TEACHERS' APPROACHES TO PROMOTING SELF-MONITORING IN PHYSICS PROBLEM SOLVING BY THEIR STUDENTS

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ABSTRACT

This study describes the professional development of physics teachers during two years in which they collaboratively addressed the pedagogical question: "How can we promote self-monitoring by students in physics problem solving?" The collaboration took place in computerized forums and e-conferences. Repeated cycles of teacher inquiry were structured to include: Developing and trying out instructional innovations, documenting classroom experiences, obtaining peer feedback, formulating and discussing questions concerning the classroom experience, and trying out improvements.

We found that teachers incorporated diverse perspectives in tandem with their growing understanding of students' problem solving: Initially adapting to different physics topics, then meeting students' diversity, finally focusing the guidance of students on revision rather than on the whole problem solving process.

The change in teachers' attitudes towards promoting self-monitoring by students in physics problem solving was not straightforward. Although at first it seemed that there was a consensus on goals, and there was just a need to consider means, in the course of implementation teachers gained a deeper sense of relevant issues and decided to re-examine goals. This led to a stronger commitment of the teachers to the workshop goal, which enabled them to dare and take diverse and non-traditional approaches in their classrooms.

1. INTRODUCTION

The pedagogical problem of promoting self-monitoring by students in physics problem solving was addressed in several instructional studies. Heller & Hollabaugh [1] designed context rich problems to impose a need to analyze a complex and unfamiliar situation, and plan a solution. They had students solve problems cooperatively to establish a discussion in which students question and evaluate the ideas of their peers. Problem solving strategies serve to guide decision-making, so an iterative perception of the problem solving process is promoted, hand in hand with students' responsibility to diagnose their mistakes and revise solutions. The "mechanics in action" project [2] included an alternative assessment method in which the students themselves diagnose and assess their own work. The previously mentioned instructional studies show evidence that students' achievements improved; yet, not many teachers adopt these innovations.

Hammer [3] argues that meeting a progressive agenda places substantial intellectual demands on teachers. Traditional test-directed physics teaching seldom aims at solving unfamiliar problems. Teachers need to undergo profound changes in their views about the goals and methods of physics teaching. Teachers need to coordinate the new agenda with the existing one. For these reasons teachers often fear trying new instruction, yet, for change to occur they must be able to face these fears. The profound changes in teachers' beliefs needed for altering classroom practice can be promoted by encouraging teachers to reflect on the very process of applying a new classroom practice. These can be met in collaborative teacher inquiry (sometime called action research). Collaborative physics teacher inquiry has consistently been found to enrich teachers' interpretations of classroom information, and support them in a process of change [3, 4, 5].

2. DESIGN OF TEACHERS WORKSHOP

Following this rationale we designed and implemented three consecutive versions of a yearlong workshop for high school physics teachers, in the form of collaborative teacher inquiry. The inquiry focused on instruction aimed at promoting students' self-monitoring in the process of searching for solutions to unfamiliar physics problems. The implementation was accompanied by a formative evaluation based on teachers' questionnaires and video documentation of the workshops.

In the first two workshops we found that teachers recognized the importance of promoting self-monitoring in physics problem solving, and developed theoretical and practical pedagogical content knowledge regarding this issue. Yet, we found that teachers were either not ready to implement change in their classrooms or did not attempt to overcome difficulties that arise. To understand this, we analyzed the extent to which action research steps were executed and repeated in the workshop. The steps, derived from Mcniff [6], include:

(1) Analysis of pedagogical question: examining existing and possible goals and practice.
(2) Setting goals for new practice.
(3) Execution: developing instruction and materials and trying them in classroom.
(4) Evaluation and revision.

We found that the teachers seldom initiated evaluation, and the steps were not repeated.

A central element of the third workshop was a management framework for the collaborative teacher inquiry that was designed to follow the steps of action research. (Another major element was an introductory summer workshop included to build ownership of teachers on the pedagogical problem). Between inquiry cycles the teachers engaged in learning aspects of the pedagogical problem by reviewing the academic literature (presented by the workshop leader), developing new teaching formats and related materials, designing a collaborative research project, and monitoring the workshop by suggesting how to improve it.

3. MANAGEMENT FRAMEWORK DESCRIPTION

The management framework consisted of a repeated inquiry cycle with a clearly defined schedule and participant responsibilities. In each cycle all participants tried out innovative instruction in their classroom. It was the responsibility of one of the teachers (in turns) to present a documentation of his or her classroom experience, and to formulate questions about his or her instructional concerns regarding this experience. The presenters were asked to include in their documentation a description of the classroom activity (e.g. teaching formats and related materials given to students in classroom), and results (e.g. students work and other feedback on classroom activities). It was the peers' responsibility to give feedback on this documentation and to participate in a discussion on the aforementioned questions. The first innovations that were tried out were suggested by the workshop leader, and were rooted in existing research based instructional innovations. The teachers, however, were autonomous in deciding what type of instruction to use. Later cycles were based on the lessons learned from previous ones and involved also instructional innovations developed by the teachers.

