's mathematical knowledge. Opportunities for more participatory student roles arose only when students were directed to respond to teacher whole class questions, or complete individual seatwork activities. The classroom learning environment was shaped largely by the teacher's autocratic style of decision making which focused on his technical curriculum interests.

Teacher Knowledge

The teacher rarely was concerned with understanding students' construction of their own mathematical knowledge. Whole class dialogue focused on eliciting correct answers to teacher questions, and omitted consideration of students' alternative ideas. Teacher questions predominantly were "closed", usually at a cognitive level that suited the highest achieving students, and often were designed only to capture student attention.

> [they] were more rhetorical questions...that I'm waiting to hear the answer that I want...just to try and engage the students for a while...I know what answer I want to hear and if I don't hear it I most probably just say 'Well, no. Not quite. Someone else'...until I get the right answer...to test whether they've been listening. (Interview 1, p9)

The teacher's understanding of the processes of students' attempts to construct their own new mathematical knowledge was based only on the few questions asked by target students (Tobin & Gallagher, 1987) during whole class activities. However, these questions prompted the teacher only to re-explain his mathematical knowledge to the whole class, rather than attempt to stimulate a discussion about the viability of students' mathematical assumptions and ideas. The teacher remained largely unaware of the viability of most students' mathematical constructs. The main indicators of students' mathematical knowledge development, used by the teacher, were the six-weekly topic tests. Nevertheless, he believed that he had a "pretty good understanding" of students' abilities and mathematical knowledge.

Student Knowledge

In class, the construction of most students' individual mathematical knowledge was a covert affair that remained unacknowledged and only indirectly supported by the teacher. For most students, whole class interactions between the teacher and target students provided the major opportunity to negotiate their own understandings with the teacher. Most students sat in friendship groupings that were associated with at least one target student. Vicarious negotiations occurred for group members when their target student asked questions of the teacher. The fruitfulness of these interactions was limited, however, by the teacher's subsequent didactic response which usually involved a reiterated explanation. The teacher's response to student questions did not involve investigatory teacher questions or redirecting student questions to the class for discussion.

Opportunities for negotiation and consensus building amongst students were more prevalent. Whole class teacher presentations were punctuated by short periods of individual student activity. Usually, the teacher allocated a few routine practice exercises and allowed several minutes for their completion. During these brief periods students collaborated to solve difficult problems. However, collaboration often took the form of sharing one student's solution amongst the group, rather than discussing individual interpretations of the nature of a problem. At times, covert negotiations amongst students occurred during whole class activities. When the teacher remonstrated with individual students for not attending to his presentation, a typical student response was an appeal that they were helping a friend. This student role remained unsupported and undeveloped by the teacher.

The role of students' prior knowledge in constructing their new concepts and solving the teacher's problems was seldom addressed in the teaching. Whole class teacher explanations of a new concept usually were linked only with related concepts presented in the immediately preceding lesson. Relations with other important concepts that students may, or may not, have developed in previous years were disregarded or only briefly referred to in the teacher's opening remarks, such as "I'm sure most of you are familiar with..." and "You most probably know...". The teacher implicitly expected that students' previous related learning experiences had resulted in their development of viable, antecedent mathematical constructs which were compatible with his own constructs, and that most students were well prepared for further development of new mathematical knowledge. Reconstruction of students' prior knowledge did not appear on the teaching agenda.

Students' newly constructed mathematical knowledge was subjected only to a teacher-directed validation process. The pedagogical focus of these activities was on the validity, rather than viability, of student knowledge. Solutions to teacher-set, class problems were presented to the whole class. Depending on the teacher's perception of the availability of time, students' "correct" solutions were recorded by the teacher on the blackboard. "Incorrect" solutions were discounted and no discussion of student's alternative ideas was promoted. Reconciliation of perceived differences in student and teacher knowledge occurred privately amongst students, rather than by pedagogical design in a social context. The teacher assumed that an exposition of the "correct" solutions without reference to students' alternative ideas would enable students to meaningfully reconstruct their mathematical knowledge.

Assertion 2: **The teacher developed a "transitional" constructivist epistemology which resulted in a more student-centred pedagogy and a continued centralist classroom teacher role.**

The teacher underwent a process of conceptual change which impacted on his classroom teaching. His expressed beliefs in constructivism were reflected in new pedagogical practices. He designed teaching strategies based on a better understanding of students' ongoing needs in relation to the construction of their own mathematical knowledge. Nevertheless, a teacher-centred learning environment was sustained and technical curriculum interests prevailed. An analysis of the teacher's beliefs revealed that his "constructivist" pedagogy was shaped by a modified positivist epistemology and by a sustained belief in a centralist classroom role for himself.

