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From Traditional Laboratory to Inquiry-Based Laboratory in High-School Physics Instruction: Professional Development of Teachers

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Abstract

For over a century, educators from all over the world, including Israel, have been recommending the integration of an inquiry-based (IB) learning approach into science teaching. However, experts are still dealing with the issue of designing a professional development (PD) framework aimed at training science teachers to do so. This study dealt with (1) the iterative investigation, design and implementation of a continuing PD program, aimed at training experienced high-school physics teachers to integrate IB laboratory activities into their practice in the laboratory learning environment, and (2) an investigation of the professional growth of teachers who participated in the PD program.

In about 95% of Israel's high-school physics classes, laboratory studies are conducted using a traditional, also termed "cookbook" approach. In this approach, laboratory activities usually focus on verifying knowledge that has been previously learnt in class through step-by-step instructions that guide all students to complete the same procedure toward the same goal in two or three lessons. Educators criticize this way of learning, as it does not promote the fundamental goals that can be achieved in a laboratory environment. These goals include: developing higher-order thinking skills (such as posing questions or designing an experiment), opportunities for independent work which engages students in the process of formulating and asking their own interesting questions, enabling students to make mistakes and learn from them, introducing students to diverse aspects of scientists' practices and the role of the laboratory experiment in scientific research. These goals can be achieved by using IB laboratory activities with a variety of inquiry levels. During the PD program that was designed and investigated in this study, five types of IB laboratory activities, divided into two levels of inquiry, were used. The basic inquiry level included traditional laboratory activities enriched with opportunities to learn inquiry skills, and guided-inquiry activities, in which different student groups investigate different aspects of the same phenomenon simultaneously using a structured manual written by the teacher. The advanced inquiry level included open-inquiry activities, in which the teacher guides the students to take part in designing an activity, and mini-projects and projects, in which the students design and conduct an experiment completely on their own.

The study aimed to investigate (1) the design and implementation of the training strategies of the PD program and the teachers' challenges; (2) the development of the

teachers' views and practices regarding integration of the IB laboratory activities into their classrooms; and (3) the reciprocal relations between the PD training strategies and development of the teachers' views and practices.

This study followed a design-based research approach which involved iterative investigation, design, and implementation of the PD program. The study consisted of two stages: a pilot study during 2010 of the first part of the PD program (version A), and a major study in 2011–2014 of two PD programs carried out simultaneously: the second part of version A and version B. In 2012, an additional PD program was developed and implemented to support the teachers. During the pilot and major studies, we investigated the teachers' challenges, development of the teachers' views and practices, and the reciprocal relations between the PD training strategies and the teachers' views and practices.

The following research samples were selected for each goal of the study: 176 training hours to investigate the PD training strategies, the 26 teachers who participated in the PD program to explore the teachers' challenges, views and practices, and a sample of 12 of those teachers to examine development of the teachers' views and practices. Two case studies were carried out to identify the reciprocal relations between PD training strategies and the teachers' views and practices.

The data were collected using a variety of research tools: audiotapes of the PD meetings, questionnaires (about the PD program, about teachers' views of inquiry and its use in teaching), classroom observations, personal conversations with the teachers, and teachers' reports on the enactment of the IB laboratory activities.

Below we present the four research questions and findings of this work.

What challenges do the teachers face when integrating the IB approach in the laboratory environment for the first time?

The teachers' challenges were investigated using 27 teacher reports submitted by 17 teachers. The results were congruent with the research literature. Some challenges related to the teachers' views regarding the IB approach in the laboratory learning environment, which could be classified into three major ones: it is impossible to integrate the IB approach in classroom; the IB approach can only be conducted with high-ability and interested students; the teacher is the main source of knowledge in the class. This last view was reported by some of both the teachers and their students. Additional challenges regarded the use of the new teaching strategies, for example, how

to deal with the integration of the theoretical background and the IB laboratory activity, how to involve students in designing the activity, how to teach the nontraditional skills, and how to allocate the longer time needed for the IB activities. Concerns were raised about ways to deal with the unfamiliar disciplinary content knowledge that might arise during the process of investigation.

What are the PD training strategies, and how were they refined during the program's implementation?

The PD training strategies, namely the training activities used in the PD program, were iteratively developed, implemented, and refined during two versions of the PD program, A and B.