Action research steps were embedded in the workshop in the following manner:

(1) Analysis of the pedagogical questions was done through peer feedback and discussion as well as in an introductory summer workshop.
(2) Setting goals was done within the documentation of the presenter associated with the innovation he or she tried.
(3) Execution of developing and trying out instruction in classroom was reported within the documentation, as well as in the development of instruction and materials in between management framework cycles.
(4) Evaluation and revision were done within the documentation of difficulties in implementation, and the formulation and discussion of concerns.

The management framework committed every teacher to try innovations in his/her classroom, focused group discussions on concrete classroom information, helped teachers to learn and support each other's practice, and maintained iterative process of improving their teaching.

4. IMPLEMENTATION

The management framework was implemented both in a face to face setting in the science teaching department at the Weizmann Institute, and in a computerized setting using communication software (Worldgroup Manager Copyright © 1996 Galacticomm, Inc.). The software features included: e-mail, e-bulletin boards (Forums), e-conferences. The computerized setting was introduced initially to enable teachers to participate in the workshop from their homes. Eventually most inquiry cycles took place in it as a response to teachers' demand. The teachers expressed their belief that the computerized setting was most effective at accomplishing informed inquiry. In the face to face implementation, a cycle (documentation, peer feedback and discussion) was carried out in meetings lasting three hours. In the computerized implementation a cycle would stretch over a week. Sample schedule would be:

Monday: Presenter sends documentation (to forum)
Peers read documentation and write feedback at home.
Wednesday: Peers send feedback (to forum)
Thursday 6 p.m.: Presenters send questions (to forum)
Thursday 10-11 p.m.: All participants join for e-discussion.

The computerized forums and conferences were password protected for security, and only the participants had access.

5. RESEARCH METHODS

In the workshop, conducted during 1996-1998, fifteen inquiry cycles took place. Within these two years the participating teachers custom tailored instructional innovations to their settings and personalities. This provided a unique opportunity to trace teachers' professional development in the subject of the workshop: promoting self monitoring in physics problem solving.

5.1 Subjects

Eight teachers participated in the workshop. All were experienced, and taught in schools of diverse levels around Israel. All had to prepare students to take the national matriculation exam. Their class size ranged between 20-35 students. Six chose to enroll in the yearlong workshop after a summer introductory workshop. One teacher left after a year, and his place was taken by a teacher who participated in an earlier version of the workshop.

5.2 Analysis

We traced instructional developments by the teachers that incorporated two main components: Problem solving via strategies and self-diagnosis by students. We looked for shared themes between consecutive cycles, both in the instruction and materials teachers developed, and in the questions they discussed. We investigated whether one can find dimensions and timetables for the changes in teachers' work.

5.3 Data

The data included teachers' documentation of trying out instruction and materials developed by them, and discussion of questions arising from their classroom experiences.

(1) Computerized meeting data: consists of e-mails and attached files sent to the forum (Documentation, peer feedback, Questions for discussion), and the protocol of the electronic conference.

(2) "Face to face" meeting data: consists of transcripts of videos of the workshop meetings, and of documents distributed by the presenter to the participants.

6. TEACHERS' PROFESSIONAL DEVELOPMENT

The following will portray the main stages that we found in the teachers professional development. Each stage was defined based on the shared themes we found in several consecutive cycles. We will describe those shared themes, both in the instruction and materials teachers developed, and in the questions they discussed. Each description will end with an illustration of the theme using the materials the teachers developed.

6.1 First stage - Introductory summer workshop

An analysis of initial questionnaires regarding the teachers perceptions about the learning and instruction of problem solving revealed a gap between their existing awareness of the processes needed to be developed in students problem solving, and their practices that did not attempt to develop those processes. As mentioned previously most of the teachers chose to engage in a yearlong workshop to reform their practice after the introductory summer workshop.

<u>Introduction of instruction and materials</u>

Several Instructional innovations [1,7,8] were introduced in the summer introductory workshop, that included the use of strategies to guide students problem solving. All strategies consisted of steps in solving problems that stretch from qualitative to quantitative, for example [1]:

(1) <u>Focus the Problem</u> (e.g. sketch the situation, identify target quantity…).

(2) <u>Describe the Physics</u> (e.g. simplify diagram, name variables, write possible physics principles needed to find target quantity…).