Teacher Epistemology

The teacher's "constructivist" epistemology was shaped by his interpretation of the theories of: radical constructivism (von Glasersfeld, 1977), knowledge induction (Larsen, 1987), knowledge restructuring (Vosniadou & Brewer, 1987), prior knowledge (Pope & Gilbert, 1983; Pines & West, 1986), cognitive disequilibration (Smock, 1971), personal knowledge construction (Bodner, 1986), and information processing (Stahl, 1987). The teacher's interpretation of these theories resulted in an adaptation to his model of knowledge transfer which was predicated on his positivist epistemology. The teacher's "constructivist" epistemology was reported (Fleming, p15, 1988) in the form of a model of "knowledge transformation" shown in Figure 1.

Fig 1 about here

The model shows that the teacher "transforms" his private knowledge into "public information" which, subsequently, is "transformed" by the student into his/her private knowledge. The model identifies the teacher as the indispensible source of knowledge whose role is to transmit inherently meaningful information that the student "mentally digests". The influence of the teacher's positivist epistemology on this "constructivist" model is apparent: new knowledge continues to be perceived as an external commodity that must be delivered to students. The model's pedagogical focus is on the role of the teacher-as-transformer, rather than on the role of students-as-constructors. The issue of the validity of student knowledge remains paramount, and overshadows concern for the viability of student knowledge which performs a key role in a constructivist epistemology.

The teacher's interpretation of constructivist theory resulted in a modification of his positivist epistemology. His positivist beliefs focused his attention on the component of constructivist theory that concerns the personal nature of knowledge construction.

> ...knowledge cannot be transmitted from one individual to another... information can be transmitted...but knowledge construction can occur only in the mind of the learner (Fleming, 1989, p51)

This component of constructivist theory induced minimal cognitive perturbation because it could readily be assimilated into the teacher's model of knowledge transformation which provided him with a personally viable "constructivist" epistemology. As a result of this interpretation of constructivist theory, the teacher identified a need to account for the influence of students' prior knowledge on their construction of new mathematical concepts.

Other important components of constructivist theory are absent from the teacher's "constructivist" epistemology, especially reflective thinking and the processes of social negotiation and consensus building which play a central part in constructing knowledge and determining its personal viability. These important components of constructivist theory emphasise the learner as the source of his/her own knowledge, rather than a recipient, or "transformer", of the teacher's knowledge.

Teacher Pedagogy

The teacher's "constructivist" pedagogy reflected his continuing epistemological concerns with the transformation and transmission of his mathematical knowledge. His pedagogical beliefs and related classroom practice are expressed in terms of two metaphors which help to explain the "constructivist" classroom roles of teacher and students. The metaphor of "interactive informer" delineated the teacher's role as the main source of student knowledge. The metaphor of "teacher as manager" determined a managerial relationship between teacher and students. Both metaphors enabled the teacher to rationalize his centralist teaching role and the predominance of his technical curriculum interests.

Teacher as Interactive Informer

The teacher reconceptualised his main classroom role in terms of becoming an "interactive informer". His language was replete with expressions associated with information delivery and retrieval. For the teacher, the key to "constructivist" teaching was to be more interactive with the students. His main pedagogical goal was to provide opportunities for students to construct valid knowledge.

> ...the way I put [constructivism] into practice is that I make a lot of effort to try and understand the way in which students are comprehending the work...and that allows me to modify my teaching strategies...to explain and direct the student towards discovering the correct way of doing it. (Interview 7, p6)

He believed that he needed to obtain "positive feedback" from the students by "information gathering" around the class.

> I obtain feedback...I'm interested in finding out what the students know...how they understand things. And in order to do that I need to monitor what they're doing and what they're thinking. And I can do that by listening to their responses to questions, looking at their work...so that I can modify my teaching strategy. (Interview 2, p5)

The teacher believed that his modified teaching strategies would enable him to better provide "new information" to students. Although he perceived a number of methods of "exposing the student to new information", he continued to believe that teacher explanations provided the best opportunities for students to develop new mathematical knowledge.

> It could come about by student questioning, but...it's mainly teacher-initiated activity...I might provide that information by means of blackboard work...in an inquiry-based manner...or I might use worksheets to introduce a topic. (Interview 2, p7)

This belief was apparent a year later when the author asked him to describe his ideal teaching role in the Grade 9 class.

> I guess I'd like to be doing pretty much what I'm doing, explaining examples on the board and giving students work to do, seeing them do it and I guess I'd just like to be doing it a bit more successfully... (Interview 6, p1)

However, he had sustained a "constructivist" belief that the efficacy of his explanations depended on their relevance to students' knowledge development needs.

> ...I'd certainly say that I think if my explanations are sufficiently student sensitive and explicit, then that will minimise the students' difficulty in developing their content knowledge, or it would enhance their development of content knowledge... (Interview 6, p10)

In practice, the teacher's "more interactive style" (Interview 1, p11) was characterised by a reduction in the amount of lecturing, and corresponding increases in the amounts of whole class teacher-directed discussion and individual student activities. In the "more interactive style" of whole class teaching teacher questioning performed a major role.

