Teacher intervention during mathematical problem-solving instruction

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In the current reform movement in mathematics education, problem solving is being emphasised as a basis of mathematics thinking and a basis of learning mathematics (e.g., NCTM 1989, 1991). Implicit in this perspective is that problem solving is an open-ended process that requires flexibility in the thinking and behaviours of both teachers and students. This view of problem solving forms the basis of this paper in considering the teaching of problem solving. The paper examines the nature of teacher intervention during students' problem solving based on a study (Chapman, 1999) that investigated the effect of a humanistic problem-solving inservice [PSI] program on elementary school teachers' thinking and teaching of mathematical problem solving. The classroom behaviours of the participants of this study are discussed from the perspective of symbolic interaction, i.e., a focus on the teachers' personal meaning and supporting symbolic systems that formed a basis for how they conceptualised and facilitated students' behaviours during problem solving. The paper describes some viewpoints on the teacher's role during problem solving, symbolic interaction in relation to the classroom, and the PSI program before focusing on the interpretation of the teachers' behaviours and implications about intervention during problem-solving instruction.

The Teacher's Role during Problem Solving

A number of differing viewpoints regarding instruction on problem solving have been proposed, the most common of these are based on Pólya's four-stage model (Pólya, 1957). Pólya, himself, suggested that the teacher must play an active role

during problem solving — actively observing and questioning students during their experiences. The overall goal is to have students do as much thinking for themselves as possible.

Charles and Lester (1982) identified two contexts in which teacher behaviours during problem solving have been described in the literature. One context identified the types of teacher behaviours that should be used at each of Pólya's stages. For example: The teacher might ask questions to help the student *understand the problem*. The teacher should direct students' attention to related problems and previously used strategies where possible to help the student *devise a plan*. The teacher should encourage students to solve the problem on their own in *carrying out the plan*. The teacher can ask students to describe to the class the strategy used in solving a problem in *looking back*. The second context was an extension of the first and identified teacher behaviours in terms of 10 teaching actions grouped into 3 distinct time periods that make up a problem-solving session: before, during and after the problem is solved. For example: *before*, the teacher should discuss words or phrases students may not understand, *during*, the teacher should provide hints as needed, and, after, the teacher should show and discuss solutions.

These conceptions of the teacher's role during problem-solving instruction have not changed over the years. They bear similarities to conceptions of how it has been recommended that teachers should behave in teaching mathematics, in general, in the context of, for example, a problem-solving oriented classroom (NCTM 1991), or a constructivist learning environment (Confrey, 1990; Pirie & Kieren, 1992). In both situations the underlying theme of the teacher's behaviour is to help students to be active learners and to think for themselves. However, while these conceptions of the teacher's classroom behaviour reflect teaching strategies that are important to enhance the learning of mathematics, the way they are presented to the teachers, e.g., as a list of actions, can be problematic.

A list of specific teaching actions may seem like a useful guideline for teachers, particularly beginning problem-solving teachers, however, the implicit assumption that teachers will apply the list as intended is questionable. Teachers could use the list as an algorithm, for example, thus creating a misleading situation for themselves and the students. Furthermore, such lists of guidelines deal with surface or observable behaviours in isolation of the teachers' thinking and how their personal experiences influence their behaviours regarding intervention. Since it is the teacher who must interpret such guidelines in the context of real classrooms, then the teacher's perspective becomes a necessary lens through which to understand classroom behaviours/actions during problem solving as opposed to the prescribed behaviours/ actions by themselves.

Symbolic Interaction in Relation to the Classroom

Symbolic interaction, as a way of understanding interpersonal communication, formed the theoretical context for viewing teacher intervention as it unfolded in the PSI program. The central idea of symbolic interaction (Blumer, 1969) is that human interactions are carried on through the medium of symbols and their meanings. Reality is not disclosed directly, but is experienced through symbols and activities mediated by language and culture. As Blumer (1978) explained:

> Human beings interpret or "define" each other's actions instead of merely reacting to each other's actions. Their "response" is not made directly to the actions of one another but instead is based on the meaning which they attach to some actions. Thus, human interaction is mediated by the use of symbols, by interpretation, or by ascertaining the meaning of one another's action. This mediation is equivalent to inserting a process of interpretation between stimulus and response in the case of human behavior (p. 97).