The starting points for the design process were the PD program's objectives and the design principles. The objectives and principles were derived from a review of the research literature, taking into consideration the unique characteristics of the Israeli high-school physics teaching. The design process benefited from the extensive experience of the physics group in the Department of Science Teaching at the Weizmann Institute regarding teachers' professional development. The PD program aimed to provide the teachers with the knowledge and abilities needed to teach the laboratory using the IB approach. The training strategies were designed according to five principles: emphasizing the unique characteristics of the IB approach versus those of the traditional approach; teachers as active learners; involving the teachers in the design, development and assessment of the IB laboratory activities; using evidence from the teachers' classes; meeting the teachers' needs and providing support during the enactment of IB laboratory activities in their classrooms. The following training activities were enacted: teachers carried out IB laboratory activities on their own; teachers' enacted IB laboratory activities in their classroom; teachers reflected on their and others' reports about the IB laboratory enactments in class. Additional training strategies involved teachers familiarizing themselves with new nontraditional skills and with the use of the students' personal portfolios to promote the students' IB learning. During the implementation of the training strategies, we followed all 26 teachers who participated in the PD program to explore their challenges and their views and practices. Most of the refinements of the training strategies resulted from the findings of this exploration. For example, when a low willingness to enact the IB laboratory activities was identified in the A Group teachers (those who participated in the A version of the

PD program), the first enactment of the B Group (who participated in the B version of the PD program) was performed earlier than planned and the consecutive enactments were redesigned.

How did the teachers' views and practices with respect to the IB laboratory activities develop during the PD program?

An investigation of the teachers' reflective discourse about the integration of IB laboratory activities was carried out for seven key events of the PD program, regarding the group as an organic unit. The PD training strategies were represented in these key events. Each reflective utterance was characterized as "traditional approach oriented", "inquiry approach oriented" or "in-between approaches oriented". A mixed quantitative and qualitative analysis of the data was used to determine whether and how the indicators of the teachers' IB orientation developed during the PD program, what the teachers' views and practices were, and how these views and practices changed during the PD program. The analysis revealed that (1) the teachers' views and practices developed toward the inquiry approach orientation; (2) the teachers needed time and multiple opportunities to examine and revise their views and practices within their teaching routine; (3) the teachers' reflections referred mainly to the following aspects: the nontraditional skills required in the IB laboratory, the additional objectives that can be achieved in the laboratory environment, the reciprocity between the theoretical background and the IB laboratory activity, their new teaching role in conducting the activity, and the way they dealt with unfamiliar content knowledge in real time; (4) the teachers' reflective utterances, which were characterized as traditional approach oriented and inquiry approach oriented, were congruent with the PD objectives and the research literature.

What were the reciprocal relations between the training strategies of the PD program and the teachers' views and practices?

The reciprocal relations between the training strategies of the PD program and the teachers' views and practices included two components. The first had to do with the influence of the teachers' views and practices on the PD training strategies. The second consisted of the influence of the PD training strategies on the teachers' views and practices.

The PD training which was investigated in this research was conducted with groups of teachers: the A Group and the B Group corresponding to the A and B versions of the PD program. Therefore, the influence of the teachers' views and practices on the PD training strategies emerged from an investigation of the views and practices of *all* teachers who participated in the PD program (as already noted in the second research question).

We might expect that different teachers will be influenced differently by a training program. Therefore, the influence of the PD training strategies on the teachers' views and practices was investigated at a *personal* level, using two case studies. Case study I was conducted with the teacher Tzlil, and followed the development of her views and practices regarding the questioning-skill enactment. Case study II was conducted with the teacher Shani, and followed the development of her views and practices regarding enactment of the IB laboratory activities.

Evidence for reciprocal relations was identified between the teachers' views and practices and four of the five PD training strategies (discussed above in the second research question). For example, the reciprocal relations between the teachers' views and practices and the teachers' enactment of the IB laboratory activities in their classroom (the second training strategy) were as follows: after investigating the first enactment of the IB laboratory activities, we found that class enactment should start as early as possible in the program and that the total number of enactments should be increased. In the case studies, this change was indeed found to be beneficial: the more Tzlil and Shani enacted in class, the more they adopted the teaching strategies they experienced as learners in the PD program, and the better their enactment was.

In summary, this study demonstrates that experienced physics teachers can be trained to integrate the IB learning approach in a laboratory environment under the following conditions: (1) the training process is continuous; (2) the process provides the teachers with time and multiple occasions to examine and adapt the IB approach to their classes following a process of implementation, reflection and analysis of the students' products; (3) examination of the adoption of the IB approach includes collaborative reflections among peers and the creation of a supportive community.