> ...with the explanations I give...I try not to simply present my understanding of it...because often I've found that it may go over t. heads...so I start explaining it, try to expose the explanation bit by bit, asking for student responses along the way. (Interview 6, p6)

The teacher introduced a number of changes into his whole class questioning techniques. He tried to stimulate widespread student thinking by avoiding "closed" questions that required only one-word answers, directing questions to more students, and lowering the cognitive level of questions to make them accessible to more students. He formulated questions to probe student understanding, and responded by reducing otherwise complex questions to series of simpler questions. At the time, the teacher explained the improvements in his questioning techniques in the following terms:

> ...avoiding the so-called yoyo type questions, asking good quality questions that require a student answer, and listening to the student answer; not just asking a question for the sake of a break or for the sake of pseudo student input sort of thing...when you're doing newer material I guess that forms the opportunity to link the new material with the old, with their pre-existing knowledge by questioning and opening up the areas. I suppose it's sort of a constructivist idea isn't it, of getting things ready to take on board the new information? (Interview 1, p11)

The purpose of the more interactive teaching style was to "engage" more students in teacher-led whole class discussion, and to increase the incidence of student questions of the teacher, especially during seatwork activities when the teacher circulated around the room and responded to individual student requests for assistance. However, classroom discussions continued not to be inquiry based or to focus on students' alternative ideas. They perpetuated the role of the teacher as the authority in relation to validating student knowledge.

During individual seatwork activities the teacher privately consulted students. His "constructivist" approach usually was to stimulate interaction with the student through questioning.

> Rather than saying 'Look you've got that wrong. Here's the right answer' or 'here's how you do it, I'll show you again the way I do it'...now, I'll say 'what went wrong, how did you get here?' So I'll ask the student to explain their line of reasoning, if they've got one, and then I'll perhaps interrupt at a point where they've gone wrong or got some false method or impression, and then I try and correct them. (Interview 7, p17)

One of the side effects of this interactive approach was that, at times, the teacher would become engrossed with an individual student, while other students sat with their hands in the air waiting for the teacher, and faster finishing students waited for a resumption of whole class teaching. The more interactive style highlighted the high degree of teacher dependence amongst the class.

Another interactive teaching strategy that enabled the teacher to obtain frequent "feedback" was the use of teacher-designed "self-paced" worksheets. The worksheets provided carefully sequenced instructions and seatwork exercises, and served to reduce the amount of time the teacher spent in whole class, non-interactive teaching. The worksheets replaced the teacher as the source of knowledge. They were designed as programmed learning materials and provided the class with a common series of tasks, each of which was to be completed "independently" by students in a "relatively short" time. The worksheets were not designed to be completed collaboratively by students.

Social negotiation among students occurred by default rather than by pedagogical design. Although the worksheets had a common starting point for all students, they provided opportunities for students to review and reconstruct some related aspects of their prior knowledge. However, an untested design principle was that the reductionist nature and linear sequencing of the tasks facilitated students' further construction of viable mathematical knowledge.

For the teacher the main advantage of the worksheets was the opportunity they provided for him to move around the class and monitor the knowledge construction of individual students. The teacher reported on his role during individual seatwork sessions:

> Sort of leading them through it in smaller steps, you can follow their progress more readily and see when they go wrong and see what they have difficulties with. (Interview 1, p8)
>
> To identify difficulties and maybe talk them through with the student in a little bit more detail than would be possible if it was during the whole class engagement. (Interview 2, p7)

Consequently, a relatively more interactive classroom environment developed in which more students consulted the teacher, or their fellow students, in relation to their immediate learning needs. Most of the "lower achieving" students, however, continued to not initiate questions of the teacher and, because the teacher operated mainly in a responsive mode, continued to be uninvolved in dialogue with the teacher. Nevertheless, most students reported that the teacher seemed to have become more interested in helping them overcome their learning difficulties, and that they were experiencing fewer difficulties in understanding new mathematics concepts. They cited the worksheets as one of the benefits of his changed classroom practice.

Another interactive teaching strategy resulted from the teacher's new belief in the important role performed by students' prior knowledge in their construction of new concepts. "<u>Mental tests</u>" which required students to reflect on the knowledge that the teacher expected them to have developed during recent lessons were administered at the commencement of lessons, .

> ...short mental tests at the beginning of a lesson...provided a useful source of feedback for students on the development of their own understanding as well as a means of recalling and establishing continuity with the content of the previous lesson/s. (Fleming, 1988, p57)

Sometimes, the subsequent whole class discussion indicated to the teacher that many students had not fulfilled his expectations by constructing appropriate knowledge. On occassions this revelation led the teacher to abandon his lesson plan and conduct extemporaneous whole class teaching in an attempt to provide a ready panacea for this perceived problem. However, a <u>dilemma</u> continually arose. Further teacher questioning revealed the continuing existence of the perceived problem which was interpreted as a need for "more of the same", an action which became increasingly problematic because of the teacher's perception of time constraints in relation to "covering" the syllabus. The dilemma was resolved by discontinuing the the questioning.