In relating symbolic interaction to the classroom, the assumption is that teachers and students rely on symbols, whether consciously or not, both to create and "read" the learning environment. Thus, these symbols are powerful influences on learning and teaching. Teachers and students do not typically respond directly to each other's actions as stimuli, but assign meanings to the actions and act on the basis of the meanings. Such meanings are socially derived through interaction with others rather than inherent in the actions themselves or idiosyncratically assigned by the teacher or student.

When viewed through symbolic interaction, the mathematics classroom can be seen as interweaving symbols and signification systems that students and teachers use, whether consciously or not, as texts of mathematics learning and teaching. These symbols emerge from a variety of situations in the classroom. During a lesson, who can talk, when, how, and about what are examples of symbols. Other examples of symbols are: the way a teacher structures a lesson (e.g., focus on drill); the way the teacher uses time (e.g., time spent on a particular concept or type of problem) and space (e.g., arrangements of desks) during a lesson; the physical presence and location of the teacher (e.g., circulating among students) during the lesson; and the number and type of word problems assigned. For both teacher and students, consciously or unconsciously, these are likely to be symbols that convey what should be valued in the mathematics classroom and about mathematics. These symbols are all relevant to the classroom during problem-solving instruction.

In the context of teacher intervention in students' learning, the presence of such

symbols can be viewed as representing some form of intervention whether or not the teacher intended them to be. Teacher intervention, then, is a complex endeavour when viewed in terms of symbolic interaction. Thus, the intent of this article is not to provide a complete picture of teacher intervention during problem-solving instruction, but to draw attention to possible symbols and meanings teachers could construct for themselves that get enacted in their behaviours in the classroom. The basis for this discussion is the problem solving inservice program.

The Problem-Solving Inservice [PSI] Study

The PSI study investigated the effect of a humanistic approach to teacher development as a basis for facilitating change in teachers' personal meanings and practice. The approach was found to be effective in allowing teachers to make significant, meaningful shifts in their thinking and teaching of problem solving. Details of this study, focusing on the nature of the PSI program and changes in the teachers' personal meanings and teaching, are described in Chapman (1999) and will not be reproduced here. However, a summary of relevant aspects of the study will be provided to set the context for the discussion on findings about intervention.

PSI participants

The participants were six inservice elementary school teachers (Grades 3 to 6) who taught mathematics very traditionally and were interested in changing their teaching of problem solving. They volunteered for the study and had no previous experience with the researcher. They participated in the inservice program over a 4-week period during their summer break. They had little or no experience solving non-routine problems as learners. They were exposed to a perspective of problem-solving instruction based on the approaches prescribed by their textbooks. These approaches generally involved a demonstration of a strategy, followed by a set of similar problems to be used to practice the strategy.

PSI activities

The activities of the PSI program were organised into four stages: introduction, reflection on personal meaning, problem-solving experiences, and reflection on problem-solving experiences. Stage 1, the introduction, focused on the nature of narrative reflection, e.g., writing and sharing self-stories and resonating in stories of

peers as a way of becoming aware of and understanding one's thinking. The main activity involved practising narrative reflection in terms of how to facilitate depth in personal reflections, sharing, and collaboration. Stage 2, reflection on personal meaning, focused on the teachers' histories, actions, and intentions in the context of teaching and learning problem solving prior to entering the PSI program. The main activity was narrative reflection with a focus on self, content, teaching, and learning.

Stage 3, problem-solving experience, focused on non-algorithmic problem solving based on three themes: the problem-solving process of an individual, the problem-solving process of a small group, and teacher-student interactions while students solved problems. The key activities allowed the teachers to solve a variety of problems that were non-routine for them and to actively experience each of the three themes. For example, they engaged in role-play taking turns being student and teacher in different scenarios for the teacher-student interaction theme. Stage 4, reflection on problem-solving experiences, focused on what the teachers learned as a result of the experiences in Stage 3. The main activity was narrative reflection on self, content, teaching, and learning, similar to Stage 2.

The participants spent approximately 20 hours working together with the researcher as facilitator and approximately 10 hours working individually, without the researcher, on the PSI activities. The goal was to allow them to construct knowledge for themselves based on their experiences with the activities. Therefore, at no time were they given any theory or provided with any prescriptions on problem solving or problem-solving instruction. There was also no support or intervention by the researcher following the program activities since the teachers were expected to determine their teaching by themselves in whatever way they wanted.

