Promoting self-monitoring in physics problem-solving: Professional development through a "cooperative teachers' inquiry" workshop

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Abstract

The goal of this project is to promote the capability to perform self-monitoring in problem-solving by high school physics students. Searching for a solution to an unfamiliar problem is a characteristic activity of scientists and engineers. The search involves self-monitoring capabilities such as choosing effective representations to analyze a complex and unfamiliar situation, planning the progress of a solution and diagnosing ones own mistakes for possible revision. These capabilities characterize expert physicists, but not necessarily novices (Reif, 1995). There exists research-based curricula (Maloney, 1994) that promote self-monitoring in physics problem-solving, yet, seldom are they fully implemented in high school physics. Several factors may contribute to this fact: Constraints set by the external matriculation; the mismatch between existing curricula and the conditions in Israeli classrooms, and; lack in teachers' will and knowledge needed to promote self-monitoring.

How to advance teaching that promotes self-monitoring in physics problems solving? In Accord with Eylon, Singer & Ganiel recommendation (1985) we suggested to develop a cooperative teachers' inquiry workshop to bridge between research-based curricula and the reality of Israeli high school. The workshop consisted of:

a) Introductory activities in which the workshop leader presented research and curricula and the teachers examined goals and practices in problem-solving instruction.
b) Yearly meetings in which the teachers planned and evaluated the implementation of curricular activities to suit their class .

We hoped that: (a) Involving teachers in the act of tailoring existing curricula to their classrooms would contribute to the development of a curriculum well suited to the local conditions. (b) Providing the participants with the opportunity to reflect on the process of applying a new classroom practice would deepen the examination of existing perceptions and promote change in practices.

Due to the novelty in the workshop goals we had to define possible standards and design a framework in which they could be acquired. To achieve these goals we designed three consecutive workshops and accompanied them with formative

evaluation. The 1st and 2nd workshop versions lasted a year. The 3rd "model" workshop was extended to two years in response to the participants' request. Between 5 to 8 experienced teachers, from diverse schools in Israel, attended each of the workshops. The analysis of initial questionnaires regarding teachers' perceptions about problem-solving learning and instruction revealed a gap between their awareness to the needed processes in students' problem-solving, and their practices that did not attempt to develop these processes. In the formative evaluation of 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 difficulties in teachers' readiness to implement change in their classrooms, and in their ability to use problems they encountered as learning opportunities.

These results led us to suggest that for physics teachers to implement instruction that promotes self-monitoring in problem-solving, and cope with difficulties inherent in changing their practice, they need to take part in a demanding learning process we termed "exploration of an extended pedagogical problem". This process focuses on a central instructional goal that requires teachers to re-examine and direct different aspects of their teaching towards that goal. The daily pedagogical problems that teachers face seldom require such a thorough examination.

We hypothesized that:

a) To explore effectively possible solutions to an extended pedagogical problem requires:
   - Ownership of the teacher on the pedagogical problem,
   - An iterative exploration process that supports the design of solutions to the problem. Such a process may include the following steps: (1) Analysis of existing goals, practices, and alternatives; (2) definition of new goals and practices to be tried out; (3) execution that consists of developing instruction and materials, and trying them out in class; (4) evaluation and refinement. These steps are associated with action research methods (Mcniff,1996).

b) We need to build ownership and structure the exploration process. This scaffolding is needed, as the requirements mentioned above do not occur spontaneously.

The following components were added to the 3rd "model" workshop to provide such scaffolding:

a) Building ownership of teachers on the pedagogical problem: In an introductory summer workshop we conducted activities that confront teachers with the difficulties inherent in changing practices and let them choose whether to stay for the yearly meetings.
b) Structuring the exploration process: In the yearly meetings we implemented a management framework for the cooperative teachers' inquiry. This involved external representation of the exploration steps in well defined activities that teachers should perform in iterative cycles: (1) Development and

implementation of new instructional strategies and learning materials in the class; (2) documentation of classroom experiences; (3) peer feedback; and (4) formulation and discussion of questions brought up in the classroom. The public components of the learning framework (documentation, feedback and discussion) were transferred to an intranet setting after several cycles.