A noticeable impact of the "self-paced" worksheets on the class was the tendency of students to complete the learning tasks at variable rates. This differential progress was limited, however, by the teacher's practice of frequently regrouping the whole class and directing discussions about the solution of selected exercises. He expressed a strong belief in the need to ensure that all students were provided with the opportunity to "cover" the syllabus.

Teacher as Manager

At the end of the collaborative stage in the first year of the study, the teacher described an ideal classroom learning environment in which his role was one of controlling students' learning activities.

> ...I believe that the teacher has to determine when new information is going to be provided and the nature of it. In other words, when to move on and expose students to the next step...controlling the rate. (Interview 5, p9)

A year later, the author asked the teacher about the most important aspects of his classroom role in relation to teaching a Grade 9 class.

> Controlling what's going on in terms of what work is being done. Controlling the pace of it. Giving explanations for it. (Interview 6, p2)

Clearly, the teacher had sustained a belief in the primacy of his role in controlling the classroom learning environment, a role which was highly compatible with his teaching role as an "interactive informer". He further justified this classroom role in terms of his belief in a fidelity model of curriculum implementation in which there is a close correspondence between the planned and implemented curricula. This model requires the teacher to exercise strong control over the nature and scope of students' learning activities, and often results in common activities for all students. In managerial language the teacher controls the rate of delivery of the syllabus content. Individualized learning activities that cater for more than one set of learning needs do not fit well into this model. In the teacher's ideal classroom a "lockstep" approach to learning prevails.

> ..I place a high emphasis on the teacher being in control of the classroom, and the rate of learning and the activities that are going on...and when a new topic will be started...I have always taken for granted...that that's the way you teach, or that's the teachers' role or prerogative, to pace the class, almost like you want to push them along, but not too fast and not too slow. (Interview 5, p8)
>
> Students are pretty much doing the same thing as one another at the same time...they might be graphing a quadratic function. They might have a certain time to do it. And then we might look at how far they've got, or what they've done. (Interview 5, p8)

A major consequence of his belief in controlling students' activities was the teacher's adoption of a managerial relationship with the students. Related teacher beliefs and classroom actions were associated with a student role of compliance with the teacher's organisational demands. The teacher's language was replete with references to their compliance and industriousness, and to his role in controlling their activities. In his ideal classroom students would be:

> ...working and interested in something, they're on-task...rather than doing some other maths work...I want them to be doing what I have set.
> (Interview 5, p5)

Students did not directly participate in the decision making processes that shaped the learning environment in the teacher's classrooms. They were were not provided with opportunities to negotiate the nature of their learning activities. Their only involvement was indirect. This occurred when the teacher shaped his teaching strategies in response to "feedback" on student understanding. Although, the teacher was willing to concede that students <u>could</u> play a part in being self-managed learners, he provided limited opportunities for them to do so.

Student compliance was the hallmark of the teacher's ideal classroom environment. His conception of students' main role was to be "involved in what's going on, thinking about it, formulating questions about it, attempting to understand it...rather than simply copying stuff down from the board" (Interview 5, p6). The "it" were the teacher's questions which he was posing during whole class teaching when presenting "new material". At this time, student involvement was an activity which the teacher was "kind of controlling...or maybe initiating".

At other times in class, the teacher believed that students should be "working individually or in small groups". However, their activities, including discussions, should be focused on the learning activities which he had prescribed.

> ...work is set in class and students do it. This happens every period...they either work on their own, or they may discuss things with their neighbours...or there may be pre-organised group work. (Interview 2, p9)

In addition to "working" in class, the teacher believed that students should "do work outside of class". Student activities would focus on completing the homework he frequently set: mostly textbook exercises or worksheets.

The teacher valued "student-initiated involvement" and believed he should facilitate its development. By this he meant that he would encourage students to "spontaneously ask questions generated by whole class discussions", or "ask for help when they needed it", or to be "responding in a whole class forum" (Interview 5, p6). In other words, student initiative was to be exercised mainly within the confines of teacher-directed whole class discussion. The teacher did not believe that students' self-management roles included participation in decision making about the nature of their classroom learning activities. He interpreted such participation as second-guessing the next activity in the prescribed sequence of syllabus topics. He expressed his belief in the absurdity of such a role for anyone other than the teacher.

> I don't believe the students are so good at initiating their own learning that they can do it entirely. I think they need guidance and...in many cases they won't know what it is that they want to know next, or need to know next, or what follows logically from where you are in the syllabus. (Interview 5, p6)

The teacher's conception of students' self-management activities did not include important self-regulatory aspects of a constructivist epistemology, such as negotiated learning, reflective thinking, and consensus building. Rather, the teacher's managerialist role was predicated on technical curriculum interests that required a major concern with "covering" the syllabus. These interests were best served by assuming unilateral control of the nature and duration of students' classroom activities.