PSI-study data

Data for the PSI study included interview transcripts of audio-tapes of open-ended interviews prior to and after the PSI program and all oral aspects of the PSI activities (e.g., group discussions and narrative reflections). Copies of all written work during the program (e.g., solutions of problems, journals of individual reflections, summaries of group discussions) were also obtained. The teachers were observed in their classrooms while teaching problem solving, before and during the three terms immediately after the PSI program. Teacher-student verbal interactions during these lessons were audio-taped and transcribed.

Data analysis of teacher intervention

The analysis of teacher intervention evolved from the PSI project in reaction to the significant shift in the nature of the participants' thinking and classroom behaviours during problem-solving instruction. The decision to use symbolic interaction to frame the analysis was made because of the explicit cues the teachers constructed to guide their interaction and the apparent symbols that were evident in the data during the PSI study analysis. Thus a formal analysis of a deductive nature was used to investigate the symbols and their meanings that seemed to underlie the teachers' behaviours.

An interpretative research approach (Bogdon and Taylor, 1975) similar to that of the PSI study was used to determine meanings associated with the teachers' actions. The data were scrutinised to identify recurring themes of how the teachers viewed and practised intervention prior to and after the PSI experience. Themes from interviews were triangulated with themes from the teachers' group discussions and their actual classroom discourse to determine the final set of themes. The symbols and descriptors (e.g., separation and connection) to reflect the essence they embodied for the teachers were deduced from the data based on these themes. The analysis built on the findings of the PSI study in terms of the personal meaning the participants constructed prior to and after the PSI experience as a basis for interpreting the themes identified in relation to their symbol systems. The teachers' personal meanings were viewed as embodying what a teacher feels, thinks, believes, and wants (Elbaz, 1990; Polanyi, 1958).

The Nature of Teacher Intervention

The outcome is presented in terms of when and how the teachers intervened and their bases for intervention in terms of plausible interpretations they used (consciously and unconsciously) to determine their actions. In reality, the teachers' basis for intervention is likely to be a complex network of related experiences. Thus what is offered here is not intended to be a complete picture of their thinking but significant aspects of it that could inform us of how they try to make sense of intervention during students' problem solving. In addition, teacher intervention will be considered only in terms of what the teacher does when and after a problem is assigned to students to solve.

The teachers' intervention before and after the PSI program was significantly different as a result of the shift in their perspective about the nature of the problem-

solving process and their experiences in solving problems. One common theme in all of the teachers' behaviour was that intervention was a process of separation and connection from the teacher's perspective. Separation involved a form of decontextualisation in which the teacher consciously removed herself from the student's experiences with the problem or from her experience with the problem. Connection involved a form of contextualisation in which the teacher participated in the student's experiences with the problem or relived her own experience with the problem. The teachers' pre-PSI behaviours reflected two general patterns of intervention in terms of when and how separation and connection unfolded. These patterns were mutually exclusive in that the teachers could be grouped into one or the other. In contrast, the teachers' post-PSI behaviours reflected one general pattern of intervention, consistent with the knowledge they constructed during the PSI program, in terms of when and how separation and connection unfolded. These patterns of intervention will be described in the context of the teachers' pre-PSI and post-PSI teaching of problem solving.

Pre-PSI Teaching

Prior to the PSI program, the teachers taught problem solving by modelling examples (problem-modelling stage), requiring students to practise similar problems (problem-solving stage), and checking students' solutions (problem-assessment stage). Intervention is being considered here as it relates to the problem-solving stage. Case 1 and Case 2 will be used to refer to the two dominant patterns of teacher behaviour during this stage, i.e., separation to student and connection to problem, respectively.

Case 1

During the problem-solution stage of the lesson, students were given the problem and left to work on it individually. Throughout this stage, there was no observable interaction between teacher and students in relation to the problem solution. For example, students were not allowed to ask questions and, if they did, they were reminded to do the problem on their own. The teacher did not circulate to observe the students. For example:

> I didn't intervened. I didn't walk around. It was almost like a contest, like here is the problem, let's see what you can do with it. ... Don't ask me for any help, use your brain. ... But the contest was can you come to an acceptable answer without any help, because I felt that my helping them was not helping them.[Susan]

> I tended to just give it [the problem] to them and then leave them with it ...because either you get it or didn't get it.[Rose]