We tested the previously mentioned hypotheses by a comparative study of teachers' professional development in the three workshop versions that varied in the degree of scaffolding teachers. In particular we asked:

a) To what extent did the introductory summer workshop help in building ownership of the participants over the extended pedagogical problem?
b) How did the teachers explore the extended pedagogical problem: Which steps did they perform? how persistent were they? what were their responsibilities as compared to those of the workshop leader?
c) What were the curricular products of the exploration process, and how well were they suited to promote self monitoring in physics problem-solving?

Question (a) was examined through a questionnaire that showed that only in the model workshop the teachers built ownership over the extended pedagogical problem. They were aware and ready to cope with the implementation difficulties.

Question (b) was examined in two ways:

a) Episode analysis: An analysis unit termed "episode" was defined as a set of workshop activities with a common focus. Each workshop version was represented as a series of episodes and was mapped into the steps of the exploration process (Analysis, definition, execution, evaluation and refinement). This analysis provides a sequential description of the teachers' performance of the process.
b) Action analysis: An analysis unit termed "action" was defined as a step in the "episode" that represents processes of information transfer between the participants. Each workshop version was represented as a series of actions that were classified into the following categories: Where have they taken place? what are the knowledge resources in the action? who was active and who initiated them? A quantitative analysis was carried out to provide answers to questions such as: What were the main knowledge resources in the workshop? and, how was the work distributed between the workshop leader and the participants?

We found that only in the model workshop the teachers took full responsibility and carried out repeatedly the exploration process steps.

The examination of question (c) revealed a substantial improvement in teachers' achievements in the model workshop. Relative to the achievements in the first two workshop versions: Teachers persisted in tailoring existing research-based curricula to suit their needs, while changing perceptions and practices to promote students' self-monitoring in problem-solving.

These results support the previously mentioned hypotheses, namely that there is a need to build ownership and structure the process of exploring solutions for an extended pedagogical problem. Furthermore, they show that the approach used in the model workshop was effective.

The management framework for the cooperative teachers' inquiry was implemented in the model workshop both in person and in Intranet setting. To identify which features of the management framework were effective we studied how the constraints of the different settings shape the features of the management framework and what features of the management framework lead to better performance of the exploration process. The main features of the management framework in the intranet setting that differed from the in person setting were: (a) Distinct and explicit steps of learning cycle; (b) extended timetable; (c) obligatory participation; (d) distribution of documents; and (e) electronic-textual discussion. The performance of the exploration of process in the intranet as compared to the in person setting had the following characteristics: (a) Comprehensive, clear and concise documentation; (b) commitment of teachers to formulate questions; (c) suggestive feedback that refers to class materials; and (d) focused, informed and tolerant discussion. We found that the intranet setting enabled to structure the cooperative exploration of the extended pedagogical problem in accord with the recommendations of Johnson & Johnson (1993) including: (a) Positive interdependence; (b) promotive interaction; (c) individual and group accountability; (d) interpersonal and small group skills; and (e) group processing .

In order to find how teachers developed professionally in the workshop subject we studied the change in curricular products of the cooperative teachers' inquiry during the two years of the model workshop. In particular we examined what was the relationship between development, implementation and evaluation of instructional strategies and materials, and what were the dimensions and timetables for the change. We found that the professional development of the teachers had the following characteristics:

a) The assimilation of the workshop goals was a very long process (two years) and consisted of reexamination and redefinition of the goals in the process of developing and implementing means to achieve these goals.
b) Teachers' perceptions about learning and teaching of problem-solving changed very slowly. Teachers' understanding of the students' characteristics relevant to their new practices changed, as well as their understanding of the problem-solving process, and their instructional role within it .

To summarize, this study shows that physics teachers can change perceptions and practices to promote self-monitoring in students' problem-solving, yet this change is slow and it proceeds along with many relapses. This study shows that to turn extended pedagogical problems into an effective vehicle in teachers' professional development one needs to explicitly build teachers' ownership over them and structure carefully their exploration. In particular this study suggests specific management features for cooperative teachers' inquiry that are effective in scaffolding teachers' exploration of extended pedagogical problems.