Assertion 3: **The teacher's positivist beliefs about the nature of constraints compromised the development of his constructivist pedagogy.**

At the end of the two-year study the teacher recorded his beliefs about the attributes of an ideal student: "independence", "responsibility" and "questioning". He explained that this student would be "...self-motivating and capable of accessing information from a variety of sources"; have "the realization...that they are responsible for their own learning; that the learning itself 'belongs' to the student rather than to the teacher"; and that they would "...formulate their own questions as a part of their problem solving technique"(Fleming, 1988, p75).

Ideally, he would teach this type of student using a "self-study" approach which would allow them to "work at their own pace", and enable him to "come around and give individual help". This "constructivist" pedagogy, he believed, would be more satisfying for students because some could be "going faster" rather than "sitting around waiting for the rest of the class to progress", and would "allow other students who are having difficulty with a section to spend more time on it, get help..." from the teacher. (Interview7, p8)

In practice, the teacher attempted to implement aspects of a self-study approach by means of worksheets, supplemented by whole class discussion. In retrospect, he believed this teaching approach had been successful for enabling him to monitor students' knowledge construction and, subsequently, to design "student sensitive" teaching strategies.

Constraints, Conflicts and Compromises

However, the teacher believed that the effectiveness of his "constructivist" pedagogy was limited by constraints which he associated with the inherent nature of both the curriculum and the students. The teacher's belief in accomodating these constraints conflicted with his "constructivist" belief in facilitating learning with understanding. He attempted to reconcile this conflict by developing a pragmatic pedagogy based on a belief in "compromise". However, the teacher's positivist belief in the external and largely immutable nature of these constraints resulted in a belief that he had little or no pedagogical influence over them. Consequently, the teacher's "constructivist" pedagogy was compromised in favour of his technical curriculum interests.

Student Expectations

Although the teacher professed a belief in a more decentralised classroom role for himself, he continued to believe that student expectations of a centralised teacher role provided a major obstacle. He attributed these expectations to students' elementary school experiences, and believed that it was difficult to change them. He believed that students would not regard a decentralised teacher role as viable, and agreed that his whole class explanations catered for these perceived student expectations.

> ...they'd say, oh this teacher doesn't teach you anything. I think that's very much their attitude, that the teacher has to teach you...in a way it would be true that the teacher is not teaching them...perhaps it's not, perhaps it shouldn't be. (Interview 6, p4)

It seems that also the teacher was not fully convinced of the authenticity of a decentralised teaching role. Earlier evidence of the teacher's belief in the primacy of a centralised classroom role was couched in terms of his own expectations of what it means to be a professional teacher.

> I kind of feel that if I'm going to be there I should be doing something positive. I guess that is a thing with teachers, you feel...probably quite wrongly...if you're instructing a whole of the class, that you're engaged in whole class instruction, you're doing what you're paid to do, you're fulfilling your role more so than if students were working individually. (Interview 2, p8)

The teacher's belief in a more decentralised role for himself seemed to conflict with his established belief that shaped his former centralist teaching style. His recourse to "external" constraints, especially those he associated with the students, seemed to provide him with self-justification of the viability of a centralised teaching role. However, he did not offer evidence to support his assertion about the nature of student expectations. During interviews with the author, many students seemed to support a decentralised teacher role. They identified the worksheets as being one of the benefits of the changes to the teaching. The teacher's perception of student expectations did not seem to be based on "current" evidence.

School Policy

One of the main perceived constraints that prevented the teacher from adopting a more decentralised role was associated with his belief in the nature of the curriculum. The teacher believed that his role, metaphorically speaking, was to take the class on a tightly scheduled "journey" through the prescribed syllabus. His language was replete with references to his concerns for "leading" and "making progress". By the end of the second year it was obvious that he had sustained an overriding concern for the "need to progress" with the syllabus.

> ...there's still this underlying thing of right we must press on. We've been doing this for the last two weeks and we haven't done anything new and we haven't got anywhere. There's still this feeling that you want to do something new and progress through the syllabus. (Interview 6, p11)

The teacher believed that his accountability to the school authorities for enacting a "tour leader" role outweighed his responsibility for providing meaningful learning opportunities for all students.

> ...if at the end of the year you said to your senior master...I've only done a quarter of the first unit but everyone can do it really well, they wouldn't be very impressed. Whereas if I said I've kept up with the top class, we've done all this, no one can actually do anything but we've gone through the syllabus, they've seen it on the board, they've been exposed to it. I feel that you have to steer a middle course. (Interview 6, p11)

In the first year of the study, he had recognised the persistent nature of the conflict between his constructivist beliefs and technical curriculum interests, and had believed that the only available option was to find a "compromise".