In this case, separation from the students characterised the teachers' behaviour when viewed from the context of social interactions. From the teachers' perspective, separation allowed the students to think for themselves. More importantly, it conveyed the teachers' meaning of how students should think for themselves based on what the teachers emphasised explicitly, by what they said, and implicitly, by what they did, during the problem-modelling stage. For example, explicitly, the use of cue words was emphasised to determine the algorithm or strategy to use in solving the problem. Implicitly, the teachers knew the cue words for solving the problems assigned and wanted students to determine those in order to solve the problems. Thus, in the context of separation, the teachers saw the students as being in search of cues as a primary strategy to solve the problem. They also assumed that the students took for granted that the teacher was the source of the cues. Separation, then, prevented the students from reading the teacher, directly or indirectly, in order to pick up cues to a solution. Such cues were to be obtained directly from the problem. Thus the teachers' goal was to help students to do the problem by themselves by not allowing them to make the teacher an extension of the text of the problem (e.g., viewing the teacher as having information not explicitly stated in the surface story of the problem). These teachers saw no conflict for their students who were expected to not treat them as the architect of the solution given that it was the approach they modelled that the students were trying to reproduce. The teachers intervened during the problem-assessment stage only to confirm the answer or to demonstrate how to get it if no one did.

The teachers' interpretation of the teacher's and students' roles during problem solving, in this case, seems to be directly related to their interpretation of their own actions, in relation to their teachers' actions, as students of mathematics. For example, as students, they were required to solve problems without any assistance from the teacher even when they were stuck and had no clue of how to proceed. Through this experience, they were led to believe that to be stuck was an indication of lack of ability to solve the problem, since, as Rose put it, "either you get it, or you didn't get it." Thus intervention prior to the problem-assessment stage of the class was redundant whether one was stuck or not. This made their approach valid from their perspective.

Case 2

In the second version of intervention for the pre-PSI teaching, during the problem-solving stage, students were given the problem and asked to work on it individually. Unlike case 1, students were allowed to interact with the teacher by asking for help, which the teacher provided in a direct way. The teachers, for the most part, did not circulate among the students. Students were expected to initiate the interaction by going to them or calling them over to ask for help. Regardless of the nature of the help requested, the teachers focused on directing the students to their predetermined solutions of the problems. For example:

> It is hard because you do have that answer in your head, and you do want them to come up with that answer. [Ann]
> I always looked at the [student's] answer. ... I looked at the written part that was important to me. ... I guess I really considered my way was the only way. [Mary]
> [If] it [the answer] didn't fit where I was intending it to be, I would say, "Well, that is not what I was looking for." [Pam]

In this case, connection to the problem characterised the teachers' behaviour when viewed from the context of social interactions. The teachers behaved as a direct link to the solution. All of the students' actions were interpreted in relation to the teacher's version of the problem, for example, a request for help was a request to know the teacher's solution. Unlike Case 1, each teacher now allowed and encouraged the students to make her an extension of the text of the problem by seeking out the solution of the problem, directly or indirectly, by questioning her and/ or observing non-verbal cues she provided. For example, a teacher would read a line of the problem and stress certain words and/or pause or stare at the students after the stressed words. From the teacher's perspective this gave the students a chance to "think for themselves" in solving the problem. If they still could not get the solution, they were told explicitly what to do. Intervention became a situation where the teachers allowed students to read them, and not merely the problem, for information about the solution and for when and how to extract this information from them.

These teachers had similar experiences as students of mathematics to that of the teachers in Case 1, i.e., they were required to solve problems without any help from their teachers, but they interpreted it differently in terms of the teacher's role in intervention. They felt abandoned by their teachers and viewed it negatively. Thus, they were both empathetic and sympathetic to their students. They assumed that any apparent abandonment of their students to solve problems without their help would create in their students the same fear they experienced and wanted to provide some

relief for them. The nature of their intervention, then, was also to minimise fear, to show support, and to aid confidence. Maintaining connection with the problem allowed them to accomplish this by leading students to the solution whenever necessary.

