DNR-Based Professional Development: Factors that Afford or Constrain Implementation

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**DNR-based professional development (DBPD)** is a long-running program spanning seven years with multiple cohorts of in-service secondary mathematics teacher participants. This report investigates teacher change among five key variables: facilitating public debate, using holistic problems, attending to students’ intellectual need, attending to meaning of quantities and use of students’ contributions. Is there evidence that DBPD contributed to higher implementation among participants over time? What factors afford/constrain DNR implementation over time? Classroom observation data indicate the largest impact was found in teachers’ attention to meaning of quantities and students’ intellectual necessity while interview data provide insights to what affords and constrains DNR implementation.

Key words: Teacher change, DNR-based instruction, Intellectual Need, Professional Development, In-service

In their review of 106 articles reporting findings on mathematics professional development programs between 1985 and 2008, Goldsmith, Doerr and Lewis (2013, p. 21) point out that “existing research tends to focus on program effectiveness rather than on teachers’ learning,” while much less has been said about “how teachers develop knowledge, beliefs, or instructional practices”. Indeed, DNR researchers have conducted, and continue to conduct, studies exploring the processes by which teachers develop knowledge of mathematics, pedagogy and student thinking while also describing the contexts in which this learning occurs. For example, Harel, Fuller and Soto (2014) described characteristics of the teaching practice of a DNR expert aimed at helping a group of teachers transition from result pattern generalizing (RPG), a form of the empirical proof scheme, to process pattern generalizing (PPG), a form of deductive proof scheme (RPG and PPG are described in Harel, 2001). Harel (2013b, 2014) describe two of the content areas covered by DBPD in summer institutes and follow-up sessions.

An extension of these studies – our current study – examines the extent to which the evidence that DNR-based professional development (DBPD) has contributed to the implementation of DNR principles by participating teachers and, in keeping with the recommendation of Goldsmith et al, seeks information about the factors that help or hinder implementation. This study reports such findings and contributes in areas by specifying a set of teaching practices we take as indicators of DNR implementation and combining direct classroom observation with participant interviews to yield both information about program effectiveness and provide insight into learning processes.

**Theoretical Framework**

DNR-based instruction in mathematics (Harel, 2008a; Harel, 2008b), is a theoretical framework that stipulates conditions for achieving critical goals such as provoking students’ intellectual need to learn mathematics, helping them acquire mathematical ways of understanding and ways of thinking, and assuring that they internalize and retain the
mathematics they learn. Though DNR is a system of premises, constructs and instructional principles, here we attend to only the necessity principle and the construct of teaching practices.

In DNR, the necessity principle stipulates that in order for students to learn what teachers intend they must have an intellectual need for that targeted piece of knowledge and the construction of this knowledge is brought about through a series of equilibrium and disequilibrium phases as learners engage in problematic situations (Harel, 2013a).

Harel (2008b) defines, “a teaching action is a curricular or instructional measure or decision a teacher carries out for the purpose of achieving a cognitive objective, establishing a new didactical contract (Brousseau, 1997), or implementing an existing one.” Characteristics of teaching actions are called teaching behaviors. Teaching actions and teaching behaviors taken together are called teaching practices. The necessity principle, described above, is a foundational claim about the importance of teacher awareness of students’ thinking and difficulties, the need to plan for and handle students’ problem-solving approaches, as well as the importance of availing oneself of the opportunities that could arise if the right problems are posed and students are given the chance to make and express their own meaning for problems that are not broken down for them in advance.

Methods

DBPD consisted of two related support structures: (1) summer institutes and mid-year follow-up and sessions similar to what was described in Harel, Fuller and Soto (2014) and (2) on-site professional development. Both efforts targeted the teachers’ knowledge of mathematics (in terms of ways of understanding and ways of thinking), knowledge of student learning, and knowledge of pedagogy. This report examined DNR implementation for 34 teachers, focusing on the following five teaching practices: public debate, holistic problems, intellectual need, attention to meaning, and taking contributions seriously as defined below.

• Assigning Holistic Problems: A holistic problem is one where a person must figure out, from the problem statement, the elements needed for its solution (Harel and Stevens, 2011). It does not contain hints or cues as to what is needed to solve it. In contrast, a non-holistic problem is broken down into small parts, each of which attends to one or two isolated elements. Often each of such parts is a one-step problem. (No/Yes)

• Intellectual need: Do students have a need for understanding the mathematics the teacher intends to teach? Does the teacher appeal to a problematic situation that puzzles students when introducing new mathematics? (No/Yes)

• Attention to meaning: When a problem has a context, unknown quantities have meaning with respect to that context (e.g. units related to quantities). Does the teacher attempt to attend to the meaning of quantities within the context of the problem? (No/Yes)