> ...the conflicting goals of covering the syllabus and developing understanding being catered for. That's always a compromise we're sort of stuck with. (Interview 2, p14)

A year later, the teacher reiterated his belief in the need to adopt a pragmatic approach, "to steer a middle course", when dealing with this perceived curriculum constraint. This metaphor suggests that the teacher believed a compromise was achieveable between his constructivist beliefs and technical curriculum interests. The actual compromise entailed directing the class "to proceed" with new learning activities when the teacher had judged that the majority of the class were conceptually ready .

> ...I'm pacing the progress through the syllabus to a degree with the speed of which the students are coping with the work or beginning to comprehend it...I try to progress at such a rate that most of the students have a reasonable grasp of what we've done before we move onto anything else. (Interview 6, p2)

He admitted that one of the consequences of this compromise was that "there is always going to be two or three that probably are not ready to proceed" (Interview 6, p9). In practice, the teacher's delivery of the syllabus slowed and more time was available for whole class discussion and independent student activities. However, the teacher maintained a policy of common syllabus content for all students, and regrouped the class for frequent teacher explanations, regardless of the unreadiness of many students who were dealing with earlier activities. Clearly the teacher's pedagogical compromise was designed to better serve his technical curriculum interests rather than his constructivist beliefs.

Although his interactive style of teaching had enabled him to monitor more closely students' individual knowledge construction and make better informed decisions about students' readiness "to progress", it also resulted in his growing awareness of the range of abilities amongst the class, and the pedagogical futility of "wanting to see the class moving along together". He realized that the imposition of a lockstep approach to curriculum implementation resulted in a major pedagogical problem.

> The problem is that...even though it's a graded class there is a wide range of ability...and they don't all progress at the same rate...They bring to the class a range of abilities and motivations and you try and lock them into all coping the same. (Interview 6, p5)

The teacher acknowledged that he was unable to fully reconcile the conflict between his beliefs in a "self-paced" approach and the need to cover common syllabus content. He explained that his role of implementing a lockstep approach in order to satisfy school policy was "somewhat of a deception anyway" (Interview7, p10) because he was aware that student understanding would be compromised.

> ...if you force them to all go at the same rate some will be understanding the work perfectly , and others will be incompletely understanding it, and so you can say "well, OK, I've got all my class working together and we've covered this material and we've all reached the same point in the same time". But I think that's just an illusion, and what's happening to each individual student is very different - one from another. So whether they seem to be in step with one another is only a cosmetic thing, I think. (Interview 7, p9)

Student Motivation

During the second year of the study the teacher expressed a concern that, although most students were "generally interested...keen to do the work", he wanted the class "to be working more efficiently...progressing more quickly...moving along together" (Interview 6, p1). He claimed that student motivation was problematic for realizing this goal, and that 20% of the class were less than well motivated. This claim is similar to the teacher's claim, made early in the study, that 30% of the class were destined to fail because they were unable to keep up with the pace of his presentations; a situation that he believed was beyond his control.

The teacher's belief that "ideal self-paced learning" requires students who are "ideally motivated" (Interview 7, p9) implies that students' motivational development should precede, rather than be a consequence of, his "constructivist" teaching approach. Although he acknowledged that he had a role in trying to motivate students, his perception of the nature of motivational strategies continued to be limited to those for controlling student behaviour. The teacher continued to be not prepared to "coerce" students to learn, and had sustained a belief that trying to do so was a futile exercise, akin to "hitting my head against a brick wall" (Interview 7, p12).

> ...I sort of feel that you can lead a horse to water. I sort of can't be bothered... I feel by [Grade] 9, and certainly by [Grade] 10, it's about time they started to be a little bit self-motivated...if they're not starting to be by then I really don't feel there's much hope... (interview 7, p12)

The teacher perceived student motivation to be problematic in relation to his technical curriculum interests of "progressing" through the syllabus, and explained his main motivational strategy in terms of meeting this goal.

> ...I feel obliged to set certain deadlines as a kind of motivation incentive for the less well motivated students in the class... (Interview 7, p9)

The teacher's belief about the largely immutable and "external" nature of the perceived constraint of student motivation helped him to justify the pedagogical "compromise" in favour of his technical curriculum interests.

Reconciliation

On the one hand, the teacher professed a "constructivist" belief in students learning for understanding. He operationalised this belief by establishing a "self-paced" teaching approach, but was unable to fully implement it because of a conflicting belief in accomodating his technical curriculum interests. The resulting cognitive conflict was partially reconciled by recourse to the teacher's positivist beliefs in the immutability of "external" constraints compatible with his technical curriculum interests. In other words, he believed that it was not possible to fully implement a "constructivist" pedagogy in a less than ideal world where unresolved constraints prevailed. He did not conceive of a meaningful role for himself in overcoming these perceived constraints.

The teacher was able to achieve further reconciliation of his disequilibrated belief system by recourse to two "systems-stabilising" beliefs. The first belief was based on a narrow interpretation of the concept of "compromise" and appealed to the socially desirable notion of "fair play". The second belief was evoked in response to a desire to deal with the emotional discomfort associated with a sense of being "compromised".