Post-PSI Teaching

There were significant shifts in the teachers' views and classroom processes of teaching and learning problem solving as a result of the PSI experience. For example, as described in Chapman (1999), the teachers emphasised group work and problem process over final answer, considered alternative solutions, and made students share solutions and meanings. But what seemed of significant importance to the teachers was asking non-leading questions and listening more to students in terms of focusing on their processes and thinking behind "right" and "wrong" answers. For example:

> I am focusing more on what students are thinking.... Before, I never really thought much about... going around and asking, you know, "Why are you doing this?" Or, "What is this all about?" [Pam]
> You have got to let go of that [answer in your head] and you have got to let them make their own discoveries. So I keep trying to do this, to ask the kids questions in the right way and not forcing them to come up with my answer.[Ann]

All of the teachers now considered interacting with the "real world" or "real things/people" to engage in problem solving to be of significant importance. For example,

> It would be neat to take the kids right into actual situations. Go to the zoo and have problems and deal with them right there or wherever. I guess just even making it more concrete for them.[Mary]
> But to relate that [problems] to everyday life, I find that that is really important. [Wendy]

The PSI experience also made them more appreciative of the necessity to provide a safe environment for students to explore and express their thinking. For example,

> We could put those insecurities [about problem solving] on the table and know that we were still going to be respected. [Mary]

These shifts in the teachers' thinking led to significant shifts in how they viewed the teacher's role and the students' role during problem-solving instruction. For

example, students were viewed as active participants in a personal process of thinking, thus, the teacher had to be flexible in her thinking and actions in order to facilitate this. The teachers' actions were dependent on the students' experience with the problem more than the teacher's experience with it. Thus the goal of intervention was not to get the students to relive the teacher's decontextualised experience in solving the problem but to allow them to construct their own experiences for themselves. In this regard, the teachers considered knowing when and how to intervene to be of most importance. For example,

> Don't jump in too soon. ... There is a fine line between jumping in too soon and staying back too long. ... The kids will need time to work things out for themselves. [Wendy]
> Questioning too is really important. ... Through questioning you may be able to help them through it so they may feel better in the end. [Susan]

Thus, intervention should be both passive and active. During passive intervention, the teacher should only listen to the students to become aware of their thinking and to give them time to think on their own. Active intervention, however, required that the teacher communicate with the students, not to tell them how to get the answer, but to stimulate their thinking to get beyond obstacles and to make sense of their processes.

In order to implement this shift to a student-centered focus of problem- solving instruction, the teachers recognised certain conditions that were necessary to lay the foundation for meaningful intervention. Based on their pre-PSI teaching, they expected their students to understand teacher-student interaction in terms of what they had experienced in the traditional, teacher-centered classroom. Thus the students would still see their role as trying, directly or indirectly, to get the teacher to do the problem for them instead of really thinking for themselves. In order to initially minimise and eventually remove this conflict, the teachers determined that it was necessary to establish a vocabulary to make explicit a different context for students to interact with problem and teacher. This vocabulary was to provide the symbols to help to facilitate mutual interpretation of when and how the teacher should intervene in order to create a learning environment that would allow the students to be more autonomous during problem solving. Based on their PSI experience, the teachers selected a set of terms they felt specified the essence of the problem-solving experience that was relevant to the classroom context. Although this was done individually after the PSI experience, for the most part, the teachers selected the same terms, i.e., obstacle/barrier, stuck, off-track, challenge, make sense, interpretation/meaning, strategy, listening to.

During the first two problem-solving classes the teachers engaged students in activities they each developed to enable them to understand how to interpret these terms in relation to the problem-solving experience and teacher intervention. These activities were in the form of sharing stories or anecdotes to illustrate the terms or discussing more concrete experiences like the following: the Grade 4 teacher blindfolded two students who then had to walk from the front to the back of the class. The other students observed. This experience was used to help students to think of problem solving as a challenge in which one encounters obstacles/barriers to a solution, i.e., obstacles were not to be interpreted as situations to be feared, but challenges to be conquered. The discussion included what it meant to be stuck or off-track, to have a strategy, to interpret and make sense of the situation. The terms were reinforced whenever the teacher saw necessary in particular situations. For example, Mary, Grade 3, often reminded her students about "listening to" and collaborating as a group. When having students discuss their solutions, she would remind them to listen to the ideas of others to see if they made sense.

Within this student-centered context, the teachers conceptualised the problem-solving lesson in 3 stages for each problem: problem presentation, problem solution, and solution sharing. The vocabulary established with the students became the basis for teacher intervention during these stages. But during the PSI program, the teachers had constructed for themselves particular meanings for some of the terms to guide their intervention. Of particular importance was stuck, off-track and lost, all of which were considered to be important indicators for active intervention. These indicators were interpreted based on the teachers' PSI experiences. For example, the idea of lost emerged when one teacher could not make sense of a problem in spite of the help all of the others tried to give. The help only made her emotionally agitated, negatively, and led another teacher to declare, "she is totally lost."