(3) <u>Plan the Solution</u> (e.g. divide problem to sub-problems in order to find unknown variables needed to find target quantity…).

(4) <u>Execute the Plan</u> (e.g. Combine equations to determine an algebraic solution. Plug in known quantities…).

(5) <u>Evaluate the Answer</u>.

Other strategies emphasized the iterative nature of the problem solving process that consists of cycles of analysis, construction, checking and revision of a solution [9].

6.2 Second stage – first year, first semester

<u>Development of instruction and materials</u>

The teachers asked their students to solve problems guided by a strategy (steps in a problem solution), or self diagnose their solutions based on the teacher's solved example. They wrote their own adapted strategies and solved examples in different topics. For example a strategy was adapted to the topic of work and energy. The teachers added to the direction "divide", in the planning step above, the following: "For each sub-problem assemble the known and unknown variables into an equation representing the principle of energy conservation".

<u>Questions for discussion</u>

The questions for discussion dealt with problems they encountered, mainly:

(1) Management considerations (e.g. "should I require my students to use a strategy in their problem solving, or should I just recommend them to do so?")

(2) Diversity considerations (e.g. "The strong students don't want to cooperate with the weak ones, how do you manage to cope with this problem?")

6.3 Third stage - first year, second semester

<u>Development of instruction and materials</u>

The teachers developed instruction that responded to those questions. To enable instruction to addresse the diversity in their classrooms, they developed a two level strategy, more and less detailed, which the students could choose from. For example, the previously mentioned direction "divide" was elaborated to include guiding questions like: "Does the object change its motion (linear or curved trajectory, constant or changing speed)? Does the forces on it change - are they conservative? Do they do work?"

<u>Questions for discussion</u>

In the end of the first year the teachers expressed their feeling that they were just in the beginning. They questioned the usefulness of basing the self-diagnosis on a solved example, since in such situation there is no need for revision of a solution. The teachers asked to prolong the workshop for another year, in which they hoped to write classroom materials and to do a systematic evaluation of at least one method of instruction.

6.4 Fourth stage - second year, first semester

<u>Development of instruction and materials</u>

The teachers did not do the systematic evaluation they planned. Instead they responded to their doubts, developed and tried other ways of instruction. For example, to assist students in revising their solutions the teachers developed a self diagnosis activity that is based on a strategy, and not on teacher solved examples. The students were asked to fill in the following form, to assist self diagnosis of their solutions:

Step	Exist?	Correct?	Explain
Focus			
Physics			
Plan			
Execute			
Evaluate			

In the "Exist" column the students were asked to check the performed steps, in the "Correct" column the students were asked to define what was wrong and in the the "Explain" column to explain what went wrong.

Questions for discussion

The teachers re-examined goals that seemed already agreed upon in the introductory workshop more than a year earlier. For example, a teacher who tried in his classroom self-diagnosis based on strategy posed the following question: "The activity demanded students to find and correct their mistakes. I see three different groups: Those who are willing and able, those who tried but did not succeed those who did not bother. What, if at all, do you think students from the second group gained from taking part in the activity?" It is our understanding that this teacher is weighing learning skills vs. content knowledge as goals for instruction.

6.5 Fifth stage - second year, second semester

Development of instruction and materials

Towards the end of the second year the teachers saw self-diagnosis as an important learning skill they have to develop in their students. They designed materials more carefully. To make the strategy work better as a diagnosis tool they phrased the strategy in the format of requirements for the final solution and not as directions for consecutive steps in the solution process. For example the direction in the planning step previously mentioned were transformed to "Identification of sub-problem: choice of a body; listing of known and wanted quantities in the sub – problem…"

6.6 Dimensions and timetables for change

We found several dimensions of change in the collaborative teacher inquiry during the two years.

(1) In the development of materials, diverse perspectives were incorporated: Initially adapting to different physics topics, then meeting students' diversity, finally focusing guidance of students on revision rather than in the whole problem solving process. While doing so, teachers dared to do more and more non-traditional things in the classroom.

(2) In the discussion, at first it seemed that there was a consensus on goals, and there was just a need to consider means. As time passed, the goals were materialized in the implementation, and the teachers acquired a deeper sense of the meaning of the goals, and there was a need to re-examine those goals.

One can see that the discussion had an impact on development, and vice versa. The changes on both, however, emerged within a very long time-scale.

7. SUMMARY

The implementation of the management framework in a computerized setting made the teachers work hard. They kept saying that they work much harder than in any other in-service workshop they had participated in. Yet, they all asked to continue the workshop for another year. They commented in the feedback questionnaires that the hard work was worthwhile. They enjoyed the quick benefits of new materials and instruction for their next day of class, as well as a continued consultation with their peers that assisted them in refreshing their practice.

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