Making Compromises

> ...there is a conflict in there, and the answer is 'what I do is a compromise between the two extremes'. (Interview 7, p9)

The teacher appears to have conceived of a "compromise" in the sense of settling a dispute by making concessions on both sides, of give and take, of "steering a middle course" between two opposing views. He seems to regard his conflicting beliefs to be analogous to social beings who are capable of negotiation and consensus building. He implies that the resolution, or "compromise", of the dispute is one to which both parties can subscribe with integrity, and that the outcome is compatible with the expectations of both parties. The teacher seems to subscribe to a model of industrial reconciliation for dealing with the cognitive "dispute" between his "constructivist" belief in student understanding and his positivist belief in the immutability of "external" constraints.

A compromise based on "fair play" has a socially acceptable sound to it. In negotiating a social consensus this concept has a high probability of evoking an empathetic response. The teacher appeared to have made recourse to this concept in negotiations with himself as he constructed a personally viable "constructivist" pedagogy. He proferred it also in negotiations with the author.

In practice, he continually abandoned the "self-paced" teaching strategy, in favour of whole class "interactive" teacher presentations of common content, when he perceived that his technical curriculum interests of "covering" the syllabus were threatened by lack of "progress". Although he interpreted his pragmatism as "steering a middle course", or achieving a fair balance, it entailed a continuous abandonment of his "constructivist" beliefs in favour of his technical curriculum interests. Although he espoused a metaphor for compromise that evoked a sense of social acceptability, the compromise only partially reconciled the teacher's cognitive perturbation. He remained aware, from his constructivist perspective, of the pedagogical futility of his pragmatism, which he described as a "deception...cosmetic" treatment of the problem of facilitating meaningful learning.

The teacher's pragmatic pedagogy best served his technical curriculum interests, while compromising his "constructivist" beliefs. The term "compromise" is used here to mean that the "constructivist" beliefs were prejudiced unfavourably, or weakened, in the interests of maintaining the integrity of his technical curriculum interests. The teacher's "system-stabilising" belief in making socially acceptable compromises was little more than a subterfuge for his positivist belief in the immutable nature of the "external" constraints which he perceived to be preventing him from fully implementing a "constructivist" pedagogy.

Being Compromised

The teacher acknowledged that he "felt" compromised by his pragmatism, but that he perceived it to be a problem of relatively minor concern.

> I guess it should and it does to a degree. But I guess it's the sort of thing you learn to live with, and most teachers live with it without probably even realising it. (Interview 7, p10)

He explained that many teachers don't have the conflicting beliefs that he now experienced as a result of participating in the study. He claimed that the narrow focus of teachers' pedagogical concerns enabled them to "live under an illusion" that their responsibility ended with their classroom presentations, rather than extending to students' (lack of) associated understanding. These claims seemed to imply that the teacher believed that his newly reconstructed pedagogy was based on a more "realistic" appreciation of students' learning processes and requirements, compared with the many teachers who continued to believe in the efficacy of the teaching style he had abandoned.

It seems likely that the teacher perceived his continuing cognitive perturbation to be little more than a minor side-effect of an advanced "constructivist" teaching style. This interpretation is supported by the teacher's further explanation that feeling compromised is a common place experience in the teaching profession.

> But I feel compromised by having classes of thirty-six too. There's lots of factors that I feel are compromises in the teaching situation. (Interview 7, p11)

The significance of the cognitive perturbation associated with the teacher's pragmatic pedagogy, seemingly, was further diminished by his recourse to a positivist belief in the inevitability of feeling compromised by immutable and "external" constraints associated with the teaching profession. In other words, feeling compromised by yet another conflict in his belief system, caused by an unresolvable constraint that he perceived to lie beyond his control, was not an unusual or significant event for the teacher. It is likely that his belief in the inevitability of being compromised served to reduce, to a tolerable level, the emotional discomfort associated with feeling compromised. However, this inference requires further data collection before it can be claimed to be fully substantiated

CONCLUSION

At the commencement of the study the teacher's established classroom practice reflected his technical curriculum interests and positivist epistemology. His managerialist classroom role enabled efficient delivery of syllabus content, and facilitated a teacher-centred learning environment in which students attended to largely non-interactive, whole class teacher presentations. The teacher's positivist pedagogy promoted mathematical knowledge as an external commodity which could be transmitted in a whole class forum to receptive students.

During a process of conceptual change the teacher developed a belief that students construct their own mathematical knowledge, and that they do so at rates that depend on the differential nature of their prior knowledge. He believed that a constructivist pedagogy should provide opportunities for students to undertake self-paced learning, and for the teacher to adopt an interactive role in order to learn about students' mathematical knowledge and to develop responsive teaching strategies. On the other hand, he sustained a belief that his main classroom role was to ensure that students were not prejudiced in their opportunities to be prepared for frequent school-based assessment as a result of his not "covering" the syllabus.