The teachers considered stuck, in relation to intervention, to be when the students tried everything they could by themselves and were about to become frustrated. Here the student should initiate the intervention and the teacher should intervene by asking open-ended questions (e.g., Where are you stuck? What have you tried? What else can you do/try?) and/or make an open-ended suggestion of something to try. Off-track was considered to be when the students were doing something incorrect based on how *they* interpreted the problem or on the strategy they were using to solve the problem. Here the teacher should initiate the intervention and intervene by asking open-ended questions (e.g., Are you sure that is what you want to do?) or making an open-ended comment. Lost was considered to be if the students were confused and disoriented, lost control of the problem, and could no longer make sense of the problem or any help provided. Here the teacher should take control of the situation

in order to re-orient them to a specific solution. This could involve the teacher explaining the problem and a possible solution directly or with the help of students who were able to do it.

Similar to their pre-PSI teaching, the teachers' post-PSI intervention during problem-solving instruction could be understood in terms of connection and separation in the context of social interactions. However, the meaning underlying the connection and separation was very different. This will be discussed for each of the three stages previously noted, i.e., problem-presentation, problem-solution, and solution-sharing stages. The level of connection and separation varied in degree for each teacher. However, only the general pattern will be discussed instead of individual situations.

Problem-Presentation Stage

The dominant goal of this stage was to let students own the problem. As Susan explained:

> I am more aware of things like [the student] owning the problem, like is this really a problem for me [the student] or is this just something that I have to do to make it through the next 20 minutes.

In order to own the problem, students were required to interpret if for themselves. For example,

> [My] focus the whole year was on meaning and thinking through things. ... I give them a problem, which is written, they read it themselves, then I ask for their interpretations. [Susan]

There were variations in how this stage evolved. For example, Mary led her Grade 3's in a large group discussion while Pam had her Grade 3's work, first, individually, then in partners to arrive at their own meaning of the problem (Chapman, 1999). Rose told her students, "tell what you think the problem means to you." She, like most of the teachers, required that the students write their interpretations.

In this stage, the teachers became detached from the problem in order to allow students to connect to it. Thus the teachers did not intervene with any predetermined interpretation of the problem. The teachers, for a few minutes, also became detached from the students in order to allow them to connect to the problem. Thus they only reminded students of their task, e.g., write your meaning, discuss your meaning with a partner. Finally, the teachers helped the students to connect with each other and the

problems as they shared their interpretations. For example, the teachers would ask for volunteers to respond to any queries raised and remind students to listen to each other's interpretations. Most of the teachers chose passive intervention at this point, i.e., they listened to the interpretations but did not try to "correct" anything, they simply acknowledged them.

Problem-Solving Stage

The dominant goal in this stage was for students to become decision makers in deciding on a strategy and testing it. The teachers continued to be detached from the problem to now allow students to develop and work on a strategy. However, they became connected to the students and the learning environment by circulating and constantly interacting with the students either passively or actively. During passive intervention the teachers either observed to learn for themselves or to be informed if help was eventually needed. They tried to see what the students saw, thus trying to connect with the students' perspective. During active intervention, they focused on when students were stuck, off-track, or lost. For stuck and off-track, Pam, for example, first intervened with questions like, "What have you tried?" "Why did you add?" "What part of the problem asked you to do that?" "What else do you think you can try?" "Why don't you try drawing a picture or using a chart?" "Is that what you really want to do?" She gave them time to resolve difficulties on their own. For lost, she provided more direct guidance by telling them what was wrong or how to get started. But in general, she allowed them to arrive at a solution in their own way even if incorrect.

Solution-Sharing Stage

The teachers remained detached from the problem in order to allow students to share and justify their solutions. Only if the teachers' solution was very different from the students' that it got presented as an alternative and not THE solution. The teachers intervened to encourage reflection and discussion of the solutions in a variety of similar ways. For example, Mary asked questions like: "What do you think of ....?" "Which of the answers do you think is/are correct and why?" "Why does it make sense?"; while Pam asked questions like, "What do you think about their method?" "Does it make sense?" "What doesn't make sense?" "How can they fix it?" Students were also encouraged to talk about what they thought about the problem, e.g., what they liked or did not like about the problem. In general, then, intervention during this stage was not simply to check solutions but to connect students, teacher, and problem in meaningful ways.