• Public debate: Is there evidence to believe that the whole class is following the discussion? Is the teacher making a successful effort to engage the whole class in debate through questioning and solicitation of contributions? Public debate also includes the need to evaluate mental images and their validity and efficiency. (No/Yes)

• Taking student contributions seriously: A student’s contribution is considered to be taken seriously when it is allowed to live in the public space for discussion without immediate teacher evaluation. When taking contributions seriously, teachers solicit ideas and mental images from students, and facilitate public debate about these ideas to highlight and critique both underlying mathematics. (No/Yes)
Repeated classroom observations of teacher participants were conducted and used to evaluate participants’ implementation of DNR and to chart changes in participants’ teaching over time. Two forms of data were generated using these observations. First, researchers examined whether or not a particular teaching practice was demonstrated in each participant’s classroom during an entire classroom observation across two later years of the program’s existence. Second, researchers looked at interview data with participants conducted after classroom observations that could be used to give insight into factors that afford or constrain implementation. A summary of findings follows.

Findings

Three forms of findings constitute results of investigation into the program’s impact on DNR implementation.

Classroom Observation Data (All classes)

The following tables show percentages of classrooms in which a particular teaching practice was present during year 3 and 4 of the program.

<table>
<thead>
<tr>
<th>Attention to Meaning</th>
<th>Intellectual Need</th>
<th>Public Debate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 3</td>
<td>Year 4</td>
<td>Year 3</td>
</tr>
<tr>
<td>25.9 %</td>
<td>61.5 %</td>
<td>63 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Taking student contributions seriously</th>
<th>Holistic Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Year 3</td>
<td>Year 4</td>
</tr>
<tr>
<td>81.5%</td>
<td>84.6 %</td>
</tr>
<tr>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Year 3</td>
<td>Year 4</td>
</tr>
<tr>
<td>81.5%</td>
<td>80.8 %</td>
</tr>
</tbody>
</table>

The most dramatic results can be seen in the change of the percentage of classrooms in which teachers attended to meaning and to the intellectual need of students and raise questions about aspects of DBPD that may have contributed to these shifts. Similarly, one might ask what may have constrained increased implementation of holding public debate, taking student contributions seriously and using holistic problems. There are many possibilities, including the difficulties inherent in the teaching practices themselves, the students’ comfort levels sharing ideas in class or even a potential ceiling effect. Note that each of these three teaching practices began with a relatively high rate of classrooms demonstrating them, 70%, 81.5% and 81.5% respectively. For this reason, we decided to investigate individual data.

Interview Data. During interviews with project staff, the following factors were reported as reasons participants felt they were able to implement DNR in their own classrooms.

- Resonance of the major principles of the DNR framework with their own values, including a strong dedication to problem-solving, belief in student-centered instruction, and a belief that current curriculum needs modifications to accomplish meaningful instruction.
- Community-driven programmatic elements such as a time, place, and leadership for sharing ideas and peer support building, one-on-one mentoring from more experienced teachers and regular contact with community members.
• Academic freedom/autonomy to implement DNR-compatible teaching practices by administrators
• The program’s on-site support
• Adoption of the Common Core State Standards in Mathematics and compatibility with DNR
• A strong sense of dedication to students

Factors reported to constrain DNR implementation included:
• Dissonance with the major principles of DNR, either throughout or growing with time
• Difficulty of Didactical Engineering/adapting DNR’s instructional principles to curriculum
• Lack of academic freedom with respect to content and/or teaching practices (either perceived or embodied in administrators and/or parents including pressure to teach algorithmic proficiency at sites/desire to maintain consistent testing results with high SES from parents, students and administrators and large class sizes generating extraneous work)
• Self-efficacy and retention issues

Discussion

We began the report with insights from Goldsmith, Doerr and Lewis (2013) describing some of what has been done and what still needs attention in mathematics professional development over nearly three decades. On the surface, this report seems to do the opposite of what Goldsmith et al recommend, appearing, at least initially, to focus on “program effectiveness” rather than teacher learning. However, we argue that DNR researchers have been carrying out the work of investigating how teachers develop the forms of knowledge, beliefs and instructional practices needed in the common core era for quite some time. Evaluation of a PD program attempting to implement DNR is a necessary part of theory building. Indeed, knowledge about the kinds of hurdles teachers face when attempting to turn theory into practice can inform the theory itself as researchers attempt to make adjustments to their theoretical perspectives moving forward, starting a new cycle of theory building, implementation and evaluation.

Intended Questions for the Audience

1. We are aware that there lurking methodological questions we have yet to ask about classroom observation protocols with respect to each of the five teaching practices. What are some of them? Would duration help on some of these variables?
2. How can these findings inform future DBPD? DNR as a theoretical framework?
3. We have data, by individual participant, with respect to each of the five teaching practices discussed. I have bar graphs readily available with mean and standard deviations. How might this data be used to address our questions?
References