The teacher made only minor adaptations to his positivist epistemology. He acknowledged the private nature of students' knowledge construction and its dependence on prior knowledge. However, he overlooked key components of constructivism, including a concern for the process of social negotiation and consensus building which is central to students' determination of the viability of their own knowledge. The teacher maintained a centralist classroom role, and an overriding concern for the external validity of student knowledge. He continued to conceive of himself as the source of students' new mathematical knowledge. His complementary technical curriculum interests continued to determine a managerialist teacher role which disempowered students from developing as self-regulated learners.

The teacher continued to experience cognitive perturbation after the conceptual change process, because of the conflict between his "constructivist" belief in student learning for understanding and his technical curriculum interests which underpinned his belief that all students should "cover" identical syllabus content. He largely reconciled the cognitive perturbation by recourse to two "system-stabilising" beliefs: a belief in making a compromise between his conflicting beliefs, and a belief in the inevitability of being compromised. Both beliefs were underpinned by the teacher's positivist belief in the immutable and "external" nature of constraints associated with both the curriculum and students. He believed that these constraints lay beyond his control and would continue to prevent him from implementing his ideal "constructivist" pedagogy.

The teacher's "constructivist" pedagogy was shaped by a modified positivist epistemology which had accomodated, with minimal disruption to his established belief system, his new belief in student-centred learning. An optimistic interpretation of the teacher's conceptual and practical classroom changes identifies the teacher as being "in transition" to developing a constructivist epistemology and pedagogy.

IMPLICATIONS

Constructivist reforms to the classroom practices of "" teachers might founder on the "submerged reefs" of positivist epistemologies which underpin their beliefs in the realist nature of perceived constaints. These resilient beliefs can narrow teachers' interpretations of the nature of a constructivist epistemology, and stabilise the cognitive perturbation in their belief systems, thereby contributing to a premature termination of conceptual change. For teachers who continue to associate a belief in maintaining the integrity of their established technical curriculum interests with a belief in the inevitability of acquiescing to perceived immutable constraints, constructivist teaching reforms are likely to be severely curtailed. Constraints will be perceived as forming "concrete" boundary conditions within which only minor classroom reform processes are to be exercised. Consequently, constructivist teaching reforms are unlikely to address importai constraints that the teacher associates with the nature of students, or school or state curriculum policies.

By contrast, a constructivist epistemology generates a perspective on constraints as personal knowledge constructs that result from social negotiation. The negotiation process occurs at a number of levels. Not only does the community of policy makers and administrators negotiate the policies that give rise to the perceived opportunities and constraints that shape teachers' classroom practices. Teachers also participate in that process. The social negotiation of teachers' professional beliefs occurs both publicly and privately. Teachers construct their beliefs as they par' .pate with colleagues in formulating, or at least in giving tacit consent to, school-based policies that shape their classroom roles. At a more informal and subtle level, teachers construct their beliefs about the possibilities of the teaching and learning process as they are encultured into the professional social frameworks of their schools.

A corollary of the constructivist perspective on constraints is the view that the individual teacher is totally responsibile for sustaining or initiating the reconstruction of their own beliefs about the constraints and opportunities that shape their classroom practice. Reconstruction of beliefs requires social negotiation at a number of levels. At the classroom level there is the individual teacher's self-negotiation, or reflection on, their personal beliefs and practices. The viability of the teacher's reconstructed pedagogy is likely to be enhanced by ongoing negotiations with students, as teacher and student assumptions about classroom environment constraints are explicitly articulated and evaluated. An additional level of reform is necessary to ensure that individually reconstructed teacher beliefs and practices are not only viable within the classroom, but are compatible with significant others in the local and professional communities. At the school level there is the social negotiation of the beliefs and practices of professional colleagues, especially in relation to the reconstruction of departmental policies associated with perceived constraints. Other levels of constructivist reform address the beliefs of the school's local community and district and state policy makers.

The effective implementation of constructivist reforms to classroom teaching requires new consensus building at all levels of the educational community. A constructivist epistemology provides a perspective that views this as an attainable goal for reform minded classroom teachers.

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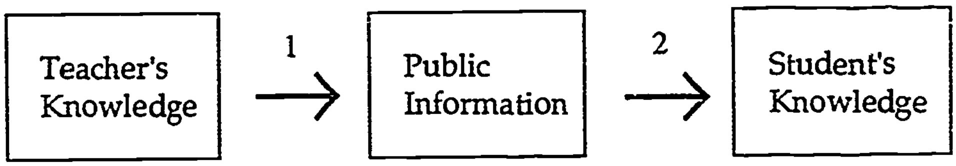

1 first transformation (reduction)

2 second transformation (synthesis)

Figure 1 Knowledge transformations in the teaching - learning process

(Fleming, 1988, p 15)