Discussion

In the context of symbolic interaction intervention from the teacher's perspective can be understood in terms of the symbols and personal meanings the teacher consciously and unconsciously uses to frame her or his actions. In this study, the symbols were particular actions of the students in relation to getting to a solution for a problem. In the pre-PSI, teacher-centered teaching, these symbols were predominantly students' questions to the teacher. Students' questions indicated for the teacher that the students were in search of the teacher's solution for which they were given direct help or delayed help to acquire. In the direct-help situation, the students were led to the solution through direct questions or telling, while in the delayed-help situation, they were abandoned to get there by themselves before having the solution explained to them. In both cases, intervention by the teachers was likely to be an obstacle to the students' development of their problem-solving ability. But from the teachers' perspective, it was for the good of the students. The teachers were unaware of how they blocked the students ways of thinking and promoted their own as a reflection of what the students' were or ought to be. However, they became aware of it through their PSI experiences.

In the post-PSI, student-centered teaching, the symbols that guided intervention were students' questions, oral responses, written responses, and physical expressions. These provided cues for the teacher about when students were stuck, off-track, and lost. These cues were dependent on the teacher's judgement or personal meaning. For example, what was considered stuck for one student could be considered lost for another based on how the teacher perceived the student's ability to solve problems. Thus the teacher's interpretations or personal meaning of the cues and not the cues in themselves guided intervention. However, the interpretations often evolved from communicating with the students. When considered necessary, the teachers were able to suspend their interpretations until after communicating with students to make sense of the context embodying the cues. For example, a student was perceived to be off-track only after the teacher got a sense of what the student was trying to do after questioning him or her. The goal of this communicating was to listen *to* the students as opposed to listening *for* specific behaviours.

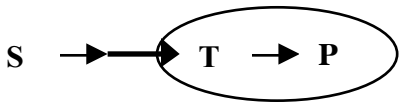
In general, the post-PSI intervention from the teacher's perspective (i.e., her personal meaning) involved a sequence of related teacher behaviours: awareness of symbols, identification of cues, communication with students about context embodying cues, interpretation of cues, enacting the interpretation. The significant difference between pre- and post-PSI intervention was allowing the students to play

an active role in the interpretation of cues in the latter and not the former. Thus the post-PSI intervention was more supportive of the students' ways of thinking and what was meaningful for their own development of their problem-solving ability. The post-PSI intervention was also more supportive of the teachers' growth in terms of their problem-solving ability by opening up the teachers to alternative ways of thinking. Thus it provided a context in which the teachers and students learned from each other. This form of intervention is consistent with the reform perspective of teaching mathematics in terms of recognising the active, social, and constructive nature of the learning process.

In the context of social interactions and from the teacher's perspective (i.e., her personal meaning), the study suggested that intervention could also be conceptualised as a process of separation and connection with students and/or problem. Separation appeared in the teachers' classroom behaviours as a distancing from, a low level of awareness of, or a decontextualising of an experience, while connection appeared as the opposite. The teachers' personal meanings underlying this separation and connection were significantly different for their pre- and post-PSI teaching. Thus separation and connection were interpreted and enacted differently in characterising intervention in the pre- and post-PSI situations.

In the pre-PSI situation, each teacher's commitment to her interpretation and solution of the problem was the focus of when and how separation and connection with students' experiences occurred. The teacher and problem existed as one entity and the students as the other. There was a one-way relationship between these two entities: For case 1,

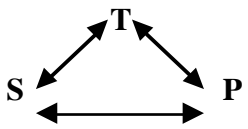
where indicates the students reaching out to the teacher and problem to determine a solution while the teacher isolates herself from them to keep them out of her context. For case 2,



where → indicates the students reaching out to the teacher and problem and ⟶ indicates the teacher drawing them into the teacher's context. In both cases, T → P indicates that the teacher specifies the problem but does not allow herself or the students to see alternative possibilities presented by the problem.

In the post-PSI situation, after overcoming the conflicts with students during the initial period of helping them to shift to the student-centered approach, the conditions that supported the teachers' ways of separating and connecting in the pre-PSI situation were invalidated. Thus the teachers became less concerned about students' fears because students began to enjoy problem solving. They were also less concerned about being treated as extensions of the text of the problems because students wanted to do the problems for themselves. In fact, if students were off-task, the teachers thought that it was the problem that was not interesting as opposed to making judgements about the students' ability as in the pre-PSI situation. In general, the teachers shifted to being more concerned about keeping themselves separated from their versions of the problems when intervening.

In their post-PSI teaching, each teacher's commitment to the students' interpretation and solution of the problem became the focus of when and how separation and connection with students' experiences occurred. The teacher, students and problem now existed as a triad of two-way relationships in which the teacher recognised a teacher-problem connection (i.e., teacher specified problem and problem specified teacher), a student-problem connection (i.e., student specified problem and problem specified student) and a teacher-student connection (i.e., teacher specified student and student specified teacher) as follows:



The specifying between two entities refers to how each allows the other to perceive it/him/her (Merleau-Ponty, 1962). For example, in the teacher-problem and student-problem situations, the specifying is dependent on the problem providing opportunities for alternative solutions and the teacher and students being able to see one or more of them.

During the teacher-student interaction, the teacher tried to separate from the problem while the students were encouraged to stay connected to it. For the most part, the teacher tried to stay connected to the students and thus to the problem through the students. Thus during intervention, the teacher had to hold more than one version of the problem simultaneously when the students had alternative ways of dealing with it. As the teachers noted, this was initially difficult to do and often challenging to maintain.

The significant differences between the teachers' conceptualisation or personal

meanings of intervention in their pre- and post-PSI classroom behaviours seemed to be a direct result of the nature of the personal experiences they had with problem solving and their interpretations of those experiences. The teachers' intervention rested on assumptions built into their way of looking at what they saw in the students' actions, when those assumptions were altered their perception of the situations altered with them and changed their personal meanings and behaviours. The PSI activities seemed to allow the teachers to construct useful symbols for interpreting students actions, which they were able to understand in terms of a different set of assumptions, or personal meanings, they had lived through.

The implication for teacher development is that if personal experience is a significant determinant of teacher intervention, then simply telling teachers how to intervene is unlikely to be effective to bring about meaningful changes to their behaviour. In particular, teachers would need to understand the nature of the symbols and personal meanings they currently use that influence intervention and what are alternative symbols that they could adopt to change their approach to intervention. The study suggests that it is of significant importance that they self-construct these alternative symbols. This would allow them to personalise the meanings through their personal experiences thus making it easier for them to articulate the teacher's personal meaning of the symbols and allowing intervention to become more natural for them.

Conclusion

Teacher intervention during problem-solving instruction has been presented as a reflection of the teacher's personal meaning of the teacher and students' roles in the classroom and of specific symbols or cues in students' actions. This focus on personal meaning makes self-understanding an important aspect of teacher development or growth in providing meaningful intervention during instruction. As reflected in the PSI findings, a meaningful pattern of intervention could emerge when teachers co-construct their understanding through individual and shared mathematical problem-solving experiences framed in a humanistic context. One such pattern, discussed in this paper, involves the follow sequence of related teacher behaviours: awareness of symbols, identification of cues, communication with students about context embodying cues, interpretation of cues, enacting the interpretation. This pattern embodies a process of separation and connection among teacher, students and/or problem that characterises their interactions. Helping teachers to understand such patterns in their own teaching could be a useful step in facilitating changes in their

teaching.

The paper did not consider student's interpretation of implicit cues in the teachers' behaviours that could lead to complication of how teacher-student interaction actually proceeds. This perspective is needed to get a total picture of how intervention could aid or hinder students' learning of problem solving.

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ABSTRACT. A humanistic problem-solving inservice program is discussed in terms of its effect on how elementary teachers intervened during problem-solving instruction. The effect is discussed from the perspective of symbolic interaction, i.e., a focus on the teachers' personal meaning and supporting symbolic systems. As a result of participating in the program, the teachers constructed a different set of symbolic systems to guide their interactions with students in a way that emphasised

an autonomous role for the students during problem solving. The paper provides insights of teacher classroom behaviour in terms of such symbols that are important in understanding the teacher's perspective of teaching problem solving and how to facilitate meaningful changes for the teacher.

Key words: *Teacher intervention; problem-solving instruction; symbolic interaction; teacher-student interaction; personal meaning; teacher's perspective.*